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Agriculture and Structural Transformation in Africa

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Abstract

Structural change during most of the first 5 decades of post-independence Africa has been productivity-reducing. It has been driven by negative diversification reflected in labor migrating from the underperforming, yet higher-productivity agricultural sector into an oversized, lower-productivity service sector. In the aftermath of the failure of the first generation of import-substituting, inward-oriented industrialization efforts of the 1960s, African governments had all but given up on the search for practical industrial policies. Meanwhile, agriculture continued to be confronted with significant policy and institutional challenges, moving from an environment marked with heavy direct and implicit taxation into an era of the controversial structural adjustment policies that significantly curtailed services support to the sector. The combined effect resulted in stagnation in the manufacturing sector and forced specialization in the primary sector. The latter continued to be dominated by a struggling agricultural sector, which could not create enough employment to absorb an increasing labor force from a rapidly growing population. In addition, people started to migrate from villages to rural towns and urban centers and in the process swelled up the ranks of the under-employed in a fast-growing informal sector.

The economic recovery of the last 15 years provides strong hope that African countries are starting to turn the page. The focus now should be on sustaining and accelerating the recovery process, enacting policies to raise productivity in the agricultural and service sectors, and revitalize the modern industrial sector. A good start is the continent-wide effort under the Comprehensive Africa Agriculture Development Programme (CAADP) to encourage evidence-based policy planning and implementation and to increase investment in agriculture. However, it needs to be complemented with innovative industrialization policies to develop comparative advantage in higher-valued manufacturing goods. Future development strategies should seek to raise productivity in the service sector, which now has a large and growing share of low-productivity labor. The objective of these strategies should be to modernize production processes and to promote innovation in the production of domestic and household goods ranging from metalwork to wood and leather processing to a host of handicraft products.
Agriculture and Structural Transformation in Africa

Introduction

This paper takes a comprehensive look at the process of structural transformation among African countries. It adds to the traditional focus on what happens or needs to happen within agriculture and includes several key issues that have been referred to marginally and not treated adequately in-depth. These additions include recent developments in the theory and measurement of economic diversification and related strategies for industrial development policies. The paper also expands the analysis to cover the theory of endogenous industrialization and its link to development of the non-agricultural segment of the rural economy, the role of agriculture, and the implication for the pace of productivity and income convergence across major economic sectors.

The role of globalization, emerging urban and regional economies, and the related development of agricultural value chains also bring an interesting new angle to the story and strategies in support of structural transformation. Finally, the trade-off faced by governments trying to meet both the short-term social need to mitigate some of the distributional impact of the transformation process and long-term need to invest in raising agricultural labor productivity under severe budgetary constraints, raises an interesting issue of public-investment optimization that needs to be part of the debate.

Agriculture and the growth process

Countries create wealth and become rich during the process of economic growth by producing more per unit of labor. They do this by producing more of the same good per unit of time and, more importantly, by producing a larger basket of higher valued goods. In the course of the process, the economy moves from a status where most economic activities are concentrated in agriculture and rural areas to a situation where industry and other urban based activities become dominant. The changes described above are summarized in Figure 1. Managing a successful economic transformation poses two key challenges: (i) to raise labor productivity sustainably in the agricultural sector and the rural economy, while (ii) diversifying into higher valued goods outside agriculture in emerging higher productivity, urban-based manufacturing and service sectors. The factors determining the success or failure of countries to transform successfully are linked to the adequacy of human and physical assets, institutional and technological resources, as well as policy and coordination capacities.

The role of agriculture in the transformation process is related to the changes reflected in Figure 1. As the economy grows, the levels of output and productivity per worker in the agricultural sector rise, while the sector’s shares in total labor force and overall output decline gradually due to faster growth in the rest of the economy. The result is a rise in per capita income levels. Despite its relative decline, the agricultural sector plays a significant role in the economic transformation process, as summarized by Johnston and Mellor (1961). As per capita incomes and population grow, the expanding agricultural sector provides greater food supplies from domestic production or through imports paid for by foreign exchange earned from agricultural
exports. The increase in food supplies stabilizes prices and prevents real wages in the nascent industrial sector from rising too fast.

**Figure 1: Agriculture in the economic transformation process**

![Diagram showing the relationship between per-capita income and various economic indicators such as share of agriculture in total labor force, agricultural GDP per worker, and share of agriculture in total GDP.](source: Based on Timmer 2009.)

During the first three decades following independence, the ratio of food import costs to agricultural export revenues of African countries was nearly identical to the ratio between food imports and total foreign exchange earnings, implying that resources to pay for the excess demand for food came almost entirely from the agricultural sector (Badiane 1991). Foreign exchange resources earned from agriculture help to meet the import cost of capital goods needed in other parts of the economy.

Agriculture plays another important role as the main source of fiscal revenue for financing road and power infrastructure, health, education, and other investments needed to stimulate growth in the rest of the economy. Finally, agriculture generates a large share of the income that fuels demand for goods produced in the emerging manufacturing sector. When agriculture grows and all the above linkages function properly, labor is released from the agricultural sector to meet demand for manpower in the expanding and higher productivity manufacturing sector. The migration of labor out of a growing agricultural sector also raises productivity in that sector. As a result, average productivity in the economy rises and so do per capita incomes.

Difficulties experienced by African economies following independence arise from the complexity of designing appropriate strategies to exploit these various contributions effectively. This outcome arises because the contributions are not straightforward and may conflict with one another, as well as with other goals outside agriculture. For instance, the need to raise foreign
exchange revenues may conflict with that of expanding domestic food supplies—both with the goal of generating sufficient fiscal revenues to finance capital goods. The latter may in turn conflict with the need to raise incentives and stimulate agricultural sector growth.

Another source of complexity in managing the contribution of agriculture to the growth process emanates sometimes from a misunderstanding of its role in that process. A historical review of the growth performance of the agricultural sector reveals that even if the most labor-intensive techniques are used, the achievable rate of agricultural growth is unlikely to be high enough to absorb the growing labor force (Mellor 1986). Analysis of industrialization by Syrquin (1989) in 100 countries has shown that the growth rate of value added and input use in agriculture is about 40 to 50 percent less than in manufacturing. While this finding underlines the fact that progressive industrialization is the engine for sustained long-term growth, development policy practitioners and analysts during the time of independence for African countries in the late 1950s and early 1960s failed to recognize the centrality of agriculture in stimulating growth in the industrial sector itself.

Johnston and Mellor (1961) define three phases, from early to late development stages, with distinct policy priorities in order to reconcile the above contradictions. In Phase 1, when the sector is dominated by subsistence agriculture, the focus should be on social innovation to remove institutional, social, and cultural constraints to improved farming practices. Programs dealing with land tenure, education, and related institutional infrastructure are required to align cultural and social practices with the need for future modernization of the sector. In Phase 2, emphasis is put on technological innovation and required systems for the provision of modern inputs and services to raise productivity and expand production based on labor-intensive, capital-saving technologies. Key elements of the technical innovation systems include research and development and related education systems to expand production possibilities, cost-competitive input procurement and distribution systems, output marketing systems, plus the required public investment in necessary infrastructure and institutions. In Phase 3, when the opportunity costs of most inputs, in particular labor, are high and rising, the focus should move to deeper penetration into mainstream financial services markets in order to meet the considerable resource needs of a transition to capital-intensive labor saving technologies.

Programs that are implemented in all three phases have to be cost effective and fiscally sustainable. Otherwise, they can become a burden on the rest of the economy and are bound to be abandoned. Sustainability is particularly problematic during the first two phases, when withdrawal of such programs can lead to a total collapse in the sector and loss of decades-worth of development. This outcome was typical in Africa in the years leading up to and through the period of structural adjustment programs of the 1980s and 1990s.

**The pace and pattern of structural transformation in Africa**

African countries have been undergoing a remarkable agricultural and economic recovery process since the mid 1990s. Average growth rates for the agricultural sector and the overall economy have been hovering around 5-6 percent. Even during the recent crises in global food and financial markets, African economies have managed to maintain positive growth rates while
economies in all other regions were contracting. More strikingly, the growth recovery has not only accelerated, it has also spread broadly across all major regions of the continent (Badiane 2008). The recent performance is taking place in the aftermath of low economic growth and stagnation during most of the preceding decades. Sustaining and accelerating the current growth recovery, therefore, requires a closer look at the process of economic transformation during the latter period and the factors underlying it, which is done in the subsequent sections.

**Trends in sectoral productivity and employment**

Analysis of structural transformation patterns among African countries starts with a review of the extent to which trends in output and employment shares of the agricultural sector are converging, as illustrated by the declining distance between the two lines in Figure 2. Given the scantiness of actual employment data and in particular for periods earlier than the 1980s, the analysis is based on agriculture’s share of the economically active population (FAOSTAT 2011). The share of agricultural value added in total GDP is used as a proxy for agricultural GDP share. A look at trends in the shares of the agricultural sector in overall gross domestic product (GDP) and employment reveals the economic challenges faced by African countries. The flat slope of the bottom line in Figure 2, which plots the difference between the two shares, is reflective of the slow pace of structural change that has characterized African economies. Successful structural change would have gradually narrowed the difference between the agricultural shares of GDP and employment and thereby gradually raised incomes in the agricultural and rural sectors toward the level of incomes in urban and industrial sectors. This process of convergence takes a long time, as illustrated by Timmer (2009), but one should have expected at least a gradual decline in the gap and a steady upward slope of the bottom line over the 50-year period covered by the analysis. The same trends (lack of decline in the gap between shares) are observable among individual sub-regions, with the exception of North Africa, where convergence has increased steadily and to a lesser extent in Central Africa.
Of particular concern is the fact that the gap appears to have taken a reverse course and started to widen since the beginning of the new millennium. This indicates that the reforms of the 1980s and 1990s may have led to stronger growth in the manufacturing sector but without a commensurate increase in the demand for labor, as has been the case in post-reform Latin America (McMillan and Rodrik 2011). A closer examination of trends in labor productivity and employment share indicate that the problem may lie elsewhere. As shown in Figure 3, labor productivity in agriculture has stagnated despite a rapid decline in the employment share, which explains the rapid decline in the agricultural GDP share. In contrast, the non-agricultural sector displays falling trends in productivity combined with a rise in its employment share. Therefore, this combination shows that the pace of labor migration out of the stagnating agricultural and rural economy has exceeded the pace of growth in the non-agricultural sector. The problem is as much of non-growth in agriculture as it is of labor absorption outside agriculture. As will be shown later, the challenge in the non-agricultural sector comes from the oversized, low-productivity service sector that is absorbing most of the labor from agriculture.

Source: Based on data from WDI 2009 and FAOSTAT 2011.
Figure 3: Trends in labor productivity and employment shares among African countries, 1980-2008

Source: Based on data from WDI 2009 and FAOSTAT 2011.
The contribution of structural change to productivity growth

The picture becomes much clearer with the decomposition of the contribution of individual sectors to growth and the role of structural change. The contribution of a given sector is calculated by multiplying its employment share at the beginning of the period \( \phi_{t0} \) with the change in productivity for the sector at the end of the period \( \Delta P_{tn}^{sec} \). The residual of overall GDP growth that is not accounted for by the contribution of individual sectors corresponds to the contribution from structural change. The latter arises from the movement of labor between sectors and the differential changes in sectoral productivity. The results are presented in Figure 4 and in Figures a1 and a5 in the Annex. The non-agricultural sector is dominated by the low-productivity service sector, which accounts for more than 50 percent of African economies’ GDP based on latest available statistics (WDI 2009). In reality, the service sector includes the largest segment of underemployed persons in the informal sector. A significant share of labor migrating from the agricultural sector lands in the informal segment of the non-agricultural sector. This segment tends to be less productive than agriculture, which can explain the rapidly falling trend in labor productivity in the non-agricultural sector depicted in Figure 3.

Figure 4: The contribution of structural change to productivity growth among African countries

Source: Based on data from WDI 2009 and FAOSTAT 2011.

The direction of movement of labor and changes in sectoral labor productivity determine the contribution of individual sectors to overall productivity growth. As shown in the numbers in Figures a1 and a2, the contribution of the non-agricultural sector has been overwhelmingly negative. In contrast, the contribution of the agricultural sector has been positive for Africa as a whole and for most major sub-regions. The onset of the growth recovery process in the mid 1990s indicates some improvement in both sectors’ contribution to productivity growth. For the non-agricultural sector, the average contribution for Africa as a whole has turned positive. It remains negative only for North Africa and Central Africa, but at considerably reduced levels.
For agriculture, its average contribution has risen strongly but with marked difference across regions. In particular, the sector’s contribution to growth has remained negative in West Africa.

The estimates of the contribution of structural change to overall growth are presented in Figure 4. In contrast to individual sector contributions, the contribution of structural change to growth is negative for Africa as a whole and in every single major region, with the exception of North Africa and Central Africa during the 1980s and early 1990s. The negative contribution is particularly significant during the post 1990s’ recovery period. The big exception here is West Africa, which has shown a significant shift between the two periods. This result is in line with the observed trends in labor movement and productivity growth (Figure 3): the migration of labor from agriculture into the lower-productivity service sector. It appears from these results that the unabated pace of rural urban migration has adversely affected overall productivity growth among African countries. Figures a3 and a4 in the Annex present the results for individual countries. In each graph, countries are ranked from lowest to highest contribution of structural change to productivity growth. In all, 44 percent or 22 out of 50 countries show a negative contribution of structural change to productivity growth during the earlier period, compared to about 30 percent in the later period.

**Sector imbalance, migration, and productivity-reducing structural change**

A main factor behind the negative contribution of structural change to productivity growth among African countries has been the outmigration of labor from a stagnating agricultural sector into a burgeoning informal service sector that has much lower productivity levels. There are no specific productivity numbers for the latter sector but there is no doubt that the sector constitutes the bulk of the non-agricultural sector in all African countries. The productivity trends shown in Figure 3 are therefore reflective of developments in the informal service sector. The case being made here is that the productivity-reducing structural change is the result of labor being forced out of a *stunted* agricultural sector into an *oversized* service sector.

To buttress that argument, the expected shares of the two sectors based on the level of development of African countries are compared to the actual shares. For that purpose, the relationship between per capita income and relative sector size was estimated for both agriculture and services using a sample including 210 countries over a period going from 1960 to 2008.1 Figures 5 and 6 show, respectively, the discrepancies between actual and expected sizes of the agricultural and services sector. The graphs rank countries in terms of actual size of the individual sectors. Invariably in all countries, the actual share of the agricultural sector in GDP is distinctly lower than the size that should have been expected based on the level of per capita incomes. Observed average shares are around 30 percent or nearly 20 percentage points below expected levels. The opposite is observed for the service sector in the majority of countries.

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1 The following random effects model was estimated: $y_{ist} = \alpha_i + x_{it}\beta + v_t + \epsilon_{it}$, where $y_{ist}$ is the log of sector-specific GDP share, $x_{it}$ is the log of per capita GDP, $v_t$ is the overall residual, $\alpha_i$ is the country-specific effects and $\epsilon_{it}$ is the time-variant residual. The results are:

$y_{ag} = 9.11 - 0.89x_{it}; R^2 = 0.75$ and $y_{ser} = 1.46 + 0.25x_{it}; R^2 = 0.29$. All coefficients are significant at 1% level.
Figure 5: Actual vs. expected agricultural sector GDP shares among African countries

Source: Author’s calculations.
Figure 6: Actual vs. expected services sector GDP shares among African countries

Source: Author’s calculations.
The extent of the sectoral imbalance can be seen by comparing sectoral shares among African countries to that of other developing regions. Figure a6 in the Annex shows that the average share of agriculture in GDP is significantly smaller among African countries compared to South Asian countries with similar levels of income. It is barely larger than the average share among countries in East Asia, the Middle East and North Africa, which have per capita incomes that are three times higher. The comparison also reveals a relatively oversized service sector. As can be seen from Figure a7 in the Annex, Africa has the highest average GDP share for services, only slightly lower than Latin America. Average per capita incomes among the latter countries are, however, nearly eight times higher than the African average.

Underperformance in the agricultural sector and the oversized service sector have delayed structural transformation in Africa; underperformance has also resulted in higher poverty levels observed among Africa countries. Figure 7 shows the relationship between poverty levels and the observed performance gap or the deviation between observed and expected agricultural GDP shares. The size of the deviation decreases away from the origin and along the x-axis. Countries with higher performance gaps also have higher poverty levels.

Figure 7: Agricultural sector underperformance and poverty levels

Source: Author’s calculations.
Trends in economic sophistication among African countries

An important part of structural change is that economies acquire greater capabilities as they mature to produce more sophisticated, higher valued goods. The basket of goods a country ends up producing competitively determines its level of economic performance and overall income level. Goods for which demand expands globally as incomes rise around the world can be exported in larger quantities and at high prices for a long time. Such goods are associated with higher levels of productivity and incomes. The more a country succeeds in producing such goods, the more wealth it will build, and the richer it gets over time. Using the expression by Hausmann et al. (2006), “countries become rich by producing rich-country goods”. In other words, “countries become what they produce”.

We use the methodology developed by Hausmann et al. (2006) to study the extent to which structural change among African countries is moving their economies on the path toward specialization in higher valued goods. They computed the level of income associated with specific products by taking the weighted average of per capita GDP of all countries exporting that good, using as weights the export shares of that product in an individual country’s exports. The product-specific income level is called PRODY. Hausmann et al. (2006) then calculated the productivity level of a given country as the weighted average of the value of PRODY for all the goods that are exported by that country, using as weights the shares of each good in the country's export basket. The productivity level is called EXPY, and is reflective of a country’s success in competitively producing and specializing in high value goods. The higher the value, the more the country is exporting products that tend to be associated with more mature economies and higher per capita incomes. The lower the value, the more the country tends to export primary, unsophisticated goods that are associated with lower levels of development and per capita incomes.

EXPY estimates are used to measure the extent to which structural change in African countries has enabled them to develop revealed comparative advantage in sophisticated, higher value goods. Estimates for the agricultural and non-agricultural sectors as well as for the overall economy are presented in Figure 8. The top graph shows the evolution of the average value of EXPY for Africa for all products from 1962 to 2000. After a rapid increase in the 1960s that saw the value of EXPY double from US$2,000 to US$4,000, no further progress has been observed. The value of EXPY for the next 25 years has hovered between US$4,000 and US$5,000. In comparison, the estimation by Hausmann et al. (2006) of EXPY for 97 countries from 1962 to 2000 yields mean values above US$10,000 (in 2000 US$). Similar estimates by Hausmann and Bailey (2007) for a sample of nine emerging countries from 1975 to 2004 produce values that are well above US$10,000 and as high as US$16,000.

The bottom graph of Figure 8 shows the trends in EXPY for agriculture and non-agricultural sectors. Estimates for the former sector are virtually flat and have not exceeded the US$1,000 mark over the entire nearly 50-year period. The estimates for the non-agricultural sector follow closely the average trends shown in the top graph, with a rapid increase in the 1960s followed by a fluctuation between US$3,000 and US$4,000. Although one would expect the industrial sector to dominate the product diversification process, it is striking that the agricultural sector has failed to make any positive contribution to economic sophistication since the 1960s. The estimates
bring out clearly the longstanding concern about continued specialization of African economies in agricultural raw materials. Even the upward shift in average EXPY estimates that is observed at the end of the period comes entirely from the non-agricultural sector.

**Figure 8: Trends in economic diversification among African countries, 1962-2000**

The lack of progress toward product sophistication in the agricultural sector has real strategic implications. First, it is hard for the sector to raise labor productivity and incomes if it fails to achieve comparative advantage in higher valued products with greater income elasticity. Greater product sophistication would allow African countries not only to raise the overall and unit value of export to global markets, but it would allow them to capture a greater share of the fast growing demand for urban food in regional markets. The latter is projected to grow by an additional US$100 billion by 2030 from just US$50 billion in 2005 (NEPAD 2009). Greater
product sophistication and trade performance in the agricultural sector is also important for the broader growth process. The review of a large body of literature by Badiane (1991) indicates that an additional 1 percent increase in agricultural export earnings can raise the rate of growth in the industrial sector by 0.4 to 1.8 percent. Furthermore, estimates by Delgado et al. (1998) suggest that an additional revenue of US$1.00 from sales of agricultural tradeables in local markets can generate an incremental income of between US$1.30 and US$3.30 in the broader rural economy.

The importance of product sophistication and trade performance for growth is also illustrated by estimates by Hausmann et al. (2006). They regressed GDP growth rates on country EXPY and an additional set of other variables including human and physical capital as well institutional quality. Their findings indicate that a 10 percent increase in EXPY raises the GDP growth rate by an average of 0.2 - 0.5 percent. They find the impact of EXPY on growth to be strongest among middle-income countries. Their analysis did not, however, yield significant relationships between EXPY and GDP growth rates among advanced countries or low-income countries. This finding may indicate that a minimum level of product sophistication has to be reached before the multiplier effects take hold.

The various multipliers presented above illustrate the cost to African countries in terms of lower growth, slow progress in structural change, and the failure to achieve greater product sophistication. Future growth strategies would have to focus on getting out of the low productivity trap in the agricultural sector and stimulating growth in the industrial sector and thereby accelerate the process of structural transformation. The following two sections discuss these strategic options.

Strategies to raise agricultural productivity and promote rural development

The preceding analysis indicates that structural transformation in Africa has not only been delayed, but that it has also been productivity-reducing in most instances. A particular problem has been the “stunting” or accelerated decline of the agricultural sector compared to the pace of overall economic growth. In terms of Figure 1, the slope of the line depicting the share of agricultural GDP has fallen faster than would have been justified by the process of economic growth. The flat trend in labor productivity shown in Figure 3 suggests that the share in agricultural employment has not declined fast enough. In Figure 1, this translates into a flatter slope of the line depicting the agricultural labor share. The combination of the two, that is the (temporary) shifting of the employment share line upward and that of the GDP line downward, means that the gap between the GDP and employment shares is larger than should have been expected at observed per capita income levels. The convergence process discussed in Timmer (2009) is being delayed further, with its implications on poverty levels and rural–urban inequalities.

It is easy to see now why revitalization of agriculture and increased productivity in that sector have to feature prominently in Africa’s future growth agenda. Fortunately, this viewpoint is also shared by African leaders, who in 2003 launched the Comprehensive Africa Agriculture Development Programme (CAADP)\(^2\). CAADP is a continent-wide framework to facilitate faster

\(^2\) The description of the CAADP process is based on Badiane et al 2011.
agricultural growth and progress toward poverty reduction and food and nutrition security in Africa. It seeks to promote policies and partnerships, raise investments in Africa’s agricultural sector, and achieve better development outcomes. It is an unprecedented, comprehensive effort to rally governments and other stakeholders around a set of key values and principles, create partnership mechanisms at continental, regional, and country levels, promote evidence-based and outcome-driven policy design and implementation, and establish inclusive dialogue and review processes to raise the effectiveness of the development process among African countries.

CAADP has defined a limited set of clear continent-wide goals, including the attainment of a 6 percent annual agricultural growth rate at the country level. For that purpose, the allocation of at least 10 percent of national budgets to the sector is another CAADP target. In addition, CAADP contains the following key values and principles:

1. **Leadership and ownership** of all aspects of the agenda at all levels by African decision-makers and their constituencies. Unlike previous development efforts that were frequently externally-driven, CAADP is a fundamentally home-grown agenda. It has the advantage of facilitating broad-based acceptance and raising the likelihood of better alignment with local priorities and concerns.

2. **Inclusiveness** of all major stakeholder groups to facilitate participation in planning and implementation decision making. Albeit far from perfect, no other development effort on the continent has invested heavily in creating a wide understanding and support of its goals and action agenda.

3. **Partnership and mutual accountability** among African governments, their constituencies and development agencies. A number of dialogue and review platforms have been established at the country, regional, and continental levels to support this principle.

4. **Evidence- and outcome-based planning and implementation** to improve growth and poverty reduction outcomes of agricultural sector strategies. One of the main innovations of CAADP has been the use of locally based empirical economic analysis to support strategic decision-making, priority setting, and investment planning in the sector.3

From an operational point of view, this strategy was established on the basis of four pillars to guide investments by leading regional economic communities4 and their member states. The pillars deal with: (i) sustainable land and water management; (ii) agribusiness development and market access; (iii) hunger and social safety nets; and (iv) science and technology.

One of the many innovations of the CAADP process is its broad use of high quality, locally based analysis to guide and inform decision-making processes on planning and implementation, as well as review and dialogue by stakeholders around agricultural program priorities and

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3 See the Regional Strategic Analysis and Knowledge Support Systems (www.resakss.org) that were established with three IT based platforms for West, East and Central, and Southern Africa.

4 The Economic Community of West African States (ECOWAS); the Common Market for Eastern and Southern Africa (COMESA); the Southern African Development Community (SADC); the Economic Community of Central African States (ECCAS); and the Union of Maghreb Arab (UMA).
outcomes. This approach is unprecedented in the majority of countries. An early impact of its adoption has been a much greater credibility of the agricultural agenda within national governments. This credibility has enabled ministries of agriculture to present higher quality strategy documents to their peers in government, articulate their agenda more transparently, and justify requests for increased funding by linking them to clear goals and outcomes. Together with efforts to promote inclusiveness, the transition to evidence-based planning has facilitated consensus among stakeholder groups and strengthened the position of the agricultural constituency in an unprecedented fashion.

The analysis which has been carried out as part of the CAADP agenda has systematically targeted a set of key strategic questions and examined alternative future growth and poverty reduction outcomes based on several possible policy scenarios. Routinely, the scenarios include at least: (i) continuation of pre-CAADP trends in agricultural sector performance; (ii) successful implementation of on-the-shelf pre-CAADP strategies, where they exist; (iii) realization of the CAADP growth target; and (iv) achievement of the millennium development goal (MDG) target of halving poverty by 2015. For the first two scenarios, the objective of the analysis is to project growth and poverty reduction outcomes by 2015. In the case of the third scenario, the objective is to simulate the expected rate of poverty decline, if the country under consideration manages to achieve the CAADP 6 percent agricultural sector growth target. The last scenario simulates the required agricultural sector growth rate to enable a country to achieve the MDG poverty target by 2015 or at a later date, depending on the extent to which the required rate of growth is judged to be realistic or not. The analysis also examines the potential sources of future growth and poverty reduction, not just at the level of agriculture versus non-agriculture, but also among various agricultural sub-sectors.

Other critical and innovative components of CAADP are: (i) the organization of a roundtable and signing of a country CAADP compact specifying policy and investment priorities and commitments guided by the analysis discussed above; (ii) the design of a comprehensive multi-annual agricultural sector investment plan by each country; (iii) the organization of a business meeting and an independent technical review to systematically evaluate the technical quality of country investment programs and to discuss funding and implementation modalities. The technical review includes evaluations of the extent to which CAADP values and principles, such as inclusive review, dialogue processes, and promotion of regional complementarities, are sufficiently embedded in country investment plans. The review also allows for an accounting of the extent to which best practices and success factors, identified in framework documents and related implementation guides that are prepared for each of the four pillars specified above, are incorporated into the plans. Moreover, it verifies whether the plans are consistent with long-term growth and poverty reduction goals that were agreed upon at the compact signing stage. Finally, the review allows stakeholders to evaluate whether proposed program interventions are adequately costed, logically constructed, and implementation ready.

While it is too early to say anything definitive about the impact of CAADP on the agricultural sector in Africa, there is no question that the implementation of CAADP is happening at a time when performance in the sector is strengthening (Badiane 2008). African economies have indeed been undergoing a remarkable economic and agricultural recovery over the last 10-15 years. Growth is accelerating and spreading to encompass an unprecedentedly large number of
countries. Total agricultural factor productivity rose by about 50 percent during the same period, and per capita food production has improved to reverse the decline observed during most of the 1970s and 1980s (Nin-Pratt and Yu 2008). It is particularly worth noting that the recovery was robust enough to survive the 2008 crisis and in fact growth has rapidly returned to pre-crisis levels within a relatively short period of time.

The broad adoption and implementation of the CAADP agenda at this particular time in the history of Africa’s agricultural sector development is of great significance. It offers the opportunity to sustain and deepen the recovery process. If, through CAADP, a large number of countries manage to maintain a 6 percent growth trajectory, living conditions on the continent would change dramatically within a generation. At the beginning of the last decade, only 5 countries exceeded the CAADP agricultural growth target of 6 percent. By the middle of the decade, the number had grown to 9. In 2009, the average agricultural growth rate for Africa as a whole as well as for two sub-regions (North and Southern Africa) exceeded the 6 percent target (ReSAKSS 2011). It is worth noting that this level of agricultural growth is similar to that witnessed by India during much of its Green Revolution.

Besides the improvement in planning and implementation of sector policies and strategies, sustaining the recovery process requires increased funding for the sector, a major CAADP goal. Conscious of the need to reverse trends in declining investment in the sector, African Heads of State at the 2003 launch of the CAADP agenda in Maputo, Mozambique committed to allocating at least 10 percent of government budgets to agriculture by 2008. As shown in Figures 9a, some progress toward that goal has been achieved but more needs to be done. Less than 10 countries have reached the 10 percent mark, while close to that number have budget shares exceeding 5 percent. Figure 9b offers an clearer picture of the changes that have taken place. Since the Maputo decision, the share of countries that have achieved the budget expenditure target has grown steadily. In contrast, the share of countries spending between 5 percent and 10 percent has declined, while the number of countries spending below 5 percent of their budget for agriculture has remained nearly unchanged. It appears from the trends depicted in Figure 9b that half of reporting countries have not yet responded to the call to raise agricultural funding. With the adoption of long-term investment plans in nearly 2 dozen countries in the last 2 years, it is to be expected that the number of countries moving toward the expenditure target will increase in the near future.

This expectation seems to be justified, based on the experience of Rwanda. Rwanda was the first to sign a CAADP compact in 2007 and complete an investment plan in 2009. According to data from the Ministry of Agriculture and Animal Resources, the country’s agricultural budget has nearly doubled from 2007 to 2009, from RWF 18.00 billion to RWF 31.00 billion, and more than doubled again to exceed RWF 66.00 billion in 2011. Its agriculture budget share has also doubled since the signing of the compact from 3.5 percent in 2007 to 6.8 percent in 2011.
Successful implementation of CAADP can help African countries boost productivity in the agricultural sector and reverse the patterns of productivity-reducing structural change discussed above. However, this would require continued commitment to the agenda by African countries, leadership and ownership by African governments and stakeholders, and full alignment by the international development community. With the ongoing changes in global food markets and the...
associated false sense of an African crisis that is being created, the biggest risk is that countries may be distracted from the strategic long-term focus of CAADP and instead be driven into a disruptive crisis management mode by an international community that is likely to turn to yet another event without hesitation. These potential diversions are of great concern, especially because the emerging long-term trends in global food markets should be seen as opportunities for African countries. This opportunity arises because the anticipated rise in food prices is taking place at a time of strong performance in Africa’s agricultural sector, growing resource constraints, and declining productivity among emerging economies in Asia and elsewhere.

In spite of the considerable impact that CAADP could have on African economies, it is also clear that a strategy focused solely on transforming the agricultural sector would fall short of creating the type of structural change needed among African countries. Therefore, CAADP needs to be accompanied by equally focused strategies to raise productivity in the manufacturing and service sectors. The contours of such strategies are described in the following section.

**Policies for successful economic transformation in Africa**

Structural transformation is the movement of labor from less to more productive sectors, such that overall labor productivity rises even with constant sectoral productivity levels. The problem in developing countries, as has been shown here for African countries, arises when: (i) labor migration stalls because of slow growth in the rest of the economy and/or rapid population growth; and/or (ii) value added in low productivity sectors such as agriculture fails to rise fast enough to erase the intersectoral productivity gaps.

Countries with successful structural change have universally achieved two things: moving labor from lower to higher productivity sectors and raising output in lower productivity sectors. Progress has to be achieved in three key areas to lead to this outcome: labor movement, productivity growth, and trade competitiveness. The movement of labor between lower to higher productivity sectors raises average productivity and incomes in the economy, even without any changes in sector productivity levels. This effect is magnified when accompanied with concomitant sectoral productivity growth.

**A new approach to rural development in future structural transformation policies in Africa**

The basic growth and development challenge is how to employ a growing number of people in an increasing number of rapidly expanding, high productivity sectors in order to reach a point where productivity and incomes converge across sectors. As shown by Timmer (2009), the convergence process has taken more time over the last 50 years. This duration in turn raises the burden on agriculture to provide a larger share of incomes for a longer period of time. The problem has been made more complicated for African countries due to underperformance in agriculture. Agricultural underperformance has primarily pushed labor into the service sector at a pace that has been considerably faster than output growth in the latter sector. Improving policies and raising investment to boost performance in agriculture, as being attempted under CAADP, has to be, therefore, a central element of structural transformation strategies. Accelerated agricultural growth is the most effective tool to generate the largest impact in terms of poverty
reduction in the short run. Rural growth also raises productivity in the rural areas and slows the pace of outmigration into the service sector.

The decade-long stagnation has created conditions that have made the effective pursuit of productivity enhancing strategies a more challenging undertaking. The extent of the challenges is illustrated in Figure 10. The top line in the graph indicates the level of poverty measured by the share of people living on one dollar per day for selected African countries. The bottom line denotes poverty levels in 2015, assuming the countries achieve the MDG target of cutting poverty by 50 percent. The clear bars represent the projected level of poverty, if the countries were to achieve the CAADP annual agricultural growth target of 6 percent.\(^5\) It appears that realizing that rate of growth would indeed allow many countries to achieve the MDG poverty target. But it would not be enough for several other countries. Yet, as shown by the shaded bars, nearly all of the countries would have to sustain double-digit rates of growth in agricultural public expenditures over many years to realize these outcomes. Such a rapid increase in public expenditures would be extremely hard if not impossible to sustain for the large majority of African countries. It constitutes the first challenge to boosting agricultural growth in pursuit of accelerated structural change and poverty reduction.

**Figure 10: Projected agricultural output and expenditure growth rates and poverty levels by 2015, selected countries**

![Graph showing projected levels of poverty and agricultural expenditure growth rates by 2015 for selected African countries.](image)

Source: Badiane and Ulimwengu 2009.

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\(^5\) Different poverty base years are used for the different countries.
The second challenge is reflected in the position of the 2015 target poverty line. The line indicates that average poverty levels among African countries would still lie around 30 percent, even after they have met the MDG poverty target. The anticipated high level of poverty will continue to put considerable pressure on African governments. They will have to deal with the symptoms of large-scale poverty and thus be forced to spend increasing amounts of money to address the social needs of the poor and vulnerable. Going forward, the biggest question facing African governments seeking to build on the ongoing recovery process is how to raise productivity enhancing investments while meeting the expenditure requirements of addressing social needs of the stubbornly large segment of the poor and vulnerable. This dilemma is a huge challenge, given limited fiscal resources and tight budget constraints under which most of these governments operate.

Figure 11 shows trends in social service expenditures compared to those in agriculture. There is no room in country budgets to sustain this rise in social expenditures and achieve a double-digit growth in agricultural expenditures. What is required is for African governments to take another look at social service provisions. The conventional approach is to look at social services from an entitlement point of view, with a primary objective of meeting people’s welfare needs. Part of that convention is to treat social services as homogeneous and to think about the impact on growth only as a function of the level of spending and efficiency of delivery. This is the wrong approach in African countries characterized by large-scale poverty that is rooted in low productivity in the main productive sector. What is required instead is a set of social policies designed to maximize their impact on labor productivity among the poor and vulnerable.

Figure 11: Trends in social services and agriculture expenditures among Africa countries, 1980=100

Source: Badiane and Ulimwengu 2009.
Social policy thus becomes an optimization problem, and the composition of services provided becomes more important than their level. The reason is that (i) social services are composite bundles of a variety of subservices, and (ii) the composition of these services, which affect labor productivity differently, is not growth-neutral. In other words, health, education, and social protection services consist of various types of sub-services with different impacts on long-term productivity. Consider a government spending an $x$ amount of money every year in the health sector, with the objective of improving average access to services across the country over a ten-year period. The same country could target a specific share of the same budget to control the seasonal diseases that curtail a significant share of the rural population during peak labor seasons. The same health budget would have a larger impact on agricultural productivity and rural growth in the latter case. The same reasoning can be applied to policies geared towards education for all compared to alternative policies that include a strong focus on vocational training to meet the growing skill needs among smallholders and other segments of the agricultural value chain.

There has not yet been a lot of research on the study of social services provision from an optimization point of view. But the existing literature indicates that there is scope to optimize the mix of social services to raise their impact on labor productivity. Estimates by Badiane and Ulimwengu (2009), using data from Uganda for health and Vietnam for education, show that an increase in expenditures to control malaria had an impact on efficiency that is twice as high as a similar increase in overall health services expenditures. In the case of education, an increase in expenditures on vocational training had significant efficiency and poverty effects, whereas none could be detected from expenditure increases on primary and secondary education.

In sum, what is being advocated here is an approach to social services that is similar to what has been done for infrastructure. When considering the impact of infrastructure on growth, it is an established convention to treat the various types of infrastructure — highways, feeder roads, tracks and trails, etc — distinctly as well as to consider the implication of their complementarities and geographic location. In other words, resource-constrained African countries have to search for practical strategies to create synergies between social services provision and productivity-enhancing investments so as to maximize the long-term poverty and growth outcomes of public expenditures in rural areas.

From an institutional point of view, the search for synergies would make it possible for governments to approach budget allocations between sectors from a win-win rather than a win-lose standpoint. This approach would increase cooperation between agriculture and social services ministries, reduce the tension around budget negotiations, raise the efficiency of public expenditures in the agricultural and rural sector, improve the effectiveness of the delivery of public goods and services in rural areas, and achieve better growth and poverty reduction outcomes. For instance, the ministry of agriculture would no longer consider budgetary resources going to social ministries as lost to agriculture. In turn, the latter would be more conscientious about the specific contribution of their programs to agriculture beyond the broader social targets in rural areas.
As summarized by Chenery (1960), the process of structural transformation is one through which the non-agricultural segment of the national economy undergoes a series of changes including: (i) a rise in the absolute and relative sizes of overall economic output coming from the manufacturing sector; (ii) a change in the number and nature of goods produced in the industrial sector; (iii) a change in the techniques used to combine labor, capital, and technology, as well as the level of costs related thereto, to produce the various goods in industry; and (iv) a change in the sources supplying the economy with existing and new products. The transformational challenges faced by industrial enterprises in this process are: (i) how to leverage existing assets into new and/or related businesses; and (ii) how to learn, and how to combine and recombine assets to establish new businesses and address new markets (Teece 2000).

More specifically, industrialization happens through the production of new, more sophisticated, higher valued goods. Hausmann et al. (2007) have developed a hierarchy of goods, identifying products that are associated with faster growth. Their work also shows that African economies tend to be located at the periphery of the product space with a concentration on low productivity goods. African countries therefore need an industrial strategy-renewal, along the lines of CAADP, with the goal of developing comparative advantage in, as well as a critical mass of, higher productivity goods. Hausman and Klinger (2006) and Hidalgo (2009) provide estimates of the distance countries have to travel in order to develop competitive advantage in higher value products on their way to economic diversification. The map of such distances can serve as a guide to designing future industrialization strategies to promote structural transformation.

Externalities that are linked to efforts by entrepreneurs to produce a new good for the first time constitute a major determinant of the capacity of economies to diversify into higher productivity goods. Economies diversify into such products because entrepreneurs successfully engage in what Hausmann et al. (2007) and Rodrik (2004) call a self-discovery process of finding out which goods can be produced profitably. They must try out a combination of new technologies and firm-level processes to discover the cost of producing these goods. The goal of industrialization policies should be to raise the number of entrepreneurs that can engage in the cost discovery process by addressing the above externalities. They include primarily information externalities and coordination externalities that can be significant deterrents to entrepreneurship growth among developing countries.

Information externalities arise because individual entrepreneurs have to bear the risk, uncertainty, and cost associated with discovering what products the economy is good at producing. When successful, they cannot capture the full benefit of their discovery as others are free to pick up production of the same good. Coordination externalities arise when the market fails to align investment and production decisions of individual entrepreneurs. This outcome could result because complementary services and inputs that are required for a profitable investment are too high for the individual entrepreneur to bear or are non-tradelable. Both types of

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6 Policies related to infrastructure development, in particular power, water, road, information and communications technologies, as well as to macroeconomic policies are treated extensively in the development literature and are not covered here. The World Bank has a new and comprehensive report on African infrastructure (World Bank 2009).
externalities reduce returns to investments by private entrepreneurs and slow the pace of growth in the industrial sector.

The new generation of industrialization strategies will have to address the above externalities effectively through technology, infrastructure, and macroeconomic policies. Rodrik (2004) defines a set of principles and key elements to guide industrialization strategies in developing countries. The strategy elements include:

1. Subsidizing self-discovery cost to raise private returns to the level of social returns through, for instance, financing of feasibility studies, technology trials, and market intelligence;
2. Facilitating access to long term, higher risk finance through development banks, venture funds, and long-term commercial loan guarantees; and,
3. Promoting public research, development, and vocational training.

The principles of industrialization policies call for: (i) focus on the reduction of discovery cost related to new technologies, processes, and products and not on individual sectors; (ii) targeting of activities with spillover and demonstration effects; and (iii) defining an exit strategy through clear benchmarking to define when an intervention is successful or has failed. Effective design and implementation of these policies would also require transparent public-private coordination mechanisms to avoid the myriad risks associated with public intervention and reduce moral hazard. The review, dialogue, and coordination mechanisms under CAADP offer a good example to follow.

The ultimate objective of industrialization policies is to expand the stock of technology capabilities and their application to create new, higher valued goods. Technological capabilities, as defined by Lall (2000), are “the complex of skills, experience, and efforts that allow a country’s enterprises to efficiently buy, use, adapt, improve, and create technologies”. A complicating factor is that technology learning and innovation tend to be path dependent and cumulative, thereby creating a pattern of specialization and comparative advantage from which is hard to escape. Learning tends to be local: firm level learning takes place in connection with existing processes, products, and transactions (Teece, 2000). Therefore, innovation and movement to new, higher value products requires learning outside firms’ existing processes, products, and transactions. The longer the distance to be traveled in the “product space” towards these new products, the more formidable the transformational challenges and the higher the related risks and costs tend to be; thus, the stronger the rationale for public action. In other words, moving to new, higher valued goods requires the introduction of different technologies and processes involving costs, risks, and uncertainties. The role of public action would be to lower the cost of discovering and implementing profitable technologies.

Public action in support of industrial growth has been a central element of economic development strategies in emerging Asian economies. In a slight deviation to one of the principles of industrial policies suggested by Rodrik, emerging Asian countries have, universally, specified strategic sectors as the focus of their industrialization policies (Dodgson 2000). In the example of the electronic industry, Mathews (1996) finds that "in all countries, governments

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7 See also Stiglitz (1987) on localized learning and implications for technology adoption and innovation.
have played a key role in shaping the industry's development, laying down conditions within which companies would operate, and reducing and spreading the risk for investments in advanced technological activities."

The development of agribusiness value chains and the modernization of the service sector in future structural transformation policies

The patterns of structural transformation marked by an oversized, low productivity service sector and underperforming agricultural sector implies that African countries need a labor productivity raising strategy for the service sector; this strategy needs to go alongside smallholder-friendly agribusiness development. Industrialization strategies must therefore target, in the short and medium run, entrepreneurship growth in the informal service sector and the traditional agricultural sector. Technology and innovation policies should seek to enhance technical capabilities and entrepreneurship in both agribusiness and informal sector industries. The current growth recovery is producing a rapidly growing middle class, and a sustained demand for processed urban food, housing, and related household equipment. The example of palm oil and rubber in Malaysia and cassava in Thailand demonstrate amply the significant potential for innovation and entrepreneurial growth in the agribusiness sector. Success stories can also be found among African countries, in particular in the processing of local food staples such as cassava in Nigeria and millet in Senegal. The scope for enterprise growth and innovation in the staples sector should be significant in Sub-Saharan Africa, judging from the projected rise in urban demand for local food to $150 billion by 2030. The same projections indicate potential income gains of $30 billion for local smallholders, should African countries succeed in positioning domestic sectors competitively in these markets (NEPAD 2009).

Technology and innovation policies also need to address the needs of the farming segment of the agribusiness value chain. African countries will in particular need to start investing heavily in the training, research laboratories, and other infrastructure required to develop biotechnological capabilities in order to compete in domestic and global agricultural markets. The current debate on genetically modified organisms is particularly unhelpful and distractive in this respect. The real strategic issue facing African countries should not be whether or not to allow or ban genetically modified organisms (GMO) based food. The real issue is whether or not African societies have enough capabilities in the broader field of biotechnology to catch up with the rapid developments around the world. They will otherwise be wiped out of the future global food systems. The case of the cotton sector is a very good example. Just a few years ago, West African producers had strong quality and cost advantages that allowed them to compete successfully in global markets. Their position is now being seriously threatened by the embracing of biotechnology cotton in major competing countries.

The strategy should also put emphasis on enterprise creation and growth in the service sector, which in national statistics includes the large informal sector dominated by handicrafts, metalwork, woodwork, furniture, garments, and leather products. It is unlikely that agriculture alone can generate the rate of employment growth needed to erase the backlog of unemployment and underemployment let alone absorb future growth in the labor force. The formal industrial sector is still small and would take a long time to make a major impact on the broader labor market. The service sector has become a major reservoir of low productivity labor due to the
pattern of structural change discussed earlier. Growth in that sector would therefore play an important role in employment creation and productivity growth among African countries.

In their studies of endogenous industrialization, Sonobe and Otsuka (2006; 2011) identify key sources of market failures that hamper modernization and growth in the informal sector. They include transaction costs related to information asymmetry and contract enforcement, innovative knowledge spillovers, and insufficient managerial capital. They propose the cluster based approach that has played a key role among Asian countries as a possible option for Africa. Required organizational competencies and other productive capabilities among enterprises in the informal sector are often tacit and not codified. Replication and imitation are therefore limited unless facilitated through clustering, which allows skill transfer through movement of labor. They see in cluster based industrialization (CBI) advantages related to technology spillover, in addition to information spillover.

CBI seems to be the best approach to facilitate migration of informal enterprises in the service sector into the more productive, formal segment of the economy. CBI could also serve as a strategy to develop industrial activities in rural towns. In their recent comparative study of clusters between Asian and African countries, including Kenya and Ethiopia, Sonobe and Otsuka (2011) found that clusters in the latter countries tended to suffer from declining profitability as they expand through new entrants. The reason is that lack of continued innovation and the emergence of larger enterprises mean that the number of enterprises keeps growing and profitability keeps falling. Growth within the cluster eventually ceases. The leather industry in Ethiopia was the only exception. Given the lack of effective industrialization strategies, CBI or otherwise, it should not be a surprise that the authors did not encounter successful clusters. The lessons from Asia do point to some potential for CBI to work in Africa’s informal sector.

The double challenge of addressing productivity both in the informal and agricultural sector in Africa requires CBI strategies to also include the agribusiness sector. CBI in agribusiness would focus on areas and sectors with confirmed high productivity and technology spillover potential, such as peri-urban processing industries, river basin areas, and other high agro-climatic potential areas, as well as regional transport corridors. CBI activities would target industry-centered technology research, quality management infrastructure, regulatory services, trading infrastructure, smallholder integration, and vocational training. In particular, CBI would promote agribusiness value chain development through the development of a variety of activities—adapted packaging and processing technology, quality management services, institutional design of procurement and distribution networks, production technology and practices, and financial intermediation services.

Conclusions

Following decades of stagnation and even decline, African economies are growing again. Growth has been strong, broadly based, and sustained over more than a decade. Underneath the recovery are troubling trends that will need to be addressed effectively. The pace and pattern of economic transformation over the preceding decades suggest that structural change has been historically productivity-reducing. The reason has been the movement of labor out of an
underperforming agricultural sector to an oversized, low-productivity service sector. The problem was made worse by the lack of effective industrialization strategies that prevented African economies from diversifying into higher productivity goods.

Sustaining and building on the current recovery process to raise incomes and reduce poverty among African countries would require innovative strategies to revitalize agricultural growth. Such strategies would have to consolidate the progress under CAADP. They would include a new approach to rural development with greater synergies between social service provision and productivity enhancing investments in order to maximize the impact of public expenditures on labor productivity in rural areas. A new approach to industrialization policies is also needed to promote transition of African economies to higher valued products. In addition to conventional priority areas such as improved macroeconomic policies and infrastructure investment, there is a need for technology and innovation policies to support enterprise growth not just in the formal industrial sector, but also the informal sector.
Annex

Figure a1. Agriculture and non agriculture productivity contribution, 1980-1995


Figure a2. Agriculture and non agriculture productivity contribution, 1995-2005

Figure a3. Structural change contribution, 1980-1995


Figure a4. Structural change contribution, 1995-2000

Figure a5. Structural change contribution

Figure a6. Average share of agriculture in GDP

Source: WDI 2009.

Figure a7. Average share of services in GDP

Source: WDI 2009.
References:


Core literature on agriculture and structural change in Africa


Johnston and Mellor provide a systematic description of the many contributions of agriculture to overall economic growth, ranging from provision of increased food supply and foreign exchange to the generation of (i) fiscal resources to invest in the rest of economy and (ii) personal incomes to buy goods produced by the manufacturing sector. This is followed by a detailed analysis of the complexity of designing appropriate strategies to effectively exploit these various contributions, which arise from the fact that the contributions are not straightforward and may conflict with one another and with other goals outside agriculture. The authors define 3 phases with distinct policy priorities in order to reconcile these contradictions. Phase 1 focuses on social innovation to remove the institutional, social, and cultural constraints to improved farming practices. Phase 2 is on technological innovation through the development of systems for the provision of modern inputs and services to raise productivity and expand production based on labor-intensive and capital-saving technologies. Phase 3 focuses on emphasizing the penetration of mainstream financial services markets and the development of capital-intensive labor saving technologies in the late stages of development.


Timmer describes the structural transformation pathway that is illustrated by falling shares of agriculture in output and employment, rising shares of industry and services, the migration of rural workers to urban centers, and a stabilization of population growth. He emphasizes the productivity gap and income convergence gap in the course of the transformation process. The gaps arise because at the early stages of growth acceleration, the share of agriculture in gross domestic product (GDP) falls faster than its labor share, thus leading to falling agricultural productivity and incomes compared to other sectors. At some point, as overall incomes grow, a reversal takes place and the two shares start to converge. Analyzing the data from a large sample of countries over several decades, Timmer finds that the turning point or the level of per capita income when the gap starts to narrow has been occurring at progressively later stages of the growth process, that is at more and more higher per capita income levels. Different structural transformation paths are introduced and used to analyze the experience of major developing regions.


The paper uses historical parameters derived from growth experience of the United Kingdom to study the relationship between the onset of industrialization and long-term income growth, on the
one hand, and the pace of productivity growth in agriculture, on the other. The authors link the difference in incomes and economic structure across countries to the pace of agricultural productivity growth. They further analyze data from 62 developing countries from 1960-1990 and find the following: (i) a negative relationship between agricultural productivity growth and the share of agriculture in employment; (ii) a negative relationship between the share of employment in agriculture and the ratio of agricultural to non-agricultural productivity; and (iii) a positive relationship between agricultural productivity growth and labor migration out of agriculture. They also examine the relative contributions of growth in agriculture and the non-agricultural sector as well as of structural change to overall GDP growth.


Structural transformation is the movement of labor from less to more productive sectors, such that overall labor productivity rises even with constant sectoral productivity levels. After examination of inter-sectoral productivity gaps, the authors decompose the change in overall labor productivity to isolate the impact of structural change among African, Asian, and Latin American countries. The results show that the productivity gaps, which are reflective of allocative inefficiencies, are largest at lower levels of development. The decomposition results indicate that structural change has been productivity-reducing in Africa and Latin America, in particular. The opposite holds for Asian countries.


The paper reviews past growth and poverty reduction performance among African countries, projected growth and poverty outcomes under the Africa-wide development initiative, the Comprehensive Africa Agriculture Development Programme (CAADP), and the required levels of public expenditure to finance the Programme and achieve the above outcomes. The authors stress the significant challenge arising from competing needs of raising investments in productive sectors such as agriculture to accelerate long term growth, on the one hand, and expanding the provision of social services to mitigate the short-term impact of large scale poverty, on the other. Noting the tight budget constraints facing most African countries, the authors argue for a strategy that would optimize public expenditures on social services such as to maximize their impact on labor productivity among farm households. An analytical framework is developed to support such a strategy, which would approach social services delivery from a productivity enhancing rather than an entitlement point of view.


The authors’ starting point is the fact that the process of economic development is one through which countries produce a larger share of higher value products. They show that knowing and investing in activities that an economy can produce at low cost determines the patterns of
specialization and thus the pace of structural transformation and growth. Hausmann and Rodrik then argue that there is uncertainty in finding out what products an economy will be good at producing and that it is the role of individual entrepreneurs to make that discovery. Successful entrepreneurs have to bear the costs, risks, and uncertainties associated with discovery of such products. But they fail to capture the full benefits of their discovery due to fact that other entrepreneurs can imitate their products and enter the market to compete with them. They demonstrate that unless governments adopt policies that reduce the above cost, risk, and uncertainty, the number of entrepreneurs and investments in new activities to produce higher value goods will remain low. The process of structural transformation would thereby be delayed.


The authors argue that not all goods are alike in terms of their consequences for economic performance. Goods that face elastic demand in global markets so that a country can export large quantities of them without negative terms of trade effects are more associated with higher levels of productivity and incomes. The more a country produces such goods, the richer it gets. The authors compute the level of income associated with specific products by taking the weighted average of the per capita GDP of all countries exporting that good. They then calculate individual countries' productivity levels as the weighted average of income associated with all the goods exported by these countries, using as weights the shares of each good in each country's export basket. Their analysis shows that countries that develop the capacities to produce and export such goods are not only richer but are also more likely to grow faster in the future.


This paper expands the work by Hausmann and Rodrik (2003) on product specialization and the economic growth process. The authors argue that the capacity of a country to competitively produce new goods depends on the level and nature of assets and capabilities acquired in the production of similar goods at relatively low cost. The number and value of potential new goods that can be produced based on a given country's acquired assets and capabilities determine the scope for and speed of structural transformation in that economy. The authors introduce a measure of the degree of similarity in required capabilities between a given pair of goods, using as a proxy the probability that both goods are found in the export baskets of a same country. The total number of goods being produced by all countries at any given time defines what they call the product space. The total number of goods that require assets and capabilities that are closely related define the product density in that part of the space. The pattern of specialization of a country and the structure of the product space, determine its pace of structural transformation.


The process of formation and development of industrial clusters as part of long-term industrial development among Asian countries is analyzed. The authors propose a model of endogenous cluster-based industrialization which describes the role of geography, transactions costs,
innovation, imitation, and spillovers on the creation and expansion of industrial enterprises. They outline a strategy of industrial development which is based on the above model and encourages support for cluster formation and innovations with the combined effect of reducing transaction costs, stimulating enterprise creation, expanding production quantities, and improving product quality.


Teece's central message is that the firm is the engine of growth and that understanding the development process requires understanding development inside the firm. He defines two transformational challenges faced by enterprises in an industrializing economy from a developmental point of view. One challenge is how to leverage existing assets into new and/or related businesses. Another is how to learn, and how to combine and recombine assets to establish new businesses and address new markets. Teece discusses the role of firm competences and capabilities and distinguishes static and dynamic elements that determine firm growth and thus the pace of structural change and development.


The importance of technological capabilities and technological learning and their role in the development of a nation's economy are the focus of this work. Lall defines national technological capabilities as "the complex of skills, experience, and efforts that allow a country's enterprises to efficiently buy, use, adapt, improve, and create technologies". Technology learning and innovation are seen as path dependent and cumulative, creating a pattern of specialization and comparative advantage which is hard to break out from. Incentives and institutions that promote investment in technology learning are therefore discussed systematically. Examples of Asian countries are used to illustrate indicators and determinants of technological competence.


Creating the capacity to acquire and use science and technology developed elsewhere as well as scaling up domestic scientific research and linking it with industry are seen as two major challenges facing countries on the road to economic development. Both challenges exist simultaneously, although the first would predominate in countries at the very early stages of the industrialization process. The aim of science, technology, and innovation policies is to overcome these challenges and create conditions for structural change and growth. The paper defines each of these policies and illustrates how they have been used by Asian countries to foster economic diversification and growth.

This is an application of the endogenous industrialization theory developed by Sonobe and Otsuka (2006) to study the evolution of industrial clusters in Africa. The authors compare the development of the garment, leather, and metalwork industrial clusters in Kenya to comparable clusters in Bangladesh, China, Pakistan, and Vietnam. They find similarity in the patterns of cluster formation between the African and Asian countries. A major source of difference in cluster formation and evolution between the two regions relates to the occurrence or absence of multifaceted innovation, which is less prevalent among African clusters. The implications for enterprise profitability and growth as well as sector expansion are discussed in details.


Binswanger-Mkhize, McCalla, and Patel note hopeful signs for African agricultural development despite structural transformation having not yet occurred. Hopeful signs include the recent renewed economic growth, an end to the circular decline in agricultural prices, growing food demand at the national and regional levels, and increasing agricultural commitments by African governments. The authors recommend that countries seize the moment to support economic growth through country specific sound macroeconomic policies, removal of disincentives in the agricultural sector, increased agricultural technology investments, and improved agricultural institutions and services for farmers. The importance of aligning these strategies with the ongoing Comprehensive Africa Agriculture Development Programme implementation agenda is highlighted.
I want to thank the organizers of this Stanford symposium series on global food security issues for inviting me to be a discussant at today’s presentation by Dr. Ousmane Badiane. We have just heard a quite profound analysis of Africa’s agricultural problems, its structural history, and the possible ways forward.

The scope of the presentation was truly impressive—not only is the task one of “getting agriculture moving,” the title of Art Mosher’s influential little book (1966), but also of “getting industry moving.” Badiane understands that part of the failure of Africa’s agriculture lies with an even more depressing failure of its industrial sector. And although he covered all the ground in his allotted one hour, I think full justice to the topic requires a full course, not a lecture.

I come to this task with a reputation as a “professional Africa skeptic.” I tend to view the world through my Asian experience—I first started working in the National Planning Agency in Indonesia in April 1970, and gained nearly all of my professional understanding of the economic growth process by working in East and Southeast Asia.

My first experience in Africa was in the early 1980s, when the Kenyan parliament tabled its first “White Paper” (1981) on food policy. I was asked to discuss the paper after I had spent time in the field. There I observed the vast differences in multi-crop farming systems in Kenya from the much more uniform, rice-based farming systems with which I was familiar on Java. My conclusion at the time was that agricultural development would be more difficult in Africa, even in such favored regions as Kenya, because of the great diversity of the farming systems and the complexity of developing profitable new technologies for them.

But more troubling for me was the policy approach being followed by the government—my report argued that “you are raping your countryside.” Despite significant success in raising agricultural output between 1970 and 1980, the economic framework for agriculture was highly exploitive and urban oriented, especially because of macroeconomic policies and marketing regulations. It was hard to imagine how the country could continue to develop its smallholder agriculture with such an anti-rural bias.

As the 1980s played out, this concern seemed amply justified. Africa went through a series of economic crises and more-or-less forced structural adjustment programs imposed by the donor community, and agricultural productivity fell in many countries. At the same time, Asia struggled with low commodity prices but continued to invest in its smallholder agriculture, especially rice and the labor-intensive export crops such as rubber, coffee, palm oil and cocoa. Over the decade, agricultural productivity continued to rise, the structural transformation was quite rapid, and poverty was significantly lower in Asia in 1990 than it was in 1980.

By the end of the 1980s and early 1990s, it became fashionable to seek “lessons from Asia for Africa.” USAID sponsored a series of conferences on the topic, with assistance from Winrock
International (Seckler 1993). As a commentator in that series, I laid out three major concerns for Africa’s agricultural development from the perspective of Asia’s historical record.

First, and somewhat paradoxically, wages in Africa were not low enough to compete with Asian workers, in either labor-intensive manufactured goods, or in agricultural export crops. It was hard to see how Africa could develop a dynamic urban economy that would help pull up labor productivity in rural areas as well. And this was before the hundreds of millions of surplus workers in China entered the world labor market as additional competitors.

Second, Africa had completely lost the capacity to do state of the art agricultural research on either food crops or export crops. Asia was making rapid progress on both. As a consequence, Africa was simply no longer competitive in world markets for many of its agricultural products—especially palm oil and rubber, but coffee and cocoa were also threatened by new Asian producers.

Third, the serious governance issues that were apparent in Kenya in 1980 showed no signs of being resolved. If anything, the anti-rural bias was becoming stronger, reinforced by the availability of very cheap food in world markets to provision the major coastal cities. Much of this imported food was made even cheaper through aggressive food aid policies pushed by the OECD countries. It was clear to me that easy availability of food aid had a clear disincentive impact on the policy environment for agriculture, even if the econometric evidence says that it had little short run impact on local market prices and incentives for farmers.

So, question number one following Dr. Badiane’s lecture: Has the Africa-Asia divergence begun to close?

My second question follows up on the implications of the startling finding that the structural transformation in Africa has been “backward,” that is, it has lowered labor productivity rather than raising it. Migration of labor has been from relatively high productivity farming activities to very low productivity jobs in the informal rural and urban service sectors.

This “push” of labor out of agriculture into the service sector has important implications for the nature of the development strategy that should be pursued. In the classic “labor surplus” model developed by W. Arthur Lewis (1954), and the basis for much of Asia’s strategic approach, low productivity (“surplus”) labor is pulled out of agriculture and employed at higher productivity in a rapidly growing industrial sector. Wages are low in both sectors until the surplus labor runs out, and these low wages permit the industrial sector to make large profits that are reinvested in expanding factory capacity, which leads to more industrial employment.

If the Badiane story is right, the surplus labor in Africa now appears to be in the informal service sector. A strategy of raising labor productivity on farms, thus freeing up food and labor for the industrial sector, will not have the same impact it had in Asia. Raising productivity in the informal sector would seem to be a much trickier task, with no clear technological innovations available that would match the Green Revolution in its broad-scale and general equilibrium impact. These concerns are similar to those raised by the RuralStruc research program, jointly hosted by the World Bank and the French development agency (World Bank 2011).

The potential importance of this informal service sector thus highlight’s Dr. Badiane’s concern for the role of social services in poverty alleviation. If social services focus on safety net
provisions based on entitlement mechanisms, the resources will not be available for the kind of social services needed in the health and education sectors that will build human capital and the potential productivity of workers in the informal service economy.

My third question grows out of Dr. Badiane’s plea for “evidence-based” policy reforms. Although I understand the plea in terms of rejecting the traditional interest-group based approach to policies, or ideological approaches, I think it is very important to clarify what kind of evidence can be brought to bear in policy analysis.

In particular, within the economic development community in the last decade, “evidence-based” has come to mean evidence from randomized controlled experiments, where selection bias in project and program evaluations can be eliminated, thus providing accurate assessments of how well specific interventions actually work in a “with versus without” context instead of a “before and after” evaluation.

The problem is that randomized trials simply cannot be used for the key policy decisions. How should exchange rate policy be managed? What border controls on food trade are desirable? What investments need to be made by sector? Within each sector? To answer these kinds of policy questions, the only resort is to comparative policy analysis and good economic history. Virtually no Ph.D. programs in economics, or even in development economics, teach these skills.

My final question has to do with what happens if Africa does begin a “successful” structural transformation by getting both its agricultural and industrial sectors “moving.” The Asian experience during this process has been a uniform widening of the gap in labor productivity between the industrial (and modern service) sectors and labor productivity in agriculture, even as that productivity is actually increasing.

A widening productivity gap had (and has) profound implications for agricultural price policy in Asia (Timmer 2009). Despite rising wages in rural economies, and rapidly falling poverty, the widening gap put enormous political pressure on policymakers to intervene on behalf of an agricultural economy that was falling behind in relative terms. The advent of democratic governments actually exacerbates this pressure, even if such governments are the only hope for reduced corruption and better economic governance more broadly. So the question is, how will Africa cope with these new pressures?
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India 1960-2010: Structural Change, the Rural Non-farm Sector, and the Prospects for Agriculture

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Abstract

This paper looks at past and likely future agricultural growth and rural poverty reduction in the context of the overall Indian economy. The growth of India’s economy has accelerated sharply since the late 1980s, but agriculture has not followed suit. Rural population and especially the labor force are continuing to rise rapidly. Meanwhile, rural-urban migration remains slow, primarily because the urban sector is not generating large numbers of jobs in labor-intensive manufacturing. Despite a sharply rising labor productivity differential between non-agriculture and agriculture, limited rural-urban migration, and slow agricultural growth, urban-rural consumption, income, and poverty differentials have not been rising. Urban-rural spillovers have become important drivers of the rapidly growing rural non-farm sector—the sector now generates the largest number of jobs in India. Rural non-farm self-employment has become especially dynamic with farm households rapidly diversifying into the sector to increase income.

The growth of the rural non-farm sector is a structural transformation of the Indian economy, but it is a stunted one. It generates few jobs at high wages with job security and benefits. It is the failure of the urban economy to create enough jobs, especially in labor-intensive manufacturing, that prevents a more favorable structural transformation of the classic kind. Nevertheless, non-farm sector growth has allowed for accelerated rural income growth, contributed to rural wage growth, and prevented the rural economy from falling dramatically behind the urban economy. The bottling up of labor in rural areas, however, means that farm sizes will continue to decline, agriculture will continue its trend to feminization, and part-time farming will become the dominant farm model. Continued rapid rural income growth depends on continued urban spillovers from accelerated economic growth, and a significant acceleration of agricultural growth based on more rapid productivity and irrigation growth. Such an acceleration is also needed to satisfy the increasing growth in food demand that follows rapid economic growth and fast growth of per capita incomes.
India 1960-2010: Structural change, the rural non-farm sector, and the prospects for agriculture

Introduction

All across the industrialized world, prior to rapid economic growth and structural transformation, agriculture accounted for the bulk of the economic output and labor force. Because productivity in the non-agricultural sector was higher than in the agricultural sector, the share of agriculture in total GDP fell short of its share in the labor force. As industrial growth took off, industry became even more productive, and the productivity differential with agriculture increased. As a result of rapid economic growth the share of agriculture in GDP fell much faster than the share of agricultural labor, and the inter-sectoral differential in labor productivity widened. Farm incomes visibly fell behind incomes earned in the rest of the economy. “This lag in real earnings from agriculture is the fundamental cause of the deep political tensions generated by the structural transformation” (Timmer 2009, p6, emphasis in original).

During structural transformation employment grows rapidly in the non-agricultural sector and labor is pulled out of agriculture at a speed that depends on the labor intensity of industry and services. Convergence is driven by rapid agricultural productivity growth that allows for a reduction of labor input per unit of output. A turning point is reached when the labor productivity differential between the sectors starts to diminish and the share of labor in agriculture starts to decline faster than its share in output. Korea from the late 1960s is a typical example, as illustrated in Figure 1, that shows the share of agriculture in employment and in GDP, and the difference between them, plotted against GDP per capita.

Figure 1: Structural transformation in Korea

This paper deals with the following topics: It first characterizes the structural transformation in India and China. It then looks at the Indian case in greater detail, first its agricultural growth and productivity growth, and then at employment, unemployment, and wage trends. The next section asks the question why, in the presence of rapid growth of the differential in labor productivity between the non-agricultural sector and the agricultural sector, and in the presence of limited rural-urban migration, has there not been a rising divergence in rates of poverty, and in per capita incomes and consumption? The next section on the rural non-farm sector shows that this is explained by the rapid growth of the rural non-farm sector, especially rural non-farm enterprises of farmers, and associated employment growth. After summarizing the findings on employment and poverty trends across sectors of the economy, the paper shows that the structural transformation in India is a stunted one, in which workers move primarily from the agricultural sector to the rural non-farm sector, rather than to more secure jobs with pension and health benefits in the urban economy. The final section develops a vision for agriculture and rural poverty reduction, and discusses policy implications on how, under the constraints of limited urban labor absorption, rural incomes can nevertheless be increased.

**Structural transformation in India and China**

Compared to international experience India’s structural transformation has been slow and atypical, mainly on account of a low share of manufacturing in the economy and of its disappointing growth and employment performance. At the same time, the share of the agricultural sector in GDP has declined and the remaining industrial sectors and services have shown growing GDP shares. Absorption of labor in the urban economy has been slow, and rural-urban migration has been far less than could have been expected in a rapidly growing economy. Therefore, the difference between the share of agriculture in the economy and its share in the labor force has widened significantly (Figure 2). At the same time, the accelerating growth of the economy since the 1980s did not lead to an acceleration of the agricultural growth rate. As a consequence of high non-agricultural growth, low agricultural growth, and continued growth of the agricultural labor force, labor productivity in the non-agricultural sector and the agricultural sector has widened at an accelerating rate, and their ratio now stands at over 4.2. These data show that India is still far away from a turning point in its structural transformation, where the shares of agriculture in GDP and in the labor force are starting to converge, and the productivity differential between the non-agricultural and the agricultural sector starts to narrow.
Figure 2: Structural transformation of the Indian economy, 1961-2010

(a) Share of agriculture in labour force and in GDP

(b) Agricultural and non-agricultural output per worker

Figure 3 shows the same relationships for China. In panel (b) the intersectoral productivity differential in China has been rising even faster than in India, and reached a ratio of nearly 6 to 1. The agricultural share in GDP has been declining even faster, but so has its share in employment. As such the absolute difference between the shares has started to decline.

The slow decline in the agricultural labor force is a consequence of the still relatively high rate of population growth in India, 1.6 percent in the past decade, and the relatively slow rate of urban rural migration. In China, on the other hand, the population growth rate has now declined to almost zero, and rural-urban migration has involved around 220 million workers in the past two decades.

**Figure 3: Structural transformation of the Chinese economy, 1978-2010**

(a) Agricultural shares of labor and output  
(b) Labor productivity in non-agriculture and agriculture


The relatively slow rural-urban migration rate is a consequence of the low share of manufacturing in the Indian economy, which has hovered around 16 percent of GDP since 1980. China’s share of manufacturing has stayed at around 33 percent since 1991. Similarly, the share of industry (that includes manufacturing) has grown slowly in India from around 25 percent in

---

1 Urban populations grew at the rate of 2.76 percent in the intercensus period from 2001-2011. Of this, natural population growth accounted for 44 percent, while the remaining 56 percent were accounted for by reclassification of rural areas to urban areas and by rural-urban migration. A large share (not yet quantified) of this second component is accounted for by the reclassification of rural to urban areas which proceeded at a rapid rate. Migration clearly is a fairly low contributor to urban population growth (Bhagat 2011).
1989 to around 28 percent today, while it has been around 46 percent in China ever since 1993. As a consequence, the GDP share of services has grown to well over 50 percent in India, more than 20 percent above the industry share, while in China it remains below the industry share at around 43 percent (Binswanger and d’Souza 2011a). The poor development of industry in India, and of labor intensive manufacturing in particular, has led to adverse urban employment consequences.

**Figure 4: Share of sectors in GDP in India**

![Share of sectors in GDP (%)](image)


**Agricultural growth and productivity growth**

The 1980s were the golden years of Indian agriculture during which the growth of agriculture (3.3 percent), labor productivity (2.3 percent), and total factor productivity growth (2.0 percent) were at their peak (Table 1). Much of this growth can be attributed to the spreading of the Green Revolution across most regions of India.
Table 1: Growth of agriculture, agricultural productivity and labor force

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Growth rates for decades in percentage or three year avg. centered on last year shown</th>
<th>Average growth rate of 2006-2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural GDP growth</td>
<td>3.8</td>
<td>1.5</td>
</tr>
<tr>
<td>Growth of Agric. output/worker *</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Total factor productivity growth**</td>
<td>0</td>
<td>0.8</td>
</tr>
<tr>
<td>TFP growth in China</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total population growth</td>
<td>2.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Agricultural labor force growth</td>
<td>1.4</td>
<td>1.7</td>
</tr>
<tr>
<td>Non-agricultural labor force growth</td>
<td>2.7</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Note: *Constant US$ of 2000, **Fuglie forthcoming, to 2007 only.

All these growth rates declined in the 1990s and 2000s. The decadal averages hide a deeper slump in agricultural production and productivity growth from the mid-1990s to the first half of the 2000s. A good illustration is the behavior of the annual total factor productivity (TFP) growth shown in Figure 5. While it hovered around 2 percent during the 1980s, it slowed to near zero in 2001 only to rebound afterwards and to reach 3 percent and above in 2006 and 2007. Growth of agriculture also accelerated to slightly above 3 percent in the years since 2006, which explains the decadal growth of agriculture of 2.8 percent despite the poor performance during the early 2000s. However, the growth rate is still around 1 percent below the target rate of the Government of India for agriculture at 4 percent. Parikh et al. (2011) also show that rates of growth of agriculture in excess of 4 percent are needed if the economy grows at more than 8 percent per year, and imports of agricultural commodities are limited to less than 10 percent of domestic availability. The rising direct demand for food associated with rapid income growth, and the rising indirect demands for agriculture as intermediary inputs from other growing sectors of the economy lie behind this increased need in the required agricultural growth rate.
Figure 5: Annual total factor productivity growth rates

![Graph showing annual total factor productivity growth rates]

Source: Fuglie forthcoming.

Table 1 also shows that since 1980 the TFP growth rate of agriculture in China has been persistently higher than in India, close to or exceeding 3 percent in all three decades since. As shown by the calculations of TFP growth of Fuglie (forthcoming), no other country in the world has ever shown such a prolonged period of high total factor productivity growth in agriculture. The faster structural transformation in China is therefore caused by its advantage in agricultural productivity growth.

**Employment, unemployment, and wage trends**

Rapid movement towards a structural transformation should show up in the Indian data by a tightening of the rural labor market and an increase in opportunities for rural-urban migration. This section shows that this is also not happening, and the following section instead shows that rural households are diversifying into the rural non-farm sector. The limited absorptive employment capacity of the urban economy has led the non-farm sector to become the main destination of growing rural labor forces. *While this is a structural transformation of sorts, it is a stunted one.*

**Rural and urban employment trends**

Table 1 shows that India’s population growth rate has slowed down from a peak of 2.3 percent in the 1970s to 1.6 percent in the 2000s and is expected to slow to about 1 percent in the current decade. The growth of the labor force has accelerated, however. In urban areas it grew at 3.1 percent in the last decade, while in rural areas the growth rate was 1.2 percent (Table 1), for a
total labor force growth rate of 2.8 percent. This is significantly larger than the population growth rate on account of the “demographic dividend” associated with a slowdown in the population growth rate. Hazell et al. (2011) cite UN population projections that suggest that the rural population will peak at 900 million in 2022, and that the rural labor force may continue to grow until 2045. *Clearly, the Indian economy as a whole is facing an enormous employment generation challenge in both urban and rural areas for more than the next 30 years.*

Rural and urban males have always had fairly similar labor participation rates while the rates for rural females have been much lower, and even lower for urban females (Figure 6).

**Figure 6: Trends in labor participation rates**

Since 1973 there has been little discernible trend in rural male labor participation and only limited fluctuations. Female rural and urban participation rates fluctuated from 1977-78 to 2004-05. During the early years of the century there were significant increases in participation rates, especially for females, in both rural and urban areas. Since then labor participation rates have gone down for rural females to their lowest level over the entire period. Himanshu et al. (2011) interprets the movement of rural women into the labor force between 1999-00 and 2004-05 as a response to the agrarian crisis of the period. The subsequent sharp drop in labor participation to 2009-10 is interpreted as a withdrawal from the labor markets as economic conditions improved again. Others have pointed to the very large increase in participation in education as a major reason for withdrawal of women from the labor market, but careful analysis by Choudhury (2012) suggests that this is not a good eplanation.

Choudhury (2011) also shows that in both rural and urban areas there are some common trends: a slight decline in the manufacturing share of employment, which is consistent with the constancy of the manufacturing share in the Indian economy and its far slower growth in the past decade than planned; a decline in the share of agriculture and allied industries; a sharp increase in construction; and a large share of the labor force in urban areas in trade, hotels and restaurants.

Source: Choudhury 2011.
(much smaller in rural areas) and in both areas they have stayed fairly constant. As a consequence, rural non-farm sector employment has grown especially fast.

The employment data also reveal a significant trend towards the feminization of agriculture. Among rural workers, females have always been more likely to be engaged in the primary sectors, most of which is agriculture, than men, and, correspondingly, less in the secondary sectors. For example, in 1977-78, 88.1 percent of female workers were engaged in primary sectors compared to 80.6 percent of males (Table 2). By 2009-10, these percentages had gone down for both males and females as a consequence of the rise of the rural non-farm sector. However, for males, engagement in the primary sector had gone down to 62.8 percent, or by 25 percent, while for females they had gone down to 79.3 percent, or by only about 10 percent. On account of their higher labor participation rate there are still more men working in agriculture than women. Nevertheless, there is a clear trend towards the feminization of the agriculture labor force.

**Table 2: Changes in the sectoral composition of the rural labor force**

<table>
<thead>
<tr>
<th>NSS Round</th>
<th>Rural Males</th>
<th>Rural Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Primary</td>
<td>Secondary</td>
</tr>
<tr>
<td>32 (July’77-June’78)</td>
<td>80.6</td>
<td>8.8</td>
</tr>
<tr>
<td>38 (Jan-Dec’83)</td>
<td>77.5</td>
<td>10</td>
</tr>
<tr>
<td>43 (July’87-June’88)</td>
<td>74.5</td>
<td>12.1</td>
</tr>
<tr>
<td>50 (July’93-June’94)</td>
<td>74.1</td>
<td>11.2</td>
</tr>
<tr>
<td>55 (July’99-June’00)</td>
<td>71.4</td>
<td>12.6</td>
</tr>
<tr>
<td>61 (July’04-June’05)</td>
<td>66.5</td>
<td>15.5</td>
</tr>
<tr>
<td>64 (July’07-June’08)</td>
<td>66.5</td>
<td>16.2</td>
</tr>
<tr>
<td>66 (July’09-June’10)</td>
<td>62.8</td>
<td>19.3</td>
</tr>
</tbody>
</table>

Source: Himanshu 2011.

As shown in Table 3, employment in India is very much concentrated in the informal sector. Between 1999-2000 and 2004-05 the proportion of workers in the formal sector declined from 8.8 to 7.5 percent. The National Commission for Employment in the Unorganized Sector (NCEUS) defines organized employment as employees who receive provident fund and social security benefits. Within the organized (formal) sector, the proportion of employees with informal contracts rose from 37.8 percent to 46.7 percent. The Indian labor market has shown a marked tendency to formalization of labor relationships, and only limited creation of high quality jobs with secure contracts and pension and health benefits for urban workers as well as for migrants from rural areas. Employment in the rural non-farm sector has always been primarily informal, but the small formal sector employment share has followed the trend to informalization as well (World Bank 2010).
Table 3: Distribution of workers by type of employment and sector organization

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Informal</td>
<td>Formal</td>
<td>Total</td>
<td>Informal</td>
</tr>
<tr>
<td>Unorganized Sector</td>
<td>341.28</td>
<td>1.56</td>
<td>342.64</td>
<td>395.47</td>
</tr>
<tr>
<td></td>
<td>(99.60)</td>
<td>(0.40)</td>
<td>(100)</td>
<td>(99.64)</td>
</tr>
<tr>
<td>Organized Sector</td>
<td>20.46</td>
<td>33.67</td>
<td>54.12</td>
<td>29.14</td>
</tr>
<tr>
<td></td>
<td>(37.80)</td>
<td>(62.20)</td>
<td>(100)</td>
<td>(46.58)</td>
</tr>
<tr>
<td>Total</td>
<td>361.74</td>
<td>35.02</td>
<td>396.76</td>
<td>422.61</td>
</tr>
<tr>
<td></td>
<td>(91.17)</td>
<td>(8.83)</td>
<td>(100)</td>
<td>(92.38)</td>
</tr>
</tbody>
</table>

Notes: 1. UPSS basis.
2. Figures in bracket indicate percentages.
Source: Estimates by NCEUS.

Source: Government of India 2008, Table 4.7.

Urban employment growth, particularly in the manufacturing sector, has been inadequate to provide enough employment opportunities for workers from rural areas. The great informality of employment in the Indian economy and in the organized sector, and the deepening of urban poverty discussed in the next section sharply reduce the attractiveness of urban areas for rural migrants, especially for unskilled and semi-skilled ones. Urban areas remain a pole of attraction of highly skilled workers. Nevertheless, the poor employment prospects for low-skilled workers in urban areas means that male, and especially female workers, are stuck in rural areas.

Agricultural employment, unemployment and wages

Employment growth in Indian agriculture slowed down between the early 1990s to 2004-05 (World Bank 2010). As discussed in Choudhury (2011), in 2009-10 the current daily status unemployment rates were the lowest for urban males at 5.5 percent, followed by rural males at 6.2 percent, 8 percent for rural females, and slightly over 9 percent for urban females. Unemployment rates were higher for 2004-05, with the growth of labor participation in the period preceding that year partly or fully driven by distress (World Bank 2010; Himanshu 2011). Urban unemployment rates, but not rural ones, today are also lower than in the 1990s. Nevertheless, the urban labor market is still very hostile for females, deterring rural-urban migration.

The growth rate of real agricultural wages declined between 1980 to the middle of the last decade, but has started to increase recently. As shown in Table 4, since then real wages in the entire economy have risen at a fairly rapid pace. The fastest real wage growth is observed for urban female salaried workers at 7.8 percent, followed by rural female casual workers at 6.2 percent and by urban male salaried workers. Since female participation rates fell, their faster rising wages are consistent with a voluntary withdrawal of females from labor markets, either as a consequence of growing family income and/or greater participation in education. Wages of casual male workers rose at 4.5 percent in rural areas and 4.2 percent for urban males, which in each case means a compound wage growth of close to 25 percent over the past five years. There is no recent trend in divergence of unskilled wages between rural and urban areas.
Table 4: Average daily real wage rate for workers

<table>
<thead>
<tr>
<th>Year</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Regular Salaried</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004-05</td>
<td>145</td>
<td>86</td>
</tr>
<tr>
<td>2009-10</td>
<td>165</td>
<td>103</td>
</tr>
<tr>
<td>Growth rate (%)</td>
<td>2.8</td>
<td>4.2</td>
</tr>
<tr>
<td>Casual</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004-05</td>
<td>55</td>
<td>35</td>
</tr>
<tr>
<td>2009-10</td>
<td>67</td>
<td>46</td>
</tr>
<tr>
<td>Growth rate (%)</td>
<td>4.5</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Source: Choudhury 2011.
Note: The wages for urban workers have been deflated by consumer price index (industrial workers) (CPI(IW)) and that of rural workers by consumer price index (agricultural labour) (CPI(AL)). This wage refers to the wage for casual workers engaged in work other than public work.

How can one explain the recent rise in rural wages? First, after a sharp slowdown in agricultural growth from the early-1990s to the middle of the last decade (which reflected itself in the slowdown of agricultural employment growth), the agricultural GDP growth rate has accelerated again. Second, since the middle of the last decade, agricultural prices have increased significantly in real terms on account of rapid increases in procurement prices of major agricultural crops (Oxus 2011), and perhaps under the influence of rising and high world market prices since 2008. Third, rural non-farm sector employment growth has also accelerated significantly over the past 20 years. Fourth, there has been a withdrawal of women from the rural labor force since 2004-05 with a shift of women to education.

A fifth explanation is the growth in public expenditures in rural areas that have increased rural purchasing power. Since before the beginning of the 11th Plan, public expenditures for the 13 flagship programs for agriculture, rural development and social development have been increasing rapidly, and now amount to Rs 186,539 crore, or approximately US$ 37 billion dollars. Two-thirds of the expenditures are in programs that are only operating in rural areas. The rural component of the social programs will likely take the lion’s share of these expenditures. The rural component of all programs therefore must reach or exceed 85 percent of the total expenditures, or about 158,000 crore, which is nearly 17 percent of agricultural GDP. Therefore, rural development, employment and social development programs, even if they encountered large leakages, are increasingly transferring purchasing power into the rural economy. These are likely to lead to increases in the demand for food and non-farm goods and services, generating multiplier effects on both agriculture and on rural non-farm incomes. In addition, a number of programs will also impact agriculture and rural development via their direct program impacts on output in these sectors. These direct and indirect impacts will be the drivers of the increase in real rural wages.
A highly visible component of the growing public rural expenditures has been the Mahatma Ghandi National Rural Employment Guarantee Act (MNREGA). The program has been described by the Planning Commission as: “With a people-centered, demand-driven architecture, completely different from the earlier rural employment programmes, MGNREGA has directly led to the creation of 987 crore person-days of work since its inception in 2006-07. In financial year 2010-11, MGNREGA provided employment to 5.45 crore households generating 253.68 crore person-days. It has also successfully raised the negotiating power of agricultural labour, resulting in higher agricultural wages and improved economic outcomes leading to reduction in distress migration.” (Government of India 2011). The program has been widely seen as the major cause of rural wage rate rises. However, it is only a relatively small share of total rural government expenditures and of rural employment. It is likely that the other five factors discussed above together have been a more important driver of the recent real rural wage rate rises, and that rural wages would have increased even in the absence of MNREGA.

Urban-rural differences in poverty, inequality, income and consumption

The analysis presented so far raises a major puzzle: For the past few years economic growth has accelerated sharply to more than 8 percent. The inter-sectoral labor productivity differential has risen rapidly; agriculture grew fairly slowly in the period between 1990 and 2005; agricultural productivity growth also slumped in the same period; urban employment opportunities have grown fairly slowly, especially for lower skilled workers and for women; and migration has been fairly slow. With these trends one would expect a rising differential between urban and rural per capita incomes and consumptions, and a rising differential between urban and rural poverty rates. However, this has not been the case. As seen in Table 5, the rural poverty rate (using the old poverty line) declined from 50.1 percent in 1993-94 to 31.8 percent in 2004-05, or by 18.3 percent, while urban poverty declined from 41.8 percent to 25.7 percent, or by 6.1 percent. In absolute terms the decline in rural areas is larger than in urban areas, but in relative terms the rate of poverty decline in urban areas is slightly faster than in rural areas. By 2004-05, in urban areas both the poverty gap and the squared poverty gap had become deeper, indicating a progressive urbanization of poverty (World Bank 2010). The poverty data with the higher poverty line resulting from the Tendulkar Committee report show similar convergence for the period 1993-94 to 2004-05 (Table 5). These trends are inconsistent with a growing divergence of rural and urban poverty.

2 Preliminary estimates of the national poverty rate prepared by Ravi and cited in Ahluwahlia (2011) suggest that the national poverty rate under the new Tendulkar committee poverty line has declined further from 37.2 percent in 2004-05 to 37.2 percent in 2009-10, or at an accelerated rate of about 1 percent per year. The urban-rural poverty rates for 2009-10 have not yet become available.
Table 5: Changes in rural and urban poverty rates

<table>
<thead>
<tr>
<th></th>
<th>RURAL</th>
<th>URBAN</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993-94</td>
<td>50.1</td>
<td>31.8</td>
<td>18.3 = 45%</td>
</tr>
<tr>
<td>2004-05</td>
<td>41.8</td>
<td>25.7</td>
<td>16.1 = 48%</td>
</tr>
</tbody>
</table>

Source: Tendulkar report (Planning Commission 2009); ¹ calculated with respect to the mean percentage.

The ratio of urban to rural per capita income declined from 2.45 in 1970-71 to 2.30 during the eighties and early nineties. On the other hand, data on consumption shown in Table 6 suggest that the ratio of urban consumption to rural consumption increased from 1.54 in 1983 to around 1.70 in 2004-05 and 2009-10. Whether rural-urban disparities have increased is therefore dependent on the data used and the period considered. But neither data series suggest a sharp change in urban-rural disparities over the past 30 years.

Given the significant increases in non-agricultural to agricultural productivity differential and the agricultural trends discussed above, it is surprising that the urban-rural per capita income and consumption gaps have not increased sharply, and that the gap between the rural and urban headcount poverty rates has not increased sharply as well.

Table 6: Consumption inequality, India

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gini Coefficient of distribution of consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>0.30</td>
<td>0.30</td>
<td>0.28</td>
<td>0.30</td>
<td>0.28</td>
</tr>
<tr>
<td>Urban</td>
<td>0.30</td>
<td>0.35</td>
<td>0.34</td>
<td>0.37</td>
<td>0.37</td>
</tr>
<tr>
<td>Urban-rural ratio of mean consumption (Constant prices)*</td>
<td>1.54</td>
<td>1.44</td>
<td>1.64</td>
<td>1.72</td>
<td>1.69</td>
</tr>
</tbody>
</table>


The drivers of rural poverty reduction

Ravallion and Datt (1996) show, in line with the international experience, prior to 1991 rural growth was the most important driver of poverty reduction and reduced rural poverty, national poverty and even urban poverty. But urban growth only reduced urban poverty and had no impact on rural poverty or national poverty. In 2009, Datt and Ravallion updated their earlier work to 2004-05. They showed that rural growth remains significant for reducing rural poverty.
and national poverty. But since 1991, when economic growth started to accelerate, urban growth has become the major driver not only of urban poverty reduction, but for both national and rural poverty reduction. *Datt and Ravallion’s new findings suggest that a spillover has emerged from more rapid urban growth to rural growth.*

Since agricultural growth had slowed down during the period 2004-05, the spillovers must have been felt primarily in the non-farm sector. In the past, the rural non-farm sector was viewed as driven primarily by agriculture (Hazell and Hagbladde 1993), so to add an urban driver is a novelty. But there is more direct evidence of such a driver: Himanshu et al. (2010) show via a multiple regression using the within estimator in panel data of regions in India that higher non-farm employment by rural adults also significantly reduces rural poverty.

These results do not imply that agriculture has lost its impact on the rural non-farm sector, and more broadly on rural poverty. In Datt and Ravallion’s 2009 update, agricultural growth remains an important determinant of rural poverty reduction. This conclusion is reinforced by the same regression analysis of Himanshu et al. (2010) that showed that higher yields are associated with declining rural poverty, suggesting the impact of agricultural productivity growth on poverty remains high. In the same regression they also show a strong and negative impact of higher agricultural wage growth on rural poverty. This strong impact is not surprising as agricultural workers constitute about half of India’s overall poverty population.

In conclusion, neither poverty nor per capita income and consumption show signs of rapid divergence between rural and urban areas as a consequence of the rising disparity of labor productivity between agricultural and non-agricultural sectors. Consumption inequality has recently increased in urban areas but stayed fairly constant in rural areas. While rural growth and agriculture were the main drivers of poverty reduction before 1991, since then urban growth has become a quantitatively more important driver of poverty reduction overall even in rural areas. Nevertheless, growth in agriculture, in agricultural productivity (as measured by yields), and in agricultural wages remain important drivers of rural poverty reduction.

*The rising importance of the rural non-farm sector*

If urban areas are inhospitable to migrants from rural areas then where has the growing rural labor force found employment and opportunities for increasing their incomes? If there had been no such opportunities, undoubtedly rural poverty would not have improved as fast as urban poverty and rural-urban income and consumption parities would have declined. However, the rural non-farm sector has become much more dynamic than the farming sector, both in terms of GDP growth and employment generation. Between 1983-2004 rural non-farm GDP has grown at a rate of 7.1 percent, more than a percentage point faster than non-farm GDP, and 4.5 percent faster than agricultural GDP (Table 7). This faster growth of the non-farm sector started in the decade from 1983-1993. In the period 1993-2004, non-agricultural employment growth in rural areas accelerated from 3.5 to 4.8 percent. In the 1980s, 4 out of 10 rural jobs were in the non-farm sector, now it is 6 out of 10 (ibid). *Given the large size of the rural labor force these numbers mean that the rural non-farm sector has emerged as the largest source of new jobs in the Indian economy.*
Table 7: Trends in non-farm employment and in national, rural non-farm and agricultural GDP

(Annualized rates of growth, %)

<table>
<thead>
<tr>
<th>Year</th>
<th>Non-farm employment</th>
<th>GDPN</th>
<th>Non-farm GDP</th>
<th>Agriculture GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983-2004</td>
<td>3.3</td>
<td>5.8</td>
<td>7.1</td>
<td>2.6</td>
</tr>
<tr>
<td>1983-1993</td>
<td>3.5</td>
<td>5.2</td>
<td>6.4</td>
<td>2.9</td>
</tr>
<tr>
<td>1993-2004</td>
<td>4.8</td>
<td>6.0</td>
<td>7.2</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Source: Himanshu et al. (2010), Table 3.
Note: GDP at factor cost at 1993-94 prices. Agriculture GDP originating in agriculture, forestry, and fishing. Non-farm GDP defined as a residual.

Growth in rural non-farm sector employment has occurred all over India, but has been highly uneven. It is highest in Kerala, West Bengal, and Tamil Nadu, and lowest in Chhattisgarh, Madhya Pradesh, followed by Uttarakhand, Karnataka Gujarat and Maharashtra (World Bank 2010, Binswanger and d’Souza, 2011b).

Until 2004, the growth in non-farm jobs had come primarily from increases in services, transport, and construction. In 1983, close to 40 percent of rural non-farm jobs were in manufacturing. Despite continued growth of rural manufacturing, this share has declined to just a little above 30 percent in 2004-05. In 1983, social services and trade, transport, and communication both generated about 26 percent of non-farm jobs. Social services have since declined to about 18 percent of the jobs, while trade, transport, and communications have grown rapidly to about 33 percent. In 1983, construction was by far the smallest sector, with a share of only 10 percent. Since then it has grown the fastest and now generates close to 19 percent of the rural non-farm jobs. The high level of rural construction has visually transformed villages all over India, with much better village infrastructure and housing.

Foster and Rosenzweig (2005) show that non-farm enterprises producing tradable goods (the rural factory sector) locate in settings where reservation wages are lower. If the rural factory sector seeks out low-wage areas, factory growth will be largest in those areas that have not experienced local agricultural productivity growth. Thus, rural non-farm growth reduces spatial inequalities in economic opportunities and incomes. Nevertheless, the location of factories where wages are low has an equalizing impact on income distribution in rural areas.

Datt and Ravallion’s 2009 analysis, suggests that since 1992 urban growth has also fueled the rural non-farm sector. More direct evidence of spillovers comes from World Bank (2010), p 66: “During the two periods of analysis, 1983 to 1993-94 and 1993-94 to 2004-05, regression estimates suggest that non-farm employment increased more in regions where urban incomes also grew faster. Disaggregating the analysis by different types of non-farm employment, the results show that it is regular salaried jobs and self-employment activities that appear to be most strongly and positively correlated with urban growth; casual non-farm employment is uncorrelated with urban growth.” Additional drivers of recent rural non-farm growth can be inferred from a closer look at the composition of employment growth (Box 1).
Box 1: Recent drivers of rural non-farm growth

Between 1999-2000 and 2004-05, rural non-farm employment increased by 16 million by principal status, of which 8 million (nearly 50 percent) was in the form of self employment, 5 million as casual employment, and three million as regular employment (Himanshu 2011). By industry, 5 million was accounted for by construction (equivalent to almost the entire increase in casual employment), 4 million by trade and hotels, 3.5 million by manufacturing, and 1.8 million by transport and communication. Within the large rural self-employment component that has been shown to be partly driven by urban growth, three industries account for nearly 60 percent of the increase: 2.2 million was accounted for by retail trade, 1.5 million by manufacture of wearing apparel, and 1 million by land transport. Another 25 percent of the increase was accounted for by 7 activity codes that include post and communications, where the largest increase was in the form of STD/PCO booths, maintenance and repair of motor vehicles, and hotels and restaurants (ibid). The STD/BCP booths and the maintenance and repairs of motor vehicles are fueled by technical change in communication, motorization of transport, and agricultural mechanization. Increases in hotels and restaurants reflect income growth that is partially driven by urban spillovers.

Who benefits from non-farm wage employment? It is primarily males in the age group of 18-26 years old who have some education that are moving out of agriculture into non-farm jobs (Eswaran et al. 2009). Women are barely transitioning into the non-farm wage employment sector. In growth terms, the number of rural men working off-farm doubled between 1983 and 2004-05; for women the increase was 73 percent. Individuals from scheduled castes and tribes are markedly more likely to be employed as agricultural laborers than in non-farm activities, even controlling for education and land. Even a small amount of education, such as achieving literacy, improves prospects of finding non-farm employment, and with higher levels of education the odds of employment in well-paid regular non-farm occupations rises. Finally, those in the non-farm sector own more land on average than agricultural laborers, except for those in casual non-farm employment (ibid).

The REDS data for 2007 show a significant differential between average farm and rural non-farm wages of 47 percent, and the premium has been stable since 1999 (Binswanger-Mkhize et al., 2011b). Eswaran et al. (2009) use NSS data to show that wage premia associated with education were growing over time. By 2004-05 NSS found these premia had increased to Rs 86 for literate workers over illiterate ones, Rs 197 for those who had attended middle school, and Rs 696 for graduates. The authors conclude that if more middle school and high school graduates were available in 2004, they would have found employment in rural industry and services.

Until 2004-05, employment growth in the non-farm wage sector had accelerated while the growth in average earnings had decreased. These two trends have cancelled each other out, and for the last two decades, growth in total non-farm wage earnings has been constant (World Bank 2010). In spite of the preponderance of non-farm jobs in rural employment generation, Eswaran et al. (2008) estimate the contribution of the rural non-farm sector to rural wage growth to be only about 22 percent of the total growth, thereby confirming the importance of agricultural growth and productivity growth to rural wage growth. In particular, the rural non-farm sector has
not contributed to wage growth among the illiterate, but only among the more educated (Eswaran et al. 2009).

Box 2 shows that the rural labor market is significantly connected to the urban labor market, and that the farm and non-farm labor markets, while supporting a significant wage differential between them, are highly integrated.

**Box 2: The behavior and impacts of farm, non-farm and urban labor markets**

Econometric results from Binswanger et al. (2011b) for the period of 1999-2007 are used to discuss labor market behavior. These come from the REDS national panel data set of over 5000 households. A first finding in the table below is that in Indian villages the farm and non-farm labor markets are linked closely in a symmetric manner: The elasticity of the rural farm wage with respect to the predicted non-farm wage is close to 0.5 and the converse elasticity of the non-farm wage is almost the same size. A rise in the urban wage increases both these wages with an elasticity of around 0.17. Moreover, the elasticity of the farm and non-farm wage to the aggregate agricultural price is almost identical at 0.04. Finally, a rise in either of the two wages leads to large reallocations of labor to the sector that has experienced the wage rate rise. The elasticities far exceed all other elasticities examined so far. The reason the two labor markets are so integrated is that the slightest change in their relative wage trends induces a lot of movement of the family labor to the other sector, quickly reducing the disparity.

**The responses of rural labor to changes in wages**

<table>
<thead>
<tr>
<th></th>
<th>Predicted farm wage</th>
<th>Predicted non-farm wage</th>
<th>Urban wage</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor force</td>
<td>0.020**</td>
<td>0.075**</td>
<td>-0.059**</td>
<td>0.036¹</td>
</tr>
<tr>
<td>Share of family labor in agric.</td>
<td>3.262***</td>
<td>-5.571**</td>
<td>Na</td>
<td>-2.309¹</td>
</tr>
<tr>
<td>Share of labor in non-agriculture</td>
<td>-2.282**</td>
<td>4.944**</td>
<td>Na</td>
<td>2.662¹</td>
</tr>
<tr>
<td>Share of students</td>
<td>-.980¹</td>
<td>.637¹</td>
<td>--</td>
<td>-.353¹</td>
</tr>
<tr>
<td>Farm wage</td>
<td>--</td>
<td>0.484**</td>
<td>0.166**</td>
<td></td>
</tr>
<tr>
<td>Non-farm wage</td>
<td>0.488**</td>
<td>--</td>
<td>0.171**</td>
<td></td>
</tr>
</tbody>
</table>

¹Standard errors yet to be calculated, ** significant at 1 percent level.

A rise in the urban wage leads to a reduction in family labor force, which means that it induces rural-urban migration. The last column sums up the elasticities of the left hand variables with respect to the wages on the top. The resulting sum tells what would happen if the farm, the non-farm and the rural wage were to rise by the same proportion. Such a rise of the national wage level would induce slightly more people to commit to work in rural areas. This suggests that people would prefer the rural areas if there was an overall income impact from higher wages. These preferences may well reflect their perception of the relatively hostile nature of the urban labor market discussed in section one. However, looking at the shares, the sums show that people would tend to move their work force from agriculture to non-agriculture, suggesting that while they prefer rural areas they would prefer to work in the non-farm sector. This supports the notion that people would rather move out of agriculture if they could.
As discussed in Box 1, a particularly dynamic development has been the growth in self-employment in the non-farm sector. The question has arisen whether such employment is a consequence of economic distress or of rising self-employment income opportunities (World Bank 2010). In order to answer this question, data on income earned by rural non-farm self-employment is required that is not available in the standard NSS consumption, poverty and employment surveys. Binswanger-Mkhize et al. (2011a) analyzed data from the 1999 and 2007 round of the Rural Economic and Demographic Surveys (REDS) of the National Council of Applied Economic research to fill this gap. REDS is a nationally representative panel of rural households that were originally selected in 1971 to study the Green Revolution with a slight tilt towards better agricultural areas.

Because of population growth and household subdivision, the sample grew from 4690 households in 1999 to 5759 households. Households have become smaller in size, contain a lower proportion of farm households, and, on average, own less land. (The decline in average owned and operational holding sizes, a consequence of rural population and labor force growth, has been a long-term trend in India since 1962 (Basole and Basu 2011)). Despite these trends, per capita income grew from 8498 Rs in 1999 to 12,370 Rs in 2007, i.e. by Rs 3881 (in Rs of 1999), or at an annual rate of 5.7 percent, which is similar to urban per capita income growth. These data also show rising rural wages, but also a more than doubling of the prices of agricultural land between the two periods. Since the wealth of farmers is primarily in the form of land, they have experienced a significant increase in their real wealth.

Between 1999 and 2007, the number of households engaged in non-farm self-employment more than doubled from under 10 percent to nearly 20 percent. Unfortunately, the gender of the owners of these enterprises is not known, but given the growth of the rural self-help movement, it is possible that women participated significantly in this self-employment growth. While agricultural profits and agricultural labor incomes grew in absolute terms, it was the rural non-farm self-employment income component that grew the fastest: For households engaged in rural non-farm employment this component of income rose from Rs. 36,767 to Rs.64,045, i.e. by 74 percent in only 8 years, or at an simple annual rate of 9.3 percent. Figure 7 shows that for the sample as a whole, the shares of income shifted from agricultural profits and wages (-9.26 percent and -2.10 percent) towards non-farm self employment income (+12.19 percent). At the same time the share of non-farm wage income has stayed nearly constant at around 7.5 percent.
Figure 7: Composition of rural incomes in India, 1999-2007

<table>
<thead>
<tr>
<th>Per capita income = Rs. 8,498</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural profit 72%</td>
</tr>
<tr>
<td>Salaries and renting out agricultural assets 7%</td>
</tr>
<tr>
<td>Nonfarm-Self employment income 7%</td>
</tr>
<tr>
<td>Agricultural wages 7%</td>
</tr>
<tr>
<td>Nonagricultural wages 7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Per capita income = Rs. 12,370</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural profit 62%</td>
</tr>
<tr>
<td>Salaries and renting out agricultural assets 5%</td>
</tr>
<tr>
<td>Nonfarm-Self employment income 20%</td>
</tr>
<tr>
<td>Agricultural wages 5%</td>
</tr>
<tr>
<td>Nonagricultural wages 8%</td>
</tr>
</tbody>
</table>

Source: Binswanger et al. 2011a.

The income data on the rural non-farm self-employment sector suggests that while it may contain some distress employment, this is not the main driver of its expansion, and that instead it has become the most dynamic source of income growth of rural households, including farmers. *What is observed among farms is not only diversification of agricultural production to higher valued products, but also to more remunerative self-employment in the non-farm sector. There is therefore a marked tendency of agriculture to move to a productive and modern model of part-time farming.*

**Summary of employment and poverty trends**

Urban and rural male labor participation have been around 55 percent for the past two decades. Meanwhile, female rural participation rates have fluctuated around 30 percent and female urban participation rates have been very low, fluctuating around 15 percent. Formal sector employment is a distressingly small component of employment in India and even in the formal sector there is a trend towards informal employment contracts. Between 1990-91 and 2004-05 the growth rate of agricultural employment (both wage and self-employment) has slowed down, while that of the rural non-farm sector has accelerated significantly, becoming the most significant source of the Indian economy. The share of women within the agricultural sector has been rising steadily, indicating a trend towards the feminization of agriculture.

Within the rural non-farm sector, self-employment accounts for as much of employment growth as wage employment, and diversification of farms into rural non-farm self-employment is now a reality for around 20 percent of farmers. Non-farm self-employment is driven by rapidly rising incomes in these enterprises, and therefore such employment cannot be regarded as distress
employment. Indeed non-farm self-employment income has become the largest source of rural income growth.

Rural non-farm wage employment is accessed primarily by young males with some education, suggesting that females are at a disadvantage in obtaining such employment, perhaps because much of it requires mobility. Rural non-farm wages are significantly higher than agricultural wages, which means that lack of access to such employment is a significant disadvantage. Unfortunately, this implies a significant impediment to women, who have increasingly concentrated on agriculture, contributing to a progressive feminization of agriculture, and on rural non-farm self-employment.

In spite of the wage differential, the farm and non-farm rural labor markets are highly integrated. Both are also integrated with the urban labor market, but to a lesser extent. Non-farm sector growth and employment growth have not only happened in favorable agro-climate zones but also in less favored areas, mitigating inter-regional income and poverty differentials. Poverty continues to be concentrated among agricultural workers.

The differences between urban and rural poverty rates, and urban-rural per capita income and consumption have not increased despite the slow migration and the very rapid rate of growth of the agricultural-nonagricultural productivity differential. This is clearly a consequence of the growth of employment and income in the rural non-farm sector, and especially in rural non-farm self-employment and income. Since the early 1990s, this rural non-farm self-employment sector has become increasingly fueled by accelerating urban growth.

**Implications for structural change**

The new growing rural non-farm dynamic has led to a revision of the standard model of structural transformation that equates non-agriculture with urban areas. It now has to include the rural non-farm sector. *Structural transformation in the form of a decline in agricultural employment and in favor of nonagricultural employment is happening in India. However, the new form of structural transformation in India is a stunted one, because it primarily generates employment that is informal and/or insecure, and without the benefits of health and unemployment insurance and pensions.*

The structural transformation trends are in sharp contrast to the trends in China. Near zero population growth rates and rapid growth of labor-intensive manufacturing and in other urban sectors have led to a world record rural-urban migration that has left rural areas without young workers. Farms are increasingly operated by older farmers, many of whom are also women. Even in China, the rural non-farm sector has emerged as a dynamic sector, probably on account of spillovers from rapid urban growth to rural areas, as well as continued rapid agricultural growth. Urban and rural wages have started to grow very rapidly at around the same time as Indian rural wages, but the pace of real wage growth is much faster. It appears that China is on the way towards a normal structural transformation.
In spite of rapid economic growth, India’s structural transformation is constrained by the weakness of employment growth in the urban economy, and most specifically in labor-intensive manufacturing. Most experts attribute the slow growth in labor-intensive manufacturing to restrictive labor legislation in India and to poor infrastructure for power, water, and transport. The dream of a structural transformation directly to a service economy with good and secure urban jobs has not been realized and is unlikely in the future as well. That there is nevertheless a structural transformation from agricultural production and employment towards non-agriculture appears to be a consequence of rising urban spillovers to rural non-farm self-employment, and this has prevented a greater divergence in poverty rates and per capita incomes and consumption. Continued growth of high urban economic growth is therefore critical for rural income growth. However, agricultural growth and higher productivity continue to be powerful drivers of rural poverty reduction, rural non-farm sector growth, and agricultural and rural wages. An acceleration of agricultural growth and agricultural productivity growth to sustained higher levels than in the past two decades would therefore be highly beneficial for rural areas. As a consequence, agricultural and rural development policies, institutions, and programs remain important determinants of rural welfare.

**Vision of agriculture and rural poverty reduction**

Using the results and insights from the past sections a vision for the agricultural sector and for rural poverty reduction over the next decades can be developed. The structural transformation in India and rural-urban migration will likely remain constrained by the slow growth of employment in urban areas, in industry, and especially in labor-intensive manufacturing. This is because it appears to be politically impossible to reform restrictive labor legislation, and because it will take a long time to overcome infrastructure bottlenecks. For most unskilled and semi-skilled workers, urban migration opportunities are likely to remain constrained, and limited to the informal sector, or to informal contracts in the formal sector. There is little chance that the urban economy will provide enough employment for the growing rural labor force to allow a large proportion to move to the urban economy. The rural labor force will therefore have to find a way to improve their incomes in rural areas.

Given the need to raise agricultural income and the economies of scale that mechanization and credit constraints bring to agriculture (Foster and Rosenzweig 2011), it may appear paradoxical that farm sizes would continue to decline. However, this tendency is in line with past trends in India, where farm sizes have grown modestly only in the Punjab, and declined everywhere else. This decline is in line with continued rises in rural populations and labor forces, and with the limited labor absorption potential of urban areas. The rapidly rising prices of agricultural land

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3 It is also consistent with trends in advanced economies that are dominated by small family farms, such as Japan, Taiwan, Korea, or European countries such as Italy, Spain, Switzerland, and Norway. However, in many of these countries the heavy subsidization of agriculture and constraints imposed on agricultural land markets have limited land consolidation via sales and rental markets.
will impart a portfolio motivation to hang on to land in the households owning land and
remaining in the country side. While land rental markets could lead to land consolidation, up to
the latest data available, land renting has also continued to decline. To provide self-employment
opportunities for family labor, and especially for women, most households will be reluctant to
rent out or sell land in the future as well. With males having better opportunities in rural non-
farm employment than females, agriculture will continue to feminize. With these trends
agriculture will be dominated by even smaller part-time farm households; with a few full-time
farmers at the top and a large majority of part-time marginal, small and medium farmers.

Some of these trends are in contrast to China: Absent or old owners of rural land rights are
increasingly renting them out to relatives, to larger farmers, and to enterprises. Land rentals have
risen from close to zero in the 1990s to around 20 percent of total agricultural land. As a
consequence average operational holdings have started to rise, while the ownership distribution
of land rights remains unaffected. These trends are also likely to continue.

Part-time farmers in India will get more income from non-agriculture than from agriculture. All
types of farmers will focus much more on horticulture, milk, poultry and eggs. Consumer
demand will drive a trend towards traceability of agricultural output, quality control, and organic
farming that will provide additional income opportunities. Farms will be much more capital-
intensive, and use advanced biological and mechanical technology for crops, horticulture,
livestock and aquaculture. Water markets and other cooperative ways will be used to realize
economies of scale. Depending on economy-wide growth, farmers will try to increase their
agricultural incomes by adoption of modern technology, further diversification towards higher
valued crops, use of more machinery, and increasing reliance on family labor. The rural non-
farm sector will continue to grow faster than agriculture, provide more income opportunities than
agriculture, and produce an increased range of services and products, using progressively more
modern technology. Declining farm size trends and the diversification of households into the
non-farm sector will undoubtedly continue. As a consequence, the emergence of a farm sector
dominated by modern part-time farmers, many of them female, whose households will combine
farming with non-farm employment of the men and/or self-employment in the non-farm sector is
likely.

While these trends are likely to continue under both very rapid and more moderate economic
growth, and regardless of agricultural policies and programs, both an optimistic and a more
pessimistic future are possible for agricultural and rural incomes, and for rural poverty reduction.
The optimistic version is based on a combination of rapid economy-wide growth as well as rapid
agricultural and rural non-farm growth; both partly driven by urban demand and technology
spillovers. Agricultural growth will be driven by rapid technological change and productivity
growth, improvements in water use efficiency and irrigation growth, and the diversification of
agriculture. Both full-time and part-time farmers will have plenty of new technologies available
and be able to adopt it, and many remunerative diversification opportunities in agriculture and
non-agriculture. This will result in the emergence of a highly modern part-time farming sector
and rapid agricultural income growth, which will also spillover into more rapid rural non-farm
growth. At the same time, the demand and technology spillovers from the urban economy will
further accelerate rural non-farm sector growth. Non-farm opportunities will continue to be more
accessible to young and educated males than to females, accelerating the feminization of
agriculture. However, this may be associated with rising entrepreneurial opportunities for the female farmers. The combination of rising agricultural and rural non-farm incomes will support rapid income growth in rural areas, including rapid rural wage growth. Rural-urban incomes and consumption ratios will improve, or at least not deteriorate, and rural poverty will decline very rapidly, except in remote regions with poor agricultural endowments and poor prospects for rural non-agricultural development.

Rising incomes from agriculture and the non-farm sector will not only sharply reduce absolute poverty in rural areas but hunger as well, except perhaps in some tribal areas. Malnutrition may, however, continue to persist, as it has in the developed world, via the addition of obesity problems.

Under a pessimistic vision, economy-wide growth will be slower, and the slowdown in economy-wide growth will reduce the urban spillovers to higher agricultural and non-agricultural demand, and technology spillovers in the non-farm sector. Slow agricultural growth could not only result from reduced demand for food, but also if (a) technical change in agriculture remains slow, (b) services for part-time smallholders are not scaled up and improved, (c) technology adoption are limited more to the full-time farmers, and (d) female farmers have limited entrepreneurial opportunities. The combination of relatively slow agricultural growth will reduce rural non-farm sector growth, which will also suffer from reduced urban spillovers. Rural income growth and wage growth will be lower. Rural-urban incomes and consumption ratios will deteriorate, and rural poverty will decline fairly slowly, even in better located and endowed rural areas.

The private sector is emerging as a key driver of many components of agricultural and rural development. All of the non-farm sector development and all of farm investment is a private sector activity. In addition, the private sector is transforming the marketing system from the farm to consumers; it has become a major source of new technology, including GMOs, and seeds supplies; it has entered agricultural extension in a significant way, via contract farming and in input supply; the private sector is providing piped water in canal systems to irrigators; it has entered agricultural credit via contract farming and microfinance; and it is assisting in the administration of land record systems. NGOs have also entered agricultural extension, natural resources management, fostering of linkages of farmers to market opportunities, and microfinance. Opportunities for public-private partnerships and partnerships with the private sector and NGOs are growing significantly, and need to be mobilized much better.

Despite the constraints arising for rural welfare from slow urban employment growth, rapid agricultural growth can also contribute significantly. Over the coming decades, agriculture will continue to diversify rapidly towards high value commodities, and deal with declining farm sizes, feminization of the labor force, increasing water stress, and climate change. These opportunities and challenges cannot be managed by small adjustments in existing institutions, policies and programs. In Centennial Group (2012), a full set of bold recommendations is spelled out that would help bring about an optimistic vision for agriculture. Box 3 further details how land reform, land administration, and land markets can support an optimistic vision.
Even though under our visions for the future of agriculture large scale consolidation of land holdings is neither necessary nor likely, flexible and secure land transactions contribute in several ways to the realization of the vision, as demonstrated by a series of careful studies using the REDS data of NCAER:

- Land reform has not led to inefficient small holdings, but instead has led to higher asset accumulation in states that underwent more land reform, higher income growth, and higher educational attainments of children.
- Land rentals have steadily declined, and are unlikely to become a major avenue for the aggregation of large farms. Instead (i) land rental has been an important avenue for land access for poor, land scarce and landless households, and therefore has supported poverty reduction in an environment with limited rural-urban migration options. (ii) Those who rent land obtain higher returns to their labor than available in the casual labor market. (iii) State level land rental restrictions reduce the ability of the poor to get access to land and their productivity.
- Land sales markets transferred land to more efficient producers who increased their incomes. However, village weather shocks encouraged distress sales by poor households. Where employment guarantee schemes were operating, they reduced such distress sales; MGNREGA will reinforce this mechanism. With such safeguards in place, constraints on land sales among land reform beneficiaries and in tribal areas can be safely eliminated.
- Amendments in the Hindu Succession Act that give equal rights to sons and daughters to inherit land significantly increased women’s probability of inheriting land, although it did not bring about full gender equality. Girls raised by women who had inherited land had significantly higher levels of education than those raised by women not subject to the amended Act. In a feminizing agriculture, women’s rights to inherit land is even more important.
- Computerizing registration of deeds and/or textual records is fully or partly completed in AP, GU, KA, MA, RJ, and TN. Computerization of textual records was facilitated through private sector contracting. In Maharashtra, computerizing registration of deeds has been associated with a 50% increase in the number of registered transfers. Stamp duty collected during the same period has more than doubled. Land transactions in sales and rental markets have been simplified and made more secure. Better land records will also make it easier to use small parcels of highly valuable land as collateral for loans to finance investments in agriculture and in the non-agricultural sector.
- In tribal areas, individual or community land rights are neither recorded nor can they be transacted. There is also no system of land administration for traditionally ‘marginal’ lands. In tribal areas land administration should first focus on the registration of communal tenure, and eventually of individual tenure, if the communities decided in an open and transparent vote to move to private property. This is the approach that is now used in Mexico and other countries. Improved land administration would ensure greater security of tenure and facilitate rental and sales to enable tribal populations to obtain the same benefits associated with land ownership as other farmer groups.

The key recommendations resulting from these studies are as follows:

- Consider further provision of land to landless and land poor people;
- Eliminate remaining constraints on land rental;
- Strengthen land inheritance rights for women;
- Clarify and record rights in marginal areas traditionally outside the system, and tribal areas, by recognizing and recording communal tenure, and by systematically resolving conflicts; and
- Further improve land administration in rural areas via computerization and spatial records.

Source: Deininger and Nagarajan (2011).
An optimistic future for Indian agriculture - vision and policies

Over the next few decades, accelerating investment and productivity growth, and maintaining income parity in agriculture will require much accelerated technical change, further diversification into high valued crops, continued growth of irrigation, and further diversification of farmers to the non-farm sector. Agricultural research will continue to be provided by both the public and the private sector, with the public sector having a particularly important role in upstream technologies and in technologies with limited private appropriability such as open pollinated varieties or agronomic practices and soil conservation. The public sector will have to become more accountable to farmers and consumers more efficient. As the failure to document adverse side effects of transgenic crops becomes ever more apparent, biotechnology and transgenic crops will become more widely accepted, and competition among private sector providers will reduce the costs of biotech inputs. Transgenic crops will therefore become a major source of total factor productivity growth.

Agricultural extension will become much more pluralistic with rapid growth of extension by input suppliers and contractors of output, via scaling up of NGO extension efforts and of mobile applications for agricultural information on technologies and practices, inputs and output markets. At the same time, the public sector, via stronger support from the state levels, should be able to strengthen the ATMA model of coordination and provision of extension in much closer coordination with private sector providers. All extension providers will continue to struggle with the issue of how to provide extension to the many small and part-time farmers, and to the rising share of women farmers. The challenges of how best to provide extension in rainfed farming, semi-arid, arid areas, and tribal areas will continue to preoccupy the public and NGO sectors, which should find it useful to cooperate more.

Technical change, diversification, and continued irrigation growth may not be enough to maintain agricultural and rural incomes in line with rapidly growing urban incomes. Instead, significant financial support to farmers may be required. Current subsidies to fertilizer, electricity, water, and support to crop prices are tied to inputs and outputs. Subsidies are large but an inefficient means to transfer income to farmers, and they have adverse environmental impacts. Reformed, and more efficient subsidies, will have to shift to broad cash transfers on a per farm basis rather than linked to products, and include input vouchers favoring small farmers.

Existing constraints on agricultural marketing via regulated markets will have to be eliminated, and marketing and value chains will have to be modernized at an accelerated pace from the farm to the retail outlet. Intense competition in marketing will help constrain the markups in the value chain and therefore assist in combating food inflation. Although some small and part-time farmers may encounter greater marketing problems than larger and full-time farmers, all classes of farmers will be able to avail themselves of better marketing options thanks to the cell phone and rising incentives of retailers and processors to ensure themselves of high quality outputs via contract farming.

Water management under canal irrigation will have shifted to more demand-driven modes of providing water in a timely and controlled manner, often via pumping and in pipes, and at much higher water use efficiencies. Groundwater irrigation as well as private pumping from canals and
other water sources will continue to be the major source of irrigation growth. The problems of reliable electricity supply to both agricultural water users and rural consumers will be resolved in many states, but not without complex political problems and twists and turns. Groundwater depletion will remain a major threat in semi-arid, arid, and hard rock areas, but solutions that are responsive to the aspirations of millions of irrigators, rather than of a command and control type, will emerge in many places. Water harvesting, groundwater recharge, and drip and sprinkler irrigation will help significantly in reducing depletion. Nevertheless, command and control interventions may be required in some of the most critical watersheds.

It is hard to see how the enormous challenges of agricultural growth, natural resource management, and social services for rural areas can be resolved without greater citizen empowerment and decentralization. Such reforms have been under discussion in India for a very long time but all initiatives so far have failed to bring them about. Reforms will have to be driven primarily by the states, but with support from strong incentives and perhaps further legislative interventions provided by the Center as well. They will not come about without pressures from below. Therefore, support for transformative institutions such as SHGs, farmer associations, and organizations of the poor and marginalized will have to expand. More than in other areas the possibility of continued failure to reach these policy intentions is high.

Agricultural and rural development programs of the Center will be consolidated from the hundreds of central and centrally-sponsored schemes to a sharply reduced set of block grants that will provide much more flexibility for implementers at state, district, block and village levels. Many of them will also become much more empowering of the final beneficiaries who will take a much greater role in planning and implementation of the schemes. Roles and accountabilities will be clarified and strengthened, along with monitoring, evaluation, and impact evaluation. As a consequence, implementation of agricultural and rural development programs could be significantly improved, become more transparent, and less a source of corruption.
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Centennial Group. 2012. *India 2039: Transforming agriculture*.


Core literature on India 1960-2010: Structural change, the rural non-farm sector, and the prospects for agriculture


This paper reviews the theory of structural transformation elaborated in the 1950s and confronts it with data from recently industrialized and developing countries. It concludes that it has become more difficult to reach the point where the agricultural and the nonagricultural sectors start to converge in labor productivity.


This classic paper develops the basic ideas and models that show the pathways by which agricultural growth can contribute to economic development and poverty reduction. Its ideas have been empirically tested many times and stood up very well.


The authors summarize the literature that emerged in the 1970s and 1980s on the composition and drivers of the rural non-farm sector. The drivers of non-farm growth are shown to be mostly the linkages with agriculture, via forward, backward and consumer demand linkages, but they have been much stronger in Asia than in Africa.


In this paper the authors update their analysis up to the early 1990s where they measured the contributions to urban, rural and national poverty reduction of urban and rural growth. They show that before 1991 rural growth was the main driver of urban, rural and national poverty reduction, which is consistent with the ideas of Johnston and Mellor (1961) in the second paper listed above. They then show that since the early 1990s, rural growth still contributes to rural poverty reduction, but that urban growth has emerged as a more important driver of urban and rural poverty reduction than rural growth.

Foster, Andrew D. and Mark R. Rosenzweig. 2003. _Agricultural development, industrialization and rural inequality_. Providence, RI: Brown University, Mimeo.

This paper shows that rural industrialization is particularly strong in areas that were bypassed by the green revolution, and therefore had slower wage growth and lower wages than the green revolution areas. This means that rural industrialization has sought out low wage environments and thereby has contributed to the inter-regional equalization of rural incomes.

This paper updates paper number three in this list with special reference to South Asia. It shows that non-farm employment and self employment has become a very important component of overall employment growth. It also warns that rural labor force growth in South Asia will continue for several decades and pose an enormous employment challenge for the countries.


This paper reviews achievements of the Indian economy in the current five year plan, such as the accelerating poverty reduction, and uses this background to analyze the challenges that have to be addressed in the coming five year plan that will start in late 2012.


The author reviews the disappointing employment trends in the Indian economy in the last decade and analyzes the reasons for it.


This paper analyzes the rapid growth of the rural nonfarm sector and the employment and wage growth that has been associated with it.


This paper brings together a number of studies that analyze the drivers of rural non-farm growth and shows how the rural non-farm sector has helped in reducing rural poverty in India.
Assisting the escape from persistent ultra-poverty in rural Africa

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Abstract

Sub-Saharan Africa (SSA) is home to two-thirds of the world’s ultra-poor today. This paper offers current thinking on the structural causes of the spatially concentrated, persistent ultra-poverty that has plagued Africa for a generation and some key entry points for facilitating Africans’ escape from persistent ultra-poverty.

The increased recognition of persistent ultra-poverty has rekindled long-dormant interest in poverty traps. The essence of a poverty trap is that there exists one or more low equilibrium level(s) of well-being in which people appear caught unnecessarily. Small adjustments fail to move people out of those equilibria sustainably. Rather, systems must change, major positive shocks must occur, or both. And in the absence of systemic change, recurring adverse shocks only drive more people into the trap.

The ultra-poverty trap that characterizes much of rural SSA today is intimately caught up with (i) the bidirectional interrelationship among hunger, ill-health, low productivity, weak institutions and natural resources degradation, all of which become manifest in low incomes, (ii) poor initial conditions associated with health and nutrition, especially early in childhood, but also with the state of infrastructure and the natural resource base on which rural livelihood disproportionately depend, and (iii) uninsured risk exposure, which is especially severe in rural areas and in agriculture. The closely coupled nature of these problems adds substantially to the challenge of addressing any one of them on its own and thereby makes integrated strategies essential.

The available theory and evidence suggests that the policy focus must fall squarely on stimulating a smallholder food productivity revolution. Toward that end, the paper concludes by identifying and explaining key entry points for assisting the escape from persistent ultra-poverty in sub-Saharan Africa.

1. Build and protect the productive asset endowments of the ultra-poor
2. Improve the productivity of the ultra-poor’s current asset holdings
3. Improve risk management options for the ultra-poor
4. Facilitate favorable transitions out of agriculture

Although the topic of persistent ultra-poverty would seem to lend itself to a pessimistic ending, the future for Africa is actually rather hopeful. The East Asian experience demonstrates that mass, rapid escape from persistent ultra-poverty is feasible. Real agricultural output growth rates are accelerating in SSA, nearly doubling from the 1980s rate so that per capita food output is growing again, helping reduce rural poverty rates in countries enjoying increased agricultural productivity. Finally, the policymaking and donor communities are now appropriately focusing on how best to stimulate investment incentives, productivity growth, risk management and productive transitions out of agriculture. These broad foci are appropriate and reasonably well-grounded in both theory and empirical evidence.
Assisting the escape from persistent ultra-poverty in rural Africa

Introduction

The Millennium Declaration of September 2000, adopted by the 189 member states of the United Nations, renewed the vigor of the global community’s commitment to improve living conditions throughout the world. The very first Millennium Development Goal (MDG) is to halve, by 2015, the proportion of people living in extreme poverty. The bold but attainable goal enshrined in MDG#1 can be met.

Rapid poverty reduction is possible, as demonstrated by a generation of rapidly falling headcount rates of poverty, defined as per capita daily expenditures under US$2.50 in purchasing power parity terms. As shown in Figure 1, the share of the world’s population living on $2.50/day per person or less fell from 75 percent in 1981 to 56 percent by 2005. Progress has been even more dramatic in East Asia, where rapid economic growth, especially in China, has lifted historically unprecedented hundreds of millions of people from abject poverty. In 1981, more than 95 percent of the residents of East Asia lived on $2.50/day or less; by 2005, less than half did. This is a truly remarkable accomplishment in both its scale and speed. The East Asian experience should inspire us to acknowledge that rapid, large scale escape from poverty is possible, and thus to pursue that aim with renewed vigor.

These tremendous accomplishments notwithstanding, an unacceptably large number of people continue to live in poverty. Moreover, in key parts of the world, notably sub-Saharan Africa (SSA), progress has been virtually non-existent. The headcount rate of poverty in SSA has oscillated between 80 and 84 percent since 1981 while the number of people living on $2.50 or less per day has effectively doubled, from an estimated 320 million persons in 1981 to 610 million by 2005. While there remains reason for hope based on the East Asian experience, clearly there is something structurally different about SSA that is causing stubborn persistence in human deprivation at continental scale. This paper offers current thinking on those structural causes and some key entry points for facilitating African escape from poverty.

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1 All poverty figures reported here were computed from the World Bank’s PovCalNet web application (http://econ.worldbank.org/povcalnet).
Figure 1: The evolution of poverty in Africa, East Asia and the World, 1981-2005

Note: Bubbles are scaled by population. Poverty figures computed from the World Bank’s PovCalNet web application (http://econ.worldbank.org/povcalnet).

Persistent ultra-poverty

Perhaps the principal reason why there has been less progress in SSA moving people beyond the $2.50/day per capita global poverty line is that the depth of poverty was – and, distressingly, remains – far deeper in Africa than in other continents. The ultra-poor – those living on one quarter or less of the global poverty line, i.e., $0.62/day per capita – are disproportionately concentrated in SSA.2 Worldwide, the headcount rate of ultra-poverty has absolutely collapsed, from 19 percent (704 million people) in 1981 to just 4 percent (221 million) in 2005 (Figure 2). The escape from ultra-poverty is nearly complete in East Asia, where less than one percent of the population now survives on $0.62/day or less, down from 36 percent in 1981 (not shown). Even in South Asia, the world region that is now home to most of the world’s poor, ultra-poverty has fallen from 13 percent to 3 percent in a generation. But in SSA, the number of ultra-poor

2 Ahmed et al. (2007) demonstrate the same point using different data and a different ultra-poverty line.
doubled from 1981 to 1999, from 84 to 165 million, and the ultra-poverty headcount rate has remain stuck around 20 percent. There has been notable progress over the past decade, coincident with significant progress in many African countries (Radelet 2010). But this progress has been slow and come late. SSA is now home to 65 percent of the world’s ultra-poor, up from just 12 percent in 1981. While poverty remains primarily an Asian phenomenon – for the simple reason that it is the world’s most populous continent – ultra-poverty is primarily and increasingly an African condition. This is the big challenge: spatially concentrated, persistent ultra-poverty that has plagued Africa for a generation.

Figure 2: The evolution of ultra-poverty in Africa, South Asia and the world, 1981-2005

Note: Bubbles are scaled by population. Poverty figures computed from the World Bank’s PovCalNet web application (http://econ.worldbank.org/povcalnet).

The preceding national poverty estimates are all based on nationally representative, cross-sectional household surveys. A different, arguably better way to get a sense of the persistence of poverty as experienced by individuals comes from looking at longitudinal household data. For how long do poor households typically remain mired in poverty? This is a surprisingly difficult question to answer in most settings because we lack adequate longitudinal data of households. That said, Figure 3 (adapted from Barrett and Swallow 2006) contrasts poverty dynamics in the United States (Naifeh 1998) with that in three rural African sites my collaborators and I have observed for some time: northern Kenya and central and south-central Madagascar (Barrett et al. 2006). These are very crude comparisons meant purely for illustrative purposes. But they clearly
make the key qualitative point that the percentage of the population that was poor at one point in time – for the year noted, as compared against the location-specific poverty line noted in parentheses, measured in real 2002 US dollars/day per person – who remain poor in subsequent periods falls very quickly in the United States, where most poverty is transitory, due to temporary unemployment spells. In the US, less than 25 percent of the households remained poor for one year and only 5.3 percent were still poor after two years; median time in poverty was only 4.5 months (Naifeh 1998).

**Figure 3: Comparative poverty dynamics in Kenya, Madagascar and the US**

![Diagram showing comparative poverty dynamics](image)


By contrast, most poverty in these African cases appears distressingly persistent. Anywhere from 60-90 percent of the ultra-poor – the poverty lines used here were half the national rural poverty lines in place at the time – remained ultra-poor 18-60 months later. In rural Africa, we do not even know the median spell length in poverty! That is because we have no longitudinal data sets in which at least half of the initially poor have exited poverty in some subsequent round, so we cannot compute the median poverty spell length.

These crude comparisons underscore an important qualitative point: it is not just the headcount poverty rate but, perhaps even more importantly, the depth and duration of poverty that
differentiates rural Africa from much of the rest of the world, even Asia. Anti-poverty policy in wealthy countries largely revolves around the provision of safety nets to cushion people against short-term shocks and to help them “get back on their feet again” quickly. In the fast-growing emerging markets of Asia it has largely revolved around ensuring inclusive growth. In rural Africa, the task is far more challenging. The persistent poverty of rural Africa is of grave concern not only because of the severe, sustained material deprivation it represents, but equally because of the feelings of hopelessness that such dim prospects can induce. This persistent ultra-poverty has complex, multi-factorial causality that has thus far rendered it impervious to simple solutions that are often motivated by relatively simplistic conceptualizations and measures of poverty, like the simple per capita expenditure measures reflected in the preceding figures.

Figure 4 (reproduced from Carter and Barrett 2006), schematically represents alternative approaches to measuring poverty. The most common (first generation) approach to poverty measurement relies on household expenditure (or income) data from a single point in time. Once a money metric poverty line is defined, the population can then be divided into poor and non-poor categories, and the standard suite of headcount and other measures can be calculated to gauge the extent and depth of poverty within an economy. Application of these first generation poverty analysis methods to repeated cross-sectional surveys allows insight into the evolution of poverty within a society. Figures 1 and 2 are examples of the sorts of descriptive analyses possible with such measures.
Cross-sectional poverty measures cannot tell us, however, whether certain households are stuck in poverty for extended periods or whether there is considerable turnover within the ranks of the poor such that many people experience poverty, but only for short spells, on average. In the first case, poverty is largely chronic, as reflected in long duration poverty spells. In the latter case, poverty is primarily transitory, manifest in short poverty spells. First generation poverty measures based on cross-sectional expenditure or income measures are incapable of distinguishing between these starkly different poverty processes.
Growing interest in poverty dynamics motivated a second generation of poverty analysis based on longitudinal or panel data that offer repeated observations over time on a single cohort of individuals or households, such as we saw in Figure 3. As illustrated in Figure 4, panel data permit a further decomposition of households into three categories: the always or chronically poor, the sometimes or transitorily poor, and the never poor. Second generation, panel data studies of poverty in developing countries have typically found that transitory poverty comprises a rather large share of overall poverty (Baulch and Hoddinott 2000).

The largest estimated share of transitory poverty based on income or expenditure underscores the inherent stochasticity of flow-based measures of welfare. People are better off one period than another without any significant or lasting change in their underlying circumstances, particularly the stock of productive assets under their control, due solely to random price and yield fluctuations and irregular, stochastic earnings from remittances, gifts, lotteries, and so forth. Moreover, the magnitude of measured transitory expenditure or income poverty may also reflect the measurement error to which flow-based welfare measures are especially prone. Barrett et al. (2006) and Naschold and Barrett (2011) show that measurement error and stochastic components to income data generating processes can completely mask structural patterns of income change over time.

The Achilles heel of second generation poverty measures is that they cannot distinguish between very distinctive sorts of poverty transitions. Individuals may appear to be transitorily poor in a standard panel study, moving from the poor to the non-poor state over time due to either of two markedly different experiences. Some may have been initially poor because of bad luck. Their transition to the non-poor state simply reflects a return to an expected non-poor standard of living (a stochastic poverty transition). For others, the transition may have been structural, due to the accumulation of new assets, or enhanced returns to the assets that they already possessed.

Similarly, those transitorily poor individuals who move from being non-poor to poor, can represent a mix of experiences. For some, the transition could represent a return to an expected standard of living, after a brief non-poor hiatus afforded by a spell of good luck. For others, the same transition could be a temporary phenomenon caused by bad luck in a later survey period. Finally, for yet others, the observed transition could reflect a structural move caused by the loss of assets (due to illness, natural disaster or theft), or by a deterioration in returns to their assets brought on by changes in the broader economy (for example, unemployment or declining terms of trade). Slightly more formally, the second generation approaches to poverty measurement cannot differentiate between stationary and non-stationary shocks to individuals' welfare.

To overcome these limitations of second generation poverty measurement, a third generation of poverty measurement arose, largely starting with the work of Carter and May (1999, 2001) to identify an asset poverty line as a natural, stock-based extension of the more familiar flow-based concept of an expenditure or income poverty line. This asset poverty line can then be used to distinguish stochastic from structural transitions, making it possible to decompose poverty transitions, as shown in Figure 4. The asset poverty line can also be used as the basis for a suite of structural poverty indicators that provide a snapshot of structural poverty, having filtered out the influence of stochastic transitions. As Barrett et al. (2006) and Naschold and Barrett (2011) show, structural economic mobility is—for simple statistical reasons—markedly less than total
economic mobility that includes transitory components. But if the underlying productive asset stock of households is slow to change, that has important implications for the persistence of poverty.

While defining and measuring poverty based on the asset poverty line provides important information on the structural foundations of poverty, it does not speak to the long-term persistence of structural poverty. Analysis based on the asset poverty line cannot by itself identify whether the currently structurally poor are likely to remain poor over the longer term, caught in a poverty trap, or indeed whether a subset of the structurally non-poor can sustain their positions over the longer term. To further decompose these groups according to their long-term, persistent poverty status requires a fourth generation approach to poverty based on an understanding of underlying patterns of asset dynamics. The growing empirical literature on asset dynamics and poverty traps (Lybbert et al. 2004, Adato et al. 2006, Barrett et al. 2006, Hoddinott 2006, Santos and Barrett 2006, Naschold 2009) points to the identification of a dynamic asset poverty threshold—the point at which current asset stocks are expected to lead to eventual escape from poverty, given the underlying asset law of motion prevailing in the economy—as the key to decomposing current structural poverty into its persistent and more transitory components over time (Carter and Barrett 2006).

Such observations have rekindled long-dormant interest in poverty traps. The idea is an old one, reflected in prominent development theories of the 1940s and 1950s that tried to explain the geographic clustering of poverty in the world (Rosenstein-Rodan 1943, Nurkse 1953, Myrdal 1957, Hirschman 1958). The essence of a poverty trap is that there exists a low-level equilibrium level of well-being in which individuals, households, communities, nations or even multinational regions appear caught unnecessarily. Small adjustments are insufficient to move people, communities or nations out of those equilibria sustainably. Systems must change, major positive shocks must occur, or both. And in the absence of systemic change, recurring adverse shocks will only drive more people into the trap. It is perhaps worth illustrating these systemic, structural features through two examples.

**Two African examples**

Pastoralists in the arid and semi-arid lands (ASAL) of northern Kenya and southern Ethiopia are among the world’s poorest populations by many metrics. They inhabit a harsh agro-ecosystem where rainfall varies dramatically within and between years, averaging only 200-750 mm annually in most of the areas my collaborators and I have worked. As a result of historically low rainfall, poor soils, high evapotranspiration rates and very sparse transportation, communications and power infrastructure—as well as other public goods and services, such as health care—these populations’ livelihood depends heavily upon the livestock herds they can sustain on the grasses and water available on the rangelands. Recent research has established reasonably convincingly the existence of multiple equilibria in both human welfare terms—a poverty trap associated with distinct wealth levels measured in herd sizes—and localized range degradation alongside (seasonally) abundant forage in large parts of the east African ASAL (McPeak and Barrett 2001; McPeak 2003; Lybbert et al. 2004; Barrett et al. 2006; Santos and Barrett 2006).
The reasons for the apparent poverty trap are several. Market imperfections – not least of which, uninsured asset risk – create two distinct modes of pastoralism: (i) a low-level equilibrium characterized by sedentarized livestock keeping of one or two cows in small, poor settlements subject to serious, but only localized range degradation, and (ii) a higher-level equilibrium based on traditional, transhumant grazing of large herds sustained by long distance treks to areas that retain abundant forage and water (Lybbert et al. 2004; Santos and Barrett 2006). There is negligible incentive to invest in education, as employment opportunities are negligible and supply-side constraints severely limit the quality of education available in most locations. Thus, investment in livestock offers the best option in this setting.

Impoverishment and range degradation seem to go hand-in-hand and are magnified by human population growth in an area facing receding available grazing lands due to the growth of towns, the gazetting of parks, and the expansion of areas of violent conflict spilling over from Somalia and southern Sudan. But those conditions by no means apply to the whole of the region. Indeed only to a very small proportion of the land area as recent, careful empirical studies find no support for classical tragedy-of-the-commons effects. That is one pastoralist’s herd size having an adverse effect on the productivity or survival of another pastoralist’s livestock (Lybbert et al. 2004; McPeak 2005). The range ecology of the region appears rather resilient in most locations, capable of supporting mobile pastoralism and climate variability of the sort traditionally faced in the region. Those who can maintain a reasonable size herd typically remain mobile on a resilient landscape and can whether natural shocks, while those who lose their herds, for whatever reason, commonly collapse into town-based destitution on a degrading local landscape.

The challenge of poverty traps in the east African ASAL transcends herd sizes and market imperfections, however. Historically, a clan or ethnic group’s grazing areas typically have flexible and contested boundaries. As a result, environmental resource management becomes closely bound up with issues of conflict management. Setting and enforcing rules to coordinate expectations and actions becomes essential to prevent collapse, not just of the fragile range ecology but also of pastoralist communities into violence and destitution (Haro et al. 2005; Munyao and Barrett 2007). It seems unlikely that one could surmount the poverty trap problem in the pastoral areas of the east African ASAL without tackling both market imperfections and coordination/ institutional issues jointly.

Somewhat similar patterns emerge in a strikingly different agroecosystem in highland western Kenya. Shepherd and Soule (1998) found, based on a simulation model calibrated using data collected across a range of western Kenyan farms, that soil nutrient mining by poorer farmers unable or unwilling to invest in soil fertility replenishment, farmers clearly falling into a resource degradation poverty trap, can co-exist alongside stable soil quality among better-endowed farmers in a homeostatic subsystem. This important finding is one of the clearest empirical examples in the literature of a resource degradation poverty trap.

Plot- and farm-level survey data collected over the period 1989-2004 in western Kenya corroborate the patterns that Shepherd and Soule (1998) first described (Barrett et al. 2006; Marenya and Barrett 2009, Stephens et al. 2011). Those who remain non-poor over time started off with statistically significantly higher endowments of land, improved livestock and educated family members, as well as greater and more remunerative off-farm employment to generate the
cash necessary to invest in chemical fertilizer and other critical integrated soil fertility management interventions. As soil nitrogen and phosphorus stocks decline after a few decades’ continuous cultivation in annual food crops, and as farms get subdivided in the face of human population growth, the better off farmers can afford to purchase and plant tea stems and to forego any earnings from the land converted to perennials during the roughly two years it takes tea bushes to mature and generate marketable leaves. The tea bushes’ roots provide outstanding erosion control, however, and the local tea factories’ natural monopsony – due to the need to process tea leaves quickly after picking – enables them to provide inorganic fertilizer on credit secured by future delivery of tea leaves. Those who can afford to invest in conversion from maize to tea as soil quality declines thereby escape the seasonal liquidity constraints that impede soil fertility replenishment by poorer neighbors. A homeostatic system of reasonably fertile soil conditions and adequate incomes results for these households.

Meanwhile, those who collapse into poverty all traced their decline to shocks that caused them to lose critical land, livestock or human assets, initiating a spiral from which their family has not recovered. The single most common cause of collapses into persistent ultra-poverty was health shocks that depleted family productive assets (Barrett et al. 2006), reflecting a pattern that appears relatively general worldwide (Krishna 2010). Those who suffer persistent poverty articulate less concern for conserving soil fertility and make fewer efforts to do so, presumably reflecting lower conditional (constrained) returns to investment in degraded soils for the poor (Marenya and Barrett 2009). The poor also point to certain higher-return activities as beyond their reach for want of financial capital, education (commonly due to inability to pay school fees), the social connections necessary to secure remunerative full-time employment, or some combination of these. These obstacles dampen the productivity of their limited labor, land and livestock holdings relative to better-off neighbors. The result is a system that appears to exhibit multiple soil fertility equilibria and associated levels of per capita income, driven in large part – but not entirely – by imperfections in markets for credit and insurance (Barrett et al. 2006, Stephens et al. 2011).

These financial market imperfections that impede optimal investment are compounded by coordination failures among farmers. Nutrient-depleted soils in sub-Saharan Africa have become infested with the parasitic weed *Striga hermonthica*, with yield losses now over US$7 billion annually (SPIPM 2003). Prevention of *Striga* encroachment depends on maintaining high soil fertility and moisture, which is difficult in rainfed lands with infrequent rotation or fallowing. Once established, “witchweed”, as Kenyan farmers understandably call the plant, has proved resistant to conventional methods of weed control via herbicides and hand or mechanical weeding. A single *Striga* plant produces thousands of tiny seeds that are difficult to notice. Most of the damage to the crop occurs before the parasite emerges from the ground and can be readily identified, and the seed can remain dormant but viable in the soil for many years. *Striga* is therefore difficult to eradicate because a single surviving plant can recolonize a large area in a single season. And with so many lightweight seeds, it spreads readily from farm to farm via wind, water, animals and humans. Coordinated measures are essential for effective eradication because the returns to an individual farmer’s efforts to block the entry of (or to eradicate) *Striga* on his fields are an increasing function of neighboring farmers’ efforts at weed control. It has proved exceedingly difficult, however, to organize communities to combat *Striga* in spite of the parasitic weed’s considerable costs. This seems to be especially true in villages with large
numbers of recent immigrants, inter-clan frictions and other social phenomena that dampen the strong ties necessary to resolve such coordination problems (Barrett 2005). Thus crop yields and soil quality continue to decline, in this case, due in large measure to the coordination failures mechanism behind poverty traps.

**Poverty traps**

The preceding examples illustrate the notion of a poverty trap, defined as any self-reinforcing mechanism which causes poverty to persist (Azariadis and Stachurski 2007). This can include single equilibrium systems where the unique equilibrium is at a low-level of well-being or systems characterized by multiple dynamic equilibria, at least one of which involves an unacceptably low standard of living. The poverty traps idea remains a conjecture – albeit a compelling one – because finding irrefutable empirical evidence that poverty traps really exist remains a difficult challenge for researchers. This difficulty arises due both to paucity of high quality longitudinal data on households and individuals in low-income countries and to disagreements among technical experts over how best to test the hypothesis that some people might be caught in a poverty trap. While it is important to attack that epistemological question via basic research in the social sciences, the core empirical fact of widespread persistent ultra-poverty – simply put, a poverty trap – has proved largely intractable to recent interventions remains regardless of the academic dispute. And there is much that we already know that can usefully inform policy even as the intellectual struggle continues to understand more rigorously and precisely the etiology of SSA’s apparent poverty trap.

First, we know that there are multiple, interacting causes behind persistent ultra-poverty. That is why it is difficult – really, futile – to find a single, simple solutions. Stocks of productive assets govern the dynamics of an economic system. But in ultra-poor communities, stocks of financial, human, natural and physical capital are typically low due to limited investment capacity – people have meager savings and scant access to credit with which to invest – and a poor risk-return profile to most assets. Low stocks are the result of both insecurity due to weak property rights and exposure to natural threats (e.g., disease, predators, hydrometeorological disasters) and low average returns due to rudimentary production technologies and weak marketing systems. This combination of limited asset holdings and low productivity of those assets tends to be highly spatially concentrated, leading to geographic poverty traps wherein the poverty of individuals reinforces that of communities – even of entire nations – and vice versa (Barrett and Swallow 2006).

This all reflects reinforcing feedback. Low productivity leads to low incomes and thus poverty. But low real incomes are in turn the primary cause of food insecurity and ill health, as well as a significant factor explaining weak institutions and natural resource degradation (Barrett 2008). Of course, undernutrition impedes cognitive and physical development, thereby depressing educational attainment and adult earnings and productivity. Disease likewise impedes the uptake

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3 See Azariadis and Stachurski (2007) and Carter and Barrett (2006) for discussion of the technical issues and empirical disagreements in the literature.
of scarce nutrients, aggravating hunger and micronutrient malnutrition problems and hurting labor productivity and earnings, further underscoring the multifactorial feedback intrinsic to poverty traps (Dasgupta 1997; Schultz 1997; Strauss and Thomas 1998). Furthermore, since much health care provision is a public good funded by tax revenues, areas of concentrated ultra-poverty commonly cannot afford the physical infrastructure or professional staffing necessary to ensure an adequate, high quality supply of preventive and curative health care in very poor communities. This relationship between the public finance problems associated with health care provision and the dynamics that lead to individual- and household-level poverty and ill-health traps is a classic example of spillovers between micro- and meso-scale phenomena that lead to what Barrett and Swallow (2006) term “fractal poverty traps”—patterns that are replicated at multiple scales of analysis. The reinforcing feedback among poverty, ill health, food insecurity, natural resources degradation and weak sociopolitical institutions and hunger – manifest at all levels of analysis in contemporary Africa – is a central characteristic of the poverty traps apparent in SSA today.

Two other key things about poverty traps merit brief review. First, initial conditions matter. This applies not just to nutritional and health status (e.g., low birth weight babies typically have retarded cognitive and physical development, with long-term economic and health consequences), but far more broadly. Those who possess the means to invest are commonly better able and more willing to secure credit, access to complementary resources, political favors or whatever else it might take to induce investment, whether in new production technologies, new marketing relationships, education and health care for children, productive new assets, or improvements to the natural resource base on which future earnings depend. And such investment is the engine for exiting long-term poverty and hunger.

In thinking about initial conditions for the ultra-poor in SSA, it is extremely important to keep in mind that they are especially likely to live in rural areas. Poverty remains a disproportionately rural phenomenon worldwide. This is especially pronounced among the ultra-poor; the average percent difference between rural and urban poverty incidences are roughly 400 percent for the ultra-poor, more than twice as large a gap as for those living in poverty but above the ultra-poor income threshold (Ahmed et al. 2007). Rural people depend heavily on the natural resource base for their livelihoods, as farmers, fishers, forest product gatherers, herders and workers. In much of SSA, soil fertility and water access are especially poor, and in many places, deteriorating. Furthermore, the physical and institutional infrastructure to support commerce, innovation and value-addition are commonly rudimentary or absent. For example, in 1999 (the most recent year for which comparable data are available), only 12.1 percent of the roads in SSA were paved, as compared with 36.3 percent worldwide and even 30.8 percent in South Asia (World Bank 2007a). These areas have been disfavored by both nature and states, creating an immediate disadvantage for rural Africans’ productivity and investment incentives.

The second key thing we know about poverty traps is the importance of risk. Even transitory shocks can have persistent effects by casting people onto a downward spiral into destitution from which they do not recover, or by keeping them from growing their way out of persistent poverty by regularly knocking them backwards as they struggle to climb out of the trap, a real-world Sisyphean tragedy (Dercon 1998; McPeak and Barrett 2001; Dercon 2005; Carter and Barrett 2006; Santos and Barrett 2006; Carter et al. 2007, Krishna 2010).
People’s response to shocks – both ex post and ex ante – can likewise trap them in poverty. Risk can have two distinct, crucial effects in systems characterized by poverty traps. First, ex ante efforts to reduce risk exposure can dampen accumulation – either voluntarily or through credit rationing – thereby creating a low-level equilibrium. Second, the ex post consequences of a shock—both the shock’s direct biophysical effects or those due to coping strategies taken in response to the shock—can knock vulnerable people back into a poverty trap.

The ultra-poor who disproportionately inhabit rural SSA are especially risk-exposed. Conflict and associated complex emergencies are perhaps the most shocking source of risk borne by rural Africans. But even where peace reigns, weather-related risks disproportionately affect rural people and the agriculture sector through drought and flooding, the effects of which are compounded by less reliable physical and institutional infrastructure for responding to shocks. These patterns are aggravated by spatial inequality in the coverage and effectiveness of public and veterinary health systems, which strongly favor richer areas. Overall, people in low-income countries are four times more likely to die due to natural disaster, and cost per disaster as a share of GDP are considerably higher in developing than in OECD countries (Gaiha and Thapa 2006). Poorer, rural areas appear far more vulnerable to disasters than are wealthier and more urban areas. Moreover, at the household level, evidence from drought in Ethiopia indicates that the medium-term effects of shocks vary by initial wealth, with poorer households feeling the adverse effects more acutely and for a longer period (Carter et al. 2007).

The most serious and commonplace catastrophic risk faced by the African rural poor, however, is ill health. As already mentioned, health shocks are the single most common explanation people offer for how previously non-poor families collapsed into persistent poverty. Those in or at risk of falling into poverty traps face a range of health challenges: maintaining an adequate diet, avoiding injuries most commonly associated with manual labor that is the mainstay of the poor, and staving off diseases commonly associated with unreliable water supplies, exposure to animal and human waste, and other standard hardships of poor communities. Furthermore, the ultra-poor are concentrated in an employment sector that is especially risky. The International Labour Organization (2000) reports that the agricultural sector is the most hazardous to human health worldwide, accounting for a majority of work-related mortality globally due to exposure to animals, chemicals, plants and weather, use of hazardous tools and machinery, long working hours under physically challenging conditions, etc.

The ultra-poverty trap that seems to characterize so much of rural SSA today is thus intimately caught up with (i) the bidirectional interrelationship among hunger, ill-health, low productivity, weak institutions and natural resources degradation, all of which become manifest in low incomes, (ii) poor initial conditions associated with health and nutrition, especially early in childhood, but also with the state of infrastructure and the natural resource base on which rural livelihood disproportionately depend, and (iii) risk exposure, which is especially severe in rural areas and in agriculture. The closely coupled nature of these problems adds substantially to the challenge of addressing any one of them on its own and thereby makes integrated strategies essential. It is therefore natural to start with agricultural and rural development as locus for developing an integrated strategy for addressing persistent ultra-poverty in rural SSA.
Start with agricultural and rural development

“Most of the people in the world are poor, so if we knew the economics of being poor we would know much of the economics that really matters. Most of the world’s poor people earn their living from agriculture, so if we knew the economics of agriculture we would know much of the economics of being poor.”

T.W. Schultz (1980, p. 639)

Several recent studies have reinforced Schultz’s seminal point. Agriculture is the lead sector for reduction of poverty and hunger, especially in sub-Saharan Africa (Christiaensen and Demery 2007; Diao et al. 2007; World Bank 2007b). Real GDP growth from agriculture is 2.7 times more effective in reducing the extreme poverty headcount in the poorest quarter of countries, including most of SSA, than is growth in non-agricultural sectors (Christiaensen and Demery 2007). And the focus must fall squarely on stimulating a smallholder food productivity revolution.

The reasons are straightforward. First, agriculture is the primary employment sector for the poor. A super-majority of Africa’s ultra-poor are small farmers who grow food, at least part time. Since earnings are determined by the productivity of one’s asset holdings and labor – and to a lesser degree, land and livestock – and are the primary asset of the poor, earnings in food agriculture are fundamental to their well-being. Rural Africans are disproportionately ultra-poor because their labor productivity is so low. Boosting the productivity of the labor, land, livestock and other assets controlled by the poor must be at the center of any strategy for breaking out of the ultra-poverty/hunger trap.

Second, although most of the ultra-poor are employed in agriculture, their productivity is so low that they typically do not produce enough to feed their families, forcing them to depend on non-farm earnings to supplement farming to pay for their net purchases of food. As Barrett (2008) documents, across a wide array of staple grain commodities, countries and years, multiple data sets consistently indicate that a small minority of SSA food crop producers are net (or even gross) sellers of these commodities; and within that minority, sales are heavily concentrated among just a few of the larger farmers. Because most smallholders are actually net buyers of the basic foods they produce, productivity gains not only have favorable real output effects on their well-being, but any induced declines in real food prices caused by aggregate supply expansion also benefit them.

Meanwhile, food is overwhelmingly the largest share of the budgets of the ultra-poor – whether or not they farm – routinely 65-80 percent of total household expenditures in this subpopulation (Ahmed et al. 2007). Since the budget share reflects the instantaneous elasticity of welfare with respect to prices (Deaton 1997), this fact signals that supply expansion that reduces real food prices is to be welcomed as it has a dramatic effect on the ultra-poor. This point is, of course, consistent with the longstanding observation that the bulk of the poverty reduction benefits of the Green Revolution in Asia (and to a lesser extent, in Latin America) came about through increased consumer surplus accruing to poor food buyers, not from income gains to farmers. Conversely, the high budget share of food among the rural poor also helps explain why recent global food price crises have been of particular concern for humanitarian agencies, although
many observers continue to overlook the fact that most small farmers are among those adversely affected by sharp food price increases. The fact that current price rises are due to demand growth far outpacing supply expansion underscores the central point that accelerating productivity growth in food agriculture is critical to the well-being of the poor.

The ultra-poor’s sectoral affiliation as agricultural producers and workers, and the heavy concentration of their expenditures on foods both point toward agricultural development as the nexus where interventions are most likely to bear substantial fruit. These sectoral and expenditure effects are reinforced by the strong (backward and forward) linkages from agriculture to secondary and tertiary sectors in the economy.

Minten and Barrett (2008) provide strong empirical evidence that better agricultural performance – as proxied by higher rice yields in their analysis of Madagascar – is strongly correlated with higher real wages, improved rice profitability and lower real consumer prices for the staple food. A doubling of rice yields in this setting leads to an average reduction of 38 percent in the share of food insecure households in the community, shortens the average hunger period by 1.7 months (or one-third), and increases real unskilled wages in the lean (planting and growing) season by 89 percent due both to lower real rice prices and to increased demand for unskilled labor by wealthier farmers. Thus greater food crop productivity reduces extreme poverty for all the major subpopulations of the poor – net rice buyers, net rice sellers and unskilled workers – with the gains accruing disproportionately to the poorest: workers and poor net food buyers.

Such findings are not surprising since agricultural and rural development have been the foundation of poverty reduction and modern economic growth throughout history. All past cases of rapid, widespread progress from poverty have been causally associated with the transformation of agriculture, from 18th and 19th century Europe and North America to late 20th century East Asia. Striking increases in agricultural productivity, improvements in food safety, and markedly reduced costs of food distribution improved the quantity, quality and variety of food available at lower prices. These advances permitted historically unprecedented growth in incomes, life expectancy and population, decreased the risk of chronic or acute malnutrition and enabled increased investment in education and non-agricultural activities in today’s advanced economies (Fogel 1994; Johnson 1997; Maddison 2001; Timmer 2002; Fogel 2004). In Asia, rapid increases in crop yields have been major drivers of historically unprecedented declines in poverty. By contrast, in SSA, staple grain yields have remained stagnant at roughly one ton/hectare for the past twenty-something years; and headcount poverty measures have remained similarly stuck at 40-50 percent of the population.

The “food problem” was Schultz’s (1953) label for the observation that until communities and countries made scientific and institutional advances to reliably meet their subsistence food needs through improved production, processing and trade, few could begin the process of modern economic growth. This view has been largely echoed in a vast subsequent social science literature (Boserup 1965; Geertz 1966; Diamond 1997; Timmer 2002; Gollin et al. 2007). Growth in agricultural productivity directly accounts for a disproportionately large share of economic growth and poverty reduction in a range of rapidly growing developing countries over the past several decades (Ravallion and Datt 1996; Gollin et al. 2002). Much of this effect arises
from agricultural linkages to non-agricultural sectors, including to human nutrition and to improved natural resources management.

Is agricultural and rural development the only thing that matters? Absolutely not. But it is hugely important and has been seriously underemphasized over the past decade or two as international assistance for agriculture has lagged, and rural institutions and public goods and services have been dismantled in the course of structural adjustment episodes. It is very difficult to envision, based on the historical or current empirical evidence, rural Africans mounting any sustained, broad-scale escape from persistent ultra-poverty without significant advances in the continent’s agricultural and rural productivity.

**Key entry points for assisting the escape from persistent ultra-poverty**

So where are the entry points for helping the ultra-poor of rural Africa enjoy sustained improvement in their and their children’s standards of living? Agricultural productivity gains are, as one would expect, strongly and positively associated with the adoption of improved agricultural production technologies, the stock of productive assets (soil quality, livestock, etc.) under farmers’ control, access to supporting services (such as agricultural extension), and the availability of irrigation and market access (Minten and Barrett 2008). The latter four variables have both direct and indirect effects – through induced technology adoption – on crop yields in rural SSA. These are perhaps the most potent policy levers available if one wants to improve agricultural productivity so as to reduce persistent ultra-poverty.

But a key is to guard against excessive generalization. No one size fits all approach exists. The binding constraints to progress vary from country to country and often from place to place within individual countries. There is no substitute for careful contextualization and empirical validation of specific policy ideas. There are, however, several key principles that can be clearly identified from a growing mass of evidence. Listed in order of importance:

1. **Build and protect the productive asset endowments of the ultra-poor**

Given production technologies and the market and non-market institutions that value what a household produces, earnings depend directly on the stock of productive assets to which a household has access. This includes both privately owned assets such as human capital, land, livestock or financial savings, as well as common property or public goods such as road or irrigation infrastructure. The most basic pathway out of poverty is to accumulate productive assets. In a poverty trap, however, investment is low because the incentives to invest are poor and thus meager asset holdings emerge as a low-level equilibrium. Changing this condition is a first-order imperative.

In some cases, assets must be provided to poor people who are simply unable to reserve any of their negligible income for investment. Examples include feeding programs for destitute sub-populations facing emergencies, free education for children, etc. This is especially important for human capital and natural capital that deliver high average returns but over time horizons typically measured in decades, so that financing constraints have particular bite.
But in most settings, the key to inducing private investment is to change incentives. In some cases, this requires firming up the institutions that ensure secure access to private property – rules of resource tenure, police protection against property crime, etc. Often, it requires investment in complementary inputs – so-called “crowding in” investment, whether in key infrastructure (e.g., roads, electrification, water) or in human capital through education and health programming, perhaps especially for pregnant women and children three years of age and younger. In other cases, this requires resolving financial markets failures – in credit and/or insurance – so as to enable people to borrow against future expected earnings and to shield their investment from transitory shocks that might otherwise imperil them. Indeed, an oft-overlooked element of changing incentives for asset accumulation concerns the provision of safety nets. Informal social arrangements commonly provide some measure of insurance against shocks for those who are reasonably well-integrated into local social networks; but many people appear to fall through the holes in social safety nets in rural Africa (Vanderpuye-Orgle and Barrett 2009; Santos and Barrett 2011). Moreover, village-level social networks necessarily cannot handle major, covariate shocks that simultaneously challenge most or all members of a social network. Hence the role for public (or external, private) provision of safety nets in the form of employment guarantee schemes, post-drought herd restocking, emergency (food and cash) assistance programs, etc. Indeed, recent theoretical work suggests that productive safety nets may be among the highest return policy instruments available in economies characterized by poverty traps (Barrett, Carter and Iukegami 2007).

One asset of special concern in rural SSA today is soil fertility. The land is the main non-human asset to which the poor have access. And it is degrading rapidly in much of SSA, contributing mightily to the apparent poverty trap in which many rural Africans presently find themselves. Recent estimates show that sub-Saharan Africa faces what a recent study refers to as “an escalating soil fertility crisis” (Morris et al. 2007, p. 18). The region lost 4.4 million tons of nitrogen, 0.5 million tons of phosphorous, and 3 million tons of potassium between 1980 and 2004, costing the continent more than $4 billion worth of soil nutrients per year (IFDC 2006). Declining soil fertility is also aggravating the problem of parasitic weeds in the *Striga spp.*, which cause more than $7 billion in yield losses and affect more than 100 million farmers annually in sub-Saharan Africa (CIMMYT 2007). Shrinking landholdings due to subdivision, continuous cropping, insecure land tenure and unaffordable fertilizer have resulted in severe soil degradation, diminished crop productivity and incomes, malnutrition and vulnerability to ill health. Without effective interventions to increase soil productivity and cropping system diversity, many farmers and their families are unable to produce enough food to feed their families or to earn adequate incomes. They then resort to the destructive, but perfectly rational, exploitation of the surrounding natural resource base, such as cutting down trees to make charcoal or clearing the river and stream banks’ protective vegetation to grow vegetables. While the importance of soil nutrient depletion to poverty reduction and overall economic development in sub-Saharan Africa was emphasized by the June 2006 international fertilizer summit in Abuja, Nigeria, and attended by many African heads of state and governments (IFDC 2006), systems level understanding of this growing crisis and of appropriate interventions remains distressingly scarce. In this setting, poverty reduction depends on improving our understanding of the economic, social and biological aspects of agricultural systems as a precursor for identifying sustainable and adoptable solutions that will enable and encourage SSA farmers to build and protect their stock of natural capital in the soil.
2. Improve the productivity of the ultra-poor’s current asset holdings

Increasing the returns to the assets held by the poor is the second core principle that must underpin strategies to facilitate rural Africans’ escape from persistent ultra-poverty. This happens both through (i) technological improvements to the physical productivity of agricultural production and post-harvest processing systems, and (ii) through advances in marketing systems that squeeze out costs from distribution channels and improve the economic returns farmers enjoy per unit of output grown while simultaneously holding down retail prices for net food buyers.

It is important to recognize that this is the second principle because adoption of improved technologies and participation in more remunerative marketing channels commonly depend in large measure on households’ asset endowments. The consistently strong positive relationship one finds in the literature between land holdings, livestock ownership, credit access or other measures of wealth and either adoption of improved technologies or natural resources management practices or participation in higher-value-added markets underscores how important asset endowment effects are to understanding patterns of agricultural productivity growth. Ultra-poor farmers commonly lack the assets to produce marketable surpluses and therefore they cannot afford new technologies nor reap the considerable gains attainable from market-based exchange. These restraints limit their ability to accumulate (or borrow) assets, reinforcing the initial condition and generating a low-level dynamic equilibrium (Carter and Barrett 2006). Making improved markets and technologies available is very important, but limited uptake is to be expected in the absence of adequate endowments to take good advantage of these new opportunities.

The returns to research on improved agricultural technologies have always been and remain high. The World Bank (2007b) estimates the average rate of return on agricultural research in SSA at roughly 35 percent per annum, far higher than returns on financial assets in virtually all SSA countries. Yet agricultural research remains severely underfunded on the continent. Although 75 percent of the extremely poor live in rural areas and are (at least partly) employed in agriculture, only 4 percent of global overseas development assistance (ODA) goes to agriculture (down from 10 percent in 1990), and only 4 percent of public expenditures in SSA are directed to agriculture (World Bank 2007b). Those figures heavily overstate the resources devoted to agricultural research and institutional development because they include the administrative costs of Ministries of Agriculture, which account for the overwhelming majority of such funds. Without a substantial reallocation of ODA and public resources in the direction of agricultural research, productivity growth in African food systems and thus progress in the fight against poverty, ill health and hunger will be slow at best.

Meanwhile, the productivity problems of ultra-poor smallholders are magnified by relatively poor integration into national and global markets and by rapid changes overtaking agrifood supply chains in the low-income world. Rapid concentration worldwide in both upstream input (e.g., seed, fertilizer) and downstream food wholesale and retail industries threatens the future of small farms worldwide (Reardon et al. 2003, 2009). We know remarkably little about who is able to participate in modern agrifood marketing channels, under what terms, and with what effects. Nor do we know much about what interventions – e.g., in supporting the creation or expansion of
farmer cooperatives, provision of infrastructure, improved monitoring and enforcement of grades and standards and of contracts, etc. – favorably affect poor rural residents’ capacity to take advantage of these changes, whether as suppliers, consumers or workers. These are key research areas because improving the incidence and terms of market participation by the rural poor is such an important principle for agricultural and rural development (Gomez et al. 2011).

3. Improve risk management options for the ultra-poor

Risk is a key impediment to investment in building up stocks of productive assets and to uptake of new technologies or participation in emerging marketing channels. Thus it is closely related to the preceding two principles. But this is where an added, tragic dimension enters: even if an ultra-poor household does make all the sacrifices necessary to invest in building up productive assets, to adopt all the best technologies, and to participate in the most remunerative marketing channels, it can all be wiped out in an instant. Catastrophic shocks – due to drought, flooding, disease, injury, conflict, crime, price spikes, etc. – are distressingly common, and relatively little of this risk exposure is formally or informally insurable in rural Africa. Therefore, improving risk management is central to the task of helping rural Africans escape from persistent ultra-poverty.

There are three big challenges in improving risk management. The first is the multidimensionality of the serious risks faced by the rural ultra-poor in SSA. Price volatility is significant and leaves producers vulnerable to sharp seasonal swings in markets. Add to this the fact that more than 95 percent of agricultural land in SSA is rainfed and particularly vulnerable to climate shocks. Pests and diseases also cause massive crop and livestock losses in much of SSA. And violent conflict has been a major burden on rural Africans, aggravating routine but pervasive insecurity of property rights due to weak tenurial institutions as well as to poor police protection. Furthermore, Africa is the only continent where infectious diseases cause more deaths than non-communicable illnesses, underscoring the severity of covariate human health risks that are especially difficult to manage.

Second, risk exposure tends also to be inversely related to standards of living, with the poorest bearing the greatest uninsured risks. For example, as soil quality declines, a parallel decline in crop vigor makes plants more susceptible to abiotic and biotic stresses; soil-borne pests and diseases appear to especially thrive under these conditions. Mycotoxins, such as aflatoxin, provide another example of an insidious threat that is particularly pronounced in poorer areas and among people who have less access to proper storage technologies and to food distribution systems with reliable food safety controls. Aflatoxin is immunosuppressive, growth-retardant and carcinogenic at lower concentrations and lethal at higher concentrations. Ill-nourished animals, like ill-nourished humans, have compromised immune function and are less productive and more susceptible to disease than their adequately fed counterparts. Meanwhile crime rates are commonly higher in poorer and more remote regions (Fafchamps and Moser 2003).

Third, the most relevant risks faced by different subpopulations are highly context specific. The most serious risks born by the rural poor vary markedly across space and time, even among seemingly homogeneous populations (Doss et al. 2008). Wealthy households owning large herds or enjoying high-paying salaried employment may bear considerable animal disease and unemployment risk, while poorer neighbors face relatively greater likelihood of contracting
serious disease or facing a disastrous staple food price spike. There are not many multiple hazard risk management options available, especially in rural areas.

Effective risk management therefore involves two distinct threads: risk reduction to dampen ex ante risk exposure and risk transfer to diffuse the impacts ex post of unavoidable shocks that occur. The primary means of risk reduction for the ultra-poor involve improvements to crop and livestock production systems, through improved cultivars, animal, human and plant disease control, water management systems, and increased access to diversification opportunities so as to build portfolios of activities offering weakly correlated returns. There is real progress in this arena. For example, improved maize cultivars that tolerate drought are coming online now, helping maize farmers in stress-prone areas of southern Africa. New varieties of rice that survive flooding are being tested, and the new rices for Africa (NERICAs) have demonstrated a remarkable capacity to combine higher yield with resistance to local abiotic and biotic stresses in West and Central Africa. Meso-level institutions associated with the establishment and maintenance of law and order and with control of infectious diseases are critical as well. Unfortunately, there has been less progress in these areas.

In high-income countries, financial systems and highly integrated markets provide the central means of risk transfer. The underdeveloped state of African rural financial systems and the spatially segmented nature of many rural food markets in SSA sharply limit risk transfer opportunities. Instead, there has been excessive dependence on external assistance in the form of emergency food aid relief and other instruments. But advances in food aid programming (Barrett and Maxwell 2005; Barrett et al. 2011) and in the design of index-based risk finance instruments (Barnett et al. 2008) show great promise for rapid progress in this area in the coming decade.

4. Facilitate favorable transitions out of agriculture

The final principle is necessarily ironic. Because agricultural productivity growth naturally stimulates relative contraction in the agricultural sector, relative to secondary and tertiary sectors, efforts to improve food systems must be accompanied by measures to help foster deliberate migration into non-farm livelihoods. Clearly, these must be of the demand-pull variety, not driven by catastrophic loss of agricultural assets. But in all past cases of successful agriculture-led growth, falling real food prices and stimulus to non-agricultural labor demand have consistently fostered such agricultural and rural transformation (Timmer 2002).

The key here is to help the current generation of adults improve their on-farm productivity so that they can invest in the health, nutrition and education of their children, thereby equipping the next generation with the human capital necessary to leave agriculture if and when the opportunity presents itself. In particular, and most appropriate to our focus on the ultra-poor of rural Africa, this underscores the especially high returns in adulthood to investments in disadvantaged children very early in life. Studies such as Heckman (2006) and Behrman et al. (2007) provide strong evidence in support of the hypothesis that early childhood (including prenatal and neonatal) health, nutrition and educational interventions have a strong effect on adult cognitive and physical performance and thus on earnings. Hoddinott et al. (2008) provide strong evidence that improved nutrition early in childhood led to significantly higher wages and total earnings among rural Guatemalans. Although there is no similar empirical evidence base from Africa – an important research gap waiting to be filled – the logic and moral imperative of
these results carries over directly. We know that early childhood investments in readying the next generation for a transition out of agriculture is essential for breaking out of the ultra-poverty/ultra-hunger/ill-health trap in the long-run.

Conclusions

Although the topic of persistent ultra-poverty would seem to lend itself to a pessimistic ending, I end on a positive note for multiple reasons. First, the East Asian experience – and increasingly, the South Asian one as well – provide ample reason to believe that mass, rapid escape from persistent ultra-poverty is feasible. Fifty years ago few commentators saw much prospect for the historically unprecedented ultra-poverty reduction on which most of East Asia embarked starting in the 1970s.

Second, real agricultural output growth rates are accelerating in SSA at long last, nearly doubling from the 1980s rate so that per capita food output is growing again in SSA (World Bank 2007b). More importantly, this contributes directly to falling rural poverty rates in countries enjoying increased agricultural productivity (e.g., Ghana). Public sector reforms, private investment and some well-targeted ODA have combined to help more than a dozen African countries achieve rapid economic growth and poverty reduction in the past several years, leading some respected observers to speculate that we may be entering an era of African economic take-off (Radelet 2010).

Third, there is reason for optimism thanks to bold new initiatives such as the joint Gates-Rockefeller Alliance for a Green Revolution in Africa, the Obama Administration’s Feed the Future Initiative and the prospect of renewed attention being paid to agriculture in Africa. This newfound emphasis was reflected clearly in the World Bank’s dedication of its flagship World Development Report to the topic for the first time in a quarter century (World Bank 2007b). But it has found perhaps its greatest and most important expression in the slowly accumulating successes of the Comprehensive Africa Agriculture Development Program in lifting the profile of agricultural and rural development within policy dialogues on the continent and eliciting increased government commitments to funding agricultural research, extension and infrastructure. Yield gaps – the difference between realized output and agronomic potential – remain significant in SSA, so the opportunities to achieve significant gains in short order are very real. And although aid to agriculture for SSA declined by roughly half from the late 1980s through 2002, it is now slowly turning around. Private investment in SSA is likewise picking up, with important innovations throughout rural Africa, from development of improved crop varieties and fertilizers to the introduction of modern agrifood supply chain management systems to the astounding rapid roll-out of mobile telecommunications systems. While there is no guarantee that these emerging opportunities will benefit the rural ultra-poor, such opportunities are necessary (albeit not sufficient) for progress. The prospects for agriculture-led reduction in persistent ultra-poverty in rural SSA are very real.

This is good news because the poverty traps apparent in rural SSA imply that intervention of some sort is essential in order to help people escape and avoid persistent ultra-poverty. Recognizing the need for some sort of intervention is the easy part, however. While intervention
is valuable, indeed essential, and the four key entry points identified above provide clear direction, there remains only limited empirical evidence to guide detailed design and implementation of strategies to stimulate agricultural and rural development so as to break the lock of poverty traps that disproportionately ensnare rural Africans.

The 1980s/90s structural adjustment era of economic reforms focused on reaping static efficiency gains from removing policies that distorted resource allocation. Unfortunately, policy design in that era was based on empirically flawed assumptions and the structural adjustment approach largely failed to stimulate either macro-level economic growth and balance of payments stability, or reduction of poverty and food insecurity in rural SSA. The focus of the policymaking and donor communities has thankfully shifted over the past decade from static concerns about “getting prices right” to dynamic concerns about incentives to innovate, invest and grow out of poverty over time, i.e., to finding “pathways from poverty”. Today, growing attention is focusing instead on how best to stimulate investment incentives, productivity growth, risk management and productive transitions out of agriculture. These broad foci are appropriate and reasonably well-grounded in both theory and empirical evidence.

But just as the (empirical and theoretical) evidence base was relatively thin at the outset of the structural adjustment era, so too does our current knowledge about the dynamics of reducing persistent ultra-poverty remain disturbingly limited today. So we need to proceed with caution and remain vigilant about rigorously investigating the premises that underpin policy designs and re-evaluating policies as the evidence base grows and sheds new light on what works best under which conditions.
References


Core literature on ultra-poverty and its manifestations in rural Africa


This landmark study by IFPRI was the first to systematically look below the dollar-a-day poverty line to determine who the poorest people are, where they live, and how each group has fared over time. This analysis called unprecedented attention to the “ultra-poor” and pointed out that they are overwhelmingly concentrated in one region: Sub-Saharan Africa. They emphasize how and why the severity of poverty in Sub-Saharan Africa, and the limited progress in reducing it, indicate that the poorest in Sub-Saharan Africa may be trapped in poverty. They underscore the close relationship between ultra-poverty and hunger and discuss some of the structural barriers to progress.


The definitive, technical summary of the theoretical economic literature on poverty traps through the early-mid 2000s. This chapter walks readers through the basic models, explains the various mechanisms posited to lead to low-level dynamic equilibria, and clarifies the formal mathematics of poverty trap models. The coverage spans both macroeconomic and microeconomic models.


This paper explains in relatively nontechnical fashion the evolution of poverty measurement from static, cross-sectional to dynamic, longitudinal measures and how the empirics of poverty traps relate to the theory. It explains how familiar flow-based measures of well-being, such as income poverty, are related to stock-based measures founded on assets and thereby makes the case for asset-based approaches to the study of poverty dynamics.


Following up on Dasgupta’s prior, seminal work on nutritional poverty traps (much of it written with Debraj Ray), this compact paper expertly describes the feedback between nutrient intake, physical capacity for work, and labor earnings. The narrative weaves together key findings from the nutritional and health literature with the essential economic theory and a clear intuition of the phenomenon.


This book is a leading contribution to the literature on risk and risk management among poor populations in developing countries. The book, edited by a leading scholar in the field, includes a variety of chapters that evaluate alternatives in widening insurance and social protection provision through both private sector initiatives and public policy. The papers span a range of
empirical methods and geographical settings, offering a nice introduction to a range of techniques and ideas.


An important contribution by an empirical political scientist who developed a novel method for collecting longitudinal recall data on poverty transitions, the “stages of progress” method, and applied it in surveys of 35,000 households in different parts of India, Kenya, Uganda, Peru, and the United States. A very readable, empirically grounded work, Krishna’s findings underscore that the reasons why some people collapse into long-term poverty are different from the reasons others escape persistent poverty. He emphasizes the cross-cultural importance of uninsured health shocks as the key driver of declines into persistent poverty.


This survey chapter by two of the modern giants of poverty analysis reviews the history of poverty measurement, as well as key correlates of poverty worldwide and the relationship between economic growth and poverty reduction. They then discuss a wide range of policies aimed at reducing poverty and the associated targeting methods and issues that influence the efficacy of anti-poverty interventions.


This paper was perhaps the first to rigorously demonstrate the existence of poverty traps, in this case among Boran pastoralists in southern Ethiopia. The paper explains how asset shocks can lead to catastrophic declines in standards of living from which rapid recovery is unlikely. It also documents that most of the risk faced by the poor is idiosyncratic, shocks experienced by one household at a time rather than by everyone simultaneously, and the implications for failures of community institutions -- such as social sharing norms – for poverty dynamics.


This paper offers the first solid empirical evidence documenting a “resource degradation poverty trap” in African agriculture. Fertilizer interventions have attained prominence in rural poverty reduction programs in Africa. Using data from maize plots operated by small farmers in Kenya, this paper shows that low soil organic matter commonly limits drop yield response to mineral fertilizer application. Although fertilizer is, on average, profitable, on roughly one-third of the plots degraded soils limit the marginal productivity of fertilizer such that it becomes unprofitable at prevailing prices. Moreover, because poorer farmers most commonly cultivate soils deficient in soil organic matter, fertilizer interventions might be less pro-poor than is widely assumed and may instead reinforce *ex ante* income inequality.

This paper uses a unique, spatially-explicit dataset to study the link between agricultural performance and rural poverty in Madagascar. It shows that, controlling for geographical and physical characteristics, communes that have higher rates of adoption of improved agricultural technologies and, consequently, higher crop yields enjoy lower food prices, higher real wages for unskilled workers, and better welfare indicators. The empirical evidence strongly favors support for improved agricultural production as an important part of any strategy to reduce high poverty and food insecurity rates.


This Nobel acceptance lecture by perhaps the greatest scholars of agricultural development lays out the core arguments for why agricultural productivity growth is central to improving the income and welfare of poor people. Schultz makes a strong argument, moreover, that the key factor in stimulating productivity growth and poverty reduction is not land or other material inputs, it is human capital: the education, health and innovativeness of the poor themselves.


This lucid survey chapter by a leading thinker on agriculture’s role in the process of economic development offers an analytical framework for understanding and quantifying the contribution of agriculture to economic growth and development. The framework points to the key areas where positive linkages, not necessarily well-mediated by markets, might exist, and it highlights the empirical difficulties in establishing their quantitative magnitude and direction of impact. Evidence on the impact of investments in rural education and of nutrition on economic growth is reviewed. The policy discussion focuses especially on the role of agricultural growth in poverty alleviation and the nature of the market environment that will stimulate that growth.


The most up-to-date summary of the empirical evidence for and theory behind agricultural development as the key engine of poverty reduction in the world. Led by two distinguished agricultural economists, Derek Byerlee and Alain de Janvry, this was the first of the World Bank’s flagship World Development Reports to focus on agricultural development in a quarter century. Its coincidence with the global food price crisis of 2007-8 made it especially influential in shaping ensuing policy debates in both developing countries and donor organizations.
Discussions on “Assisting the Escape from Persistent Ultra-Poverty in Rural Africa” - April 27, 2011

William A. Masters, Professor of Food Policy, Friedman School of Nutrition Science and Policy, Tufts University

Chris Barrett’s paper and presentation for this symposium is very rich in detail offering many starting points for discussion. Following his work can be a challenge, since he writes faster than most of us can read! A quick check on Google Scholar reveals the many other articles that cite his research and build on his ideas in multiple directions.

My job is to open up discussion here today at Stanford, and also for those joining this symposium later on. Professor Barrett’s summary of the pathways out of poverty is admirably specific and clear, so there is no need for me to restate any of it. Instead, I would like to spark discussion with a bit more context, and to frame these ideas in a way that might open up further dialogue from a variety of perspectives. I will do that first in terms of methodology and style of research, then in terms of research findings and their implications for poverty reduction.

Methodology

Some of the most striking features of today’s symposium involve research methods. Barrett’s approach offers an extremely valuable way of thinking, which helps account for the wider success of his work.

One feature of Barrett’s methods that I hope everyone appreciates is his balanced approach. He avoids monocausal hypotheses, and instead, explains observed outcomes as the result of some kind of interaction between multiple causes. The goal is to identify a structural system in which outcomes are not determined by any one force, but rather by the way in which many forces interact. For example, outcomes might depend on the interaction between each year’s income and a cumulative stock of assets, or between an average level of returns and the riskiness of those returns, or between individual and group characteristics.

Barrett’s focus on a structural system of interactions is of course an attribute of economics in general, whereby economists try to explain each observed outcome and predict changes as being an equilibrium among forces. He makes it look easy, but it is very difficult to keep an eye on several forces at once, see how each one operates and how they interact, without jumping to the conclusion that any one of them actually dictates the outcome. Thinking in terms of equilibria among many forces can help make discussions more productive by avoiding determinism about negative outcomes, and revealing opportunities to intervene in the system so that it works better. Those ‘points of entry’ as Barrett calls them are collective actions, guided by a research-based

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5 As of this writing, such a search can be conducted as: www.google.com/scholar?as_q=c.b.barrett.
diagnosis, that reveal how to overcome the market failures and political-economy constraints that currently limit the speed of poverty reduction, especially in Africa.

**An empathetic approach**

A second key feature of Barrett’s approach, which others and I appreciate, is the empathy he shows towards the decision-making of the ultra-poor. That is, trying to understand their choices from their point of view. Again he makes it look easy, but in fact it is very difficult to understand the choices of other people in a helpful way, especially when many of the outcomes for them are so awful. All too often, analysts think of people in bad situations as either passive victims of circumstance, or as having made bad decisions. Here again, the empathetic approach that Barrett uses is characteristic of good economics in general. To understand poor peoples’ decisions from their point of view requires the use of constrained optimization; however, calculus is not needed to understand the basic idea. Economics research starts by admitting ignorance about what other people want, assuming only that their observed choices must have optimized something. The task is then to ask what objectives and constraints could have led them to choose what they did.

Barrett uses optimization very skillfully, starting from faith that even the very poorest are already doing the best they can. He then looks for explanations in the structure of each person’s objectives and constraints and the resulting outcome in interactions with other people. Following his approach also helps make discussion more productive. Once a constraint or structural trap is diagnosed, it can perhaps be sprung through collective action, informed by that diagnosis.

To advance the discussion I would like to zoom out from the specific results of Barrett’s very detailed fieldwork in Kenya, Ethiopia, and Madagascar, and to frame those findings in terms of much broader, long-term forces. Over the long span of history, it seems clear that rural Africans were driven into extreme poverty much more recently than the poor in Asia, and have only just begun to escape from that poverty in the past decade. It seems promising to search for common underlying forces, whose parameters might explain the speed at which specific interventions are most needed.

**Results and implications**

To frame Barrett’s findings in a more general context, I would like to look at two broad dimensions: the extent of poverty and the distribution of income at a given time, and then, the changes in that distribution as it moves from year to year. This approach will help place the experience of the ultra-poor in the context of the entire income distribution, and their escape from poverty in the growth dynamics of an entire society.

Economists who study inequality generally find that income is distributed asymmetrically, with a mass of poor people and fewer rich people. This skewed outcome has been found almost everywhere that income has been measured, and is typically approximated by a log-normal distribution. Many structural processes could lead to such an outcome, but the simplest explanation for the skewness is that underlying variations interact multiplicatively rather than
additively. For example, if it takes money to make money, or more generally if one advantage begets another, then income distribution will be skewed in this way. Over time, however, income distributions do not always become more skewed. Diminishing returns may set in to limit how fast money begets money, thereby slowing the pace at which the rich get richer so that the poor can catch up. One of Barrett’s many useful ideas is thinking of interventions to help the poor as being a ‘cargo net’ rather than a ‘safety net’, where the goal of the intervention is to help the poor rise rather than to prevent their fall.

Barrett’s work is quite technically sophisticated, so for discussion purposes I would like to frame it in what I think is the simplest possible story about income distributions and its change over time. The goal here is to explain why there might be a mass of people in poverty, from which some can rise at different speeds, if they are helped by appropriate intervention.

The (over) simplified model I find most useful explains income distribution as resulting from half of a group being relatively lucky, and the other half unlucky. Furthermore, half have relatively high skills, while the others are unskilled. This is a 2x2 example of what in reality would involve many different abilities and sources of income. The system can be symmetric in every dimension, but if it takes skill to use luck, then only those who are both skilled and lucky can escape from poverty. In the simplest 2x2 example, three-quarters of the members would be relatively poor because they were either unlucky or unskilled or both, and only one-fourth escape from poverty. In Barrett’s terms the unskilled are ‘structurally’ poor, while the skilled will fluctuate stochastically in and out of poverty.

To see how income grows over time, another feature is needed in the model. There must be some way to save and invest in man-made capital, making for a 2x2x2 model. There are many kinds of capital, of course, and if the capital that is introduced requires both skill and luck to make income, then the rich get even richer and income distribution becomes even more skewed. On the other hand, if the capital can be used directly by the poor, it will help them advance and perhaps even acquire the same skills that the rich used to get ahead in the first place. That process would make income distribution less skewed.

In reality, as the old cliché says, the rich get richer… and the poor get children. Demography and population growth are two influences on poverty that Barrett rarely addresses in his work. He is in very good company in abstracting from population growth, because almost all development economists now realize that population density is no absolute barrier to poverty reduction. The issue is rather how demographic structure changes during the demographic transition, particularly in two dimensions: first by changing the mix of ages in the population, and second by changing the number of farmers and hence the area of land available per farmer.

The role of changing age structure in economic growth has been well explored since Bloom and Williamson’s research (1998). They show how historical patterns of demographic transition – in which socioeconomic improvements lead to child mortality decline followed by a decline in fertility – creates an initial rise and then a fall in children as a share of the population. This ‘demographic drag’ can slow economic growth as it did earlier in Asia and even more so in Africa a few decades later. However, the later ‘demographic dividend’ can help accelerate growth when child dependency rates fall. The fraction of people available for productive work is
now rising in Africa, as it did earlier in Asia, offering a powerful opportunity for faster income growth in each household and for the economy as a whole.

The influence of demographic transition on land area per farmer is less well understood among economists, but it has special resonance in this particular setting. Professor Bruce Johnston worked here at Stanford for the entire second half of the 20th century. One of his most important discoveries was how demographic transition, when combined with the growth of nonfarm employment, changes the land available per farmer.

In the early 1970s, Johnston’s findings from Asia led to his clear prediction for Africa. Even if nonfarm employment grew at world-record speed, the small fraction of Africans who already had nonfarm employment ensured that the absolute number of farmers would grow for several decades before it could fall (Johnston and Kilby 1975). Johnston’s prediction was that Africa’s rapid total population growth could not be absorbed through urbanization. As a consequence, the decline in land area per farmer would drive them ever further into poverty. He stressed this Malthusian phase of development would eventually come to an end as cities grew and absorbed more workers. The implications of this idea for modern African are illustrated in Masters (2005; 2011).

The arithmetic of rural population growth helps explain the dramatic worsening of African poverty through the 1990s. When available land per farmer is falling, that land gets used with increasing intensity of labor, capital and other inputs per acre, but diminishing marginal returns drive down each worker’s earnings and living standards. The speed and timing of this decline depends on how fast the country’s total workforce is growing, how fast nonfarm employment grows, and also on the fraction of workers already in nonfarm employment.

To see how this matters for income distribution and growth, I return to the simple 2x2x2 model, and recognize that capital accumulation mainly pulls people up out of poverty through nonfarm employment. The distribution of agricultural income generally falls further and further behind the distribution of income from services and industry, both rural and urban, until nonfarm employment outgrows the total population. At that point the absolute number of farmers can begin to fall, acreage per farm family begins to rise, and the distribution of farm income begins to catch up with the distribution of nonfarm income. Development specialist, Peter Timmer, has shown how this leads to a U-shaped curve in agricultural as opposed to nonagricultural incomes; contributing to the overall problem of poverty worsening before it improves (Timmer 2009).

This fall-and-then-rise relationship in land per farmer and hence farm living standards is driven fundamentally by the arithmetic of demography and migration. So returning to the simplified model of income distribution and growth, it is useful to think of two separate sources of income: earnings from agriculture follows a 2x2x2 model in which earnings depend on farmland per worker; in contrast, earnings from nonfarm work can grow without that constraint.

In conclusion, I hope that the development profession can sustain Barrett’s very productive approach of balanced explanations (equilibrium) with empathy towards the decisions of the poor themselves (optimization). It is important that we see how the poverty traps he documents are embedded in the larger economy wide distribution of income. Finally, I am concerned about the several decade-long impact population growth has farmer income. Growth drives down land per
farmer and hence farmer income, and until that trend reverses, farm income will be unable to catch up to nonfarm income.

References


Managing Price Volatility: 
Approaches at the global, national, and household levels

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Abstract

Political dynamics, not economic analysis, drive the domestic policy response to sharply rising food prices. The political objective during a food price crisis is almost always to keep it from happening. In the short run, this means “stabilizing” domestic food prices despite whatever is happening in world markets. Stabilizing domestic food prices in the face of sharply escalating world prices is not a foolish goal—most countries try to do it. The real issue is whether this can be done effectively and efficiently. The answer is always “no” unless the country has planned well ahead for such a contingency and already has an operational food price stabilization program in place.

As a matter of “good practice,” all countries are discouraged by international donors from conducting such programs. Instead, countries are urged to implement “social” safety nets in times of food price spikes. The economic rationale is clear: let market prices signal the scarcity of food resources so that supply and demand can adjust, and then compensate the poor for deterioration in their standard of living when food prices rise. The problem is that safety nets that reach the poor quickly and effectively take considerable time to design and implement, and are quite costly in fiscal terms if the poor are a substantial share of the total population. Historically, unless the country is already running a cash transfer program to the poor, the emergence of a food price crisis is too sudden for an effective government response. Gearing up emergency food relief safety nets is not an effective response to a sudden spike in food prices.

More active measures to prevent food price spikes are needed, both domestically and internationally. One starting point would be for countries with large populations to gradually build their grain reserves to the point where they do not feel vulnerable to spikes in world prices and to possible grain embargoes from their regular suppliers. It would be desirable to have such stockholding strategies coordinated internationally, but this is unlikely in other than rhetorical terms. Still, the mere existence of these stocks, even if domestically controlled, would have a calming influence on world grain markets (especially on the very thin world rice market). With calmer markets, recourse to more open trade policies becomes politically feasible (and it is almost always economically desirable). Eventually, the reality of the high costs of grain storage will stimulate a more balanced approach to food security, with both reserves and trade playing significant roles.
Managing Food Price Volatility: Approaches at the global, national and household levels

Introduction

There are strongly contended views on how best to address current food price volatility and its socio-economic consequences. For example, in Bangladesh in what is now the fifth year of extreme price volatility for basic foods the Prime Minister is responding to rice prices that were at least 30–40 percent higher than a year ago by proposing a massive increase in food subsidies through open market operations and the extension of ration and fair price to around a quarter of the population. In contrast the World Bank President in an open letter to the French G8/G20 Presidency identifies a range of ways of doing better to enable poor people to cope with price volatility whilst conspicuously de-emphasising international or national level interventions through trade measures, open market operations and stock management: ‘the answer to food price volatility is not to prosecute or block markets, but to use them better.’ (Zoellick 2011) [Quoted from Clay et al. 2011, p. 4]

Both of these approaches cannot be right. Either the Government of Bangladesh is pandering to popular demands and ignoring good economics, or the World Bank is pandering to economic ideology and ignoring good politics. Is there any way for good economics to be politically sensible, or good politics to be economically rational? These questions, difficult as they seem to be, are at the core of this paper.

Most economic analysis of the impact of volatile food prices has focused on the welfare of micro-based decision agents—poor consumers, smallholder farmers, sometimes on investment decisions by firms, especially in the marketing system (Newbery and Stiglitz 1981). The insights from such analyses are fairly predictable: price spikes hurt consumers, price drops hurt producers, and volatility in general confuses investors. The policy recommendations are equally straightforward: help producers cope with price risks through financial insurance instruments, help poor consumers via targeted safety nets, and help investors by making price formation more transparent (World Bank 2005). Price formation itself, however, must not be altered, because prices send signals about the scarcity of resources, and the willingness of consumers to pay for the productive use of those resources, that are essential to the efficient functioning of a market economy.1

There are two problems with this approach. First, much of the damage from highly unstable food prices occurs at the macro level, especially on the rate of economic growth and how well the poor participate in that growth (Timmer 2000). Second, behavioral economics has shown clearly that decision agents strongly prefer stable environments, and are willing to punish governments that fail to provide them (Timmer 2010c). Stable food prices are not a natural market outcome—the provision of stability is a public good, not a private one. Food security, as proxied by the

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1 As noted in the opening quotation, this is the approach recommended by Robert Zoellick, President of the World Bank, to the G-20 meetings convened by the French government to recommend measures for managing food price volatility (Zoellick 2011).
stability of staple food prices, is primarily a macro political economy problem, not a micro decision agent problem.

The micro problems are real, and household-level interventions that take the instability of food prices as given are needed to cope with them. But the macro political economy problems are larger and more long-lasting, and will require national and international interventions that seek to alter food prices themselves. The failure of the international community to agree on such interventions is understandable given the sharply different interests of key players (Sharma 2011), and greater attention needs to be devoted to “second-best” approaches at the national level. If stable food prices are recognized as the responsibility of governments, they will seek to provide them. The key questions are whether they can do this effectively in the short run while still building a market-friendly food economy in the long run.²

A framework for discussion

There is no question that food prices have been highly unstable, both recently and in the long run (see Figures 1 and 2).

We start by asking a basic question: what does price volatility have to do with food security? This is actually a very controversial question.³ Still, there is surprisingly wide agreement in the development community that, in general:

1) Price spikes hurt poor consumers, who buy most of their food;
2) Price collapses hurt farmers with crop surpluses to sell; and
3) Price risks reduce the quantity and quality of investments, including by smallholder farmers for agricultural modernization.

Thus highly unstable food prices have negative consequences at the micro level for household-level decision makers. One likely conclusion from these agreed points is that measures to alleviate the impact of food price instability will also need to be micro based. But my own work suggests that food price instability also has a deeper and more insidious impact: it slows down economic growth and the structural transformation that is the pathway out of rural poverty (Timmer 1980, 2009). Thus food price instability really hurts the poor in both the short run and the long run. An immediate conclusion from this perspective is that efforts to stabilize food prices, if successful, will have much larger economic benefits than suggested by the micro perspective, and the implementation measures are likely to be considerably different (Timmer 1989, 1991).

² The Indonesian experience with stabilizing rice prices in the short run while building a dynamic private marketing sector in the long run is discussed in Timmer (1996, 1997). Its broader relevance is presented below.
³ For example, see Barrett and Bellemare (2011). Their provocative title is “The G-20’s error: Food price volatility is not the problem.” Naylor and Falcon (2010) provide a quantitative assessment of changes in food price volatility.
Figure 1. Annual grain prices (constant US$2000) historically high, and forecast to stay high in medium term

Source: Christiaensen 2011. Note: These are almost certainly nominal prices, not constant US$2000.

Figure 2. Long-run trend in real rice prices, 1900-2008

Source: Data from Eberstadt (2008), analysis by author.
Consider a very simple model of food security that focuses on the short run versus the long run, and on the macro level (of policymakers) versus the micro level (of household decision makers) (see Figure 3). When the global economy is reasonably stable, and when food prices are well behaved, policymakers can concentrate their political and financial capital on the process of long-run, inclusive growth. Keeping the poor from falling into irreversible poverty traps is easier and less costly in a world of stable food prices, and the poor are able to use their own resources and entrepreneurial abilities to connect (via the small horizontal arrow) to long-run, sustainable food security for themselves.

If the food economy is highly unstable, constantly in crisis, policymakers spend all of their time and budget resources in the “upper left” box, trying to stabilize food prices and provide safety nets for the poor. During food crises, vulnerable households often deplete their human and financial capital just to stay alive. This is the world of poverty traps and enduring food insecurity. We are also trapped in short-run crisis management, both macro and humanitarian. Donors such as USAID can be trapped in crisis mode as well as governments, and end up spending their human and financial resources on emergency relief rather than longer-run development strategies and investments.

With success in achieving the objectives in the upper right and lower left boxes, market forces gradually—over decades—bring the poor above a threshold of vulnerability and into sustained food security (connecting macro to micro and short run to long run). The goal is to get to the “lower right” box where households have sustainable access to food in the long run. That is, they are food secure.

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4 This framework was originally worked out for a presentation to a food security conference sponsored by the Asian Development Bank in Manila in July 2010, and is presented in more detail in Timmer (2010d).
Figure 3. Basic framework for understanding food security issues in Asia

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<th></th>
<th>Short Run</th>
<th>Long Run</th>
</tr>
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<tbody>
<tr>
<td><strong>Macro</strong></td>
<td>Rice price stability and the role of rice reserves and international trade. Budget costs of safety nets to protect the poor, and impact of these transfers.</td>
<td>Policies for creating inclusive economic growth, including fiscal policy, management of price stability, the exchange rate, and the role of international trade.</td>
</tr>
<tr>
<td><strong>Micro</strong></td>
<td>Receipts from safety nets (including from the government), vulnerability to price shocks, and resilience in the face of other shocks to household welfare.</td>
<td>Sustained poverty reduction and regular access to nutrition and healthy food. This is the definition of sustainable food security.</td>
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How do we break out of these traps? Franck Galtier (2009) and his colleagues at CIRAD in France have designed a simple framework to think about managing food price instability. It builds on two critical distinctions: first, between preventing food price instability and coping with the consequences of unstable food prices; and second, between the role of the private sector in each domain and the public sector. Thus there is a 2x2 matrix with four cells -- A, B, C and D (see Figure 4).  

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5 The HLPE (2011) manuscript expands the Galtier matrix from 2x2 to 3x3 by differentiating the B and D mechanisms into ex ante management measures and ex post coping measures, and by adding a third level of actor—civil society.
With the rise of market fundamentalism since the mid-1980s, most donor efforts have concentrated on A and B measures, and on D measures when food crises still erupted. In view of the relative lack of success with the ABD approach, the issue is whether approaches to “C” might work. Are there public interventions that could stabilize food prices?

The answer depends on a variety of general and specific issues, especially on the level of action: local, national, regional and/or international. Although most analytical attention focuses mainly on the distinction between national and international actions, examples exist where farmer organizations at the local level and regional bodies such as the Association of Southeast Asian Nations (ASEAN+3), for instance, have engaged in price stabilization initiatives.

**General issues facing price stabilization efforts**

Within these four levels of action—local, national, regional and international, five main issues are relevant.

1) Where is price instability a problem?

At the local level, highly unstable farm gate prices are a significant burden to small farmers seeking to invest in modern agricultural techniques and to raise their productivity. Consuming households (and many smallholder farm households are net consumers) are obviously the locus of burdens from high food prices and especially from price spikes.

At the national level, the concern is for price stability in major urban markets and is often the focus of action by macro policymakers.
At the international level, the concern is for the level and stability of food prices from the major exporters, and the possibility that export barriers might prevent access to food by importing countries in times of rising prices.

2) Which commodities need more stable prices?

Three categories of agricultural commodities might be considered for stabilization activities: food staples, cash crops and perennial tree crops. Prices of cash crops are a real concern to farmers but have relatively little impact on consumers—perhaps onions in India and red chili peppers in Indonesia are exceptions. Perennial tree crops present special financing problems because of the long time horizon for the investment to start to pay off, and there is a very sharp distinction between short-run marginal costs and long-run average costs. But price variability has little impact on consumers—perhaps palm oil in Indonesia and coffee in the United States are minor exceptions.

Accordingly, recent emphasis has been on price stabilization techniques for the major staple food grains, especially rice, wheat and maize. Although these commodities have much in common because they often form a large share of energy input among the poor, the world rice market behaves very differently from the world markets for wheat and maize (Timmer 2010b). There are other food grain markets with their own unusual trading regimes: cassava, millet and white maize, for example, often behave more like “non-tradable” commodities than the tradable commodities with large, liquid international markets. Any efforts to stabilize food grain prices will need to recognize the special characteristics of individual commodities.

3) What instruments are available to stabilize food prices?

In general, there are three main categories of stabilization instruments: border (trade) controls, buffer (reserve) stocks, and regulation of financial markets involving agricultural commodities.

Border controls are a national issue because nations are defined by their borders. Economists do not like political borders very much because they impede the free flow of goods and services (and hence reduce the “gains to trade”), but the nation state is the main modern actor in many areas of economic, political and diplomatic initiatives. Borders, and border controls over trade, are a reality. The World Trade Organization (WTO) seeks to impose disciplines on what border controls are legitimate, and agriculture has been included in those disciplines since the Uruguay Round. However, the food crisis in 2007/08 revealed a serious asymmetry in how the WTO approaches border controls for food grains. Virtually all of the trade disciplines, and all of the current negotiations under the Doha Round, refer to import barriers rather than export controls. There is now wide agreement that export controls on food grains have been a significant source of price instability (Martin and Anderson 2011; Sharma 2011). The asymmetry of trade discussions should be rectified, but it is difficult to imagine grain exporting countries agreeing to significant restrictions on their ability to control exports as a means of stabilizing their domestic food prices. Food security is simply too important as a political mandate for national leaders to forgo this policy instrument. Only significantly more stable world grain markets are likely to change this reality—an obvious challenge in the face of export barriers.

Large reserves of grain, at whatever level, have the obvious advantage that they can be drawn on when harvests are damaged or there are surges in demand. Large reserves tend to hold price
levels down as well, although there is a clear endogenous relationship, explained by the theory of supply of storage, between expectations of price changes and levels of stocks held by the private sector. The issue is whether the public sector should be holding reserve stocks of grain above and beyond the willingness of the private sector to hold stocks (and the subsequent willingness of the private sector to hold these stocks in the presence of public stocks).  

Holding public reserve stocks faces three key issues: their costs (and who should pay), monitoring the level and quality of stocks (and who should manage them), and enforcement of agreements to buy and release stocks according to some transparent rules. Each of these issues has been difficult to resolve even in the case of national stocks. There is virtually no experience at the international level of procuring, managing and releasing reserve stocks on behalf of an agreed protocol to stabilize grain prices. The experience of using Japanese “WTO” rice stocks in 2008 as an external supply source to prick the rapidly rising spike in world rice prices was clearly a unique episode (and even then the stocks were never actually released) (Slayton and Timmer 2008). Very serious doubts exist that any internationally viable scheme of holding reserve stocks of grain for stabilization purposes could be agreed and implemented (but see the specific discussion below).

Regulation of financial markets for agricultural commodities is being vigorously discussed, especially within the context of the French chairmanship of the G-20 this year. Attention is focused on two possibilities: re-imposition of position limits on speculative positions for important food commodities traded on futures markets (such as existed before the financial deregulations in the 1990s), and a “Tobin-tax” on each financial transaction to slow the emergence of speculative bubbles. The difficulties with either approach are clear—many of the financial transactions in commodity markets do not actually take place on organized exchanges where regulators can see what is happening, no single market could initiate such regulations unless others around the world did as well, and there is no experience with taxing financial transactions of this sort. Still, it is recognized that the “financialization of food commodities” is a relatively recent and rapidly growing phenomenon and urgently needs more research and understanding.

4) How can stabilization interventions be governed?

The issue is important at three different levels (four, if the regional level is somehow distinct from the international level because of greater commonality of interests).

At the local level, especially for farm or community organizations, governance would seem to depend on active participation and “voice.” The great advantage of local initiatives, of course, is precisely their ability to be responsive to local conditions and aspirations. General guidelines on how to manage them are probably not very useful.

At the national level, democratic processes are widely thought to be the basis of good governance generally, and should provide appropriate feedback to national leaders on how well they are doing in managing the country’s food security. Still, it is important for outside analysts,  

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6 Gilbert and Morgan (2010) are emphatic that increased public stockholding are a bad idea (“This policy direction is dangerous,” p. 3031), because it displaces private stocks. However, clear release mechanisms for public stocks alleviate much of this concern. The HLPE (2011) report simply dismisses the notion that private stocks will be adequate for food security purposes.
donors and the private sector to realize that food security is inherently a political issue subject to political decision making. It is certainly desirable that good technical analysis, especially economic analysis, be brought to bear on these decisions, but history has shown how difficult it is to make such analyses relevant and implemented.

At the international (and regional) level, negotiations informed by transparent technical rules would seem to be the best way forward. But there is deep skepticism that such negotiations can be successful. Even within ASEAN, for example, the interests of Vietnam and Thailand diverge sharply from those of the Philippines and Indonesia.

5) How do we evaluate success or failure in stabilizing food prices?

At the local level, the basic issue is whether sustained gains are seen in agricultural productivity on small holder farms. Of course, many other ingredients are needed for “getting agriculture moving,” but a major rationale for stabilizing commodity prices at the farm gate is to enhance the profitability of these other investments. The feedback from success at this level is also critical: nothing would improve the outlook for food security more effectively than rapid increases in farm productivity, especially for staple food crops grown by small holders.

At the national level, success in stabilizing food prices is likely to be seen primarily in greater political support for the government that gets credit, and ultimately in a more stable investment climate that should stimulate economic growth. Although the political payoff is likely to be primarily in the short run, the contribution to economic growth will be apparent to economic historians, and to the country’s consumers as they gradually escape from poverty.

At the international level, if a price stabilization accord can be agreed to and implemented, success will almost certainly have to be measured using technically sophisticated but transparent methodologies that are part of the initial framework. Cost-benefit analysis is a powerful tool when stakeholders agree on the methodology and the result.

Policy responses during food crises:
An Asian perspective with implications for Africa

Reducing food price volatility is likely to be a highly specific process—depending on commodity, country, and global market conditions. The following discussion focuses mostly on Asia and on rice, for three reasons. First, most Asian countries have taken seriously the “mandate from heaven” by which rulers are expected to provide their citizens with a generally stable political environment. Because of the importance of rice in the diets of most Asians, stable rice prices were seen as part of political stability. Nearly all Asian countries have tried to stabilize their rice price.

Second, rice is overwhelmingly the food of the poor (Asia Society 2010; Timmer et al. 2010). More than one billion of the world’s population live on less than $1 a day, and rice is the daily staple food for nearly two-thirds of them. Any broad-based reduction in poverty will need to find a way to make rice accessible in a reliable fashion to this population.
Third, rice is a globally traded commodity with a number of African countries increasingly dependent on Asian supplies to feed their rapidly growing demand. Total rice consumption in Africa has been growing at a steady 3.8 percent per year, whereas all other regions show a declining growth rate for rice consumption (see Figure 5). Africa’s steady growth will make it a large factor in global rice demand as early as 2030.

But the world rice market is distinctly different from other staple food markets (the small world market for white maize shares many of the characteristics of the rice market).

The world rice market is a thin, segmented, and imperfect market in which price discovery is difficult. With many different grades of rice and price differentials between origins which do not reflect only transportation and quality differentials, there is no single “world rice price.” Also, unlike the other grains, there is no futures market which allows global market participants to hedge their trading risks (Slayton 2011).

Because of these characteristics, the world rice market is highly unstable, with very little transparency in price formation. Most significant rice import and export “deals” are struck behind closed doors, often on government account, with very little accountability to other participants in the system, especially farmers and consumers. It is understandable that countries dependent on this market make serious efforts to protect themselves from its instability. History demonstrates that rice prices within many Asian countries can be kept reasonably stable with respect to world prices (Timmer and Dawe 2007). Africa may well want to learn how Asia did this, and why (Timmer 1993).

Figure 5. Rice consumption trends by region

Source: Timmer et al. 2010.
Rice has not been “financialized” to a significant extent, but there are still speculative hoarding episodes driven by widespread expectations of scarcity and surplus. As countries try to protect themselves from these speculative episodes, there are often spillovers from their actions, and these spillovers increase price instability in world markets. A little-researched topic is how to minimize the impact of these spillovers, or cope with them on a country-by-country basis, rather than to follow the standard policy advice, which is to avoid the actions altogether, and thus avoid the spillovers in the first place. The standard policy advice turns out to be politically impossible in times of turbulent markets. Are there better alternatives?

Lessons from history

Three controversial lessons from historical experience with food crises inform the discussion here. They stem from the world rice crisis in 1972/73 (which pre-dated the more general food crisis in 1974/75), the experience with spiking food prices in 2007/08, and the most recent episode of soaring maize and wheat prices in 2010/11.

The first lesson is obvious in retrospect, but no less important. Political dynamics, not economic analysis, drive the domestic policy response to sharply rising food prices. If economists do not understand this political dynamic, their economic analysis tends to be irrelevant. Finding ways for sound economic analysis to be part of the political dialogue during food price crises is a real challenge to the profession. A good starting point would be to encourage countries seeking to stabilize their domestic food economies, not discourage them.

Second, the political objective during a food price crisis is almost always to keep it from happening. In the short run, this means “stabilizing” domestic food prices despite whatever is happening in world markets. Stabilizing domestic food prices in the face of sharply escalating world prices is not a foolish goal—most countries try to do it. The real issue is whether this can be done effectively and efficiently. The answer is always “no” unless the country has planned well ahead for such a contingency and already has an operational food price stabilization program in place. As a matter of “good practice,” all countries are discouraged by international donors from conducting such programs (World Bank 2005).

Instead, the third lesson from past food crises is that countries are urged to implement “social” safety nets in times of food price spikes. The economic rationale is clear: let market prices signal the scarcity of food resources, and then compensate the poor for deterioration in their standard of living when food prices rise. The problem is that safety nets that reach the poor quickly and effectively take considerable time to design and implement, and are quite costly in fiscal terms if the poor are a substantial share of the total population. Historically, unless the country is already running a cash transfer program to the poor (as, for example, Indonesia has done since the compensation program for increasing fuel prices in 2008), the emergence of a food price crisis is too sudden for an effective government response. Gearing up emergency food relief safety nets is not an effective response to a sudden spike in food prices. More active measures to prevent food price spikes are needed, both domestically and internationally.

These lessons are drawn from Timmer (2010a).
Can (groups of) countries cooperate to manage food price volatility?

It has been understood for a long time that cooperation to keep national borders open to international trade can have very large pay-offs from the efficiency gains that come from better allocation of resources. The argument for keeping national borders open to the world rice market is even more powerful. In addition to the “gains from trade” in the strictly economic domain, more open borders to rice trade also help stabilize the world price of rice and reduce the tendency for hoarding behavior to set off price panics.  

So, why don’t countries cooperate to keep their borders open to rice trade, and thus prevent much of the price instability that plagues the world rice market? The answer lies in the “prisoner’s dilemma,” where one of the most basic insights from game theory shows the logical outcome of two independent parties (countries) presented with two choices—cooperate or act independently, where the payoff to cooperation is high, but highly costly if the other party fails to cooperate. Without communication between the parties, or credible forms of commitment, the parties chose to operate independently, lowering welfare for all. The outcome for rice policy is clear: individual countries make decisions about domestic prices, and the trade policies needed to defend those prices (e.g. a rice export ban by India or subsidized imports by the Philippines), based strictly on their own domestic political constituency. They are protecting their national sovereignty. The potential for all countries to cooperate, keep rice trade open, and thus reduce rice price volatility, is missed.

There are two ways to resolve the prisoner’s dilemma. The best is to agree on a formal mechanism for cooperation, with binding commitments of the sort that have allowed the General Agreement on Tariffs and Trade (GATT) and WTO to gradually reduce trade barriers and greatly expand international trade. The world rice economy has not benefited from these protocols because most of the major players in the world rice market have been exempt from binding commitments (Martin and Anderson 2011; Sharma 2011). Still, the current level of concern about instability in the world rice market may offer a window of opportunity for the major global players in the world rice market—ASEAN+3, Bangladesh, India and Pakistan, and the United States—to convene meaningful discussions on how to put rice trade on a more open basis through cooperation.

The alternative to cooperation to solve the prisoner’s dilemma is not particularly appealing—it involves the gradual learning by both parties through “repeated games.” In the context of the world rice market, such learning would be stimulated by repeated rice price crises, a painful and inefficient way to reach an agreement that could come from active discussions instead.

An important case study: Indonesia

Indonesia’s experience with rice price stabilization and pro-poor growth reveals a number of broad lessons for other countries seeking a rapid emergence from poverty (Timmer 2004). As the

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8 See Timmer (2010b) for the evidence behind this argument.
largest and most diverse economy in Southeast Asia, Indonesia has had to cope with a wide variety of challenges—climatic, political, economic, and religious—in order to transition from the failed economic policies of the Sukarno era in the 1950s and early 1960s, to the rapid pro-poor growth stimulated by the Suharto regime’s revival of a market economy, and to the democratic governments that had to assemble new political institutions in a rush after Suharto was forced from office in 1998 in the wake of the Asian Financial Crisis. A number of governments in Asia and Africa have sought to learn from these experiences.

During these tumultuous decades, Indonesia has almost always been a significant player in the world rice market, and has learned that its engagement is a two-way street. Imports were used routinely to stabilize domestic prices, but great care was needed in procuring these imports not to push up prices in the world market. Significant fluctuations in Indonesia’s own rice production also caused large variations in its import demands. Indeed, under the impact of favorable weather, new technology, cheap fertilizer and price supports for farmers, Indonesia actually exported small quantities of rice in the mid-1980s. It is impossible to understand the world rice market without understanding Indonesia’s rice economy.

The country is also starting to play a much more visible role in world affairs. As a member of the G-20, Indonesia has been asked to support the French initiative in 2011 to manage food price volatility. As the Chair of ASEAN in 2011, Indonesia is using its leadership to move forward the longstanding discussions on how ASEAN might coordinate its rice trade and reserves policies to make the world rice market more transparent and stable. What should Indonesia do with these unique opportunities?

It should be obvious that Indonesia can only promote initiatives that will be in its own self-interest, in either the short run or long run, or both. The whole point of national borders is to promote the welfare of citizens within the borders. The political economy of determining who benefits (and who might lose) from policy initiatives is complicated, but the bottom line will be perceived national self-interest. No one expects Indonesia to act otherwise.

That said, it is clear that Indonesia has an enormous stake in regional stability and economic growth. As Chair of ASEAN in 2011, Indonesia has the opportunity, almost the obligation, to provide leadership on these key issues. As the largest player in this “neighborhood,” Indonesia’s actions will also play an important role in maintaining a positive external environment in which investors and diplomats both can act with confidence. A positive “neighborhood effect” is demonstrably a powerful determinant of performance of individual countries within the neighborhood.

The problem is that the current “neighborhood effect” for the region’s rice markets is actually quite negative. Consequently, there is a real opportunity for Indonesia to highlight the issues at ASEAN forums, provide a sounding board for ideas from partners, and perhaps to take leadership in translating good ideas into concrete proposals and plans for implementation.

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* For a somewhat whimsical explication of the political economy of food security, based on an *Economist* article on January 29, 2011, see Annex 1.
Two initiatives seem worth consideration. First, Indonesia could take the lead in emphasizing that the long-run goal of national rice policies should be to engage in an integrated Asian rice market, with more open trade policies the major vehicle for such integration. As rice consumption begins to fall in most of the countries of ASEAN, such integration should be easier because high-cost production will not be needed to satisfy strictly local demand (Timmer et al. 2010). Indeed, a concrete step Indonesia could take to move forward rice market integration in the region would be to stop insisting that the goal of domestic rice policy is rice self-sufficiency, but instead is food security.\(^\text{10}\)

There is clearly a tension between a rice price policy designed to achieve self-sufficiency and one designed to enhance food security. It is well understood that high rice prices increase the level of poverty—the current parameter for Indonesia is that a 10 percent increase in rice prices causes a 1.3 percentage point increase in poverty (although the arguments for updating this parameter with more recent data are valid). At the same time, maintaining domestic rice prices at a level that is somewhat higher than the trend of world prices also makes it much easier to maintain stability of domestic prices, via varying levels of imports that complement domestic production. Avoiding price spikes for rice is highly beneficial to the poor, perhaps even compensating for somewhat higher prices on average (especially if rapid economic growth is raising rural wages and creating lots of employment opportunities for unskilled labor) (Timmer and Dawe 2007).

The trick is to use a transparent mechanism—visible to both domestic and international traders—for arranging the rice imports. The optimal mechanism is probably an openly published schedule of variable import duties, but other mechanisms are no doubt available that would not destabilize world prices. One promising sign is that several ASEAN countries, including Vietnam on the export side and the Philippines on the import side, are actively considering transparent trade levies as a way to stabilize their domestic prices. Such transparency would be very helpful in rebuilding confidence in the reliability of the world rice market as a source of supplies (and demand). Indonesia could reinforce this very desirable policy direction by moving to a variable levy system for rice imports as the mechanism to stabilize domestic rice prices.\(^\text{11}\)

The second concrete initiative the Indonesian government could make as Chair of ASEAN is to promote larger rice reserves in member countries. This could be part of the initiative to create an ASEAN + 3 rice reserve for emergency purposes, but this rice reserve is unlikely to be of a scope, or with management rules, that would permit its use for preventing rice price crises. Instead, larger rice reserves at the country level, promoted by active discussion at an ASEAN Roundtable, would still enhance confidence in the world rice market, as individual countries would feel less vulnerable to sudden trade shocks, and thus could continue to use the world rice market as the source of efficient imports (and exports) to complement their domestic supplies.

\(^{10}\) As part of this emphasis on long-run efficiency and lower costs of rice production, Indonesia could encourage very small-scale rice farmers, most of whom are net consumers, to diversify into higher value agricultural products or to exit agriculture altogether as part of a successful structural transformation. See Timmer (2009), for comparative and historical perspective.

\(^{11}\) See Martin and Anderson (2011) for a model that examines the impact on world price variability if all countries isolate themselves from the world market price.
Larger domestic rice reserves are not an economically efficient instrument for stabilizing domestic (or international) rice prices. Trade, and open borders, is the efficient vehicle for that purpose. But larger domestic rice reserves would serve two important functions: (1) they would enhance confidence among national policy makers that they could use the world market to lower their average costs of rice consumption (on the import side), and (2) the resulting reduction in price instability in the world rice market could reinforce political support for the trade-opening actions. Greater stability in the world rice market opens many important avenues for political actions domestically. Although not economically efficient, greater domestic rice reserves may be politically efficient.

The final question is what role Indonesia should be playing as a member of the G-20. Somewhat controversially, France, as the Chair of G-20 in 2011, has tabled a proposal to manage price volatility in world food markets. How should Indonesia respond? In the first instance, Indonesia should insist that the world donor community needs to invest vastly more in basic agricultural research and development. The shameful decline in donor funding to support agricultural development, which started in the mid-1980s and lasted until the mid-2000s, needs to be corrected. Sharply higher funding levels need to be sustained for the next two decades.12

Second, the “financialization of food commodities” is a trend that is very worrisome. Huge volumes of financial liquidity looking for the next best speculative return have turned to commodities, including basic food commodities, as a venue for diversifying financial portfolios, and increasing returns to investors. The world has never lived with the reality of pricing of food commodities as a direct function of financial speculation, rather than the reality of movements in basic fundamentals of supply and demand. The two are not disconnected, of course, but the volatility of financial investments, especially by hedge funds, large banks on behalf of rich clients, and even amateur speculators able to play as day traders, vastly overwhelms the reality of real movements in the supply of and demand for basic food commodities on a short-run basis.

The impact of financialization of food commodity markets is a highly controversial topic and it is important not to overstep the evidence. Still, a number of recent reviews of food price volatility have suggested that financial speculation has probably played a role, at least in the “bubble” phase of food price commodity spikes in 2008 and again in 2011. One suggestion is to use a “precautionary principle” as an innovative step forward.

In the absence of any conclusive evidence that the significant increase in speculative activities on the performances of futures markets carries benefits (by reducing the cost of hedging in particular), and the demonstrated existence of risks regarding the occurrence of price bubbles and the exclusion of commercial actors because of the higher costs of participating in the deregulated commodity exchanges, a precautionary approach dictates tighter regulation of speculation on agricultural commodity exchanges (HLPE 2011, p. vi).

12 A fascinating article by Lobell et al. (2011) reports that roughly 10 percent of productivity gains from agricultural research since 1980 has been lost to climate change, which is already having a measurable impact on the yields of wheat and maize. The need to “run even faster” is clear. For a very helpful review of the institutional architecture needed to bring about this increase in funding for agricultural research, see Global Author Team (2010).
President Sarkozy of France has urged the EU to start this process of greater regulation, so it is clearly on the G-8 and G-20 policy agenda.

It is not clear that the financialization of food commodities can be stopped, even with a precautionary approach. Greater regulation of financial markets for commodities is highly problematical, as financial “innovations” often stay several steps ahead of regulators, and many of the most questionable investments in commodities do not even occur on open markets, where informed regulators might see what is happening. A transactions tax has been proposed as a way to slow the emergence of commodity price bubbles, but getting all commodity trading floors to go along with such a tax is also problematic. In the end, individual countries and the international community may simply have to learn to live with this influx of financial “hot money” into the system, and concentrate instead on stabilizing the real market.

Finally, because of the great uncertainty surrounding the world food system right now, there would be great merit in having Indonesia host a roundtable discussion on the way forward in the ASEAN + 3 forum (or, ideally, to have an ASEAN + 6 forum, to include Bangladesh, India and Pakistan, with the United States as a “side” participant). Perhaps with ADB assistance, such a roundtable could provide a neutral forum to discuss key impediments to making the world rice market more open, transparent, and reliable. Identifying the impediments is the first step to removing them. That is the long-run agenda for both ASEAN and the G-20.

**Are there lessons for Africa from the Asian experience?**

Asia has been relatively successful in isolating itself from movements in world food prices. Africa has not. Figures 6–8 show that the differences are quite dramatic. In Figure 6, Martin and Anderson (2011) demonstrate that the spike in rice prices in 2008 was followed closely by producer prices for rice in Africa, but Asian countries managed to isolate themselves from the spike to a considerable extent (Dawe 2009).
Figure 6: Indexes of real international and producer prices of rice, developing countries’ unweighted average, 2006-2010 (2005=100)

Rice


Figure 7, from Clay et al. (2011) shows that India was able to isolate itself from the rice price spike (indeed, India’s actions to isolate itself—a ban on rice exports—explain much of the sharp spike in world rice markets). Rice prices in Bangladesh, which normally follow Indian rice prices quite closely, rose sharply when access to Indian rice supplies was cut off. Even so, rice prices in Dhaka did not rise nearly as sharply as in Bangkok, where the world price is set.
Figure 7. Dhaka, Delhi and Bangkok Rice Prices from Jan 2000 to Oct 2010, converted to Taka

Source: Clay et al. 2011.

Figure 8, also from Clay et al. (2011) shows how different the situation is in at least one closely watched African country, Malawi. White maize prices in Malawi are considerably more unstable than either relevant international market price—for white maize from South Africa or yellow maize from the United States. Explaining these sharply differing patterns of price instability for staple grains in Africa and Asia should be a high research priority. One important focus could be the aggregate welfare impact from Asian policies designed to stabilize domestic rice prices as they spill over to the world market and actually cause much of the instability facing African countries.
Figure 8. Monthly Malawi and international export prices in US dollars since 2004

Source: Clay et al. 2011.

Stabilizing rice prices: The agenda

Serious new confidence-building measures are needed to renew trust in the world rice market. Very severe damage to this trust was inflicted during the 2007-08 food crisis, mostly because of the Indian ban on exports, the on-again, off-again ban on Vietnamese rice exports, and open talk in Thailand of withholding stocks from the market and creating an “OREC,” or Organization of Rice Exporting Countries, to boost prices in the world market. Still, there is plenty of blame to go around in explaining the growing political distrust of the world market for rice. Important importing countries, such as Indonesia and the Philippines, speak publically of their desire to end “dependence” on supplies from the world market. Such rhetoric does not make them a market that exporting countries can trust (although this rhetoric also has little impact on rice traders, who tend to judge market impact from actions rather than political statements).

This retreat into autarky comes at a very high price to economic efficiency and the welfare of poor consumers. It makes the world market even more unstable and less reliable. Is there anything we can do to re-build confidence and trust in international trade in general and in the world rice market in particular? Any confidence-building measures will need to involve both exporting and importing countries, acting in their own self-interest. One possibility is a country-by-country investment in greater rice reserves to cope with shocks to rice supplies, while gradually increasing the use of trade to lower costs of rice consumption. A higher level of stocks does not alter the requisite flow of rice from producers to consumers, but it does create a buffer against interruptions to that flow. Thus:
Specifically, we need larger rice reserves at four different levels of the global rice economy—
those held by the private sector, in small importing countries by the public sector, in large rice
producing and consuming countries held publicly, and internationally.

Most of the rice stocks in the global economy are held by the private sector—farmers, traders,
processors, retailers, and consumers—to even out seasonal production patterns and to keep trade
pipelines flowing smoothly. Few private stocks are held to even out inter-annual price
fluctuations, but the pipeline stocks carried across crop-years are probably equal to a month or
two of consumption, a considerable quantity. With greater price instability expected in the future,
and greater uncertainty about the reliability of supplies in world markets, optimal (profit-
maximizing) levels of privately held rice stocks will increase. Although we know little about the
actual levels of these stocks, or the behavioral parameters that affect them, even the most basic
models of supply of storage suggest there will be a significant increase in privately held rice
stocks going forward. Of course, if publicly held stocks succeed in stabilizing world rice prices,
privately held stocks will then gradually be drawn down.

A completely overlooked potential for the private sector to provide greater stability of rice prices
through stock management comes from the “supermarket revolution” in Asia. Before the turn of
the Millennium, supermarkets in the region were niche players catering mostly to the urban
middle and upper classes. Now they provide—via modern supply chains—perhaps a third to as
much as half of the rice consumed in East and Southeast Asia, with the share growing rapidly
(although even the rough numbers are not really known).

The potential of modern supermarkets to stabilize rice prices comes from the large market share
of individual companies under central management control. If consumers desire stable food
prices, astute supermarket managers can supply it. This potential of supermarkets to stabilize
prices contrasts with traditional small, competitive, retail rice markets, where prices change
regularly on the basis of daily supply and demand. Historically, “food price stability” has been a
public good because no private entity found it profitable to provide it. The rise of supermarkets
may mean that stable food prices could become primarily a private good. This would truly be a
revolution in the food industry.

Next, for similar reasons, small countries that rely heavily on imports for their rice supplies, such
as Malaysia, Singapore, or Brunei, will find it desirable to increase the level of stocks held
publically, or (as in Singapore) held privately but with levels determined by public regulations. 13
Even a modest increase in rice stocks in these countries will increase confidence that the world
market remains their best long-run source of supply (which, of course, it is).

Large countries face a somewhat different situation. Because of the sheer size of their domestic
rice economies, actions to increase production, reduce consumption, or alter the size of stocks
held by public agencies will also have a noticeable impact on the international rice economy.
These countries certainly include China and India, probably Indonesia, and possibly the

13 To obtain a license to import rice into Singapore, the trading company must agree to hold three months of normal
consumption in storage. In view of the increased instability and uncertainty in the world rice market, expanding
these stocks to 3.5 or even 4 months of supplies probably makes sense. Of course, higher storage costs will be
incurred and these will have to be paid by consumers.
Philippines and Bangladesh. Larger rice reserves in these countries are probably desirable for reasons of domestic food security, but they will also alter the perception of global observers about the adequacy of worldwide stocks. That is, larger rice reserves in these countries will have a positive spillover impact on the global rice economy by stabilizing price expectations, and thereby actual rice prices. An important question for the international community, especially the major donors, is whether any actions can be taken to encourage the gradual build-up of rice reserves in these large countries.

A role for the international community?

Finally, the hardest question is whether there is any role for international ownership and control of rice stocks as a means to stabilize rice prices on global markets. Ever since the publication of the classic Newbery and Stiglitz volume, The Theory of Commodity Price Stabilization, in 1981, the answer has been a clear “no.” Both history and theory demonstrate that it is impossible to stabilize the price of a commodity in world markets for long periods of time—from cocoa to coffee to copper to tin to wheat to whatever—using internationally managed buffer stocks. Budget constraints and the asymmetry of storage—it can never be negative—mean that stochastic variations in supply or demand will eventually overwhelm the ability of a buffer stock to stabilize prices (Williams and Wright 1991). No international commodity agreement (ICA) with binding provisions has been negotiated since the Newbery and Stiglitz volume.

Still, it is important to address a more modest question. Would the availability of a limited amount of rice under international control help stabilize expectations about the behavior of world rice prices? If expectations can be stabilized, panicked behavior on the part of multitudinous participants in the world rice economy could be sharply reduced, with self-reinforcing price bubbles and collapses made less frequent and less extreme. The availability of international stocks would not need to keep rice prices within some legally specified band, but could be useful if world rice supplies suddenly tighten and prices threaten to spike. Is this more limited objective possible?

There are four levels at which this question should be addressed. First would be within Asia: the ASEAN + 3 (which includes China, Japan and South Korea), or possibly a new ASEAN + 6 (to include also India, Bangladesh and Pakistan) would include nearly all of the world’s major rice importers and exporters (except the United States), not to mention about 90 percent of world production and consumption. An expanded ASEAN rice buffer stock has been under “active” consideration for years, with little discernible progress. How do we stimulate such progress, beyond the steps underway to improve information flows and policy coordination? Would an agreement to focus on a specific quality of rice, say 25% broken long-grain rice, help build confidence that the reserve could help meet demand from the poorest consumers when prices spike?

Second, by an accident of international trade negotiations and strong protection of domestic rice producers, Japan holds over 1.5 million metric tons of high quality “foreign” rice that it imports

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14 Thailand and Vietnam, as the world’s leading rice exporters, carry substantial stocks both seasonally and as part of their normal pipeline for regular deliveries to their customers. They are unlikely to need larger stocks for food security reasons.
under its WTO agreement but which it refuses to sell to domestic consumers. The potential availability of this rice in May of 2008 was sufficient to prick the rapidly exploding rice price bubble at that time, once the stocks were put “in play” by U.S. policymakers in private negotiations with Japanese officials. Would it be possible to manage these Japanese stocks with a more active concern for movements in international rice prices?

Third, could Australia, under AusAID auspices, use its mostly redundant rice industry to build up stocks of rough rice from surplus countries in Asia (shipping it to Australia in otherwise empty cargo carriers that go up to Asia filled with coal, iron ore or bauxite) and then offer these stocks, after milling, back to the world market when rice supplies get tight? The Australian rice industry has an excellent record of managing rice stocks and shipments and has little vested interest in exploiting price movements on the international rice market. Could Australia provide an important international public good by helping to stabilize world rice prices?

Finally, the question inevitably comes up: can the international community itself commit to publically managed international rice stocks that would be an effective stabilizer of world rice prices? At the height of the world food crisis, the International Food Policy Research Institute (IFPRI) put forward a proposal to create “virtual reserves” of grain to dampen financial speculation on world grain markets (Robles et al. 2009). Whatever the merits of such “financial” reserves for wheat, corn and soybeans, they clearly will not work for rice. Without deep futures markets, and with less-than-transparent price discovery in the world market, virtual reserves for rice will not influence real participants in real transactions.

The historical record on managing an international commodity agreement, with fixed price bands and the ownership of physical stocks, is not encouraging, and it was never even tried for rice because of the difficulties of stock deterioration, quality variations, and poor information on the prices of actual rice trades. None of those problems has gone away. Probably the best that could be done from an international perspective is for the major donors interested in rice—the World Bank, the Asian Development Bank, USAID, AusAID, and perhaps the Bill and Melinda Gates Foundation, to agree on modest incentive payments to large rice consuming countries to store more rice, at the margin, than they would store under normal conditions. Knowledge of the size, location, and condition of such stocks (a necessary condition for receiving incentive payments to hold them) would be an important stabilizing element for participants in world rice trade, even if the trigger mechanisms for stock release, domestically or internationally, were not enforceable by the international community.

The proposals here are incremental. They seek to change the long-run incentives for stockholding behavior, and to use increased stocks to build confidence in the international market for rice, which is clearly the most efficient source of supply for many countries. Because holding larger stocks will turn out to be very expensive, a scenario can be imagined where the larger stocks gradually build renewed confidence in the world rice market, prices become more stable, and stocks will then be reduced gradually as the reality of the fiscal burden sinks in.
Concluding thoughts

The policy discussion here has been almost entirely about stocks and trade, with little discussion of policy initiatives needed in the spheres of production and consumption. There has been little discussion of access by poor households to rice—the basis of food security for individuals. Such a discussion would focus much more on the causes of poverty and approaches to reducing it in a sustainable fashion.

These are the truly important variables in the world rice market. Productivity growth in rice production has slowed visibly in the past two decades, and renewed investments in speeding that growth are urgently needed (Asia Society 2010). Rice consumption patterns are changing rapidly, with consumption by the poor rising (often stimulated by subsidies) and consumption falling in the better-off, especially urban, households. The world rice economy, and the various domestic participants in it, is a dynamic system subject to shocks and self-reinforcing, herd-like behavior that creates price spikes and collapses. This instability has enormous costs, economically and politically, to farmers and consumers. But Asia is considerably richer now than it was even a decade ago, and rice is no longer the overwhelming determinant of food security for most of Asia’s consumers, or of income for its farmers. The new reality of a less rice-dependent Asia in purely economic terms means we should be able to do better politically for a commodity that still feeds two-thirds of the world’s poor.

Although less urgent, Africa’s stake in a more stable global rice economy is rising. Further, the Asian approach of linking a dynamic agricultural sector to rapid structural transformation, accompanied by sharp reductions in poverty in less than a generation, would also seem to offer hope to African countries seeking rapid reductions in poverty and enhanced food security.
Annex 1. The Political Economy of Food Security: Players, Fears, Hopes and Options

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[Based on a less detailed table in the *Economist*, January 29, 2011, p.57]
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Core literature on food price instability

Although concern over unstable agricultural prices and incomes is centuries old—the English Corn Laws date to 1688 and were concerned with both—the first modern treatment of the causes and consequences of instability in agriculture dates to this volume by T.W. Schultz. He was emphatic in attributing much of the causation of unstable agricultural prices to macroeconomic instability rather than the peculiarities of individual crop supply and demand, a position that put Schultz at odds with much of the agricultural economics profession at the time. In his later volume, *The Economic Organization of Agriculture*, published in 1953, Schultz carried his perspective to its logical conclusion: “The instability of farm prices is an important economic problem. It is, however, exceedingly difficult to organize the economy so that farm prices will be on the one hand both flexible and free and on the other hand relatively stable.” Schultz resisted efforts to stabilize individual commodity prices from then on.


This volume had a sharp impact on the development community when it appeared three decades ago. One of the first major efforts to put development economics on a firm micro foundation, it treated commodity price instability as a problem for households and firms, which needed to cope with the risk of price fluctuations. A dynamic optimization model that incorporated risk into household decision making was expanded to prove that international commodity agreements (ICAs) to stabilize prices on world markets could not work—eventually they would run out of funds to buy at low prices or commodities to inject into markets at high prices. The profession has taken to heart the key conclusion from this analysis: it is impossible in theory and in practice to stabilize commodity prices. Of course, this holds only globally, not for individual countries, and all the costs and benefits are micro-based. No costs to the macro economy stemming from unstable commodity prices, or benefits from stabilizing them, are dealt with in the analysis.


At one level this paper is an attempt to confront the conclusions from Newbery and Stiglitz (1981) with the reality of successful food price stabilization efforts in a number of countries in Asia. The rationale for these stabilization programs is developed at length, with considerable attention to the macro dimensions of food price instability, which rely heavily on signal extraction problems for investors. Without food stability at the macro level in major urban markets—proxied in Asia by stable rice prices—countries have a very hard time lengthening investors’ time horizons to fit the needs of modern economic growth. Stable food prices speed up that growth.


This volume builds on a half-century of work on the supply of storage as the basic analytical framework for understanding inter-temporal price formation. A unique feature of commodity storage—it cannot be negative—is used to build a dynamic model of commodity prices. The
model is very successful in reproducing the common features of commodity prices, especially their tendency to be low and stable for long periods of time, and then subject to sharp upward shocks. This volume remains the basic reference on how storage affects price formation.


This paper appeared in a special issue of *Food Policy* that honored Art Mosher and his insights on how to “get agriculture moving.” One of the key questions in the agricultural development literature is the role of price incentives to stimulate adoption of new technology. The basic argument in this paper is that prices on world markets for the key food staples—rice, wheat and maize—often do not reflect either their long-run scarcity value with respect to investments in agricultural development, or their potential to create added value in the form of rural incomes, and thus faster poverty reduction. Donors should not use short-run prices in world markets to judge the impact of their investments in agricultural research and infrastructure, but should look at long-run trends and the feedback from current investment decisions to future food abundance and scarcity.


This paper demonstrates the interactions among the rate of economic growth, of who participates in that growth, and the level of food prices, as they affect the numbers of people counted as “food insecure.” The basic methodology follows from earlier work by Reutlinger and Selowsky (1976), but introduces food price instability as an important causal factor changing the level of food security. An important conclusion is that stable food prices make the achievement of “macro” food security much easier, and “pro-poor” growth makes “micro” food security feasible. In combination, a rapid escape from poverty and hunger is possible.


Many of the papers in this volume also appeared in a special issue of *Food Policy* edited by Derek Byerlee, Thom S. Jayne and Robert J. Myers that appeared in May 2006. The volume was the result of a free-ranging conference arranged by the World Bank, but this summary reflects a clear neo-classical approach that allows unrestricted price formation with follow-up activities to protect food consumption of the poor if prices suddenly spike. Producers are urged to use modern financial derivatives to hedge their risks from price volatility, whereas poor consumers will need to rely on government-sponsored safety nets when food prices spike. This “Washington Consensus” view of how to deal with food price instability has been challenged by the food crises in 2008 and 2011.


This volume makes the case that food price stabilization implemented via parastatals was necessary and effective for Asian countries to introduce Green Revolution technologies to small
holders in the context of poor marketing infrastructure. However, as infrastructure and private marketing capacity have developed rapidly, and food parastatals have been subject to gross mismanagement and corruption, the time has come to turn most of food marketing in Asia over to the private trade. The editors/authors are especially knowledgeable about India.


This was among the first scholarly efforts to understand what was driving the food price crisis in 2008 and has been the standard since. The update for 2011 argues that the drivers are somewhat different than in 2008, when exchange rate movements received a great deal of attention. In 2011, the authors place most of the blame on US and EU bio-fuels policies and on the Chinese decision to build substantial stocks of soybeans even as the world price was rising. They are increasingly nervous that demand growth for food will outstrip growth in production, with continuing high and unstable prices.


Similarities and differences between the rice price crisis in 1972/73 and the one in 2007/08 are analyzed, especially from the perspective that long-run cycles in funding for agricultural research and infrastructure are the basic cause of periodic food crises. The changes in political economy of responses to spikes in rice prices between the two episodes are dramatic, and are determined largely by how well insulated domestic consumers were from world markets. Case studies of Indonesia, India and Thailand also show a significant difference in policy response in the face of democratic pressures, which were present only in India in 1972/73, but were a force in all three countries in 2007/08.


This volume grows out of a FAO-sponsored conference early in 2009 to examine what went wrong with the world rice market. It pulls together a number of country studies as well as several analyses of how the world rice market functioned in 2007/08. The Dawe and Slayton chapter in particular analyzes the role of Japan and its WTO stocks of rice in pricking the speculative bubble in world prices that had formed as a result of panicked buying by the Philippines and widespread hoarding at all levels of the rice system—hoarding that was caused by the expectation of higher prices themselves. The need for more open trade policies, and larger rice reserves as a way to build confidence in such trade, is stressed in the conclusion.


This commissioned review of the literature on food price volatility provides a very careful and sober assessment of recent claims that price volatility is increasing (the evidence is not in, but volatility in the 1970s was as great as now). Gilbert has done much of the high-quality analysis of commodity price trends and variations over the past two decades, and this article summarizes his findings very effectively. Evidence is provided that financial speculation did increase volatility of food prices in 2001, but not as much as in energy and mineral markets. The paper
makes a clear case for why the world rice market is quite different from the markets for wheat, maize and soybeans.


This paper summarizes results from a major research program at Stanford on food security and the environment. It clarifies the debate over how to measure food price volatility and how those measures have changed over time, for the key food staples (and petroleum). The impact of food price volatility on the rural poor is examined in depth, perhaps for the first time. Concerns are raised about the restrictions on trade, and especially the widening of FOB-CIF price bands for important food importing countries, that seem to represent a structural shift after 2008.
Discussant comments on “Managing Price Volatility: Approaches at the global, national, and household levels”

T. S. Jayne, Professor of International Development, Michigan State University

When I was a graduate student in the mid 1980s, I remember reading a number of Peter Timmer’s works, which were on the syllabi of almost all of the development oriented courses that I took at Michigan State University. Professor Timmer was, and still remains, one of the luminaries of our field, and because of that, I feel a bit reticent to say that I find myself in disagreement with him on a number of his points. I believe that several of Timmer’s key conclusions derive from his many years of working primarily on rice-based food systems in Asia, whereas my conclusions derive more from my work on maize-based systems in Africa. I think it is not a case of one of us being right and the other being wrong, but rather a reflection largely of the structural differences between Asia and Africa with respect to cropping systems, governance, country size, infrastructure, and human capital. Our collective challenge, therefore, is to highlight these differences and to see what policy lessons each region can learn from the other.

I will illustrate these differences by first summarizing the major points of Timmer’s presentation, and then explain my problem with each of them, especially as they apply to Africa. I will then conclude with my list of policy do’s and don’ts for helping governments manage the problems associated with food price volatility.

Timmer makes three basic points:

1. Price volatility is a major economic problem – price stability contributes to economic growth.
2. Food price volatility is a major political problem. Policy analysts need to address these real problems to be taken seriously by policy makers. He stresses that “greater attention needs to be devoted to ‘2nd -best’ approaches at the national level mainly because policy makers tend to ignore standard economic arguments discouraging major interventions in food markets.
3. Timmer offers four guidelines for policy makers:
   a. Help households cope with price risks;
   b. Help countries stabilize domestic food prices, with minimal spillover to global markets;
   c. Help regional organizations provide productive forums for coordinated food reserve policies;
   d. Stop thinking of price stabilization as something to be avoided but rather something to be done, and done better.

These points are all articulately and compelling argued in Timmer’s paper, yet I have some fundamental misgivings. Why?

Price stability contributes to economic growth, but price stabilization efforts too often do not contribute to price stability. The empirical evidence of governments’ track record in stabilizing food prices has been mixed at best (Kherallah et al. 2002; Dehn et al. 2005; Byerlee et al. 2006;
Tschirley et al. 2006; Rashid et al. 2007; Chapoto and Jayne 2009; Sarris and Morrison 2010). In Africa, two of the countries that have taken the most aggressive steps to stabilize food prices in the region, Zambia and Malawi, have experienced the most volatile food prices of all the countries examined in a comparative analysis by Chapoto and Jayne (2009). Clearly, the weight of the research evidence in Africa shows that price stabilization has only rarely contributed to price stability, and in many cases it has exacerbated it, at massive costs and foregone investment in other areas where positive impacts might otherwise have been achieved. While the stabilization objective may be noble, most measures to implement it have been counterproductive in Sub-Saharan Africa.

In other developing areas, such as Latin America and Asia, governments have had more success in stabilizing prices, but even here many researchers question whether the payoffs to price stabilization are really worth the costs (Rashid et al. 2007). Moreover, the political economy literature underscores many cases in which government actions taken ostensibly to stabilize markets for the benefit of farmers and consumers are often the smokescreen for patronage activities that may undermine the interests of the majority (Bates 1981; Bates and Kruger 1993; Sahley et al. 2005; van de Walle 2001). I personally saw, as a Peace Corps Volunteer in Ghana in the early 1980s, how the hard efforts of smallholder farmers could be undermined by the stroke of a pen by unfortunate and often self-serving actions taken by politicians.

My conclusion regarding Timmer’s first main point is that, despite agreeing that there are indeed benefits to price stability, government attempts in many developing countries to stabilize prices often create instability in the food markets. I am aware of little evidence to support the view that countries that attempt to stabilize have greater productivity growth or food security than those that do not.

Timmer’s second point is that food price volatility is a major political problem, and that policy analysts need to devote greater attention to “2nd -best” solutions that take into account politicians’ concerns in order to be taken seriously by them. I believe that there is a lack of clarity about what the fundamental problem really is. As Barrett and Bellemare (2011) recently pointed out, there is sometimes confusion between price instability and rising food prices. Food price instability can cause confusion in price signals, but most analyses show that high food prices are the much more important and dangerous problem. Barrett and Bellemare argue that they “find no rigorous evidence” to indicate that political unrest is associated with food price instability.

It is also instructive to ask whether there is evidence to suggest that food prices are becoming more unstable or less affordable to the world’s poor. Figure 1 shows the world food price index from 1960 to 2010 in nominal terms. There appear to be three distinct structural periods over this time frame: one in the 1960s and up to 1972; one starting in 1972 when food prices jumped amid panic of a world food crisis but then stayed relatively constant over the next three decades up to early 2008; and, one that seems to have started in 2008 with the increasing integration of food and fuel markets, the expansion of the biofuels industry, and the rising growth in the demand for food associated with income growth in middle-income countries. A major conclusion evident from Figure 1 is that while the nominal price of grains has increased over time, there has been no
major change in the instability of food prices (as measured by the coefficient of variation) between these three periods.\(^\text{15}\)

**Figure 1. Are food and fertilizer prices becoming more unstable?**

![World Bank World Price Indices for Grains and Fertilizer (Pink Sheet) 1960-2011](image)


Furthermore, when food prices are deflated by the world GDP deflator to provide a rough measure of the cost of food relative to incomes (Figure 2), it becomes clear that food has become considerably less costly over time, and the episodes of price run-ups, as in 2008-09, look considerably less severe. Even deflating prices using the Sub-Saharan Africa GDP deflator, shows that food prices have fallen in real terms and become less unstable. In short, incomes are growing faster than food prices -- a testimony to long run economic growth and agricultural productivity growth. Other studies from Africa examining food prices relative to wage rates and urban worker incomes reach very similar conclusions (Mason et al. 2011; Headey 2010). Obviously, many consumers’ wages did not rise as fast as the GDP deflator, but even if they rose

half as fast, the real cost of food has surely declined over the past 40 years for the vast majority of the world’s consumers.

**Figure 2. Higher food price levels?**

![Graph showing World Bank World Price Indices for Grains: Nominal and deflated with SSA and World per capita GDP (1960-2011)](image)


Africa is also apparently in the midst of a 15-year trend in rapid income growth and poverty reduction (Figure 3). Earlier this year, the World Bank documented the rise of the African middle class. In the past 10 years, the middle class has risen from 50 million to 200 million. About 1 in 5 persons in Africa are now regarded as middle class. There is obviously still very far to go, but the macroeconomic and sectoral reforms that most of Africa underwent in the early and mid-1990s – as politically painful as they were – appear to be reaping major benefits.
Figure 3. Trends in poverty rates and income per capita, Sub-Saharan Africa

Source: Sala-i-Martin and Pinkovskiy 2010.

Based on the foregoing evidence, I conclude that there is little evidence to suggest that food prices are becoming more volatile: GDP and wages are rising faster than food prices in most developing areas, including most of Africa, hence the problem of food affordability is generally declining over time, and should continue to do so if governments continue to make the right investments to promote long-run and sustainable agricultural productivity growth; farmers producing a surplus are hurt by low prices, but these surplus-producing farmers are usually considerably better off than the rural poor, who tend to be net buyers of food and are hence made worse-off from efforts to raise food prices (Naylor and Falcon 2010). Efforts to raise farm prices often hurt the poor and tend to have a regressive effect on income distribution; and high food prices (not volatility per se) constitute the major problem. The strategies for addressing structurally high food prices differ from the strategies to address price volatility. The best defense against unaffordably high food prices is income growth, so a focus on the public investments and policies that can best achieve that seems the preferred option.

With respect to Timmer’s conclusion that good economics must take account of political realities, my conclusion is, “let’s not be so quick to give in to 2nd best approaches.” Dismissing
1st best strategies as not worthy of consideration because politicians will not accept them strikes me as settling for less than what could be achieved. How many seemingly unattainable policy reforms may have seemed politically impossible to achieve for so long but indeed occurred with surprising quickness? The break-down of the Berlin Wall, economic liberalization in eastern Europe, and more recently, major political change in the longstanding autocratic regimes of the Middle East were all once viewed as politically infeasible not long before they actually happened.

Africa’s agricultural policy environment is fundamentally less shackled by state control now in 2011 compared to the late 1980s when many African governments controlled food markets, prices, external trade, and exchange rates as a matter of state sovereignty. In short, it is important not to underestimate what kind of 1st best policy reform is possible. I entered the agricultural field in order to identify and make the case for the policies and investments that would most effectively promote the welfare of poor people in the developing world. I would like to keep the pressure on to ensure that public funds are allocated in the way that makes the greatest contribution to long-term poverty and hunger reduction.

I would thus have liked to have seen Timmer put more focus on the policy and investment strategies that represent the best prospects for sustainable poverty reduction and livelihood improvement, rather than focus on 2nd-best options involving very expensive price stabilization. To be fair, however, I recognize that his lecture today was but one in a series, that volatility was his topic, and that the merits and demerits of alternative investments are the topics of other presentations.

So, concretely now, what should be done? Timmer’s paper highlights the importance of helping households cope with price risks, helping countries stabilize domestic food prices (with minimal spillover to global markets), helping regional organizations provide productive forums for coordinated food reserve policies, and encouraging governments to think of stable food prices as a “good” rather than a “bad.” Timmer also highlights the importance of long-run investments too, such as crop science, infrastructure, and basic education, but does not underscore the major trade-offs involved. Last year, the Zambian government’s efforts to stabilize maize prices cost 2 percent of its GDP, more than the treasury’s entire annual outlay to the Ministry of Health. Think of the added gains in child and maternal health and the long-term productivity impacts that could have been achieved if 2 percent of Zambia’s GDP could have been invested in addressing its severe health problems!

My list of concrete actions for Sub-Saharan Africa would encourage a shift in public budgets from price stabilization (some of which is often destabilizing) to investments with a proven track record in reducing poverty and promoting income growth: sound macroeconomic management, crop science / R&D, improving farmer knowledge and management through viable agricultural extension systems, basic education and health, marketing infrastructure, and more rules-based as opposed to unpredictable government actions in markets (trade bans, sudden changes in marketing board operations, etc). The weight of research evidence from the development economics literature over the past 40 years highlights these investments as having the greatest positive impact on agricultural development, income growth, and the livelihoods of the poor.

In a world of constrained resources, every dollar spent on price stabilization is a dollar potentially not spent on crop science, R&D, farmer extension systems, health and education,
sustainable use of the world’s available water, and other investments necessary to enable more of
the world’s farmers to respond to high food prices and to raise the world’s food production. And,
therefore, cope with the huge growth in world demand.

In the long run, I believe that Timmer and I agree on the way forward — using public resources
to promote productivity growth. In part, I learned this from Timmer himself a long time ago!
Where we differ is in the short-run.

What should be done in the short run? First, distinguish between emergency reserves and buffer
stocks. The former are smaller, meant to cover an immediate shortfall until imports can arrive.
The latter are explicitly meant to stabilize prices and so need to be large. In spite of a compelling
theoretical rationale, buffer stocks have a very poor record in many developing countries, Africa
in particular. Second, there is a need to combine relatively small emergency reserves (two to
three months maximum) with robust and layered safety nets, involving school feeding programs,
conditional cash transfers, and temporary food aid.

What should not be done—at least in Sub-Saharan Africa? I believe that advising governments to
undertake large-scale food procurement and buffer stock policies would be disastrous for many
developing countries and their citizens. It is true that stabilizing well could be good economics.
But stabilizing badly is neither good economics nor good politics.
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African Agricultural Productivity Growth and R&D in a Global Setting

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Abstract

Relative to other regions of the world, most African economies are still heavily reliant on agriculture as a source of income and employment. And with more than 70 percent of the continent’s poor residing in rural areas, the production and productivity performance of African agriculture is pivotal to overall economic growth and the well-being of the poorest people in the region. After a dismal decade of output growth in the 1970s, the rate of aggregate agricultural output growth picked up for each of the subsequent three decades, and averaged 2.83 percent per year during the 2000s. With population growing at still record rates by world standards, per capita output grew much more slowly, just 0.36 percent per year during the past decade.

The productivity evidence is mixed and difficult to summarize. The rate of African crop yield growth (at least for the four crops given closer attention in this paper: corn, wheat, rice and soybean) is generally slower than elsewhere in the world, and in keeping with patterns seen elsewhere there has been a slowdown in the pace of average crop yield growth in Africa since around 1990. African land and labor productivity levels also generally lag those found elsewhere in the world, although aggregate land productivity in Africa outperformed that of Australia and New Zealand, another region of the world with challenging agricultural soils and heavy reliance on erratic (and often agriculturally marginal) weather. The reported rates of growth in multi-factor productivity (MFP) for African agriculture are also low by world standards, but the body of available evidence suggests that African MFP growth rates picked up in recent years. Unfortunately, the lack of reliable data and differences in the analytical details between the available studies makes it hard to reconcile the evidence and reach robust conclusions about MFP performance throughout sub-Saharan Africa.

Productivity levels and growth rates are affected by a host of factors, not least the technologies linking inputs to outputs and, by implication, the amount, nature and effectiveness of the innovative effort that develops and deploys these technologies. Although overall investments in African public agricultural research and development (R&D) have increased during the past decade or so, the growth in spending is not especially widespread and dominated by growth in just a few countries. Nigeria and Ethiopia account for half the region’s increase in agricultural R&D spending from 2000-2005—the latest year for which data are presently available. The intensity of public investment (i.e., agricultural R&D spending relative to the value of agricultural output) has increased as well. However, during the 2000-2005 period Africa spent just $0.54 on public research for every $100 of agricultural output, almost half the corresponding rest-of-world intensity ($1.05) and one-fifth of the rich country average ($2.70). Fragmented and typically small research agencies, and unstable funding streams still bedevil African agricultural research endeavors and undermine efficiencies in agricultural research that are intrinsically long-term in nature. Turning around these research realities in a meaningful and sustained fashion will be critical to realizing the long-term growth in African agriculture productivity that will be required to grow that sector in particular and the region’s economies more generally.
African Agricultural Productivity Growth and R&D in a Global Setting

Introduction

In 2009, 13.1 percent of Africa’s gross domestic product (GDP)—just 1.64 percent of world GDP—came from agriculture. If the more prosperous South African and Nigerian economies were set aside the agricultural GDP share for the remaining 44 countries would increase to an average of 18.1 percent of total output (World Bank 2012). 1 Although Africa is urbanizing faster than any other continent on earth, in 2010 its rural residents still accounted for 62.6 percent of the region’s total population (Economist 2009; FAO 2012). 2 Moreover, estimates indicate that more than 70 percent of the region’s poor live in rural areas and depend largely on agriculture for their livelihoods (IFAD 2012). Clearly the fate of Africa’s economic future, and, especially, the well-being of the poorest people on the continent rest in ramping up the performance and productivity of agriculture.

A fundamental driver of sustained productivity growth is the technical changes embodied in improved inputs such as seeds, fertilizers, and machinery, as well as the improved production practices that directly stem from investments in R&D (Lipton 1988; Lipton 1989). The next 30 years and beyond will call for even more of the same kinds of technological changes and productivity growth. This need is especially great for many countries in Africa whose economies remain heavily reliant on agriculture, particularly as a major source of employment. In this paper I review the available, and, unfortunately, comparatively thin, sometimes questionable, and often difficult to reconcile evidence on the productivity performance of African agriculture and juxtapose this evidence against what is know about agricultural R&D in the region.

The structure of production

African agriculture is quite different from agriculture elsewhere in the world in many important respects. In 2010, sub-Saharan Africa produced 6.5 percent by value of the world’s food and agricultural output compared with 5.6 percent in 1961. 3 It was Asia’s output that grew the fastest—an average of 3.3 percent per year from 1961-2010, compared with 2.6 percent per year for Africa. Although during the past three decades African agricultural growth (2.9 percent per year) substantially outpaced rich-country growth (0.8 percent per year), it still lagged growth in Asia (3.4 percent per year). 4 While these aggregate growth relativities help position African

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1 In 2009, Africa’s agricultural GDP totaled US$153.7 billion, representing 6.97 percent of world agricultural GDP.
2 In this paper Africa will be taken to mean sub-Saharan Africa. According to FAOSTAT (2012), by 2033 half of Africa’s population will be living in urban areas; whereas in 2010, urban population percentage for Asia was 40.5, 79.3 for Latin America and the Caribbean, and 77.4 for high-income countries.
3 Here I refer to the gross value of production and, unless otherwise stated, these values are expressed in an average of 2004-6 international agricultural purchasing power parity prices obtained from FAO.
4 The pattern of aggregate agricultural output growth has been uneven. During the 1960s and 1970s, the constant priced value of agricultural output grew by 3.30 percent per year and 1.33 percent per year respectively. In the 1980s it was 2.58 percent per year, picking up to 2.88 percent per year in the 1990s, and 2.83 percent per year during the past decade (2000-2010). On a per capita basis aggregate output grew by 0.76 percent per year in the 1960s, -1.44 percent per year in the 1970s, -0.27 percent per year in the 1980s, 0.22 percent per year in the 1990s, and 0.36 percent per year in the 2000s.
agricultural output performance vis-à-vis other regions of the world, they conceal substantial differences in the composition of that output.

Averaging over the period 2008-2010, the three basic crop staples (maize, wheat and rice) accounted for barely 12.7 percent of the value of African crop production; less than half the corresponding rest-of-world share of 30.5 percent (Figure 1). More dramatically, the U.S. maize share alone accounted for 35.0 percent of that country’s crop output: with all three staple cereals totaling 44.9 percent of U.S. crop output. Rest-of-world (i.e., the world excluding sub-Saharan Africa) production is also much more heavily oriented towards income-elastic fruits and vegetables compared with Africa. Nonetheless, the constant-priced value of African fruits and vegetables output grew more rapidly (2.40 percent per year from 1990-2010) than the value of output of cereals and other crops (including treenuts, spices, coffee, cocoa, and various fiber crops). However, the growth in African roots and tuber production (3.86 percent per year) as well as pulses and oils (2.77 percent per year) outpaced that of fruits and vegetables. Although these growth rate differentials over the past several decades resulted in substantial structural shifts in the composition of production, a large share of African crop production is still concentrated in roots and tubers. Crops such as cassava, sweet potatoes and potatoes dominate this crop category, although more than 43 percent of the continent’s production comes just from Nigeria. Setting aside the five largest producers of roots and tubers (Nigeria, Ghana, the second largest producer with 10 percent of the region’s total production in 2008-2010, plus Cote d'Ivoire, D.R. Congo and Angola), the rest-of-Africa share of roots and tubers in total crop production almost halved to 16.1 percent (compared with 29.2 percent overall). Panel b shows that the 2008-2010 livestock value share (i.e., including meat, milk, wool, eggs, skins, and all other livestock products) in Africa was just 27.9 percent compared with a rest-of-world share of 37.5 percent.

Figure 1. The commodity composition of African agricultural production, 2008-2010

Panel a: Crop composition
Panel b: Crop vs. livestock shares

Source: Calculated by author based on data from FAO (2012). Data represent share of the 2008-2010 value of agricultural production denominated in 2004-2006 purchasing power agricultural prices.

The growth in real per capita incomes in Africa has recovered of late—averaging -0.8 percent per year during the 1980s, -0.5 percent per year in the 1990s, and 2.1 percent per year since 2000. If that trend continues or accelerates, one would expect the composition of African agriculture to continue to respond to changing demand realities and begin diversifying beyond roots and tubers with a commensurate shift in the composition of production towards fruits, vegetable and livestock products (Frazão et al. 2008). This change would have a kick-on effect, increasing the demand for livestock feed, including maize production. Notably, during 2008-2010 African agriculture produced more maize by value than wheat and rice combined, and, since 1990, maize output has grown by 2.1 percent per year. This is about the same rate of expansion of wheat production (2 percent per year) but slower than the growth in rice output (2.7 percent per year).  

African agricultural production is spatially concentrated. The horizontal axis in Figure 2 arrays countries from the largest (left) to the smallest (right) by value of production, while the vertical axis reports the cumulative share of production as one moves to countries with an ever smaller share of the region’s output. A plot tracking the 45-degree line would indicate that each country in the region produced the same value of agricultural output in 2008-2010 (i.e., they had equal shares of the region’s output). The marked convexity of the plot indicates that just a handful of countries account for the lion’s share of the continent’s agricultural output. Nigeria is the largest agricultural economy, producing almost one-quarter of the region’s total output. Add-in South

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5 However, rice production is also highly concentrated, with only two countries (Nigeria and Madagascar) accounting for 44 percent of sub-Saharan Africa’s total rice output. Rice output in Madagascar grew by 3.3 percent per year from 1990-2010 and declined by 0.1 percent per year in Nigeria over the same period. In contrast, output from Rwanda, Sudan and Benin (each of whom produced less than 0.7 percent of the region’s rice output in 2010) reported output growth of more than 10 percent per annum since 1990. African cassava production, meanwhile, increased by 2.9 percent per year since 1990.
Africa, and these two countries alone produce almost one-third of the regional total. Including Ethiopia, Sudan and Tanzania yields half of Africa’s total agricultural production. In contrast, the smallest 24 agricultural economies (i.e., almost half of the region’s 49 countries) produce just 5.6 percent of the region’s output. Clearly changes in regional and even sub-regional production (and productivity) trends will be heavily skewed by developments in a handful of countries.

Figure 2. The country concentration of African agricultural production, 2008-2010

<table>
<thead>
<tr>
<th>Country</th>
<th>Cumulative Share (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigeria</td>
<td>22.2</td>
</tr>
<tr>
<td>South Africa</td>
<td>31.3</td>
</tr>
<tr>
<td>Sudan</td>
<td>39.0</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>45.1</td>
</tr>
<tr>
<td>Tanzania</td>
<td>49.8</td>
</tr>
<tr>
<td>Kenya</td>
<td>54.3</td>
</tr>
<tr>
<td>Ghana</td>
<td>58.7</td>
</tr>
<tr>
<td>Uganda</td>
<td>62.8</td>
</tr>
<tr>
<td>Ivory Coast</td>
<td>66.7</td>
</tr>
<tr>
<td>Cameroon</td>
<td>69.8</td>
</tr>
</tbody>
</table>

Source: Calculated by author based on data from FAO (2012).

Figure 3 provides an indication of how agricultural supply has evolved vis-à-vis demand over the past half a century for sub-Saharan Africa and the rest-of-the-world. Overall, the growth in the real value of production in total—including 155 agricultural commodities—in Africa (2.6 percent per year) has slightly outpaced growth in the rest-of-the-world (2.3 percent per year) since 1961. This is also true for wheat, rice, and soybeans. However, population growth in Africa averaged 2.7 percent per year, substantially faster than growth elsewhere in the world (1.5 percent per year), and so the longer-run per capita growth in agricultural production of the four crops in Figure 3 has uniformly flat lined or trended downward in Africa, with the opposite trend elsewhere in the world. Moreover, even though output growth in Africa for 61 crop commodities outpaced the rest-of-world growth since 1961, for almost half of these commodities (accounting for 30 percent of the region’s total value of agricultural production in 2010), the growth rate differences were less than one percent per year.
These data point to the enormity of the challenge that lays ahead in meeting the region’s food demand for a population that is expected to grow by 1.8 percent per year over the next four decades and total 1.8 billion by 2050 (FAOSTAT 2012). The key to rebalancing these supply-demand trends is to expand production at a rate that exceeds the expected rate of population...
growth.\textsuperscript{6} Given that 55 percent of the region’s population is presently engaged in agriculture (and
66 percent if the better off, diversified economies of South Africa and Nigeria are excluded)\textsuperscript{7} this
outcome will mean ever greater reliance on increasing agricultural (including labor) productivity
at higher rates going forward than has been the norm hitherto.

**Productivity patterns**

Much has been written by economists on how to measure productivity and how to interpret the
measures (e.g., Jorgenson and Griliches 1967; Alston et al. 1998; Morrison-Paul 1999). Different
concepts and corresponding measures of productivity may be appropriate for different purposes,
though they all express some measure of output relative to some measure of input.

The simplest measure of all is a measure of output of a single commodity per unit of a single
input, such as yield in tons per hectare of wheat per year. This measurement seems
straightforward. However, even such a seemingly simple and intuitive measure is prone to
conceptual and measurement problems. For instance, land quality varies such that individual
hectares are quite unequal in their productive capacity. Do economists use planted or harvested
areas (that exclude abandoned areas or areas that fail to produce a measurable grain yield) and
measure seasonal or annual acreages when forming measures of yields? Should the units of land
be adjusted for quality to make the individual hectares more nearly comparable? If not, how
should changes in observed yields that may reflect changes in the intensity of use or average
quality of the land input be interpreted?

Similarly, on the output side, wheat quality varies significantly, depending on protein content
and other attributes that are not independent of the physical yield—in particular, higher yield
tends to be associated with lower quality (James 2000). What should be done about changes in
output quality? If nothing is done to correct for variations in the quality mix over space and time,
how should the measures be interpreted? Further complications arise from the implicit
aggregation over time. For instance, in some cases multiple crops are grown on the same fields
within one year; in other places a crop is grown in a multiyear rotation with other crops or with
fallow years. How should the measures of yield per hectare per year be adjusted to allow for
these characteristics of the production process so as to make the measures comparable over space
and time?

Individual grain yield is an example of a *partial factor productivity* (PFP) measure. It is “partial”
in the sense that it only accounts for changes in the amount of land used in production. It does
not account for changes in the quantities of other inputs—such as labor, capital, fertilizer,
rainfall, or irrigation—that also affect production. By the same token, grain yield per hectare of a
particular crop also does not account for changes in other outputs that might be associated with
the crop in question, such as crop biomass or other by-products. Thus yield and other partial
measures can be seen as partial with respect to their treatment of outputs as well as inputs. At the
opposite end of the spectrum are measures of *total factor productivity* (TFP), the aggregate

\textsuperscript{6} To the extent this will increase standards of living generally, ramping up the growth in agricultural output is likely
to shift the expected rates of population growth to the lower end of the projected growth spectrum.

\textsuperscript{7} In 2010, South Africa’s per capita GDP was $9,477 (2005 international dollars) and Nigeria’s was $2,135,
compared with $1,430 on average for the rest of sub-Saharan Africa.
quantum of all outputs divided by the aggregate quantum of all of the inputs used to produce those outputs. TFP is a theoretical concept. All real-world measures omit at least some of the relevant outputs and some of the relevant inputs, and therefore it is more accurate to refer to the real-world measures as *multifactor productivity* (MFP) measures. Particular MFP measures differ in the extent to which they fall short of the counterpart ideal TFP measure because of methodological differences as well as differences in the consequences of incomplete coverage of the inputs and outputs.

Here I briefly review the evidence on partial- and multi-factor productivity developments in agriculture over the past half a century using the range of measures at my disposal. Developments in Africa will be placed in a global context, but interpretation of the evidence is subject to the limitations broached above and other aspects, including the spatial dimensions of production discussed briefly below.

*Crop yields*

During the almost 50-year period from 1961-2010, global average maize and wheat yields rose worldwide by 1.53 and 1.62 percent per year respectively (Table 1). Average rice and soybean yield rose much more slowly, both growing closer to 1.00 percent per year on average. Notably, yields for the top 20 producing countries worldwide rose more rapidly than the world average for all four crops and substantially exceeded the average growth in crop yields throughout sub-Saharan Africa. Crop growth in sub-Saharan Africa also lagged average growth rates in the “other producers” category (i.e., countries other than the top 20 producers and those in sub-Saharan Africa) with the exception of rice. Rice was the only commodity in this group for which African yields—growing by 1.19 percent per year—outperformed growth in the other country group (0.99 percent per year).

**Table 1. Worldwide crop yield growth for maize, wheat, rice and soybeans, 1961-2010**

<table>
<thead>
<tr>
<th></th>
<th>Maize</th>
<th>Wheat</th>
<th>Rice</th>
<th>Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>1.33</td>
<td>1.79</td>
<td>1.53</td>
<td>2.44</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>0.75</td>
<td>1.12</td>
<td>1.03</td>
<td>1.65</td>
</tr>
<tr>
<td>Top 20 producers</td>
<td>2.22</td>
<td>2.12</td>
<td>2.32</td>
<td>2.69</td>
</tr>
<tr>
<td>Other producers</td>
<td>1.43</td>
<td>2.10</td>
<td>1.62</td>
<td>2.72</td>
</tr>
</tbody>
</table>

Source: Calculated by author based on data from FAO (2012). Growth rates calculated as differences of natural logarithms. Some sub-Saharan African countries fall within the top 20 producer group for some commodities, i.e., Madagascar (rice), Nigeria (rice, maize, soybeans), and South Africa (maize and soybeans).
These longer-run changes mask a worrisome feature in the pattern of crop yield growth. Crop yield growth for the period following 1990 is generally slower, and in some instances substantially slower, than yield growth before 1990.\(^8\) The exception is maize, a crop subject to substantial private-sector research interest and a continuing stream of new technologies, and where yield growth since 1990 has matched (and for some of the groupings in Table 1) exceeded the pre-1990 pace.

As Alston, Pardey and Beddow (2010) pointed out, the interpretation of average global and regional crop yields is problematic for several reasons. One of the most confounding (but often ignored) factors is that countries located in tropical and temperate regions of the world differ considerably in terms of their propensity to plant multiple crops per year, and cropping intensities have changed considerably over time for certain regions of the world.\(^7\) The yield data used here (and by most other observers) report yields on the basis of harvested area, which will count the same land twice if it is cropped twice in a given calendar year. An alternative is to report yields on the basis of arable area, which will count the land area only once per year regardless of how often it is cropped. Reporting yields on the basis of harvested area would understate the rate of growth in crop yields compared with crop yields measured on the basis of arable area if the intensity of crop plantings per year had increased over time.\(^10\)

Other partial productivity measures

Figure 4 uses the graphical technique developed by Hayami and Ruttan (1971) to track land and labor productivity movements globally and for ten regions of the world, including sub-Saharan Africa (Pardey 2012). The horizontal axis is a measure of labor productivity and the vertical axis a measure of land productivity for the period 1961-2010. The productivity loci were formed by taking a ratio of the value of aggregate output and the respective land and labor inputs. Output is a FAO estimate of the total value of agricultural production (spanning 155 crops and livestock commodities for sub-Saharan Africa and 185 commodities for the world) expressed in 2004-

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\(^8\) These comparative yield growths are sensitive to end point choices. Breaking the periods in years other than 1990 changes the specifics of the growth rates but splitting the data at different years around this date does not alter the general finding of a widespread (but by no means universal) slowdown in growth.

\(^7\) Wood et al. (2000) developed measures of cropping intensities worldwide that expressed the annual harvested area as a proportion of total cropland (including land in use and fallowed land). Swidden agriculture, for example, relies on maintaining a significant share of production in fallow every year (thus having a cropping intensity of less than one) whereas some irrigated areas in the tropics can produce up to three crops a year from the same physical area (thus having a cropping intensity of three). In 1997, the global average annual cropping intensity was estimated to be about 0.8 (Wood et al. 2000, p. 23). In South Asia, with its extensive use of irrigation, the average intensity was 1.1, whereas in Western Europe and North America the intensities were in the 0.6 to 0.7 range. The estimated intensity for sub-Saharan Africa was 0.9. Wood et al. (2000, p23) observed this “… is surprisingly high and implies a greater intensity of farming than expected of a region with little irrigation and the common use of fallow periods. But this finding might simply reflect data weaknesses, in this case associated with the under reporting of agricultural lands, where fallow lands, land farmed under subsistence crops, and crops that grow within forested areas are often not correctly accounted for in agricultural land use statistics.”

\(^10\) For example, Alston, Pardey and Beddow (2010) noted that if rice yields averaged 2 tons per harvested hectare in 1961 and doubled to 4 tons per harvested hectare by 2007, that would be equivalent to an average annual yield growth of 1.5 percent per harvested hectare per year. In contrast, if yields per harvested area doubled from 2 to 4 tons per hectare from 1961 to 2007 while the cropping intensity also increased from one to two crops per calendar year, yields reported on the basis of arable area would have grown from 2 to 8 tons per arable hectare, or 3.1 percent per year.
2006 average purchasing power parity agricultural prices (FAO 2012). Land is a measure of harvested and permanently pastured area, and labor is a head count of the total economically active workers in agriculture. Both axes are measured in natural logarithms so that a unit increase in either direction is interpreted as a proportional increase in land or labor productivity, and the length of the productivity locus is an indication of the average annual rate of change in productivity. Most, but by no means all, of the productivity paths move generally (but not uniformly) in a northeasterly direction, starting in 1961 and ending in 2010, indicating productivity growth.

**Figure 4. Agricultural labor and land productivity patterns, 1961-2010**

Panel a. Global trends
Moving beyond crop yields to these more broadly construed productivity measures, global productivity trends show a 2.6-fold increase in aggregate output per harvested area since 1961 (equivalent to annual average growth of 2.0 percent per year) and a corresponding 1.8-fold increase (or 1.2 percent per year growth) in aggregate output per agricultural worker (Figure 4, Panel a). These productivity developments reflect a comparatively faster rate of growth in global agricultural output against relatively slower growth in the use of agricultural land and labor (0.3 percent and 1.1 percent per year, respectively).

The diagonals indicate constant land-to-labor ratios. As the productivity locus for a particular country or region crosses a diagonal from left to right, it indicates a decrease in the number of economically active workers in agriculture per harvested acre in that region. Substantive but gradually changing differences can be seen in the land-labor ratios among countries and regions. In Japan’s case, land-labor ratios rose from 1.5 hectares per worker in 1961 to 5.8 in 2010. Land-labor ratios in Australia and New Zealand have changed little, whereas they doubled in North America (from 111.9 ha per worker in 1961 to 229.6 ha per worker in 2010). They also rose, albeit very slowly, for the Latin America and Caribbean region, consistent with the region’s labor productivity growing slightly faster than its land productivity. Sub-Saharan Africa has become much more labor-intensive so its land-labor ratios have declined. In 1961, the region
averaged 14.4 hectares per agricultural worker, but by 2010 the land-labor ratio had halved to 7.0 hectares per worker.

The relative positions of the productivity loci are revealing as well. In the terminal year of the data series, 2010, low-income countries as a group averaged just $527 of output per agricultural worker, compared with $1,473 per worker for middle-income counties and $34,035 per worker for high-income counties when taken as a group. The land productivity relativities are less clearly tied to per capita incomes. For example, middle-income countries as a group had similar output per hectare in 2010 ($335 per hectare) as the high-income countries ($365 per hectare). And, according to these data, in 2010 the average land productivity in sub-Saharan Africa ($105 per hectare) exceeded that of Australia and New Zealand ($75 per hectare).11

These broad, regional productivity trends fail to reveal the significant local variation caused by a host of agro-ecological, market-, and policy-related factors. Figure 4, Panel b plots productivity loci for four regions in sub-Saharan Africa plus Nigeria and South Africa.12 The sub-Saharan locus masks a large amount of variation in productivity performances within the continent. Notably, the South African and Nigerian productivity loci follow distinctly different paths than the other regions of sub-Saharan Africa plotted in Panel b. Both countries had increases in land and, especially, labor productivity that were at considerably higher rates than the rest of Africa. Moreover, the value of output per unit of labor in 2010 for both countries was also considerably higher than the rest-of-Africa: $11,356 per worker in the case of South Africa and $2,503 per worker for Nigeria compared with an average of just $547 per worker for the rest-of-Africa.

South Africa is distinctive in that it is the only entry in the figure for which the land-labor ratio increased substantially over time (implying more pronounced growth in labor versus land productivity): from 54.5 hectares per worker in 1961 to 85.0 hectares per worker in 2010. In Nigeria, the land-labor ratio (starting from a much smaller initial value) increased a little: from 9.8 to 11.8 hectares per worker over the comparable period. In almost all the other regions depicted, real output per worker stagnated or in the case of Eastern Africa actually declined, although land productivity in all regions improved over time. Thus the horizontal spans of the productivity loci were smaller than their vertical spans so that land-labor ratios were smaller on average in 2010 than they were half a century earlier.

For the region as a whole, labor productivity grew by just 0.58 percent per year for the period 1961-2010 (compared with 1.29 percent per year for the rest-of-the-world). Nigeria and South Africa are the only entries in Figure 4, Panel b where average labor productivity growth exceeded 1.0 percent per year during this period. Labor productivity in Eastern Africa declined, and in Southern Africa (excluding South Africa) it barely budged from $413 per worker in 1961 to a still lowly average of $425 in 2010. These labor productivity trends speak to the dismal record of poverty and chronic food insecurity that befall a large share of the populations in these parts of Africa.

Notably, the lackluster growth in labor productivity in Central, Eastern and Western Africa (excluding Nigeria) belie their comparatively rapid rates of growth in total output. These three

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11 Part of story here is that 83 percent of the land area in Australia and New Zealand is classified as (likely less productive) pasture, compared with just 59 percent in sub-Saharan Africa (and 41 percent for the rest-of-the world).
12 The series presented here is an updated and revised series from that reported in Liebenberg and Pardey (2012).
regions report real agricultural output growth in the range of 2.48 percent to 3.03 percent per year over the period 1961-2010, in some instances much faster than the comparative rates of growth in total output for South Africa, which averaged just 2.0 percent per year. However, South African agriculture ended the period with fewer agricultural workers than it had in 1961, whereas the economically active population in agriculture in the rest-of-Africa regions (like their populations generally) grew in the range of 0.21 percent to 2.61 percent per year. Thus, the poor labor productivity performance of Central, Eastern, and Western Africa (excluding Nigeria) reflects a failure of labor to leave agriculture for gainful employment elsewhere in these economies rather than a comparatively low rate of growth in agricultural output. Moreover, although the land area in agriculture has continued to expand in these parts of Africa, it has done so at a rate less than the rate of growth in agricultural workers. With land-labor ratios ranging from 3.3 to 11.1 hectares per worker in these regions, it is difficult to envisage raising output per worker to substantial levels, especially given the generally poor rural infrastructure and other market and environmental constraints that limit the transition to higher-valued forms of agricultural output.

Multifactor productivity estimates

Turning to an assessment of the differential rates of growth in aggregate input and output measures, Table 2 summarizes estimates of multi-factor productivity (MFP) growth for various countries in sub-Saharan Africa and average rates of growth for the region as a whole. Extracting plausible patterns from this evidence is difficult, in part because of substantive differences in the specific details of the treatment of the data used, differences in estimation methods, and the varying periods for which growth rates are reported. Overarching all of these aspects is a fundamental lack of data required to construct meaningful MFP estimates, forcing analysts to rely on incomplete, inconsistent or proxy measures (especially with respect to agricultural inputs), which have implications for the resulting MFP estimates that are difficult if not impossible to discern.

Table 2. Estimated African MFP growth rates

<table>
<thead>
<tr>
<th>Authors</th>
<th>Publication Date</th>
<th>Region</th>
<th>Crop/Industry</th>
<th>Methodology</th>
<th>Sample Period</th>
<th>Average Annual Growth Rate Percent per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1947-1965</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1965-1981</td>
<td>2.15</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>2.88</td>
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Notes: The input distance function used by Irz and Hadley (2003) is a conventional measure of the largest factor of proportionality by which the input vector can be scaled down to produce a given output vector with the technology that exists at a particular time. The premise of the
sequential Malmquist TFP index used by Alene (2010) is that past production techniques are also available for current production activities. The distance metrics in this instance are calculated using linear programming techniques formulated with respect to a “sequential” technology frontier.

Reports four MFP growth rates per period based on different measures of output.

One fairly consistent finding is that the average longer-run rates of MFP growth in Africa are generally low compared with those reported for other countries or other regions of the world (see, for example, the cross-country evidence presented in Alston, Babcock and Pardey 2010). Summarizing the changing pattern of MFP performance over time, Nin-Pratt and Yu (2008) and Alene (2010) suggest that MFP growth in more recent times, beginning in the early- to mid-1980s, has increased relative to the rates typically reported for the preceding two decades. The empirical basis for this result is an increase in the measured rate of growth in aggregate agricultural output largely absent off-setting increases in the estimated rate of growth of aggregate input use.\textsuperscript{13}

The weight to be given to even these limited “stylized facts” about MFP growth in sub-Saharan Africa is questionable. For example, there is a large variation in the reported longer-run average rates of MFP growth for the region included in Table 2. The large discrepancies among ostensibly similar MFP growth rates points to the overall fragility of the estimates.\textsuperscript{14} They may also reflect more fundamental sources of variation in African agriculture which is heavily exposed to the vagaries of climate and related (and typically unmeasured) natural factors of production such as pest and diseases, thus making period MFP growth rates especially sensitive to fluctuations in (end-point) MFP values (Pardey 2012).

In stark contrast to the general notion that African MFP growth has recovered of late, Liebenberg and Pardey (2012) report evidence on the nature and rate of long-run MFP growth for South African agriculture using a detailed, newly compiled (but still less than ideal) series of aggregate inputs and outputs. They estimate that from 1947-2007 aggregate output grew by 2.69 percent per year, inputs by 1.20 percent per year and so MFP increased by 1.49 percent annually. However, since 1988 both aggregate output and input growth slowed, and so too did South African MFP growth, down to just 0.02 percent per year from 1988-2007.

\textsuperscript{13} Commenting on this recovery in MFP growth rates, Nin-Pratt-Yu (2008, p.42) concluded that “The evidence in this study points to policy changes conducted by sub-Saharan Africa countries between the mid-1980s and the second half of the 1990s as one of the many factors determining the agricultural sector’s improved performance.”

\textsuperscript{14} Notably, Lusigi and Thirtle’s (1997) estimate is 1.27 percent per year (for the period 1961-1991), Fulginiti, Perrin and Yu (2004) report a rate of 0.83 percent per year (1961-1999), and Ludena et al. (2006) estimated 0.21 percent per year growth (1961-2000), which are all less than Avila and Evenson’s figure of 1.44 percent per year (1961-2001). And even for the earlier years where there is a consensus that MFP growth rates were comparatively low, the variance in the estimates is large. Block’s (2010) recent estimate puts MFP growth for the 1961-1980 period at 0.14 percent per year, Nin-Pratt and Yu (2008) have much lower estimates spanning a similar period (specifically -2.35 and -1.67 percent per year for the 1964-1973 and 1974-1983 periods respectively), and Avila and Evenson (2010) report a much higher rate (namely 1.20 for the period 1961-1980).
Spatial perspectives on productivity

Agriculture is a physically expansive sector. Ramankautty et al. (2008) estimated that that world’s 15 million square kilometers of cropland occupy about 12 percent of the total ice-free land mass in 2000. It is also an inherently spatial process, with yields (and hence output) being greatly influenced by local factors such as weather and climate, soils, and pest pressures. Consequently, agricultural production and productivity are especially sensitive to spatial and inter-temporal variations in natural factors of production. Agriculture is also continually on the move, and this spatial shifting has profound (but hitherto largely ignored) implications for how productivity metrics can and should be interpreted (Beddow et al. 2010). For example, Alston et al. (2010) illustrated that the location of worldwide wheat production has moved markedly, even since the early 1960s. During the three-year period 1961-1963, Russia accounted for 15 percent of the world’s wheat production (35.4 million metric tons) and ranked first among wheat producers worldwide. By 2005-2007, Russia had slipped to the world’s fourth-ranked wheat producer, accounting for 7.8 percent (47.4 million metric tons) of world wheat production during those years. The massive increases in production by India and, especially, China saw their combined share of world wheat production increase from 11.8 to 28.6 percent over this same period.

Beddow (2012) shows that these spatial movements are not limited to shifts in the balance of production among countries, but are also evident as substantial shifts in the location of production within a country. Using a newly constructed set of county production data he showed that from 1929-2007 the centroid of U.S. corn production—that is, the geographical pivot point of corn production in the United States—moved a total of 748 kilometers, shifting the country’s center of gravity in corn production from central Illinois to southeastern Iowa. These changes in location of production imply changes in average productivity (yields) to the extent that different locations have different endowments of soils and climate, different incentives (e.g., relative input and output prices, and, in some instances, agricultural regulations and policies), and different technological opportunities.

The consequences of location in terms of crop yields are graphically illustrated in Figure 5. This map indicates the area extent of global wheat, corn, rice, and soybean production for year 2000 on a 10x10 kilometer pixilated grid for the world. The local yields for each of the four crops is grouped into yield deciles, with light pink indicating the pixels with yields falling in the lowest yielding decile and dark purple representing the highest yielding decile. Each of these four crops has dramatically different global footprints, and, interestingly, the locations of the highest yielding areas for each of the crops are not spatially concordant.
Table 3 indicates the respective U.S., African, and Australian shares of the world’s highest yielding pixels. In 2000, the United States accounted for almost one-third of the world’s highest-yielding corn acreage, and a quarter or more of the highest-yielding wheat and soybean areas. However, it only accounted for 5.3 percent of the highest yielding rice areas, with Africa home to a larger share of high-yielding rice acres. Although the African share of high-yielding

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15 The area shares reported here are the areas that fall within the top three yielding deciles.
maize, wheat and soybean acreages is much smaller than the corresponding U.S. share, Australia had an even smaller share of the world’s higher yielding acreage than Africa.

**Table 3. Share of the world’s high-yielding area, 2000**

<table>
<thead>
<tr>
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<th>US</th>
<th>Africa</th>
<th>South Africa</th>
<th>Australia</th>
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<tr>
<td><strong>(percent)</strong></td>
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<tr>
<td>Maize</td>
<td>32</td>
<td>2.5</td>
<td>1.7</td>
<td>1.6</td>
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<tr>
<td>Wheat</td>
<td>28</td>
<td>3.6</td>
<td>1.4</td>
<td>1.6</td>
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<tr>
<td>Soybean</td>
<td>25</td>
<td>5.6</td>
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<td>2.1</td>
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<tr>
<td>Rice</td>
<td>5.3</td>
<td>5.7</td>
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<td>1.3</td>
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</table>

Source: Calculated by author based on data underlying Figure 5.

These crop yield data reinforce the land productivity relativities shown in Figure 4, wherein the average land productivity of sub-Saharan Africa in 2010 exceeded that of Australia. However, Australian and New Zealand agricultural land-to-labor ratios in 2010 of 718 hectares per worker were substantially higher than the African average (7 hectares per worker) such that agricultural output per worker in Australia and New Zealand was $53,811 (2005 prices) compared with just $728.1 per worker for sub-Saharan Africa. Agroecological similarities may account for much of the comparatively low and similar land productivity performances in Africa and Australia (versus the rest-of-the-world), but the two continents have evolved very different agricultural sectors with different technologies and input mixes that manifest in starkly different output per worker outcomes.

Table 4 reveals the patchy and typically limited uptake and use of purchased inputs (including chemical fertilizers, pesticides, improved seed and irrigation) throughout farms in Ethiopia, Ghana, and Kenya, and is likely illustrative of the pattern of agricultural input use throughout a substantial number of other countries in sub-Saharan Africa. Chemical fertilizers are the most widely used off-farm input, but in 2005 only one-third of the farms in Kenya used this input, and the extent of use was even less in Ethiopia and Ghana. This contrasts with Australian agriculture, which likely has factor use uptakes and intensities similar to those in the United States, where material inputs (including energy, purchased seed, chemicals and so forth) accounted for 38 percent of the measured cost of inputs in 2020 (and 52 percent if the cost of capital use was also factored in) (Alston et al. 2010).
Table 4. Structure of African agricultural inputs, various years

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Number of Holders</th>
<th>Area per Holder</th>
<th>Percent of Farm Households Who Use</th>
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<tr>
<td></td>
<td></td>
<td>million</td>
<td>ha</td>
<td>Fertilizers</td>
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<td>Ethiopia</td>
<td>2008/9</td>
<td>12.9</td>
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<td>66.8</td>
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<tr>
<td>Ghana</td>
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<td>3.3</td>
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<td>8</td>
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<td>Kenya</td>
<td>2005</td>
<td>4.4</td>
<td>1.2</td>
<td>42</td>
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</table>

Source: Calculated for the author by Melanie Bacou based on farm household surveys from the respective countries for the years indicated in the table.

Pervasive rural poverty and dysfunctional credit markets are likely two key impediments to the use of purchased inputs (Kloeppinger-Todd and Sharma 2010). Another is the farm-level cost of accessing these inputs (and the commensurate costs of delivering any surplus production to sizable markets). Figure 6 plainly illustrates the magnitude of these market access problems. It shows the time-distance to markets (and hence the implied farm-level cost) of purchasing off-farm inputs and delivering marketable surpluses to markets of 25,000 or more people (Panel a) and 100,000 or more people (Panel b). According to these estimates, only 28 percent of African cropland is less than 2 hours away from market centers of 20,000 people or more, and it takes at least 6 hours to reach markets in excess of 500,000 people for around two-thirds of the cropland throughout sub-Saharan Africa. Excessive time distance to markets means it is prohibitively expensive for many African farmers to participate in input (and output) markets of some significance, even if those inputs were physically available and adapted to their local agro-ecologies and other production realities. Most off-farm inputs embody technologies and know-how that take time to develop and adapt to local circumstances. So while investments in transportation and communication infrastructure will be necessary to improve the lot of African farmers (Torero and Chowdhury 2005), so too will the investments in research and development (R&D) required to develop and deploy new on- and off-farm technologies for the diverse and complex production systems that are a hallmark of African agriculture.
Figure 6. African time distance to markets

Panel a: Population > 20,000  
Panel b: Population > 500,000

Source: Calculated for author by Joe Guo based on data from HarvestChoice and Joint Research Centre of the European Commission. See www.HarvestChoice.org for details of these estimates.

Agricultural R&D

There is ample evidence that the productivity enhancing effects of the new knowledge and innovations arising from spending on agricultural R&D can be profound (e.g. Alston et al. 2000). Innovation in agriculture has many features in common with innovation more generally, but also some important differences. In many ways the study of innovation is a study of market failure and the individual and collective actions—notably investing in agricultural R&D—taken to deal with it. Like other parts of the economy, agriculture is characterized by market failures associated with incomplete property rights over inventions. The atomistic structure of much of agriculture means that the attenuation of incentives to innovate is more pronounced (and particularly so in many of the poorest parts of Africa where the average farm size is small, and getting smaller) than in other industries that are more concentrated in their industrial structure. On the other hand, unlike most innovations in manufacturing, food processing, or transportation, agricultural technology has a degree of site specificity because of the biological nature of agricultural production, in which appropriate technologies vary with changes in climate, soil
types, topography, latitude, altitude, and distance from markets. The site-specific aspects circumscribe, but by no means remove, the potential for knowledge spillovers and the associated market failures that are exacerbated by the small-scale, competitive, atomistic industrial structure of agriculture.

**Distinctive attributes of African agricultural R&D**

1. *Agricultural R&D benefits are difficult to appropriate.* The partial public-good nature of much of the knowledge produced by research means that research benefits are not fully privately appropriable. Indeed, the main reason for private-sector underinvestment in agricultural R&D is inappropriability of some research benefits: the firm responsible for developing a technology may not be able to capture (i.e., appropriate) all of the benefits accruing to the innovation, often because fully effective patenting or secrecy is not possible or because some research benefits (or costs) accrue to people other than those who use the results. Consequently, those who invest in R&D cannot capture all of the benefits—others can “free-ride” on an investment in research, using the results and sharing in the benefits without sharing in the costs. In such cases, private benefits to an investor (or group of investors) are less than the social benefits of the investment and some socially profitable investment opportunities remain unexploited. The upshot is that, in the absence of government intervention, investment in agricultural research is likely to be too little.

The types of technology often suited to African agriculture have hitherto been of the sort for which appropriability problems are more pronounced—types that have been comparatively neglected by the private sector even in the richest countries. In particular, until recently, private research has tended to emphasize mechanical and chemical technologies, which are comparatively well protected by patents, trade secrecy, and other intellectual property rights; and the private sector has generally neglected varietal technologies except where the returns are appropriable, as for hybrid seed. In less-developed countries, the emphasis in innovation has often been on self-pollinating crop varieties and disembodied farm management practices, which are the least appropriable of all. The recent innovations in rich-country institutions mean that private firms are now finding it more profitable to invest in plant varieties; the same may be true in some less-developed countries, but not all countries have made comparable institutional changes.

2. *Agricultural R&D lags are especially long.* The lags between investing in R&D and realizing a return from that investment are long, often spanning decades, not months or years. The dynamic structure linking research spending and productivity involves a confluence of processes—including the creation and destruction of knowledge stocks and the adoption and disadoption of innovations over space and time—each of which has its

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16 This section draws from Pardey and Alston (2010).
17 For instance, an agronomist or farmer who developed an improved wheat variety would have difficulty appropriating the benefits because open-pollinated crops like wheat reproduce themselves, unlike hybrid crops, which do not. The inventor could not realize all of the potential social benefits simply by using the new variety himself; but if he sold the (fertile) seed in one year the buyers could keep some of the grain produced from that seed for subsequent use as seed. Hence the inventor is not able to reap the returns to his innovation.
own complex dynamics. That science is a cumulative process, in which today’s new ideas are derived from the accumulated stock of past ideas, influences the nature of the research-productivity relationship as well. It makes the creation of knowledge unlike other production processes. The evidence for these long lags is compelling. One form of evidence is the result of statistical efforts to establish the relationship between current and past R&D spending and agricultural productivity. The dozens of studies done to date indicate that the productivity consequences of public agricultural R&D are distributed over many decades, with a lag of 15-25 years before peak impacts are reached and continuing effects for decades afterwards.\textsuperscript{18}

3. \textit{Agricultural R&D spills over, but not equally everywhere.} As will be evident from the evidence presented in the next section, underfunding of African agricultural R&D is clearly problematic, and the stage is set for the problem to worsen. In addition to the distinctive features of most African (and other developing countries) described above, the inadequacy of agricultural knowledge stocks may be exacerbated by changes occurring in developed countries. While the most immediate and tangible effect of the new technologies and ideas stemming from research done in one country is to foster productivity growth in that country, the new technologies and ideas often spill over and spur sizable productivity gains elsewhere in the world. In the past, developing countries, including many throughout Africa, benefited considerably from technological spillovers from developed countries, in part because the bulk of the world’s agricultural science and innovation occurred in rich countries.\textsuperscript{19} Increasingly, spillovers from developed countries may not be available to developing countries in the same ways or to the same extent.\textsuperscript{20}

Second, technologies that are applicable may not be as readily accessible because of increasing intellectual property protection of privately owned technologies (Wright and Pardey 2006) and, perhaps, more importantly, the expanding scope and enforcement of biosafety regulations. Third, those technologies that are applicable and available are likely to require more substantial local development and adaptation, calling for more sophisticated and more extensive forms of scientific R&D than in the past. The requirement for local adaptive research is also likely to be exacerbated as changes in global and local climate regimes add further to the need for adaptive responses to those changed agricultural production environments. Large areas in African agriculture seem

\textsuperscript{18} Alston et al. (2010) reviewed the prior literature. They also developed their own estimates using newly constructed U.S. state-level productivity over 1949-2002 and U.S. federal and state spending on agricultural R&D and extension over 1890-2002. Their preferred model had a peak lagged research impact at year 24 and a total lag length of 50 years.

\textsuperscript{19} Developed countries have also benefited substantially from spillins of R&D done in or directed toward the developing world. Alston (2002) reviewed work by economists in quantifying these benefits.

\textsuperscript{20} Decreasing spillover potential is caused by several related market and policy trends in developed countries. First, the types of technologies being developed may no longer be as readily applicable to developing countries as they were in the past. As previously noted, developed country R&D agendas have been reoriented away from productivity gains in food staples toward other aspects of agricultural production, such as environmental effects, food quality, and the medical, energy, and industrial uses of agricultural commodities. This growing divergence between developed-country research agendas and the priorities of developing countries implies fewer applicable technologies that would be candidates for adaptation to developing countries.
especially susceptible to the consequences of climate change (Lobell et al. 2008; FAO 2009; Müller et al. 2011).\textsuperscript{21}

4. \textit{Economies of size, scale, and scope in agricultural R&D}. In evaluating the extent of underinvestment in agricultural R&D and potential means of increasing investment, it is important to consider the economies of size, scale, and scope in knowledge accumulation and dissemination. For instance, if technological spillovers continue to be fairly available and accessible, as they have been in the past, it might not make sense for small, poor, agrarian nations to spend their scarce intellectual and other capital resources in agricultural science. However, if spillins from developed countries decrease, developing countries will need to conduct more of their own research; but many nations may be too small to achieve an efficient scale in many, if any, of their R&D priority areas (e.g., Byerlee and Traxler 2001). In 2000, for example, 40 percent of the agricultural research agencies in sub-Saharan Africa employed fewer than five full-time-equivalent (fte) researchers in 2000; 93 percent of the region’s agricultural R&D agencies employed fewer than 50 researchers (James, Pardey and Alston 2008).\textsuperscript{22} Creative institutional innovations to collectively fund and efficiently conduct the research in ways that realize these scale and scope economies will be crucial.

\textbf{R&D trends}\textsuperscript{23}

In light of the complex relationship linking agricultural R&D spending to productivity changes, an assessment of the state of, and potential for, innovation in African agriculture requires at least a long-run look (to deal with the reality of long lags) and a multi-country cum multi-continent look (to develop a sense of the spillover potentials). Figure 7 provides preliminary, new estimates of public agricultural R&D spending worldwide spanning a thirty-five year period and measured in 2005 international dollars. Pardey and Chan-Kang (2012) estimate that in 1970 the world spent $11.4 billion dollars on public agricultural R&D, which more than doubled to $28.7 billion by 2005. There was a substantial spatial shift in where this research was performed. In 1970, the high-income countries as a group (including the United States) accounted for 60 percent of the world’s total. By 2005 that share had slipped to 53 percent. Although the low- and middle-income countries as a group gained market share, notably, sub-Saharan Africa lost ground. The region accounted for a smaller share of the world’s spending in 2005 (4.8 percent) than it did in 1970 (6.6 percent). If spending by South Africa and Nigeria—the two largest agricultural economies in the region—were set aside, the rest-of-Africa accounted for just 2.8 percent of the world’s agricultural R&D spending in 2005.

\textsuperscript{21} An important caveat is that farmers can (and have) responded to all sorts of changes in the past, including what crops to grow where, and when. For example, Beddow (2012) graphically illustrated the capacity of corn producers in the United States to change both the location and timing of production in ways that have more than offset any overall climate warming effects over the past century or more.

\textsuperscript{22} In fact, in 2000, one third of the public agencies in India and almost all the public agencies in the United States employed more than 100 fte researchers.

\textsuperscript{23} The research and development estimates reported here draw in part from estimates made by Pardey and Chan-Kang (2012) are preliminary and subject to revision. The estimates exclude the Former Soviet Union and Eastern European countries due to lack of data.
Looking more carefully at the growth in constant-priced public R&D spending, Africa grew by 1.2 percent per year from 1970-2005 compared with 2.7 percent per year for the rest-of-the-world total. During the 1970s, African spending on public agricultural R&D grew by 2.7 percent per year, slowed substantially to 0.5 percent per year during the 1980s, and increased slightly to 0.8 percent per year during the 1990s (Figure 8). Spending growth rebounded during the first half of the 2000s to average 2.1 percent per year, but the recovery appears fragile and was not widespread. Over half of the increase in spending from 2000-2005 came from just two countries, Nigeria and Ethiopia (see also Beintema and Stads 2011).**

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**Notably, 13 of the 33 African countries (i.e., 39 percent) increased their spending by less than 0.6 percent per year during the period 2000-2005. Thus a substantial share of the countries in the region saw virtually no growth in spending (including the regionally important South African system), and, after accounting for inflation, 17 countries spent less during the 2000s than in the 1990s.**

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Figure 8. Growth in public food and agricultural R&D spending, 1970-2005


It is the pattern of spending over the long haul that is critical for agricultural R&D, especially given the long gestation period for new crop varieties and livestock breeds, and the desirability of long-term employment assurances for scientists and other staff. Variability encourages an over-emphasis on short-term projects or on projects with short lags between investment and outcomes, and adoption. It also discourages specialization of scientists and other resources in areas of work where sustained funding may be uncertain, even when these areas have high pay-off potentials. Pardey, Roseboom and Beintema (1997) identified fluctuating and uncertain spending trends as being a major constraint for African agricultural research.²⁵ Using more recent data, (Beintema and Stads 2011, p. 27) reaffirmed that this problem still bedevils many of the agricultural research agencies in the region, particularly those that remain heavily reliant on fickle external (donor) sources of funding.

Another disturbing feature of the data is the dramatic slowdown in the growth of funding for the rest-of-world group (Figure 8). If China and India are set aside, Pardey and Chan-Kang (2012) estimate that rest-of-world grew by just 1.0 percent per year during the period 1990-2005. Moreover, spending in the high-income group slowed after the 1990s, and grew by only 1.7 percent per year the first half of the 2000s (versus 2.6 percent per year from 1970-2005). The productivity performance of the rich countries will bear the brunt of this slower growth in spending, but knowledge and innovation spillovers to Africa and the rest of the developing world

²⁵ See also Lipton (1989).
are also likely to be compromised, not least because rich countries still collectively conduct more than half the entire world’s public agricultural R&D (and substantially more than half the world’s private food and agricultural R&D).

**Intensity of agricultural research**

Countries with larger (smaller) agricultural economies are likely to invest more (less) in agricultural R&D simply due to a congruence effect (Pardey, Kang and Elliott 1989). For this reason, normalizing agricultural research expenditures with respect to the size of the agricultural economies they serve provides an indication of the intensity (distinct from amount) of research spending. The research intensity ratios summarized in Figure 9 show (weighted) averages by decades of the amount of public agricultural R&D spending relative to the corresponding agricultural GDPs (agGDP).

**Figure 9. Intensity of public agricultural research spending, 1970-2005**

![Intensity of public agricultural research spending, 1970-2005](image)


According to these estimates, during the 1970s African agriculture spent just 33 cents on public agricultural R&D for every $100 of agricultural output. Over the following decades this ratio rose modestly, so that 54 cents was spent on research for every $100 of agGDP in the 2000s (a research intensity ratio of 0.54). Notwithstanding this increase, the intensity of investment in African agricultural R&D remains substantially below the corresponding rest-of-world ratio (0.78 in the 1970s and 1.05 in the 2000s). As one might expect, it is also substantially below the rich-country average (2.7 in the 2000s), although above the intensity of investment in Asian agriculture which averaged 0.42 in the 2000s. Factoring in the private sector widens the Africa versus rest-of-world gap quite considerably. Beintema and Stads (2006, p. 26) estimated that in
2000, privately performed research represented just over 2 percent of the total (public and private) agricultural research conducted throughout sub-Saharan Africa (and two-thirds of that private research was performed in South Africa alone). Adding in private food and agricultural R&D raises the rich-country overall research intensity ratio for the 2000s to 5.5, almost 10 times the corresponding African ratio (Pardey and Chan-Kang 2012).26

African agricultural R&D (or perhaps more precisely, some countries within the region) has made some progress, but that progress is erratic and there remain persistent (and wide) investment gaps between Africa and the rest-of-the-world. These measures suggest the immensity of the challenge of playing catch-up in sub-Saharan Africa. The measures also underscore the need to transmit knowledge across borders and continents and to raise current amounts of funding for agricultural R&D while also developing the policy and infrastructure needed to accelerate the rate of knowledge creation and accumulation in Africa over the long haul. Developing local capacity to carry forward findings will yield a double dividend: increasing local innovative capacities while also enhancing the ability of local research agencies to tap discoveries made elsewhere.

Conclusion

The imperatives of African agricultural development, and the sheer scope, rural concentration, and dire outcomes of poverty and hunger in many African countries gives a sense of urgency to improving the production and poverty alleviating performance of the region’s agriculture sector. A key to ramping up productivity growth in African agriculture will be increased, sustained, and, possibly, refocused investments in agricultural R&D and the rural infrastructure that is essential to economically link farmers to markets. The conundrum is that agricultural R&D, and the productivity gains that flow from those investments, typically take considerable time to realize their full effects. The politically expedient option seems to be to defer investments in agricultural innovation and rural infrastructure (in favor of other spending, including fertilizer and other subsidies) or skew those investments to politically more vocal urban constituents.

The legacies of such choices made in earlier decades—most notably almost two lost decades of agricultural R&D spending growth in the 1980s and 1990s—are now evident. While overall agricultural output growth in Africa during the past decade has been comparatively strong, the growth is from a low base and the evidence presented here suggests that this output growth has not been accompanied by a pervasive increase in agricultural productivity.27 Absent broad-based growth in agricultural productivity it will be hard to generate and sustain increases in per capita production and per capita incomes, both of which will be required to efficiently support the increasingly urbanized economies throughout the region. While more and, especially, sustained funding for agricultural R&D is likely to yield sizable social payoffs, the more systematic use of evidenced-based approaches to retargeting the region’s innovative effort could also maximize the development potential of these scarce research dollars.

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26 This is assuming the 2 percent private share reported by Beintema and Stads (2006) for 2000 is indicative of the private share for the first half of the 2000s.
27 Notably, less than half the countries in sub-Saharan Africa had faster agricultural output growth in the 2000s compared with the previous decade.
References


Core Literature on Agricultural Productivity and R&D


Presents and critically reviews the available evidence on interstate and international agricultural R&D spillovers. In studies of aggregate state or national agricultural productivity, interstate or international R&D spillovers might account for half or more of the total measured productivity growth. Similarly, results from studies of particular crop technologies indicate that international technology spillovers, and multinational impacts of technologies from international centers, were important elements in the total picture of agricultural development in the 20th Century.


This book reports a range of contemporary evidence regarding recent trends in agricultural productivity around the world. The fundamental purpose of the volume is to better understand the nature of the long-term growth in the supply of food and its principal determinants. The evidence is presented from two perspectives. One is from a general interest in the world food situation in the long run. The other is from an interest in the implications of U.S. and global productivity patterns for U.S. agriculture.


In this book the authors document and assess the evolving path of U.S. agriculture in the 20th century and the role of public R&D in that evolution. They provide a detailed quantitative assessment of the shifting patterns of production among the states and over time and of the public institutions and investments in agricultural R&D. Then, based on newly constructed sets of panel data, some of which span the entire 20th century and more, the authors present new econometric evidence linking state-specific agricultural productivity measures to federal and state government investments in agricultural research and extension. The results show that although the benefits from past public investments in agricultural research have been worth many times more than the costs, the time lags between R&D spending and its effects on productivity are longer than commonly found or assumed in the prior published work. Also, the spillover effects of R&D among states are important, such that the national net benefits from a state’s agricultural research investments are much greater than own-state net benefits.


This report provides a comprehensive (statistical) assessment of the entire body of published evidence from 1953-2000 on the returns to agricultural R&D. In doing so, it attempts to answer five key questions of interest to both researchers and policymakers, specifically: 1) Has the rate of return to agricultural R&D declined over time? 2) Do the returns to agricultural R&D differ internationally among regions of the world, or between national agricultural research systems
and international centers? 3) Does the return to research vary according to its problematic focus, and how does the rate of return to environmental or natural resource research compare with more traditional agricultural production R&D? 4) Does the rate of return vary between basic and more applied research, or between research and extension? and 5) Is systematic bias built into the estimates from particular evaluation techniques and estimation details from other aspects of the analysis, or according to who does it?


This book reviews, synthesizes and extends the economic methods used to evaluate and prioritize investments in agricultural research. In doing so it covers such methods as productivity measurement, economic surplus analysis, econometric techniques, mathematical programming procedures and scoring models. It discusses these practices in the context of scientific policy, describes their conceptual foundation, and explains how to do them.


This report provides the most up-to-date data concerning investments in and staffing of agricultural R&D agencies throughout sub-Saharan Africa. It describes some of the key institutional realities of African agricultural R&D and the important challenges to improving innovation effort in the region. Additional agricultural R&D data for Africa and elsewhere in the world can be obtained on line at http://www.asti.cgiar.org/.


This volume develops the analytical and empirical basis for the induced innovation hypothesis within the context of agriculture. The authors describe how differences in factor scarcity induce technical changes that are consistent with country’s resource endowments. The authors also extend the theory of induced technical change to encompass associated processes of induced institutional change.


This paper gives an overview of the existing evidence on African agricultural productivity growth and presents new evidence on the evolution of sub-Saharan Africa’s agricultural total factor productivity (TFP) over the past 40 years using a nonparametric Malmquist index. The authors identify a recovery in the performance of sub-Saharan Africa’s agriculture during the 1984–2003 period after a long period of poor performance and decline and discuss possible factors that gave rise to this apparent rebound in productivity growth.

Agricultural production and productivity is heavily reliant on, and in turn has major implications for, ecosystem services. This report assembles and compares information already available on a global scale to show how human action has profoundly changed the extent, condition, and capacity of agroecosystems. Agriculture has expanded at the expense of grasslands and forests, engineering projects have altered the hydrological regime of most of the world’s major rivers, settlement and other forms of development have converted habitats around the world’s coastlines. Human activities have adversely altered the earth’s most important biogeochemical cycles—the water, carbon, and nitrogen cycles—on which all life forms depend. While intensive management regimes and infrastructure development have contributed positively to providing some goods and services, such as food and fiber from forest plantations, the authors argue that they have also led to habitat fragmentation, pollution, and increased ecosystem vulnerability to pest attack, fires, and invasion by nonnative species. Information is often incomplete and the picture confused, but there are signs that the overall capacity of ecosystems to continue to produce many of the goods and services on which humanity depend is declining.
Climate Change and Agricultural Adaptation

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Food policy makers are increasingly faced with the question of how to adapt to climate change. The increased attention on climate adaptation is partly related to the fact that greenhouse gas emissions and climate change show little sign of slowing, partly because of prospects for large sums of money devoted to adaptation, and partly because of well publicized recent weather events that have affected agricultural regions and rattled global food markets. A common and reasonable reaction from the food policy and agricultural community has been to argue that climate variations have always been a challenge to agriculture, and that climate change just makes addressing these variations more important. A logical conclusion from this perspective is to emphasize activities that help build resilience to unpredictable weather events, as well as to focus on the types of weather variables that exhibit a lot of year-to-year variability and cause the bulk of farmers’ concerns in current climate.

However reasonable as a starting point, this perspective is misguided and risks taking a challenging problem and making it even harder. Anthropogenic global warming (AGW) is fundamentally different from the natural variations driven by internal dynamics in the climate system. Indeed, predicting the course of climate change is less like predicting the weather next week than it is like predicting that summer will be warmer than winter. Progress in climate science has shown that the most indelible hallmarks of AGW will be increased occurrence and severity of high temperature and heavy rainfall extremes in all regions, and increased frequency and severity of drought in sub-tropical regions. Changes in the timing and amount of seasonal rainfall also appear likely in some regions, but at a much smaller pace relative to natural variability. In all of these cases, predictions from climate science are most robust at broader spatial scales, with considerable uncertainty in predicting changes for any single country.

Meanwhile, progress in crop science has shown that most crops show fairly rapid declines in productivity as temperatures rise above critical thresholds, with as much as 10 percent yield loss for +1°C of warming in some locations. Both sub-Saharan Africa and South Asia appear particularly prone to productivity losses from climate change, in part because major staples in these regions are often already grown well above their optimum temperature.

Approaches to climate adaptation should recognize these realities, and should not equate anticipating climate changes with the considerably harder task of predicting next year’s weather. Predicting and building resilience to climate variability still remain important goals for agricultural development, but adaptation efforts should balance these activities with those focused more on the specific threats presented by climate change. Heat tolerant crop varieties and strategies to deal with heavy rainfall provide two examples of important needs. Similarly, balance is needed between the local-scale efforts that attract most of adaptation investment currently, and regional and global networks to develop needed technologies. Given the greater certainty of climate changes at broader scales, as well as the positive track record of international networks for crop breeding, investments in these global systems are very likely to deliver substantial adaptation benefits. Finally, given the downward pressures that climate change will exert on smallholder farm productivity in sub-Saharan Africa, and the critical role productivity gains play in catalyzing an escape from poverty, speeding the pace of investment in African agriculture can also be viewed as a good bet for climate adaptation.
Climate Change and Agricultural Adaptation

Introduction

In the summer of 2011, a prolonged drought in the Horn of Africa contributed to widespread hunger in Somalia, with tens of thousands of deaths and many more refugees. For the first time since 1992, the United Nations issued a formal declaration of famine in Somalia on July 20, 2011. Meanwhile, across the world, and at the other end of the development spectrum, the Corn Belt of the United States experienced a massive heat wave in July 2011, during the critical flowering phase of maize. Subsequent yields were well below trend line, helping to prop up an already high world price of maize.

In the eyes of some, these two recent stories exemplify the threats that climate change poses to food security: conditions for crop growth in subsistence areas deteriorate from bad to worse, leading to massive food insecurity and migration; conditions in high production areas deteriorate by enough to raise world prices, harming food importers; and efforts to cope with the changes are not enough to avoid the suffering of millions.

The two examples also raise many questions that characterize the difficulty of adapting to climate change: were the droughts in Eastern Africa related to global warming or simply natural variability? Is climate really the main culprit, or is focusing on political institutions and overall development the best long-run approach for coping with climate disasters? And will the private sector in the United States rapidly develop new heat tolerant seeds, or are major investments in public research and development needed to avoid global impacts of climate change?

Many food security experts are now more interested in climate change than ever before, as evidenced by the presence of climate in the short list of topics addressed by this policy series. This interest is partly a response to weather events in recent years - including droughts in China in 2010-2011, in Australia in 2007-2008, and heat waves in Russia in 2010 - but also to at least two additional factors. First, there is widespread recognition that international efforts to reduce greenhouse gas emissions have stalled, for various political and economic reasons, and that even if agreements are quickly reached to pursue aggressive emission targets, there is enough inertia in energy infrastructure and the climate system to ensure further warming for the next few decades. In fact, climate projections that assume slow versus rapid changes in emissions begin to diverge only after 2050. Until then, the Earth is essentially locked into further climate change as a result of past actions.

Another important reason for renewed interest is the prospect, and indeed the beginning, of large flows of money into climate adaptation. It is conceivable, although by no means guaranteed, that tens of billions of dollars per year will be available for adaptation efforts in developing countries by 2020. Only a small fraction of this money is likely to be directed at agriculture, but nonetheless the sums could add substantially to other sources of investment in food security.

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1 The UN formally defines a famine as more than 20 percent of households facing extreme food shortages, a crude mortality rate of more than 2 people per 10,000 per day, and malnutrition rates of above 30 percent.
2 Barring the possibility of geo-engineering schemes that attempt to rapidly cool Earth, for example, by blocking sunlight with aerosols or giant mirrors into space.
3 For a current summary of funds, see www.climatefundsupdate.org.
How, then, can these adaptation resources be most effectively used? Although large, the amount of money will continue to be a small fraction of estimated needs\(^4\), forcing tough decisions on selecting priorities for investment. The premise of this paper is that sound science should be an important part of these decisions, and therefore that policy makers should understand the key aspects of the science.\(^5\) Rather than attempt a review of a vast and growing literature, I seek to outline a handful of lessons that those working in food security and climate should know, and to suggest some implications of the science for policy design.

**Climate change versus climate variability**

Weather has always been a concern to farmers and herders. Every year brings a different combination of temperature, rainfall, cloudiness, and various other factors that affect agriculture. This inter-annual variability results from the simple fact that the Earth is a spinning sphere of land and (mostly) water, with sunlight unevenly distributed across the world. As energy and water moves around the Earth’s atmosphere and oceans, many patterns of natural variability emerge. A well-known example is the El Niño Southern Oscillation, driven by changes in the tropical Pacific that then propagate throughout the world.

Just as no two years are the same, decades can also differ significantly because of natural variability of the climate system. For example, Figure 1 shows rainfall in the Sahel region over the 20th century. Some decades are very wet, such as the 1920s or 1950s, and some are very dry, such as the 1970s and 1980s. Although some of this variability is due to changes in external factors, such as aerosol concentrations, most of the variability is simply the result of internal dynamics in the climate system (Giannini et al. 2003).

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\(^4\) The World Bank recently estimated a need of $75 billion USD per year by 2030 to adapt to a 2°C warmer world.

\(^5\) In focusing on adaptation, I recognize that adaptation may not be the only goal of adaptation finance, and in some cases it may not even be the main objective. Often these funds are viewed simply as a way of transferring wealth to those who are least responsible for global warming but bear much of the impacts, or as an incentive to participate in broader agreements on mitigation commitments.
Climate change is distinct from climate variability. The former term describes changes that occur because of human activities, especially the emissions of greenhouse gases, whereas climate variability refers to changes that result from internal dynamics of the climate system, independent of any external forcing. At first glance, the distinction between climate change and variability may seem arbitrary and unhelpful. After all, no one is exposed to only climate variability or only climate change, but to the combination of the two. If the weather is changing in a farmer’s field, why does the cause of this change matter when deciding how to respond?

However, the distinction is very important for anyone seeking to understand adaptation to climate change, for two main reasons. First, the processes underlying climate change are very different than those behind natural variability. In the former case, accumulation of greenhouse gases in the atmosphere traps outgoing heat, leading to an increase in the overall energy of the climate system. Natural variability occurs because of internal dynamics in the climate system, which are fed by gradients in solar radiation and ocean circulation. As a result of different underlying processes, one should expect different weather variables to be affected.

For example, internal natural variability leads to large fluctuations in rainfall from year to year in many locations, as illustrated for the Sahel in Figure 1. But natural variability in temperature is quite low throughout the tropics, with the warmest and coolest years often differing by less than 2°C. In contrast, global warming has its strongest effect on temperatures, with often much smaller effects on rainfall than natural variability.

In climate science, the distinction between climate change and variability is also often referred to as “forced” vs. “unforced” climate response.
Thus, confusing climate variability and change runs the risk of focusing on the wrong aspects of weather when designing adaptation strategies. For instance, if climate change is perceived as simply amplifying variability (a common view among many farmers and agricultural scientists), then there will be a tendency to overemphasize the importance of rainfall.

A second important reason for distinguishing change from variability is the risk of overreacting to short-term trends driven by natural variability. Returning to Figure 1, if an observer in the mid-1950s assumed that the rainfall trend since 1920 was mostly the result of anthropogenic climate change, then he or she would reasonably have argued for adaptations to permanently wetter conditions, only to be confounded when rainfall declined for the next few decades. For this reason, climate scientists expend great efforts to understand the potential magnitude of trends driven by natural variability in order to be able to identify when trends are truly out of bounds. The recent drying in Eastern Africa, for instance, still appears within the range of natural variability. Devoting a lot of adaptation resources to coping with this rainfall trend might therefore be misguided, especially since it would pull resources away from other trends that are much more certain to continue.

With this general background on the meaning of climate change, and why it is distinct from climate variability, I now turn to a discussion of the current state of climate science.

What is known about climate change?

Scientific understanding of climate change has made great progress in the past few decades, both in terms of explaining the recent past and in providing a clearer picture of the next few decades. There are still clearly many uncertainties and shortcomings in the ability to predict the future, but there are also many near-certainties that are often underappreciated by the public. In fact, one of the disservices of the politically-motivated “debate” about whether humans are causing climate change is that policy makers and the public often underestimate how much climate science can say about the future.

Here I provide a brief review of the aspects of climate science that I find most relevant to the future of food security, with an emphasis on areas where the science is most firm. Although a detailed discussion of how climate science arrives at a consensus view is beyond the scope of this paper, an important general point is that multiple lines of evidence are typically required for consensus. For example, a projected increase in heavy rainfall events is considered very likely because the basic physics underlying that change are fairly well understood (Allen and Ingram 2002; O'Gorman and Schneider 2009), many independent climate models repeatedly simulate an increase in heavy rainfall (Tebaldi et al. 2006), increases in heavy rainfall have already been observed in many regions (Alexander et al. 2006), and the magnitude and pattern of these changes are consistent with model predictions (Min et al. 2011). Any of these alone, without the others, would not result in consensus.
The critical importance of scale

For any specific climate variable of interest (such as those discussed below) one can consider changes at a range of spatial scales, from an individual field or village to an average for the entire globe. It is difficult to overemphasize the importance of making scale explicit in any analysis of climate change impacts, because the overall magnitude and uncertainty of any climate change will be scale dependent. Statements such as “rainfall changes are too uncertain” or “we don’t know enough to design good adaptation strategies” fail to make the scale distinction. Three factors in particular contribute to the scale dependence of climate projections.

1. *Spatial differences in projected changes.* The simple fact that projected changes are not uniform across space means that averages over larger areas will tend to be less extreme than averages over small areas. For example, Figure 2 shows projected changes in July rainfall by 2050 for two different climate models. Both models show some individual grid cells (roughly 50km x 50km near the equator) with large percent increases, and other areas with large decreases. For several individual cells or even countries (e.g., Kenya), there are large differences between the two models. However, if one considers averages over broader regions, such as continents, the magnitudes of change and the differences between the models become smaller. The bottom panel of Figure 2 shows a histogram of changes for all cells, along with averages over the crop areas in each continent. Both models indicate less rainfall for crop areas in North America and slightly more rainfall for Asia. Although important differences still exist at the continental scale (e.g., for Europe), there are no longer any changes greater than 30 percent in absolute value, whereas this value was commonly exceeded for individual cells. Thus, the main point is that magnitudes and uncertainties change with scale.
Note: (Top) Projections of precipitation change (%) by 2050 for two climate models, as an illustration of the spatial variations present in projections. (Bottom) The corresponding histograms of values in the top figures (shown in gray bars) along with lines showing the change in average rainfall over large cropping regions. Changes tend to be much more muted over large areas because of the spatial heterogeneity.

2. **Natural variability is larger at smaller scales.** A second important factor is that natural variability is more muted over large spatial scales. The ratio of signal (in this case the climate change) to noise (natural variability) therefore tends to be higher at broad scales, even if the signal itself becomes more muted. One example of this fact is that global temperature increases have been much easier to detect and link to greenhouse gas emissions than changes over individual countries.

3. **Many climate forcings differ across space.** Greenhouse gases such as carbon dioxide or methane are well-mixed in the atmosphere, meaning that they diffuse from the source of emission and eventually spread throughout the atmosphere. Other types of human activities that affect climate, however, are much more local in scope. A primary example of a local forcing is emission of microscopic sulfate particles (aerosols) from power plants, which can strongly affect climate by altering the amount of sunlight reflected back to space. However, these particles typically fall out of the sky after a day or two, so they only affect the climate in the vicinity of the emissions. Another example is conversion of
forests into agriculture, which can also affect local climate but has little effect in remote regions. These local effects will continue to be important in some regions, but not others. In general, as one considers broader scales the importance of these local factors will diminish, making it somewhat easier to predict the future course of climate.

All of these factors point to the fact that climate predictions at broader scales are generally more reliable than predictions at finer scales. In contrast, many of the adaptation needs are at local scales, and some go so far as to claim that “all adaptation is local” (Kostel 2009). The tension in scale between what the adaptation community demands and what climate science can provide is a topic to which I will return to below. First I turn to a brief discussion of trends in climate variables most relevant to food security.

**Observed and projected climate changes**

Underlying any prediction of climate change are a couple of basic physical principles, both of which have been known for more than 100 years. First, gases such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) absorb outgoing radiation emitted from the Earth’s surface and re-emit part of it back towards the surface, much like a blanket keeps warm air from escaping. Raising the concentration of these greenhouse gases therefore leads to an increase in energy within the Earth’s atmosphere, reflected in an increase in global temperatures (i.e. the greenhouse effect). Second, the amount of water vapor that air can hold increases exponentially with air temperature, so that a world with higher average temperature will tend to have more water vapor (itself a greenhouse gas). These and other physical principals form the core of general circulation models (GCMs), which are used to project future changes in climate.

As mentioned, output from GCMs are frequently tested against observations, as well as compared to other models, and confidence is highest in those aspects of GCMs that agree with historical trends. This logic leads to a question commonly asked by agricultural scientists of whether it would be simpler and just as reasonable to take simple linear extrapolations of recent trends in order to predict climate changes over the next few decades. This approach is especially attractive to those who do not wish to rely on models they neither understand nor trust. The simple answer is no, although again the answer depends partly on scale. For sub-continental regions, it is likely that some or even all of the historical trends are driven by natural variability or by regional climate forcings like aerosol, which may not continue into the future. Thus the emphasis in the climate community on using output from physics-based models.

As a rule of thumb, however, it is difficult to imagine any large changes over the next few decades that have not already shown signs of changing. Similarly, there are few cases of variables that have been changing fast at global scales but are not expected to change greatly in the future.7 Indeed, many of the predictions of climate models are consistent with observed changes, particularly at global scales. At finer scales, the main disagreements between models

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7 An exception is diurnal temperature range (DTR = the difference between day and night temperatures). For many years night temperature rose faster than day temperature, and this was especially true in Asia since 1950. However, these changes were mainly due to changes in aerosols and the DTR has not changed much since 1980 (Wild 2009). Despite this, many agricultural scientists persist in thinking that night temperatures will go up faster than day temperatures.
and data are traceable to forcings such as aerosols or land use that existed in reality but not in the model, or to natural variability.

Table 1 provides a summary of key expected and observed changes. The most ubiquitous feature of climate change is an increase in global mean temperatures (GMT) (hence the name “global warming”). Models project an average increase of 0.2°C per decade in GMT. Warming in agricultural areas is expected to be faster than GMT, because the global mean includes the 75 percent of Earth’s surface that are oceans, which warm more slowly than land because of constant upwelling of deeper, cooler waters.

Table 1. Summary of projected and observed changes in key climate variable (T = temperature, P = precipitation)

<table>
<thead>
<tr>
<th>Climate aspect</th>
<th>Projected Changes to 2050</th>
<th>Observed Changes as of 2011</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average growing season T</td>
<td>• +0.2°C per decade increase in global mean temperature&lt;br&gt;• +0.3-0.4°C per decade increases for most cropping regions (Fig. 2)</td>
<td>• Warming in most major cropping regions, with exceptions of North America and South Africa</td>
<td>(IPCC 2007; Lobell et al. 2011b)</td>
</tr>
<tr>
<td>T extremes</td>
<td>• Decline in frost occurrence&lt;br&gt;• Increase in occurrence of very hot days and nights.</td>
<td>• Decline in frost occurrence&lt;br&gt;• Increase in occurrence of very hot days and nights.</td>
<td>(Alexander et al. 2006; New et al. 2006; Tebaldi et al. 2006; Kharin et al. 2007; Zwiers et al. 2011)</td>
</tr>
<tr>
<td>Average growing season P</td>
<td>• Potential changes as much as 10 percent in some regions, but expected changes fairly small</td>
<td>• Some regions with positive rainfall trends in past 30 years, some with negative. Nothing outside of natural variability</td>
<td>(IPCC 2007; Lobell et al. 2011b)</td>
</tr>
<tr>
<td>P extremes</td>
<td>• Increased fraction of rain falling in heavy events&lt;br&gt;• Increased magnitude of heavy rains</td>
<td>• Increased heavy rainfall in many regions&lt;br&gt;• Increased magnitude of heavy rains</td>
<td>(Alexander et al. 2006; New et al. 2006; Tebaldi et al. 2006; Kharin et al. 2007; Min et al. 2011)</td>
</tr>
<tr>
<td>Start and length of rainy season</td>
<td>• Delay in start of rainy season in</td>
<td>• Lack of scientific literature</td>
<td>(Biasutti and Sobel 2009; Seth et al. 2011)</td>
</tr>
</tbody>
</table>
| Soil moisture / drought | • Increases in frequency and spatial extent of droughts in most regions  
• Trends not likely to be detectable (compared to natural variability) for a few more decades | • No detectable trends outside of natural variability | (Wang 2005; Sheffield and Wood 2008b; Sheffield and Wood 2008a) |
|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Year-to-year variability | • Potential increases, particularly for T variability in interior of continents  
• Still considerable model disagreement | • Lack of scientific literature | (Räisänen 2002; Giorgi and Bi 2005) |

Figure 3 shows expected June-August temperature changes averaged over crop areas in each continent, with warming rates ranging from 0.2-0.6 °C per decade depending on model and continent.

**Figure 3. T and P changes (2050 minus 2000) June-August for 16 climate models averaged over crop area by continent**
Note: Crop regions warm by a projected 1.2°C for 50 years, or .2-.6 per decade. This is considerably faster than the rate of GMT increase.

Consistent with these projections, an increase of roughly 0.7°C GMT has already been seen since 1950, and most agricultural areas have warmed more quickly. For example, in many cropping regions the growing seasons have warmed by more than 1°C since 1980 (Lobell et al. 2011b). Climate models are consistently able to reproduce these trends globally and in individual regions. In fact, models can only reproduce the trends if the increase in greenhouse gas concentrations are specified, indicating that the trends are not plausibly the result of natural variability alone (IPCC 2007).

Along with mean temperature increases, models agree in projecting several other relevant changes: (i) a reduction in the occurrence of extremely cold days or extremely cold nights (i.e. frost); (ii) an increase in the occurrence of extremely warm days and nights; (iii) an increase in the occurrence of heavy precipitation events; and (iv) an increase in the frequency and severity of droughts in subtropical regions. The first two can be understood as a direct consequence of the rise in mean temperatures, which shifts the temperature distribution toward historical warm extremes and away from historical cold extremes (Figure 4). The latter two changes, in heavy rains and drought, can be understood as the consequence of an increase in water fluxes within the atmosphere, which causes dry areas and seasons to be even drier, and wet areas and seasons to be wetter (Figure 5).

**Figure 4. Effects of a simple shift of the entire distribution toward a warmer climate**

![Figure 4](image)

Source: IPCC 2012. An increase in mean temperature leads to more hot extremes and less cold extremes, where extreme is defined based on the frequency of occurrence in historical data.
Figure 5. Intensification of the hydrological cycle in the Geophysical Fluid Dynamics Laboratory (GFDL) climate model

Source: GFDL 2012. (a) Average annual precipitation by latitude; (b) change in average precipitation by latitude by 2100. Dry areas (where rainfall is less than evaporation) in the subtropics tend to get drier and wet areas tend to get wetter.

As with GMT, the above changes are not only predicted for the future but have already been observed in many regions. For example, Figure 6 displays observed trends in measures of cold extremes, warm extremes, and heavy rainfall events for 1951-2003 throughout the world (Alexander et al. 2006). In most locations, cold nights (defined as the 10th percentile of night temperatures for 1961-1990) are less common, warm days are more common, and rainfall events over 10mm/day are more common. The availability of data is insufficient throughout most of Africa to discern trends, although more detailed studies of Africa indicate a similar picture. For example, extremely warm days (defined as the 95th percentile of historical values) were nearly twice as frequent in Southern and West Africa by 2000 compared to 1961 (New et al. 2006).
Figure 6. Observed trends in global measures of cold extremes, warm extremes, and heavy rainfall events for 1951-2003

Cold Nights  Warm Days  Heavy Precipitation Days

Source: Alexander et al. 2006. Maps of trends (in days per decade, top) and annual global time series of anomalies relative to 1961-1990 mean (bottom) for cold nights (10th percentile of Tmin for 1961-1990), warm days (90th percentile of Tmax) and heavy precipitation days (days with more than 10mm precipitation).

The magnitude and speed of all of these changes are unprecedented on a global scale, and even in individual countries the changes are likely to produce unprecedented weather in the next few decades. A good example is the case of very hot days. The hottest single day over a 20 year period, for instance, is expected to be on average 1.7°C warmer by mid-century than in 1980-2000 (Kharin et al. 2007). At first glance this change may seem unremarkable, but consider that what had been the warmest single day in 1980-2000 would occur on average every 1.5 years. In the tropics, where year-to-year variability tends to be lower than in temperate systems, this historical “extreme” would be expected every single year by 2050. Similarly, throughout the tropics the majority of growing seasons by mid-century are expected to be warmer than any growing season experienced in the 20th century (Battisti and Naylor 2009).

In addition to temperature, rainfall is of obvious relevance to agriculture. The increased frequency of heavy rainfall events has already been mentioned, but beyond that the picture gets murkier. Global precipitation is expected to increase, but in many regions the changes in average precipitation disagree in sign from model to model. Figure 3 presents precipitation changes for June-August averaged over crop regions in each continent, illustrating that in each region one can find models that show increases or decreases in precipitation. A related point, but one less emphasized by many, is that very few models show absolute changes of more than 10 percent (or 2 percent per decade) in any region, with the exception of some projections for European and North American crop areas. Observed trends in average growing season rainfall since 1980 similarly show relatively small changes (Lobell et al. 2011b), with the number of countries with positive trends roughly equal to the number with negative trends. Thus, it is unlikely that
changes in average rainfall are likely to be a major feature of climate change (although year-to-year changes in rainfall will undoubtedly remain important).

However, total rainfall per se is not of concern to agriculture, but rather the availability of moisture for plant growth. Moisture depends on the balance between inputs of rainfall into soils and losses from evaporation and plant transpiration. Given that more rainfall will fall in heavy events, the fraction of rainfall entering soil is likely to decrease because heavy events tend to produce more runoff into rivers (leading to floods in extreme cases). Higher temperatures will also mean faster rates of evaporation. Taken together, these two factors explain why most models indicate reductions of soil moisture and increased occurrence and spatial extent of drought, particularly in currently dry areas (Sheffield and Wood 2008b). However, these trends tend to emerge more slowly than the temperature trends, with significant changes reached relative to natural variability reached only by 2050.

Throughout the tropics, the length of the rainy season is a major concern. More specifically, the onset of the rainy season is important since it is closely linked to the length of the rainy season (the end of the season is typically less variable from year to year) (Sivakumar 1988). Most climate models indicate a delay in rainy season onset in many monsoonal systems, such as the Sahel (Biasutti and Sobel 2009; Seth et al. 2011), as well as in Indonesia (Naylor et al. 2007). A likely reason for this delay is the melting of sea ice, which affects the seasonality of temperatures in the Northern Hemisphere (water responds more slowly to seasonal changes in sunlight than ice) (Biasutti and Sobel 2009). Although models consistently show a delay, it is important to note that this delay will likely be less than one day per decade in the Sahel. Moreover, a trend toward later onset has not yet been noted in the published literature, perhaps because the signal is small relative to natural variability.

In addition to rainfall, much of the world relies on irrigation to supply soil moisture. Irrigation is less important in sub-Saharan Africa, where it comprises less than 5 percent of cereal area, but in Latin America and Asia irrigation is very common and often dependent on meltwater from upstream glaciers. In Asia, all major rivers begin in the Tibetan plateau and adjacent mountains, where warming is expected to accelerate melting. In the next couple of decades, this melting will likely contribute to greater streamflow as the glaciers melt, but by 2050 the net streamflow from glaciers is expected to decline (Immerzeel et al. 2010). Regional increases in precipitation may partially offset this loss of meltwater, but net water availability is expected to decline significantly in basins that depend heavily on glaciers. In particular, the Indus and Brahmaputra basins in India will likely be the most affected, while the Ganges, Yellow, and Yangtze basins are much less dependent on glaciers. A similar story exists in Latin America, where Andean glaciers are already receding and increased streamflow has been observed in several rivers (Vuille et al. 2008). One particular concern with glacier melting is that the temporary increases in streamflow will encourage expansion of irrigation and settlements, which only increases the vulnerability to the eventual decline in flows once the glaciers shrink or disappear.

Finally, many agricultural scientists and policy makers are often under the impression that climate change will cause year-to-year variability in weather to increase. However, there are not very clear patterns of changes in inter-annual variability, either in models or observations (Meehl et al. 2007). In many regions, rainfall variability is expected to rise, whereas temperature variability is likely to go up in regions that experience drying (because soil moisture is one buffer against temperature fluctuations). But there are few universal statements that one can make about
changes in variability. As mentioned, hot extremes and heavy rainfall will become more common, but more extremes is not the same thing as more variability. The latter implies, for example, that highs will get higher and lows will get lower, whereas observations and models indicate that cold extremes will get less frequent.

Implications for food security

What do these changes in climate imply for food security? There are arguably two main avenues of impacts on food security in any location: impacts on local productivity of agriculture, and impacts on global productivity that affect local prices. The relative importance of these two pathways will obviously depend on location. North Africa, for instance, is highly reliant on food imports and likely more sensitive to global changes, whereas much of sub-Saharan Africa remains largely subsistent. Although both local and global productivity will continue to play important roles in shaping food security, the increasing connectedness of agricultural markets and the urbanization of poverty means that global aspects will be increasingly important in 20 or 30 years. Discussions of climate change impacts often address only local to regional changes, and therefore miss an important dimension of the problem.

Although effects on agricultural productivity are the focus of this discussion, it is worth noting that other pathways may also emerge as important. Non-agricultural sectors of the economy can depend on weather in surprising ways. Total economic output in Central America and the Caribbean, for example, is negatively correlated with annual temperatures, with a 1°C increase in mean temperature lowering GDP by roughly 3 percent (Hsiang 2010). Interestingly, this effect is driven not by agriculture but by the effect of very hot days on productivity of labor in sectors such as retail and restaurants. Losses in overall economic performance for warm years has also been detected in Africa as well as poor countries in other regions (Dell et al. 2008; Dell et al. 2009), although richer countries show no effect (presumably because of air conditioning). Thus, warming can be expected to affect productivity in a range of activities that either affect food supply chains (including processing and distribution of food) or the ability of poor people to generate incomes for purchasing food. There is also some evidence that warming increases the risk of conflict (Burke et al. 2009; Hsiang et al. 2011), which is a major impediment to food security (World Bank 2011).

Productivity impacts within Africa and South Asia

As stated by several speakers in this series, improving on-farm productivity is one of, if not the most, effective ways to improve food security. Among other things, higher farm productivity improves farmer income, raises local food availability and lowers prices, improves farmers’ assets and ability to invest, and frees up labor to pursue education or employment in off-farm activities. Anything that slows (or reverses) productivity growth therefore stands as an important threat to food security.

Given that food insecurity is most prevalent in sub-Saharan Africa and South Asia, this section discusses only these two regions. In both regions, work has focused mainly on the staple crops (e.g., maize and sorghum in Africa, wheat and rice in South Asia), and so for brevity and lack of
ample science, the discussion will omit “minor” crops as well as non-crop sources of food and food security, including livestock and fish.

There have been three main approaches to understanding impacts of climate change on crops. First, greenhouse or field experiments under manipulated environments, such as elevated CO2 or temperature, provide a direct measure of plant responses. Second, crop simulation models have been developed from these types of experiments and used to predict responses under a wider range of conditions. Third, statistical approaches have combined historical weather data with harvest data (either from fields, states, or entire countries) to define a statistical relationship between weather inputs and crop outputs. Each of these approaches has strengths and weaknesses, the details of which are beyond the scope of this paper. As with the discussion of climate above, the scientific confidence is greatest when all three methods converge on the same view. Among the main lessons from these studies are the following:

1. Higher CO2 raises yields in crops with a C3 photosynthetic pathway (e.g., rice, wheat). In C4 crops common in tropical areas (e.g., maize, sorghum, millet), the response is much more muted and only observable in drier settings, because CO2 helps to improve water use efficiency. Crop response appears to be limited, in part, by the ability of grains to use additional carbohydrates without equal supply of other nutrients. Thus, responses are typically greatest in well-fertilized conditions, and for non-grain crops that require less nutrients per carbohydrate. In particular, root crops like potatoes and cassava show responses that are double those for rice and wheat, and that far exceed maize.

2. Even slight warming tends to reduce yields throughout the tropics, because most crops are already growing beyond their optimum temperatures. Figure 7 shows the current yields of four crops relevant to the discussion for each country in the world compared to the average T for the growing season in its current area within the country. Although many factors contribute to differences between countries (for instance, cooler countries tend to be richer and apply more fertilizer), it is clear that each crop exhibits a negative relationship with T beyond a certain point. For wheat, this point is roughly 15°C, for maize roughly 20°C, and for rice and sorghum closer to 25°C. For 1°C of warming, yield losses in the tropics vary from a few percent for crops that are currently growing near their optimum, to as much as 10 percent or more for crops growing well beyond their optimum. The reasons for yield loss are multiple and vary by crop. For example, rice appears particularly sensitive to warming at nighttime, and actually benefits from daytime warming until T is hot enough to damage pollen (~35°C) (Welch et al. 2010). Maize is particularly sensitive to hot daytime temperatures, with rapid losses when T exceeds 30°C (Schlenker and Roberts 2009; Lobell et al. 2011a).

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8 Although this analysis is simplistic it agrees well with optimum temperatures derived from other studies.

9 The main mechanisms include shortening of the crop season, increased respiration rates, reduced photosynthesis rates, damage to cells at high T, and increased evaporation rates.
Figure 7. Scatterplots of average national yields and growing season temperature for four major crops

Source: Lobell et al. 2011b. Size of dots is scaled to total production of country.

3. Both the effects of high CO2 and T depend on fertilizer and irrigation practices (see Table 2). A main reason that CO2 benefits yields is that it helps cope with dry conditions, and this benefit is mainly forfeited under irrigation. As mentioned, CO2 responses also tend to be higher for well-fertilized crops.

The presence of irrigation helps crops to handle high T, both because of cooling the microclimate and providing water for crop transpiration. For example, sensitivity to high T was 1.7 times higher in maize trials grown under intentional water stress than in well watered conditions (Lobell et al. 2011a). Similar effects have been noted for wheat and rice in India (Lal et al. 1998). Nitrogen, in contrast, tends to increase the yield difference between favorable and unfavorable weather conditions, and therefore increases overall sensitivity to T. For example, yield sensitivities to T are higher in South Africa (high fertilizer rates) than in neighboring Botswana (low fertilizer rates) (Schlenker and Lobell 2010).
Table 2. The effects of irrigation or fertilizer on crop sensitivities to CO2 and T

<table>
<thead>
<tr>
<th></th>
<th>Irrigated</th>
<th>Well-Fertilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity to benefit from high CO2</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Capacity to cope with high T</td>
<td>↑</td>
<td>↓</td>
</tr>
</tbody>
</table>

Note: CO2 is more beneficial for well-fertilized crops, whereas high T is most damaging to well-fertilized and rainfed crops.

Admittedly, the above is a rather short list of key lessons from crop studies, and there are many aspects scientists would like to know better. What are the effects of heavy rains on crop productivity? How is nutritional quality of crops affected by climate change and CO2 increases? How do biotic pressures like disease and pests change with climate? Will the delay in rainy season onset mentioned earlier be fast enough to rival the challenges presented by warming? The science continues to progress on these questions, but no consensus has yet emerged.

Projections of future impacts generally indicate a net downward pressure on yields from changes in T, P, and CO2 within Africa and South Asia. Exceptions include rice in Asia, which will benefit from higher CO2 over the next few decades more than it will be harmed by higher T. In addition, high elevation areas that tend to be cooler, such as in parts of Eastern Africa will tend to cope well with warming. East Africa is also expected to see increased rainfall, although this projection is a topic of ongoing debate (Shongwe et al. 2010; Williams and Funk 2011).

At the continental scale, staples yields in Africa have been projected to decline without adaptation by 22 percent for maize\(^{10}\), 17 percent for sorghum and millet, 18 percent for groundnut, and 8 percent for cassava by 2055 relative to 1980 (Schlenker and Lobell 2010). These numbers do not include CO2 fertilization effects, which would be substantially positive for groundnut and cassava. Other studies find similar results at the continental or country scale (Nelson et al. 2009; Thornton et al. 2009; Lobell et al. 2011a; Roudier et al. 2011), with many also evaluating impacts within countries. Of course, national or continental averages mask considerable variations, and there will be some parts that gain from climate change, such as the high-elevation areas in East Africa mentioned before. Some authors emphasize this heterogeneity as reason to focus adaptation entirely at finer scales (Thornton et al. 2009), since different places face different threats and opportunities. However, it is also at these scales that differences between climate scenarios and crop models are largest, a point to which I will return later.

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\(^{10}\) It is worth recalling that average temperatures in Africa are expected to rise by ~0.3°C per decade. Also mentioned is that 1°C of warming tends to reduce yields by up to 10 percent in the tropics. Thus, the numbers stated for impacts (roughly 3 percent loss per decade for maize) are consistent with this view.
In South Asia, most work has focused on rice and wheat, the two key staples, although some projections exist for sorghum, mustard, and sugarcane among other crops (Boomiraj et al. 2010; Knox et al. 2011). Growing conditions for both rice and wheat are hot relative to most regions of the world, and declines are expected even for moderate warming (Lal et al. 1998; Lobell et al. 2008). Because both wheat and rice are C3 crops, elevated CO2 should impart significant yield benefits over the next few decades. To some extent, however, these gains will be counteracted by a large and increasing loss of yield from high ozone levels (Van Dingenen et al. 2009).

Overall, without effective adaptation the productivity impacts of climate change are likely to be more severe in Africa and South Asia than in any other region (Lobell et al. 2008). In Africa, damages result from a combination of very low rates of irrigation (less than 5 percent of staple crop area), high prevalence of C4 crops that do not benefit from CO2, and high dependence on maize which is already grown above its optimal temperatures in many parts. In South Asia, climate change is challenging because it is already very hot, and because food security is very dependent on wheat, which is highly sensitive to warming in this region.

Global productivity and price impacts

For both producers and consumers, food prices are an important concern. Although local markets can be insulated from fluctuations in global prices (see chapter by P. Timmer), the latter are increasingly relevant to the food insecure. For example, sub-Saharan Africa now imports 42 percent of total rice consumption and 63 percent of wheat (Naylor and Falcon 2010). Even if one is interested only in climate change impacts on food security in Africa or South Asia, an analyst’s imperative is now to consider impacts across the world.

Having already discussed that Africa and South Asia are the most threatened by climate change, it stands to reason that global impacts on production will, on average, be smaller than in these regions. Indeed, the Intergovernmental Panel on Climate Change (IPCC) concluded in 2007 that benefits from higher CO2 and warming at high latitudes were likely to more than compensate for losses in lower latitudes (Easterling et al. 2007):

“Higher output associated with a moderate increase in the GMT likely results in a small decline in real world food (cereals) prices, while GMT changes in the range of 5.5°C or more could lead to a pronounced increase in food prices of, on average, 30 percent.”

Embedded within this statement are at least two important assumptions that may paint an overly optimistic view. First, all of the global price studies used in the IPCC assumed some level of on-farm adaptation, such as adoption of new varieties or expansion of irrigation. Second, recent evidence from field experiments suggests that most modeling studies have used overly optimistic CO2 fertilization effects (Long et al. 2006; Ainsworth et al. 2008). Thus, a more accurate statement may be “Given effective adaptation efforts, small increases in GMT likely result in small changes (positive or negative) in world food prices”

Policy makers, of course, must contend not only with expected changes but also with the range of possibilities. Studies since the IPCC point to the possibility of larger price increases, for instance 20-30 percent average increases for major cereals by 2050 (Nelson et al. 2009), or in a
pessimistic scenario of rapid climate change and little adaptation, as much as 30 percent increase for 1°C of additional warming (Hertel et al. 2010). Conversely, optimistic scenarios of high CO2 effects and low warming effects result in significant price declines for the next few decades.

Policy makers must also worry about increased volatility of prices, in addition to changes in average prices (reference Timmer Chapter). Studies of climate impacts on price volatility are just emerging, but there is some basis to expect global prices to become more volatile. Specifically, as the risks of intense heat waves and heavy rainfall events rise, so do the chance of sharp production shortfalls in important producers. In the US, for instance, projections indicate on average that maize production will increase its coefficient of variation by ~40 percent by mid-century (Urban et al. 2011).

Most studies of climate change continue to frame the issue in terms of anticipating future impacts (e.g., impacts by 2050). An emphasis on the future is understandable, since the goal is to take actions now to prevent future losses. However, this framing risks overlooking an important fact discussed above: that significant climate changes, such as warming and increased heavy rainfall, have already been observed in most cropping regions.

The same models used to project future impacts can also be used to assess impacts of past change. In a recent study, we evaluated the impacts on various crops at the national scale and for total global production (Lobell et al. 2011b). Table 3 presents estimates of the impacts on global yields, and compares them to overall yield progress. Although yields of all four crops have improved by 50-60 percent since 1980, maize and wheat yields have been held back by warming.

**Table 3. Global average yield increases for major crops and estimated impacts of climate trends for 1980-2008**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield in 1980 (ton/ha)</th>
<th>Yield in 2008 (ton/ha)</th>
<th>Yield Increase (ton/ha)</th>
<th>Impact of T and P trends (ton/ha)</th>
<th>Ratio of climate impact to yield increase fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>3.1</td>
<td>5.0</td>
<td>1.9</td>
<td>-0.19</td>
<td>-0.10</td>
</tr>
<tr>
<td>Rice</td>
<td>2.9</td>
<td>4.3</td>
<td>1.4</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Wheat</td>
<td>2.0</td>
<td>3.0</td>
<td>1.0</td>
<td>-0.16</td>
<td>-0.16</td>
</tr>
<tr>
<td>Soybean</td>
<td>1.6</td>
<td>2.5</td>
<td>0.8</td>
<td>-0.04</td>
<td>-0.05</td>
</tr>
</tbody>
</table>

Source: Lobell et al. 2011b. All crops except maize have benefitted by ~3 percent from CO2 trends over the period.

This retrospective analysis highlights two important points. First, the challenges to agricultural productivity are already upon us. There are therefore immediate benefits to adapting, and policy makers should not view climate adaptation as simply preparing for the distance future.
Second, there are clear differences between crops. Wheat and maize appear particularly hurt so far, which results from the fact that several major producers of each are already warmer than the optimum T for yields (Figure 7). At the global scale, these are also among the crops for which demand is rising most quickly (Table 4). For example, demand for rice, whose production is relatively unhurt by warming, is leveling off on a per capita basis, whereas per capita consumption of wheat and maize, which are most sensitive to warming, continue to increase (FAO 2006).

Table 4. The coincidence between crops with strong demand growth and sensitivity to warming

<table>
<thead>
<tr>
<th>Crop</th>
<th>Highest favorable growing season T (see Figure 7)</th>
<th>Climate Related Yield Losses (1980-2008) (as % of 2008 yield)</th>
<th>Projected Demand Increase (%), 2030 vs. 1998*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>15</td>
<td>-5.4</td>
<td>67</td>
</tr>
<tr>
<td>Maize</td>
<td>20</td>
<td>-3.7</td>
<td>98**</td>
</tr>
<tr>
<td>Rice</td>
<td>25</td>
<td>0.3</td>
<td>40</td>
</tr>
<tr>
<td>Sorghum</td>
<td>25</td>
<td>-0.6</td>
<td>98**</td>
</tr>
</tbody>
</table>

Note: Tastes appear to be getting more temperate while climate gets more tropical. * Based on projections in (Bruinsma 2003). ** Projected increase for coarse grains, which includes maize and sorghum.

There is therefore an interesting dynamic playing out at the global scale. As poorer countries develop, they demand more of crops typically consumed in more developed, temperate countries. At the same time, conditions for crop growth continue to get more tropical (i.e. warmer), giving a comparative advantage to those crops for which demand is slowing (rice, sorghum, cassava). Thus, the ongoing shift in diets can be viewed as a “mal-adaptation” to climate change.

Beyond 2050

The above discussions of climate change and impacts on food security have emphasized changes over the next few decades, given that food policy rarely looks beyond this time period. However, it should be noted that emissions today affect climate well beyond 2050, given the long lifetime of CO2 in the atmosphere. Unregulated emissions could plausibly lead to 4°C of GMT increase as early as 2060 (Betts et al. 2011), and to much greater warming by 2100 or beyond. The adaptation challenges presented by this magnitude of climate change would be enormous, and impacts even with adaptation would likely be severe. Efforts to adapt to the inevitable climate changes over the next few decades should therefore not be perceived as reducing the need to limit emissions.
Implications for food policy

Two dilemmas in adaptation

Recommendations for adapting agriculture to climate change are typically of two types, which appear to stem from two different views on the meaning of adaptation. On the one hand are what I will call the “welfare improvers”, who define adaptation as anything that restores welfare to what it would have been without climate change. For example, the International Food Policy Research Institute (IFPRI) suggests an additional $7 billion USD per year to help agriculture adapt to climate change (Nelson et al. 2009), with much of this going to building roads or general agricultural research. Similarly, in an effort to measure the costs of adapting to climate extremes, the World Bank poses the question (World Bank 2010a):

“As climate change increases potential vulnerability to extreme weather events, how many additional young women would have to be educated to neutralize this increased vulnerability? And how much would it cost?”

Thus, the goal is to compensate for welfare losses, not to avoid the impacts of the extremes. To be fair, the World Bank is also emphasizing “climate-smart” development: for instance, cities should not be developed in areas prone to future flooding, and should be built with adequate drainage.

On the other hand are what I will term the “impact avoiders”, who view adaptation as an action that adjusts explicitly to the change in climate. For example, the IPCC defines adaptation as:

“Adaptation is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.”

Both views of adaptation have some merit, but both also have some weaknesses. The welfare improvers are correct to point out that adjusting to the new climate, for instance by improving drought tolerance of seeds, may not be the most cost-effective way to improve productivity or food security. Better to build up overall welfare levels, they would say, which will improve resilience for any shock, including those related to climate. At the same time, the welfare improver perspective can be a convenient stance for those who do not understand the specifics of the climate risks, or who are simply advocating for more resources for their existing activities.

The impact avoiders can reasonably say that there are unique activities associated with adjusting to climate that are not covered by traditional development activities. At the same time, a narrow focus on avoiding impacts could arguably result in worse food security outcomes than a broader strategy.

In theory, the welfare approach appears superior – who can argue against using resources most efficiently? In practice, however, the welfare improver strategy can result in simply “more of the same,” with progress that is potentially too slow to deal with impending climate impacts. The impact avoider strategy forces us to identify new goals, which may well prove to have faster and higher payoffs. It may well be a lot cheaper, for instance, to develop heat tolerant seeds than to improve welfare by an equivalent amount using a broader approach. Thus, a balanced approach, where some fraction of adaptation funds is set aside for impact avoidance activities, appears
appropriate. This view is similar to the World Bank’s perspective that “development may need to be done differently, with much greater emphasis on climate and weather risk” (World Bank 2010b).

A second dilemma that pervades discussion of adaptation concerns scale. As repeatedly noted above, the science tends to be most uncertain at the finest spatial scales. For instance, the global incidence of both droughts and floods are very likely to rise, but one cannot say with any certainty whether drought will become more frequent in Arusha, Tanzania. There is similarly little doubt that crops around the world will be increasingly exposed to severe heat, but it is conceivable that some locations will avoid this fate if, say, regional land use changes or aerosol emissions modify local climate.

However, policy makers are typically and justifiably concerned with their part of the world. They want to know what will happen in their province or country, and if the answer is too uncertain, they will reasonably resort to strategies that build overall resilience.

The current structure for adaptation funding also reinforces the emphasis on adaptation at local scales. To qualify for funding, each country must develop its own national adaptation program of action (NAPA), which in turn is often developed from stakeholder meetings at the subnational level. One result of this is that each country prioritizes plans that are tractable at a local scale of implementation. Another consequence is poor coordination among neighboring countries, such as in the case of central and eastern Africa (Nzuma et al. 2010). This lack of coordination is troubling given the important role of regional and global networks in key areas such as developing water resources (Denton 2010) and new crop varieties (Alene et al. 2009).

A brief survey of existing strategies

With these general dilemmas as background, it is helpful to look at specific strategies that have been put forth by various people. All have some merit, but each misses some important aspects of the challenge:

1. **Focus on variability.** Several authors have rightly pointed out that climate risks already incur large costs to developing world farmers, and they suggest society focuses on these risks as an “essential first step” to climate adaptation (Washington et al. 2006; Cooper et al. 2008). A focus on dealing with these current risks is attractive because farmers may be more eager to participate when they see immediate benefits, and because the institutions required to cope with variability (e.g., seasonal forecasting capabilities, better farmer extension services) will also be needed to deal with longer-term changes. An added benefit could be that dealing with variability will register higher on national priorities than climate change, and therefore may capture more domestic resources. The emphasis in this approach is on the need for, and current lack of, capacity to deal with weather-related risks. The shortfall, however, relates to the important differences between climate variability and change. A focus on variability will inevitably emphasize dealing with variations in rainfall amounts and timing. Yet it is very likely that rainfall amounts and timing will be changed only slightly in 20 or 30 years, whereas incidence of extreme heat or heavy rain events will have increased. A focus on variability thus risks missing those aspects of weather that are changing fastest.
2. *Focus on mitigation.* Others have emphasized the importance of accelerating climate mitigation activities in agriculture, such as activities that increase soil carbon (e.g., Lal 2004) or reduce methane emissions from crop and livestock systems. They argue that the potential to sequester carbon in agricultural soils is high, and therefore that carbon payments for these activities will provide an important source of revenue if and when carbon markets become solidified. Thus, they view investments in setting up certified carbon projects as a good use of initial adaptation funds, since it will spark a much larger and continuous source of revenue for poor farmers than adaptation funding would provide. Moreover, more soil carbon will improve soil quality and resilience to periods of drought or heat.

Three main problems hamper this approach in my view. First, the science on potential sequestration in agricultural soils is far from clear, and it may be much less than what some advocates claim (Baker et al. 2007). Second, the logistics of monitoring actions and making payments to millions of poor farmers are potentially prohibitive, or at least too cumbersome to attract private investment from carbon creditors. Third, improving soil quality is surely helpful for dealing with climate change, but again the magnitude of this benefit relative to other measures, such as improving seeds or access to irrigation, is unclear.

1. *Get out of agriculture.* An interesting combination of both the welfare improver and impact avoider are those who advocate simply transitioning as many people as possible out of agriculture (Collier et al. 2008). The logic here is that if conditions for agriculture are deteriorating, better to invest in other sectors of the economy and subsidize movement away from agriculture. Of course, “getting out of agriculture” could be considered the overall goal of development (Timmer 1988). But as emphasized in other talks in this series, agricultural labor and GDP shares decline only after agricultural productivity improves. The best way to speed the structural transformation away from agriculture is to invest more, not less, in agricultural productivity. In addition, even if skipping the development of domestic agriculture could work as a poverty-reducing strategy, it would leave a country very dependent on food imports. Many countries will be understandably reluctant to rely too much on imports, especially if climate change and other factors stand to increase the volatility of market prices.

### Summary and recommendations

Climate change has emerged as a preeminent challenge for society in the 21st century, not least because it threatens the productivity of agriculture in many regions of the world. This challenge, combined with the fact that climate related funds are likely to comprise a sizable fraction of development assistance, means that food policy makers should strive to achieve a basic literacy in climate science and its implications for food security. The following list summarizes some of the main scientific lessons discussed in this chapter.

- There is a key distinction between natural variability, which is inherent in an unforced climate system, and climate change, which results from external forcing of the system. A
farmer experiences the combination of variability and change, but separating the two is important for understanding future risks.

- Climate projection uncertainties are largest for local scales, because natural variability is higher at these scales, local climate forcings like aerosols become more important, and projected changes tend to average out over larger regions.

- The most significant aspects of climate change relative to historical variability will be increased occurrence of hot days, warm nights, and heavy rainfall events. Individual days or seasons that were once considered extreme will be increasingly common.

- One consequence of higher temperatures and heavier rainfalls will be less available moisture for plant growth in many places, with drought becoming more common. Rainfall seasons will tend to shorten in many regions, although most changes will be from natural variability and not climate change.

- Significant warming has already been observed since 1980 for most agricultural regions. The increase in global mean temperatures of 0.2 °C decade \(^{-1}\) belies significantly faster changes in cropped regions, given that land warms faster than the oceans. Changes in average rainfall have been modest and in nearly every region can be explained solely by natural variability.

- Warming is productivity-reducing in most agricultural areas, because of a range of plant physiological responses. Effects of extremely hot days (i.e. with peak temperatures greater than 30°C) appear especially important for many crops. Impacts of heat tend to be lower in irrigated fields, and in poorly fertilized fields where nutrient constraints dominate. Efforts to increase rainwater harvesting and irrigation are thus critical to adaptation, whereas efforts to increase fertilizer rates should be coupled with other measures to reduce sensitivity to heat.

- Average global prices are unlikely to change significantly because of climate change in the next few decades. However, sub-Saharan Africa and South Asia are likely to experience damages that exceed those in the rest of the world.

- One plausible outcome from climate change is increased year-to-year variability of global or local production. However, limited research has addressed this topic to date.

- Dietary trends are likely to increase demand for the crops that are most affected by climate change. Among the major crops, maize and wheat appear most vulnerable, and most impacted by changes that have already occurred. Rice is less affected by climate change, but also experiencing smaller increases in demand. In effect, diets appear to be shifting toward temperate tastes while climate is getting more tropical.

The appropriate policies for climate adaptation will depend on how these scientific factors intersect with various economic and political considerations. The range of viewpoints discussed in this chapter reflects how little we know about what actually works, because serious efforts at implementing adaptation efforts are only beginning. As with any area of food policy, it will be important to critically evaluate ongoing activities to identify and learn from successes and failures. Although the details of any strategy will depend on the context, three general questions
seem especially useful for policy makers to ask themselves, and are often missing from the current debate:

1. **Is there a suitable balance between addressing climate variability and climate change?** Significant gains in farmer welfare and institutional capacity can be made by improving management of current, short-term climate risks. However, climate change means that some risks which are relatively small now will be much higher in 20-30 years. Given lags in developing and implementing new technologies, resources need to be devoted now to these growing risks. For example, adaptation should address extremely hot days (such as through improved seeds or irrigation schemes) and heavy rains (such as with break dams, erosion controls, and rainwater harvesting), even if these factors are not perceived as a major source of current year-to-year variability.

2. **Is there a suitable balance between investing in local (national and sub-national) scales and broader (regional to global) scales?** There are many political and practical reasons that adaptation has focused primarily on national or sub-national scales. However, there are several unambiguous and threatening trends at the global scale which can easily get masked by climate uncertainties at sub-national scales. The need for heat, drought, and flood tolerant crops is unambiguous, for example, but no individual country will definitely need all three. In addition, regional and global coordination is critical for some types of adaptation, such as breeding new varieties, conserving genetic resources, and coordinating water management.

3. **Is there a sufficient acceleration of existing activities to improve food security, in light of the future risks of large productivity losses?** As discussed throughout this lecture series, improvements in productivity can lead to a virtuous cycle of reductions in poverty and food insecurity. Once higher levels of productivity have been reached, a farmer or village becomes more resilient to weather shocks. Yet the pressures caused by climate change are already apparent, and will only grow with time. The best preparation for the coming storm may be to get as far along in agricultural development as possible while productivity improvements are still within grasp.

Overall, policy makers should resist the common tendency to take the hard and complex challenge of climate adaptation and make it even harder and more complicated. Much confusion and uncertainty results, for instance, when one focuses on the scales and variables for which climate changes are small relative to natural variability, and for which climate models produce uncertain projections. A greater emphasis on the key aspects of climate change, such as extreme heat and heavier rainfall, and on the most predictable scales, namely regional to global, will help to ensure that efforts to adapt are successful.
References


Core literature on climate change and agricultural adaptation


This study synthesized observed changes in various measures of extreme climate over different periods in the past century. The results demonstrated clear increases in the occurrence of hot days, warm nights, and the fraction of rainfall falling in heavy events. The paper also provided clear descriptions of how these data are obtained and processed, and how to assess whether trends are significantly outside the range of natural variability.


Similar to the Washington et al. paper (see below), this study provided some more concrete examples of how much climate variability currently constrains agriculture in sub-Saharan Africa, for example, by providing a disincentive to invest in productivity-enhancing technologies like fertilizer. As with the other paper, it made a few important arguments, but glossed over the fact that challenges posed by climate change are often quite different from those posed by climate variability.


The most recent IPCC chapter on climate change impacts on food production, this assessment presented a good summary of the state of science as of 2007. Among its arguable shortcomings are that it downplayed the recent evidence that early studies and many models overstated the benefits of elevated CO2, and that it presented model projections of changes in world prices without making clear the fairly strong assumptions of successful adaptation in these models.


This paper presents a modeling study of changes in streamflow in the five major river basins fed by the Himalayas: Indus, Ganges, Brahmaputra, Yangtze, and Yellow rivers. As the Himalayas melt, an eventual decline in meltwater delivered downstream is likely, but the importance of meltwater varies a lot by basin. The Indus and Brahmaputra are the most susceptible basins to
declining surface water resources, and the authors estimated the decline in water flows threaten
the food security of roughly 30 million people in each basin.


This article attempts to identify which cases, among all possible crops and regions of concern to
food security, for which climate change represents the greatest threat of local food production.
The study developed datasets on historical weather experienced by crops in each country since
1961, and paired this with national crop production data in statistical models of crop response to
weather. Projections from multiple climate models were then used to project impacts to 2030.
The study emphasized Southern Africa and South Asia as two regions of greatest risk.

Lobell, D. and M. Burke. 2009. Climate change and food security: Adapting agriculture to
a warmer world. Springer Verlag.

This book outlines the major issues and approaches for assessing the impacts of climate change
on food security. Intended as a textbook for a graduate or upper-level undergraduate class,
emphasis is placed on clear descriptions of different methods to evaluate crop and farmer
responses to climate changes.


This study estimated changes in weather conditions experienced by major crops over the past 30
years. Historical data were used both to map trends in temperature and precipitation, as well as to
develop statistical models of yield responses to weather. Results indicated that many regions
have seen significant declines in yields of wheat and maize because of warming, with roughly 5
percent impact on global production. Rice and soybean yields were affected in some regions, but
on balance global effects were insignificant. Effects of rainfall were essentially zero at the global
scale for all crops, emphasizing the relative importance of adapting to warming. The study made
clear that climate change impacts are of concern not only for the future, but already represent a
significant drag on global productivity growth for maize and wheat.

Schlenker, W. and D.B. Lobell. 2010. Robust negative impacts of climate change on African

This paper presented an analysis of crop responses to weather in Africa, using national reported
data to build various statistical models. These models were then combined with climate
projections to estimate impacts by mid-century in the absence of effective adaptation. The study
estimated expected impacts by 2050 relative to 1980 of −22, −17, −17, −18, and −8 percent for
maize, sorghum, millet, groundnut, and cassava, respectively. In all cases except cassava, there is
a 95 percent probability that damages exceed 7 percent, and a 5 percent probability that they
exceed 27 percent.

This study helped to establish the critical role that extreme temperatures play in crop yields. Using extensive, county-level datasets on maize, soybean, and cotton production in the United States, the authors estimated the yield impact of time spent at each degree interval experienced during the growing season. They showed that yields exhibit a sudden decline in productivity when temperatures exceed roughly 29 °C. This study also helped to dispel a common notion that agriculture in developed countries is not very vulnerable to warming of a couple degrees.


This article is a lengthy but interesting study of model projections of drought changes throughout the 21st century. The study described how such projections are made, and shows that climate models do a reasonable job at reproducing historical frequency of droughts. The study also highlighted that projections of drought frequency and intensity exhibit a monotonic increase in most regions and globally, but that the trends are not likely to result in significant shifts away from historical probabilities for at least a few more decades.


This recent paper is a clear description of how common representations of climate projections tend to overstate the uncertainties surrounding rainfall projections. In particular, disagreement across climate models in the direction of change is usually used as a measure of uncertainty. This paper showed that in most cases where models do not agree on sign of change, it is because they are all projecting changes that are close to zero and not statistically significant. The authors propose first describing agreement in terms of whether a model shows a statistically significant trend, and then secondarily in the direction of change. Very few places have some models showing significant increases with other models showing significant decreases. This agrees well with agricultural impact studies that downplay the role of precipitation changes.


An early and cogent argument that the best approach to climate adaptation is to focus on coping with climate variability. The primary argument is that climate variability presents a more immediate concern to farmers and policy makers and is more likely to capture their attention. They authors also argued that capacity for monitoring weather and providing advice to farmers is so limited in Africa, that until these capacities are built up there will be little hope for adapting to climate change. Success in coping with climate variability will also go a long way towards coping with climate change in the authors’ opinion.
This volume included several valuable chapters, including one that provides a uniquely concise and clear summary of climate science, and another that details estimates of the cost of climate adaptations. Not surprisingly the report emphasizes the need for development to reduce poverty around the world, but concludes that “economic growth alone is unlikely to be fast or equitable enough to counter threats from climate change, particularly if it remains carbon intensive and accelerates global warming.” The overall conclusion that development needs to become “climate smart” and the call to “act now”, “act together”, and “act differently” are very consistent with the recommendations in this chapter.
Discussant comments on “Climate change and agricultural adaptation”

Fatima Denton, Team Leader, Climate Change Adaptation in Africa

I am immensely pleased to be invited to Stanford University. I am particularly happy to be given this opportunity to respond to the presentation of the very prolific and esteemed professor, David Lobell.

I have listened attentively to David’s presentation. His arguments on the intersection between food security and climate change and food policy make sense and resonate with the experiences that I have seen across Africa.

Let me start with this premise: Climate change is reinforcing and multiplying known threats to development – poverty, malnutrition, and disease. If climate risks are not mastered, they will derail hard won development achievements. The irony is that Africa is a basket case where all these problems are already conspiring to threaten the economic prosperity, social welfare, and environmental security of millions of people.

David’s talk provides some answers on areas where our understanding of science and knowledge can serve as a buffer. This understandably will help vulnerable communities cushion the many blows that are associated with climate variability and change. He has provided us with arguments that can help us understand the distinction between climate variability and change. He has also mentioned the potential dangers in conflating every threat to climate change, especially non-climatic factors that contribute to food insecurity.

The central thrust of David’s presentation on current and future climate trends, and their cumulative impacts on local and global productivity are arguments that few will disagree with.

However, I do have a couple of observations. I place a lot of emphasis on a word that David mentioned once – and that word is “transformation”.

My first observation is that biophysical processes and social vulnerability are intricately linked, and both will need strong institutions to arrive at a transformational change. I start with what can be called institutional transformation. For many of the changes that David referred to, robust institutions will be necessary to manage and maintain resilience to climate change at different levels, scales, and time horizons. Institutions sit at the intersection of social and ecological resilience, and the ways in which these changes can be managed.

David places lots of emphasis on food production, which is one element of food security. Access and use, as well as the stability of production, is relatively problematic to many smallholder farmers in Africa. Institutions tend to influence many of the long-term impacts that David mentioned with regard to local productivity, i.e. health of local economies, rural infrastructure, assets, and risks. Without strong institutions, the processes of achieving ecological and social resilience will become disabled. Equally, the current financial landscape and the different funds (e.g. the adaptation and green funds) will all require management and delivery mechanisms that have strong institutional underpinnings. In addition, David’s point on adaptation and mitigation as an essential part of the climate equation cannot be fully exploited in the absence of strong institutional and transparent governance mechanisms.
Many of the biophysical processes that David describes that can enhance soil fertility, crop production and growth will also need institutions that will create incentive structures that will give people choices to make strategic and sustainable decisions in terms of their farming practices. All of this is quite complex and does not fit into linear patterns of thought. However, climate change has allowed us to understand the complexity of the governance systems; its challenges and limitations, and difficulties in understanding the interrelationships between adaptation and mitigation. It is true that we cannot soldier on with our weak institutions until the bitter end – they may not make it to the finish line. We need to capacitate existing ones, and we also need to build new ones. We need to see how we can retrofit or customize current institutions to match our institutional aspirations, and to gravitate towards institutional renewal in order to deal with new and emerging risks.

My second observation is that the tension between the advocates of agricultural intensification and proponents of agricultural diversification can find some middle ground, but if only we expand and explore both adaptation and mitigation options as an optimal mix. We are gradually coalescing to this central point that focusing on adaptation or mitigation separately as response strategies is only reinforcing the flawed development system that we have. It runs the risk of distanc ing us from a sustainable development pathway. Agriculture is a key contributor to greenhouse gas emissions. Equally, the agricultural sector can play an avant-garde role by showing us the efficacy and potential opportunities of bringing both adaptation and mitigation together.

The notions that risks are interconnected and that addressing climate risks in an integrated manner can create multiple benefits are valid. How can we use climate change as a pretext to stimulate transformational changes in agriculture and food systems? By increasing the content of soil carbon, we can increase the productivity of many agricultural systems. Carbon sequestration and good crop management practices can help increase agricultural productivity. These practices have mitigation benefits by reducing emissions and they have many co-benefits related to improving soil carbon retention, enhancing soil fertility, reducing the use of nitrous oxide and methane, and discouraging unsustainable practices such as slash and burn agriculture and the burning of crop residue.

Sustainable and organic agriculture can offer multiple win-win solutions in terms of reducing greenhouse gas emissions, but also in increasing soil nutrient, conserving and improving diversity by using different crops and encouraging mixed farming strategies. Many of these technical solutions are not new, e.g., agroforestry, rotational grazing, composting and mulching. However, they provide new incentives and rationale for why they need to be done. Transformational change can be reached through the understanding and exploration of opportunities for both adaptation and mitigation in the agricultural sector.

My third and final observation is that while David has intuitively referred to Africa’s plight with reduced production, degrading environmental conditions, and failure of the market system, he needs to stress more that human security is at stake. This plight is about ecosystems and services – but it is especially about people. Hence, the third type of transformation is transformation from adaptation and mitigation to sustainable development. It is becoming increasingly obvious that the fight against climate change is increasingly about development choices and the development pathways that are chosen. Climate change is a threat to sustainable development because it challenges the three core principles of sustainable development: economic prosperity,
environmental preservation, and social equity. Our first challenge is to ensure that we do not repeat the same historical mistakes. Although the Green Revolution was transformational in many ways it did not sufficiently take notice of local and indigenous knowledge as foundational. Adaptation processes cannot ignore what people know and are already doing.

Knowledge is a fundamental tool in the development toolbox, but this knowledge needs to be tested, challenged and strengthened. We cannot take it for granted under a changing climate. Our second challenge is to ensure that smallholder farmers do not become further peripheralised by climate trends and uncertain economic futures. Strong institutions are needed to ensure that smallholder farmers are key agents in the transformations they seek. Smallholder farmers need to be key brokers in important climate funds and investment flows that will bring changes to their welfare and security.

Our last challenge is that women, who are key agents in the agriculture sector and the food production chain, do not get “short changed” through exclusionary processes that lock them out of strategic decisions and technologies that will further affect their livelihood structures. Women’s nutritional security and access to production systems are constantly under threat, and we need to create buffers that will afford them sufficient capacity to make good, sustainable choices.

I want to end with saying that science is both the problem and the solution. We want to arrive at a science that reinforces the good features inherent in the world economy: one that acts as a regulator, that leads to incremental steps and small transitions, where both the quality of process and outcomes matter, and that impacts positively on the lives of the peripheralised masses - the millions of small holder farmers who continue to live on the margins of poverty. This is the magnitude of our challenge. Transformational change needs to come full circle by integrating the scale of climate change in biophysical terms with understanding and resolution of the complex tensions between nature and society.
Emerging Land Issues in African Agriculture: Implications for food security and poverty reduction strategies

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Abstract

Despite the fact that sub-Saharan Africa in 2012 contains much of the world’s unutilized and underutilized arable land, a significant and growing share of Africa’s farm households live in densely populated areas. Based on two alternative spatial databases capable of estimating populations at the level of one square kilometer and distinguishing between arable and non-arable land, we find that in at least five of the 10 countries analyzed, 25 percent of the rural population resides in areas exceeding 500 persons per square kilometer, estimated by secondary sources as an indicative maximum carrying capacity for areas of rain-fed agriculture in the region. The apparent paradox of a large proportion of Africa’s rural population living in densely populated conditions amidst a situation of massive unutilized land is resolved when the unit of observation is changed from land units to people.

A review of nationally representative farm surveys shows a tendency of (1) declining mean farm size over time within densely populated smallholder farming areas; (2) great disparities in landholding size within smallholder farming areas, leading to highly concentrated and skewed patterns of farm production and marketed surplus; (3) half or more of rural farm households are either buyers of grain or go hungry because they are too poor to afford to buy food; most households in this category control less than one hectare of land; and (4) a high proportion of farmers in densely populated areas perceive that it is not possible for them to acquire more land through customary land allocation procedures, even in areas where a significant portion of land appears to be unutilized.

Ironically, there has been little recognition of the potential challenges associated with increasingly densely populated and land-constrained areas of rural Africa, despite the fact that a sizeable and increasing share of its rural population live in such areas. Inadequate access to land and inability to exploit available unutilized land are issues that almost never feature in national development plans or poverty reduction strategies. In fact, since the rise of world food prices after the mid-2000s, many African governments have made concerted efforts to transfer land out of customary tenure systems (where the majority of rural people reside) to the state or to private individuals who, it is argued, can more effectively exploit the productive potential of the land to meet national food security objectives. Such efforts have nurtured the growth of a relatively well-capitalized class of “emergent” African farmers. The growing focus on how best to exploit unutilized land in Africa has arguably diverted attention from the more central and enduring challenge of implementing agricultural development strategies that effectively address the continent’s massive rural poverty and food insecurity problems, which require recognizing the growing land constraints faced by much of its still agrarian-based population. The final section of the paper considers research and policy options for addressing these problems.
Emerging Land Issues in African Agriculture: Implications for food security and poverty reduction strategies

Introduction

In his 2010 Presidential Address of the Agricultural and Applied Economics Association, Thomas Hertel raised the specter of a Malthusian “perfect storm” hitting the world’s arable land base. Could the rising demand for food, increased use of farmland for fuel, more extreme weather events, and reactive responses by rattled governments quickly exhaust the world’s remaining arable land? There is widespread agreement that accelerating productivity growth on existing farmland has the brightest prospects for relieving these pressures. But under very plausible scenarios, the global demand for new farmland could rise sharply, potentially triggering a rush for new arable land. Ironically, sub-Saharan Africa, the most food insecure continent in the world, has the largest and cheapest supply of unutilized arable land in the world (Fischer and Shah 2010).

This study assesses the potential impacts of rising demand for agricultural land in Africa in the context of the continent’s longstanding challenges: how to address its hunger problems and the livelihoods of its poor people, the majority of whom live in rural areas.

Our study is motivated by the need to understand the nature and magnitude of land constraints in African agriculture, the impacts of status-quo policies on food security and poverty, and the implications for development strategy. To our knowledge, there has been little recognition of the potential challenges associated with increasingly densely populated and land-constrained areas of rural Africa. Nor has there been sufficient discussion of how institutions and policies relating to land would need to be modified to provide the greatest prospects for achieving broad-based agricultural growth and reducing rural poverty.

The paper begins by casting these issues within two important conceptual models of development economics: the structural transformation and induced innovation processes. The structural transformation process has long been considered by development economists to be the main route through which poverty and hunger in Africa would be overcome. A major feature of the structural transformation processes achieved in other parts of the world was broad-based and small farm-led agricultural growth (Johnston and Kilby 1975; Mellor 1976; Lipton 2005). This paper examines the potential for this kind of growth in light of evidence that a growing proportion of the rural population is either landless or resides on farms under one hectare, dependent on rain-fed agriculture in semi-arid conditions, largely unable to feed themselves, and increasingly vulnerable to pressures on customary authorities to relinquish land to non-local interests. The paper also draws upon theories of induced innovation (Binswanger and Ruttan 1978) to explain

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2 Fischer and Shah’s assessment is reported in Deininger and Byerlee 2011 (p.xxxiv). Of the 445.6 million hectares of uncultivated arable land in the world, 201.5 million hectares are in sub-Saharan Africa; over 60 percent more than in Latin America, which has the next most uncultivated arable land.

3 In recent years, a small number of scholars have questioned whether Africa’s development will follow this structural transformation trajectory (e.g., Collier and Dercon 2009), an issue taken up later in this paper.
how rising land pressures in many parts of Africa are likely to be affecting the evolution of farming systems and the welfare of African farmers.

The paper then presents recent household panel survey analysis on the distribution of land within African farming systems and the impacts of rising population densities on household behavior and welfare. We consider the potential for an agricultural development strategy focused on large-scale commercialized farms to absorb rural labor and support broader structural transformation processes. The final section of the paper considers the implications of these findings for the design of land policies that are holistically integrated with agricultural and poverty reduction strategies in Africa.

Data

This study draws on two types of data. The first are detailed spatial databases of rural populations and arable land. Estimates of rural population density are derived from two sources: the Global Rural-Urban Mapping Project (GRUMP) at Columbia University\(^4\) and the AfriPop Project hosted at the University of Florida.\(^5\) Both datasets provide gridded estimates of population densities at the level of one square kilometer grid cells, based on census data at the most localized units available. GRUMP and AfriPop differ principally in the means of allocation: the GRUMP separates the urban and rural components of local population, with the rural portion being equally allocated to all rural grid cells contained in the most disaggregated spatial reporting unit of the most recent census. The AfriPop dataset uses remotely-sensed data on land cover to weight this allocation, such that cells corresponding to areas with evidence of human settlement receive higher allocation weights (than, say, a cell that corresponds to forest or desert). Given the different sets of assumptions built into the construction of these datasets, both datasets are used to give robustness to our analytical conclusions.\(^6\)

Information on the portion of arable land within each grid cell was obtained from the Global Agro-ecological Zones (GAEZ) 3.0 database.\(^7\) The GAEZ data consist of gridded estimates of local land and agro-climatic resources -- including soils, terrain, land cover, and a variety of climatic indicators -- as well as derived estimates of agricultural suitability and potential yields for a variety of commodities under given management levels. Drawing from the land cover components of the GAEZ database, the authors assembled three definitions of “arable land”: areas classified as (a) under cultivation; (b) under cultivation or grassland; and (c) under cultivation or grassland or forest/woodland. Analysis in this paper presents population density estimates based on definition (b). Future analysis will evaluate the robustness of our analyses to alternative definitions.


\(^5\) Data available from [http://www.clas.ufl.edu/users/atatem/index_files/AfriPop.htm](http://www.clas.ufl.edu/users/atatem/index_files/AfriPop.htm). See Tatem et al. (2007) for a description of the methods used to compile the dataset.

\(^6\) We excluded grid cells categorized as rural that exceed 2,000 persons per km\(^2\) based on the assumption that population densities over this level were approaching peri-urban status or were mis-categorized.

\(^7\) Data and information available at: [http://www.iiasa.ac.at/Research/LUC/GAEZv3.0/](http://www.iiasa.ac.at/Research/LUC/GAEZv3.0/) See Fischer et al. (2010) for methodological details of the database’s construction.
with classification (a) reflecting currently available farmland, and (b) and (c) reflecting potential available farmland if sufficient costs are incurred to convert grassland and forest land to farming.\(^8\)

Use of these data allows for much greater localized variation in rural population densities than would be possible if estimated at more aggregated spatial units. As will be shown, this leads to some surprising insights.

The second source of data is drawn from farm household surveys. These datasets are generally nationally representative and carried out by the official national statistical agencies or by local universities. Details of data sets reported in this study are contained in Jayne et al. (2010).\(^9\)

**Conceptual framework: The role of land in affecting development trajectories**

*Structural transformation*

Smallholder-led structural transformation is considered by most development economists to be the major pathway from a semi-subsistence agrarian society to a more prosperous, food secure, and diversified economy. The pioneering work of Johnston and Mellor (1961), Johnston and Kilby (1975), and Mellor (1976) first documented the structural transformation process in the regions of Asia that experienced Green Revolutions. The structural transformation process starts with an exogenous productivity shock (e.g., the creation and mass adoption of new farm technology), causing a build-up of purchasing power by millions of small farmers. These millions of farmers subsequently spend and recycle more money through the economy, igniting demand and employment growth in non-farm sectors, which in turn increases the demand for food and other farm products in a virtuous cycle in which the rural and urban labor forces provide a market for each other. Rising demand for food and fiber products attracts private investment flows into the storage, transport, processing, and retailing stages of commodity value chains, further expanding employment and diversifying the economy. Over time, broad-based income growth causes the share of food in overall consumption to fall, making available more disposable income to fuel the development of non-farm sectors. As the demand for non-farm goods and services rise, the labor force responds by shifting gradually from the farm to non-farm sectors, the demand for education and job skills rises, and the economy becomes increasingly diversified and urban. Rural households are pulled off the farm by better paying non-farm jobs, not pushed into low-paying desperation jobs in the towns due to poor prospects in agriculture.

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\(^8\) Land pressures would be intensified further after accounting for land required for grazing and fallow. Rotational systems involving fallowing are necessary in many areas of Africa, e.g., Myiombo woodlands, where soils are leached and acidic. Under currently available technologies, there would be major constraints on sustainable intensification that involved the elimination of fallows (Holden, Otsuka, and Place 2009). Land issues that are particular to pastoral communities, while important, are outside the scope of this study.

\(^9\) Each of these survey instruments, which contain the details of the types of information collected and used in this study, can be viewed and downloaded at [http://www.aec.msu.edu/fs2/kenya/index.htm](http://www.aec.msu.edu/fs2/kenya/index.htm), and [http://www.aec.msu.edu/fs2/zambia/index.htm](http://www.aec.msu.edu/fs2/zambia/index.htm).
Recently, the feasibility of a small-farm based structural transformation in Africa has been questioned by some scholars (e.g., Collier and Dercon 2009), and, by their actions, a growing number of African policy makers. These views have been bolstered by frustration over the slow rate of development in African agriculture. There is increasing receptivity to viewing large-scale farm development in Africa at least as a complement if not an alternative to broad-based smallholder-led agricultural growth.

Yet, clearly, agricultural growth alone is not sufficient for poverty reduction; the distribution of the growth is critical. Johnston and Kilby (1975), Mellor (1976) and more recently Deininger and Squire (1998) and Vollrath (2007) have demonstrated that relatively egalitarian land distribution patterns have tended to generate more broadly based growth, and consequently higher rates of economic growth than in cases where land distribution was highly concentrated. The basic reason for this is that broad-based agricultural growth tends to generate greater second-round expenditures in support of local non-tradable goods and services in rural areas and towns. These multiplier effects tend to be much weaker when the source of agricultural growth is concentrated in relatively few hands. Another argument for small-farm led development has to do with the productivity advantages of farms operated primarily with family labor as opposed to hired labor (Hayami and Otsuka 1993; Binswanger, Deininger and Feder 1995; Vollrath 2007). Thus the rate of growth is likely to be affected by the distribution of assets in the agricultural sector, particularly land.

Moreover, evidence indicates that not only does the initial distribution of assets affect the rate of economic growth, but it also affects the poverty-reducing effects of the growth that does occur. For example, Ravallion and Datt (2002) found that the initial percentage of landless households significantly affected the elasticity of poverty to non-farm output in India. In a sample of 69 countries, Gugerty and Timmer (1999) found that, in countries with an initial “good” distribution of assets, both agricultural and non-agricultural growth greatly benefitted the poorest households with positive poverty reducing effects. In countries with a “bad” distribution of assets, however, economic growth was skewed toward wealthier households, causing the gap between rich and poor to widen. It is especially noteworthy that in this latter group of countries, agricultural growth was associated with greater increases in inequality than was non-agricultural growth. Mellor, Johnston, Lipton and others clearly documented that productivity growth on millions of small farms in Green Revolution Asia was crucial to structural transformation and rapid poverty reduction. They contrasted the Asian experience with parts of Latin America, which also achieved agricultural growth, but not in an inclusive way. Latifundia estates expanded production impressively in many cases while millions of small peasant farms remained mired in poverty and were often dispossessed of their land.

A major lesson for...
Africa from these contrasting experiences of smallholder-led Asia and estate-led Latin America is that for agricultural growth to rapidly reduce poverty, it must be broad-based.

Land intensification and yield gaps

The brightest prospects for agricultural-led structural transformation would be if it could be achieved through productivity-enhancing yield growth on currently utilized farmland. Productivity growth on existing farmland would both ease the demand for new farmland being brought into production as well as help to conserve the world’s remaining forests from being destroyed to meet rising food needs (Hertel 2011). Land productivity growth could occur either through yield growth or shifts in crop area to higher-valued crops or a combination of both. Farm surveys are already showing evidence of gradual increases in the share of cropped area devoted to high-return agricultural activities in some regions, especially on relatively small farms. Much greater potential for this form of productivity growth will depend on the pace of food and input market development, improvements in physical infrastructure, investments in commodity value chains for high-value commodities, and stable marketing and trade policies.

The potential for yield growth of the basic staples is enormous. Actual yields in sub-Saharan Africa show a persistently yawning gap compared to attainable yields, i.e., yields that could be attained if available technologies and management practices were used (Fischer, Byerlee and Edmeades 2009; Licker et al. 2010). Maize yields even in the breadbasket regions of Africa average roughly 25 percent of attainable yields, and seldom exceed 40 percent (Deininger and Byerlee 2011). Given that roughly half of all cropland in sub-Saharan Africa is devoted to staple grains, closing the yield gap even partially could simultaneously improve the world’s supply-demand food balance and contribute to rural poverty reduction in Africa.

However, given current food and input prices, it is unclear how far yield gaps could be narrowed in a way that would be profitable for farmers. Recent studies from the region show that recommended fertilizer application rates are often not profitable or are highly risky given the soil conditions and drought-prone environments that farmers live in (Xu et al. 2009; Marenya and Barrett 2009; Smaling et al 1992; Sheahan 2011; Burke 2011). Other studies conclude that optimal fertilizer application rates on maize appear to be much lower than official recommendations, and that these optimal levels are fairly close to observed application rates on farmers’ fields given existing input and output prices and reduce rural poverty even during periods of rapid agricultural growth (Lopez and Valdes 2000; World Bank 2009). Latin America has the most concentrated farm structure of all regions of the world. Landholding size Gini coefficients reported by Vollrath (2007) range from 0.81 for Latin America to 0.59 for South Asia to 0.49 for sub-Saharan Africa.

12 Farm survey data from Kenya and Zambia show that fresh fruits and vegetables, dairy, and other forms of animal production are rising as a share of total farm production, and that this trend is associated with improvements in the reliability of food markets (Jayne et al. 2010). In Kenya, horticulture production as a share of total farm production is especially high on small farms, suggesting that land-constrained households may, at the margin, be devoting more of their scarce area to crops with relatively high returns (Kimenju and Tschirley 2009).
response rates (Matsumoto and Yamano 2011; Sheahan 2011). Improvements in agronomic practices and measures to reduce transport costs could promote the profitability of fertilizer use and lead to higher optimal application rates. Along with output market development, these interventions could help farmers to close the currently high yield gap.

Another factor that would help farmers around the world close the yield gap is increased global food prices (Hertel 2011). If global food prices should rise, as they are projected to do for at least the next ten years (e.g., OECD 2011), farmers may have greater incentives to intensify their use of modern inputs and to use more intensive management practices. The issue of which African farmers would be able to respond to these price incentives and the potential income distributional effects is treated later.

*Rising population densities and induced innovation*

Increasing rural population density is a third factor that may contribute to closing the yield gap in African food production. The ways in which increasing population density affects the evolution of farming systems was first laid out in the pioneering work of Esther Boserup (1965). Growing population densities, land scarcity, and access to markets generally lead to the intensification of land use, the development of land and labor markets, investments in land-augmenting practices such as irrigation and drainage, and the gradual emergence of individual property rights for land. These ideas were later formalized in Ruttan and Hayami’s (1971) theory of induced innovation, which explains how changes in relative prices of land, labor, and capital affect the evolution of farming systems to make more productive use of the scarce factor of production. Seminal works in the induced innovation literature (e.g., Binswanger and Pingali 1988; Binswanger and McIntire 1987) argued that increases in rural population density in sub-Saharan Africa should induce a number of changes including greater intensification of land through the use of fertilizer and improved seed, decreased fallows, investment in land-augmenting technologies such as irrigation and drainage, more labor time devoted to each unit of land cultivated (e.g., weeding labor per unit of land rises), the development of land, labor and informal financial markets, increased landlessness, and declining availability of common land for livestock (Table 1). Given this kind of innovation, Binswanger and McIntire (1987) argue that through input intensification farmers can raise land productivity (i.e., either increase yields or shift to crops that offer higher net returns per unit of land), and maintain or raise labor productivity growth even in the context of rising labor/land factor proportions. This literature has explained how agricultural systems in many parts of Africa have, over the past century, transitioned from one end of the continuum in Table 1, shifting cultivation, to the other side of the continuum, intensive annual or multiple cropping with less and less land being held in fallow to restore soil productivity.

13 Reasons commonly stated for a secular rise in global food prices include rising incomes in populous middle-income countries such as China and India, the rising use of food for fuel, and the apparent tightening supply/demand balance in world oil markets.
Table 1. Farming systems evolution in response to rising population density

<table>
<thead>
<tr>
<th></th>
<th>Forest fallow system</th>
<th>Bush fallow system</th>
<th>Short-fallow system</th>
<th>Annual cultivation system</th>
<th>Multiple cropping system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor-land ratios</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td>high</td>
</tr>
<tr>
<td>(reflecting pop. density)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>no land preparation</td>
<td>use of hoe to</td>
<td>plow</td>
<td>animal-drawn plow</td>
<td>animal drawn plow and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>loosen soil</td>
<td></td>
<td></td>
<td>tractor</td>
</tr>
<tr>
<td>Fertilization</td>
<td>none</td>
<td>ash</td>
<td>manure, green manure</td>
<td>green manure, inorganic</td>
<td>intensive use of</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>fertilizer</td>
<td>inorganic fertilizer</td>
</tr>
<tr>
<td>Weeding</td>
<td>minimal</td>
<td>required as</td>
<td>weeding</td>
<td>intensive weeding</td>
<td>intensive weeding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>length of fallow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>decreases</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fallows</td>
<td>extensive</td>
<td></td>
<td></td>
<td></td>
<td>minimal</td>
</tr>
<tr>
<td>Factor proportions</td>
<td>Low labor/land and</td>
<td></td>
<td></td>
<td>High labor/land and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>capital/land ratios</td>
<td></td>
<td></td>
<td>capital/land ratios</td>
<td></td>
</tr>
</tbody>
</table>

Source: Condensed and adapted from Binswanger and Pingali (1988) and Boserup (1965).

Outstanding policy questions deriving from rising land pressures

The induced innovation literature for the most part has not considered what lies beyond the last stage of Boserup’s farming systems continuum in the context of more intense land pressures and ever smaller farm sizes in increasingly densely populated rural areas. Can land intensification and productivity growth be sustained in a linear trajectory as population density rises without incurring diminishing returns from soil nutrient depletion, the elimination of fallows, and scale-diseconomies on ever smaller farm sizes?

There are several reasons why declining farm size below a minimum level might be associated with higher production and marketing costs. The first reason concerns soil nutrient depletion. Using cross sectional data from 37 African countries, Dreschel et al. (2001) confirm a significant relationship between population density, reduced fallow periods, and soil nutrient depletion in sub-Saharan Africa farming systems. In their view, rising rural population density is a major cause of declining per capita food production in many parts of sub-Saharan Africa. Restoring and improving soil fertility requires much more than nitrogen, phosphorus, and potassium, hence greater use of conventional inorganic fertilizers, while necessary, certainly will not be sufficient to reach attainable yields. Second, the efficiency advantages of small farms in relation to large-scale farms do not apply when comparing, for example, 4-hectare vs. 0.5-hectare farm sizes. There may be scale economies in input procurement, output marketing, and ability to obtain...
financing that may disadvantage small farms (Collier and Dercon 2009). Survey data regardless of location in sub-Saharan Africa indicate that farms below one hectare tend to be net buyers of staple food (Jayne et al. 2010). The FAO/IFDC argues that the “carrying capacity” of land for sub-Saharan Africa agriculture ranges between 100-500 persons per km² depending on agro-ecological potential for intensive production and market access conditions (Henao and Baanante 1999). The evidence presented below shows that a surprisingly high percentage of the rural population lives in areas exceeding this upper range.

In fact, most of sub-Saharan Africa has witnessed a gradual but steady decline in mean farm size over the past 50 years as rural population growth has outstripped the growth in arable land. Table 2 shows the changes in the ratio of land cultivated to agricultural population over the past five decades for a number of African countries. About half of the countries in Table 2 show a substantial decline in land-to-labor ratios in agriculture. In Kenya’s case, for example, cultivated land per person in agriculture has declined from 0.462 hectares in the 1960s to 0.219 hectares in the 2000-08 period. A consistent story emerges from farm survey data; most but not all countries show a gradual decline in median and mean farm size over time. More comprehensive evidence of mounting population pressures and land constraints in smallholder agriculture and why they sometimes exist in environments of apparent land abundance are reserved for the following section.

Table 2. Hectares of arable land per person in agriculture (10 year average) in selected countries

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethiopia</td>
<td>0.501</td>
<td>0.444</td>
<td>0.333</td>
<td>0.224</td>
<td>0.218</td>
<td>43.5%</td>
</tr>
<tr>
<td>Zambia</td>
<td>0.643</td>
<td>0.607</td>
<td>0.398</td>
<td>0.342</td>
<td>0.297</td>
<td>46.2%</td>
</tr>
<tr>
<td>Kenya</td>
<td>0.462</td>
<td>0.364</td>
<td>0.305</td>
<td>0.264</td>
<td>0.219</td>
<td>47.4%</td>
</tr>
<tr>
<td>Uganda</td>
<td>0.655</td>
<td>0.569</td>
<td>0.509</td>
<td>0.416</td>
<td>0.349</td>
<td>53.3%</td>
</tr>
<tr>
<td>Malawi</td>
<td>0.480</td>
<td>0.466</td>
<td>0.357</td>
<td>0.304</td>
<td>0.307</td>
<td>64.0%</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>0.613</td>
<td>0.550</td>
<td>0.452</td>
<td>0.420</td>
<td>0.469</td>
<td>76.5%</td>
</tr>
<tr>
<td>Rwanda</td>
<td>0.212</td>
<td>0.213</td>
<td>0.195</td>
<td>0.186</td>
<td>0.174</td>
<td>82.1%</td>
</tr>
<tr>
<td>Mozambique</td>
<td>0.356</td>
<td>0.337</td>
<td>0.320</td>
<td>0.314</td>
<td>0.294</td>
<td>82.6%</td>
</tr>
<tr>
<td>Ghana</td>
<td>0.646</td>
<td>0.559</td>
<td>0.508</td>
<td>0.492</td>
<td>0.565</td>
<td>87.5%</td>
</tr>
<tr>
<td>Nigeria</td>
<td>0.982</td>
<td>0.860</td>
<td>0.756</td>
<td>0.769</td>
<td>0.898</td>
<td>91.4%</td>
</tr>
</tbody>
</table>

Source: FAO STAT (2010).

Notes: Data on land utilization is only available for the period 2000 to 2008. Land-to-person ratio = (arable land and permanent crops)/(agricultural population). For the periods 1960-69 and 1970-79, agricultural population is estimated by multiplying rural population by an adjustment factor (mean agricultural population 1980-84/mean rural population 1980-84). This is because data on agricultural population was only collected from 1980 onward.
The following basic model synthesizes the challenges for farming areas facing rising land pressures in a structured way. Labor productivity in agriculture \((Y/L)\) is defined as the product of two terms: net farm income per unit of land \((Y/A)\) and the ratio of land to labor \((A/L)\).

\[
\frac{Y}{L} = \frac{Y}{A} \times \frac{A}{L}
\]

We focus on labor productivity in agriculture because it is normally considered to be the closest reflection of returns to labor in agriculture. \(Y\) is defined as net farm income (gross value of output minus all input costs such as seed, fertilizer, hired labor, etc., except own family labor). In most of the countries shown in Table 2, \(A/L\) appears to be declining over time, as rural population grows at a faster rate than arable land.\(^{14}\) This implies that in order for labor productivity to rise over time, the net value of output \(Y/A\) (net value of output per unit land), must rise faster than the ratio \(A/L\) declines.

Raising the growth rate of \(Y/A\) puts a major burden on technology and changes in farmer management practices to outpace the decline in \(A/L\), which may be especially challenging in the decades to come due to likely changes in weather patterns (Schlenker and Lobell 2010). To reduce the dependence on technology to save the day, some extensification of land might be needed (i.e., \(A\) may need to rise over time to sustain labor productivity growth in agriculture). Hence, important questions arise over the feasibility of area expansion, \(A\), and whether and how arable land can be conserved for current and future generations of rural African farmers as part of a long-term and broad-based structural transformation development strategy. These questions relate front and center to current policy issues about how best to utilize Africa’s available arable lands.

Evidence of land constraints in sub-Saharan Africa

Distribution of arable land by rural population

There is a widespread view that sub-Saharan Africa is a land abundant region with low rural population density. Tables 3a and 3b present the distribution of rural population density in 10 countries according to the Global Rural-Urban Mapping Project (GRUMP) and AfriPop spatial databases described in the data section. Use of these data allows for much greater localized variation in rural population densities than has been typically reported previously using more aggregated spatial units.

\(^{14}\) See Appendix 1 for data on rural population growth rates in sub-Saharan Africa countries.
Table 3a. Rural population density distribution on land categorized as arable, GRUMP 2010

<table>
<thead>
<tr>
<th>Percentiles of all pixels with arable land ranked by population density</th>
<th>Mean across all pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th</td>
<td>10th</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>20</td>
</tr>
<tr>
<td>Ghana</td>
<td>25</td>
</tr>
<tr>
<td>Kenya</td>
<td>18</td>
</tr>
<tr>
<td>Malawi</td>
<td>96</td>
</tr>
<tr>
<td>Mozambique</td>
<td>12</td>
</tr>
<tr>
<td>Nigeria</td>
<td>47</td>
</tr>
<tr>
<td>Rwanda</td>
<td>222</td>
</tr>
<tr>
<td>Tanzania</td>
<td>15</td>
</tr>
<tr>
<td>Uganda</td>
<td>65</td>
</tr>
<tr>
<td>Zambia</td>
<td>7</td>
</tr>
</tbody>
</table>

Source: Year 2010 population estimates from GRUMP.

Notes: These estimates are based on all 1 km² grid cells (“pixels”) categorized as rural. Urban and peri-urban areas, as defined by GRUMP, were not included. Pixels with more than 2000 persons were also not included in analysis. Arable land, used in the denominator of population density estimates, was defined as cultivated land + grasslands, as defined by GAEZ 3.0 database.

Table 3b. Rural population density distribution on land categorized as arable, AfriPop 2010

<table>
<thead>
<tr>
<th>Percentiles of all pixels with arable land ranked by population density</th>
<th>Mean across all pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th</td>
<td>10th</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>19</td>
</tr>
<tr>
<td>Ghana</td>
<td>22</td>
</tr>
<tr>
<td>Kenya</td>
<td>15</td>
</tr>
<tr>
<td>Malawi</td>
<td>90</td>
</tr>
<tr>
<td>Mozambique</td>
<td>9</td>
</tr>
<tr>
<td>Nigeria</td>
<td>32</td>
</tr>
<tr>
<td>Rwanda</td>
<td>209</td>
</tr>
<tr>
<td>Tanzania</td>
<td>16</td>
</tr>
<tr>
<td>Uganda</td>
<td>58</td>
</tr>
<tr>
<td>Zambia</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: Year 2010 population estimates from AfriPop.

Notes: These estimates are based on all 1 km² grid cells (“pixels”) categorized as rural. Urban and peri-urban areas, as defined by AfriPop, were not included. Pixels with more than 2000 persons were also not included in the analysis. Arable land, used in the denominator of population density estimates, was defined as cultivated land + grasslands, as defined by GAEZ 3.0 database.
Both data sources indicate great variation in rural population densities. While the bottom 50 percent of the rural population in all countries live in relatively sparsely populated areas, conforming to conventional perceptions, a sizeable proportion of the rural population are in heavily populated areas exceeding 500 persons per km$^2$ of arable land (defined as cultivated and fallow land plus grasslands). According to the GRUMP data in Table 3a, over 25 percent of the rural population lives in areas exceeding 500 persons per km$^2$ of arable land in five of the 10 countries examined in this study. According to AfriPop (Table 3b), at least 25 percent of the rural population lives in areas exceeding 500 persons per km$^2$ in six of these 10 countries. Because rural population growth is rising faster than land under cultivation in most countries, these proportions are most likely rising over time. Recall that according to a joint FAO/IFDC report, the maximum carrying capacity of the land for intensive cultivation in most areas is 500 persons per km$^2$ (Henao and Baanante 1999); while this threshold cannot be considered to be precise for all areas, e.g., those with multiple cropping seasons and/or irrigation potential, it does give a first-order approximation of land supporting capacity for the dryland farming conditions on which the vast majority of Africa’s rural population is located.\textsuperscript{15}

A visual representation of the dispersion in rural population density on arable land is shown for Kenya in Figure 1. Roughly 40 percent of Kenya’s rural population resides on five percent of its arable land. On the other end of the continuum, three percent of the population controls 20 percent of the nation’s arable land. An alternative visual impression of the dispersion of population density is shown in Figures 2 and 3 for Kenya and Zambia, respectively.

\textsuperscript{15} Binswanger and Pingali (1988) show that after accounting for soil and climate conditions as well as potential technological options, it is possible to compute standardized agroclimatic population densities for various countries measuring the number of people per million kilocalories of production potential. They report that when countries are ranked conventionally by population per square kilometer of agricultural land, Bangladesh comes first, India comes seventh, Kenya falls somewhere in the middle, and Niger is near the bottom. When ranked by agro-climatic population density, the rankings change dramatically: Niger and Kenya are more densely populated than Bangladesh is today, and India ranks only twenty-ninth on the list.
Figure 1. Lorenz curve showing the percentage of arable land by percentage of rural population in Kenya, 2009


Notes: Gini coefficient: 0.51. A Lorenz curve shows the degree of inequality that exists in the distributions of two variables, and is often used to illustrate the extent that income or wealth is distributed unequally in a particular society.

Figure 2. Population density in Kenya

Source: LandScan data for 1999 Census, Kenya.
Moreover, the effects of increasingly crowded rural areas are not confined to those living in such areas. At least some part of rapid urbanization and its associated problems of the spread of slums, health and sanitation problems, and congestion are due to inadequate living standards in rural areas giving rise to migration. Jayne and Muyanga (2012) show that the net outflow of adult labor is four times higher from the top 20 percent of villages ranked by population density than from the bottom 20 percent of villages. Therefore, the question of appropriate development strategies for densely populated rural areas would appear to be increasingly relevant to a significant portion of Africa’s population.

**Trends in farm size and land concentration in customary lands**

Despite widespread acceptance that “pro-poor” agricultural growth is strongly associated with equitable asset distribution, surprisingly little attention has been devoted to quantifying land distribution patterns within Africa’s small-scale farming sector. To examine the degree of concentration of land within African farming sectors, Table 4 presents basic information on farm size and distribution within the smallholder farm sector in six countries for which nationwide survey data were available. As shown in column b, mean farm size in the small farm sector range from 2.76 hectares in Zambia to

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15 Much of the material in this section draws from Jayne et al. (2003).

16 Some notable exceptions include Haggblade and Hazell (1988) and Holden, Otsuka, and Place (2009).
0.71 hectares in Rwanda in 2000. The three Rwanda surveys indicate that mean household land access has declined significantly over the past 15 years.18

Table 4. Land distribution within the smallholder farm sectors in selected African countries

<table>
<thead>
<tr>
<th>Country (year of survey)</th>
<th>(a) Sample size</th>
<th>(b) Mean farm size (ha)</th>
<th>(c) Farm Size (hectares per capita)</th>
<th>(d) Gini Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean 1 2 3 4</td>
<td>Land per household</td>
</tr>
<tr>
<td>Kenya, 1997</td>
<td>1146</td>
<td>2.28</td>
<td>0.41 0.08 0.17 0.31 1.10</td>
<td>0.55 0.56 0.54</td>
</tr>
<tr>
<td>Kenya, 2010</td>
<td>1146</td>
<td>1.86</td>
<td>0.32 0.07 0.12 0.25 1.12</td>
<td>0.57 0.59 0.56</td>
</tr>
<tr>
<td>Ethiopia, 1996</td>
<td>2658</td>
<td>1.17</td>
<td>0.24 0.03 0.12 0.22 0.58</td>
<td>0.55 0.55 0.55</td>
</tr>
<tr>
<td>Rwanda, 1984</td>
<td>2018</td>
<td>1.20</td>
<td>0.28 0.07 0.15 0.26 0.62</td>
<td>-- -- --</td>
</tr>
<tr>
<td>Rwanda, 1990</td>
<td>1181</td>
<td>0.94</td>
<td>0.17 0.05 0.10 0.16 0.39</td>
<td>0.43 0.43 0.41</td>
</tr>
<tr>
<td>Rwanda, 2000</td>
<td>1584</td>
<td>0.71</td>
<td>0.16 0.02 0.06 0.13 0.43</td>
<td>0.52 0.54 0.54</td>
</tr>
<tr>
<td>Malawi, 1998</td>
<td>5657</td>
<td>0.99</td>
<td>0.22 0.08 0.15 0.25 0.60</td>
<td>-- -- --</td>
</tr>
<tr>
<td>Zambia, 2001</td>
<td>6618</td>
<td>2.76</td>
<td>0.56 0.12 0.26 0.48 1.36</td>
<td>0.44 0.50 0.51</td>
</tr>
<tr>
<td>Mozambique, 1996</td>
<td>3851</td>
<td>2.10</td>
<td>0.48 0.1 0.23 0.4 1.16</td>
<td>0.45 0.51 0.48</td>
</tr>
</tbody>
</table>


Note: Numbers for Ethiopia, Rwanda, Mozambique, and Zambia, including Gini coefficients, are weighted to be nationally representative.

On a per capita basis, farm sizes range from 0.56 hectares per person in Zambia to 0.16 hectares per person in Rwanda in 2000 (Table 4, column c). Mean farm size figures mask great variations in land access within the smallholder sector. After ranking all smallholders by household per capita farm size, and dividing them into four equal quartiles, households in the highest per capita farm size quartile controlled between eight to 20 times more land than households in the lowest quartile. In Kenya, mean landholding size for the top and bottom land quartiles were 1.10 and 0.08 hectares per capita, respectively. These figures already include rented land, which is marginal for most countries examined. It was also found across all countries a tendency for the poorest households to control the least amount of land, and to have relatively high labor-to-land

Andre and Platteau (1998) present an in-depth case study which shows acute competition over land and suggests a connection between land disputes and the civil war in 1994.
ratios within their households. In this respect, Africa’s rural poor are similar to those in much of Asia as reported by Sen (1990).

In each country, the bottom 25 percent of small-scale farm households are approaching landlessness, controlling less than 0.12 hectares per capita. In Ethiopia and Rwanda, the bottom land quartile controlled less than 0.03 hectares per capita. It is important to stress that these surveys contain only households engaged in agricultural production; households not engaged in farming are not in the sample.

Nevertheless, it is possible that the bottom land quartile may contain mostly “Sunday farmers” who are engaged primarily in off-farm activities for their livelihoods. To examine this possibility, income shares from crop production, animal and animal-derived production, and off-farm income for each land quartile were computed. As expected, off-farm income shares are highest for the bottom land quartile and decline as landholding size rises. However, in none of the five countries do households in the bottom land quartile earn more than 50 percent of their total income, on average, from off-farm activities, despite having very small farms. In Zambia, Rwanda, Mozambique and Ethiopia, the off-farm income shares for households in the bottom land quartile were 38.5 percent, 34.5 percent, 15.9 percent and 12.7 percent, respectively. By contrast, this figure was 50 percent in Kenya, which can be attributed to that country’s relatively developed and diversified economy, and which affords land-constrained rural households greater opportunity to earn a livelihood through the labor market.

Survey evidence also indicates declining landholding sizes over time. A nationally representative survey of Kenya’s small-scale farm sector in 1977 carried out by the Central Bureau of Statistics reports mean farm size ranging across provinces from 2.10 to 3.48 hectares (Greer and Thorbecke 1986). By contrast, mean farm size in Egerton University’s nationwide surveys from 1997 to 2010 show mean farm size to be 1.97 hectares per farm; these longitudinal surveys show a decline in farm size even within that 13-year period.

Using survey data from Kenya, Jayne and Muyanga (2012) examined how population density is related to the amount of land inherited from the previous generation. Respondents in a nationwide survey in 2007 were asked how much land the father of the household head owned. The previous generation had considerably larger farms (three times larger) than those of the current survey respondents themselves. After ranking respondents’ answers according to the population density of the village, the mean size of respondents’ parents’ farms was found to vary from 7.80 hectares in the low-density quintile of villages to 4.41 hectares in the high-density quintile. Survey respondents were also asked about the amount of land inherited by the household head from his father. This ranged from 1.49 hectares in villages in the low-density quintile to 0.89 hectares in the high-density quintile, where the mean amount of land inherited by survey respondents was roughly one-fifth of the total landholding size of the father. An important policy question is how the current generation of adults in the high population density areas with one hectare of land or less are going to subdivide their land among their children when they reach their old age (the average age of household heads was 48 years in 2010) and whether farming can provide a viable livelihood for those remaining on the land. These findings are consistent with Yamano et al. (2009) who found that roughly a quarter of
young men and women in rural Kenya start their families without inheriting any land from their parents, forcing them to either commit themselves to off-farm employment or buy land from an increasingly active land sales market. We speculate that, because farm sizes in the high density areas are already quite tiny and cannot be meaningfully subdivided much further, an increasingly smaller fraction of people born on farms in Kenya will be able to remain there. This may point to even higher rates of rural-to-urban migration in the future, or at least from agriculture to non-agriculture.

In all countries, the various Gini coefficients displayed in Table 4 column (d) also indicate a high degree of dispersion in farm size. The Ginis for these African countries are -- perhaps surprisingly -- comparable to those estimated for much of Asia during the 1960s and 1970s (Haggblade and Hazell 1988). If land is allocated according to household size or labor availability, more equal land distribution in household per capita or per adult land holdings than per household land holdings should be found. This would imply that the Gini coefficients of landholding by per capita and per adult measures should be smaller than those of landholding per household. This is not the case in any of the five countries examined in Table 4. The Gini coefficients of per capita and per adult land holdings are virtually unchanged in Kenya, Ethiopia, and Rwanda, and are even higher in Mozambique and Zambia when family size is accounted for in the estimates of land distribution inequality.

What is the evidence on trends in landholding inequality over time within the small-farm sectors? This is difficult to assess because of inevitable differences in sample design and variable definitions across surveys; results must therefore be interpreted cautiously. However, Haggblade and Hazell’s (1988) survey of available landholding Gini estimates for Africa, Asia, and Latin America during the 1960s and 1970s provides some grounds for comparison. They report that the basic sampling unit is landholdings, not households, and thus landless households are excluded from these calculations. At least in this way, their estimates are consistent with the data reported in this study. Their sample includes three of the same country/farm sector combinations as in this study: Ethiopia, from 1976/77 survey data; Kenya’s small-scale farming sector from 1960; and Mozambique’s smallholder sector from 1970.

On the basis of these comparisons, it appears that landholding concentration within the small-scale farm sector has increased slightly to moderately over the past 20 to 30 years. The Gini coefficients for landholdings per farm increased from 0.50 to 0.55 between 1960 and 1997 in Kenya; from 0.41 to 0.45 between 1970 and 1997 in Mozambique; and from 0.44 to 0.55 between 1976/77 and 1995/96 in Ethiopia. Ethiopia’s case is particularly intriguing because it had undergone a radical land reform program during the 1970s, yet land concentration appears to have increased.

Probably the most robust case for changes in land concentration is in Rwanda, where the Ministry of Agriculture used relatively consistent survey methods across three surveys for 1984, 1990, and 2000. Changes in the distribution of land access in Rwanda are shown in Table 4. Civil disruption undoubtedly has had a critical effect on land distribution over this period. Mean household land access (use rights plus rented land) has declined by 43 percent over this 16-year period, from 0.28 to 0.16 hectares per capita. In absolute terms, the decline in farm size has been borne mostly by the relatively large
farms. Mean land access for households in the highest land quartile declined from 0.62 to 0.43 hectares per capita, while it declined from 0.07 to 0.02 hectares per capita for the bottom land quartile. In relative terms, however, the dispersion in land access across the distribution has widened. There was a nine-fold difference in mean land access per capita between the top and bottom land quartiles in 1984, but this has worsened to a 21-fold difference in 2000. While Gini coefficients from 1984 are not available, the Gini coefficients of household access to land between 1990 and 2000 increased from 0.43 to 0.52. These results, though tentative, indicate that land concentration may be worsening over time in many of the region’s small-scale farming sectors.

**Relationship between farm size and household income**

The importance of these findings for rural growth and poverty alleviation strategies depends in part on the degree to which land allocation patterns influence household income and poverty. If non-farm activities are able to compensate for small landholdings and provide land-poor households with adequate alternative income sources, then disparities in land ownership should not necessarily be a policy problem. To examine these issues, the bivariate graphs in Figure 4 relate household per capita landholding size to household per capita income, including non-farm income and crop income from rented land. The three dashed vertical lines show the 25th, 50th, and 75th percentiles of sampled households along the x-axis. For example, 25 percent of the sample households in Kenya have between zero and approximately 0.10 hectares per capita, while the top quartile owns on average 1.1 hectares per capita.

**Figure 4. Log of per capita landholding size and per capita household incomes**

Note: The vertical lines are drawn at 25th, 50th, and 75th percentiles of per capita land owned for each country. The top five percent of observations are excluded from the graphs because lines are sensitive to a few extreme cases.
In each country, a positive association is found between household per capita land holdings and per capita income (the sum of crop, livestock, and off-farm income). The association between household income and land is especially steep among households whose land size is below the median level in each country (the middle dotted line in each country graph in Figure 4). Because the vertical axis showing per capita income is in log form, differences in numbers can be read as percent changes. For instance, the line for Kenya starts at the log of per capita income at 9.2 and has a kink at 9.6. The difference between these two points is 0.4, which indicates a 40 percent increase in per capita income when household per capita land size increases from zero to 0.25 hectares. The same increase in land holdings (from zero to 0.25 hectares) increases per capita income by more than 40 percent in Rwanda, just less than 40 percent in Mozambique, and about 30 percent in Ethiopia. In all four countries, the association between land and income becomes weaker somewhere within the third land size quartile, and nearly disappears in the fourth quartile.

What do such land-income relationships mean for feasible smallholder-led development pathways? Improving access to land among the most land-constrained smallholder households would be a seemingly effective way to reduce poverty. For small farms, a very small incremental addition to land access is associated with a large relative rise in income.

Another recent study from Kenya analyzed the impact of endogenous population density on the evolutions of farming systems and farm productivity (Jayne and Muyanga 2012). Household farm size, cropped area, and asset wealth were strongly inversely related to local population density, other factors held constant. Input intensity and farm productivity per unit land and labor all rise with population density to roughly 600-650 persons per km$^2$; beyond this population density threshold input intensification and farm productivity decline. What would explain these threshold effects? Market participation studies consistently show that farm sales are related to farm size (Barrett 2008). If farm sizes decline beyond a given point due to sub-division and land fragmentation caused by population pressures, households are less likely to generate cash from crop sales that would allow them to purchase modern productivity-enhancing inputs. Less intensive input use then reinforces small farms’ difficulties in producing a surplus. Furthermore, access to farm credit also tends to be restricted for farmers with limited land and other assets that could otherwise act as collateral. For these reasons, population density threshold effects may be very plausible and may explain why in Kenya a number of important farm productivity indicators tend to decline beyond a certain level of population density. In 2009, according to Tables 3a and 3b, roughly 35 percent of Kenya’s rural population resides in areas exceeding 650 persons per km$^2$ of arable land.

The structural transformation processes in Asia, as documented by Johnston and Kilby (1975) and Mellor (1976), show that a smallholder-led agricultural strategy was necessary to rapidly reduce rural poverty and induce demographic changes associated

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19 The major determinants of district-level population density in 2009 were found to be distances to infrastructural facilities, the population and stock of arable land of the district at independence, and village-level rainfall, rainfall variability, soil quality, and agro-ecological potential.
with structural transformation. An inclusive smallholder-led strategy is likely to provide the greatest potential to achieve agricultural growth with broad-based reductions in rural poverty in most of sub-Saharan Africa as well. However, it is not at all clear how such a smallholder-led agricultural strategy must be adapted to address the limitations of very small and declining farm sizes in densely populated areas that are dependent on rain-fed production systems with only one growing season per year.

Of course, nothing presented so far necessarily confirms that inadequate access to land is a binding constraint on smallholder agriculture in Africa. It might be possible that rural households could acquire more land if they chose to. And perhaps factors of production other than land are the more binding constraint on agricultural intensification.

*Is land expansion possible for smallholder farmers?*

Zambia provides an interesting case study for exploring rural households’ perception about the availability of unallocated land for future expansion of agricultural production. Zambia has one of the lowest national population densities in sub-Saharan Africa and it is widely believed that there is major potential for area expansion.

One of the questions asked of households in the nationally representative 2001 Post Harvest Supplemental Survey (CSO 2001) was “Is there unallocated arable land that is available to households in your village?” Nationwide, 44.1 percent of households felt that there was unallocated arable land that was available in their village area. Table 5 presents respondents’ answers to this question by province. Also included in the table is the amount of unutilized arable land in each province according to Central Statistical Office estimates in 2004.
<table>
<thead>
<tr>
<th>Province</th>
<th>Is there unallocated arable land?</th>
<th>Arable &amp; unutilized (kms(^2))</th>
<th>Arable and unutilized minus already cultivated land (kms(^2)) (i.e., unutilized)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Responding Yes</td>
<td>% Responding No</td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>57.9</td>
<td>42.1</td>
<td>65,800</td>
</tr>
<tr>
<td>Copperbelt</td>
<td>39.2</td>
<td>60.8</td>
<td>23,172</td>
</tr>
<tr>
<td>Eastern</td>
<td>32.6</td>
<td>67.4</td>
<td>6,769</td>
</tr>
<tr>
<td>Luapula</td>
<td>38.6</td>
<td>61.4</td>
<td>28,120</td>
</tr>
<tr>
<td>Lusaka</td>
<td>40.0</td>
<td>60.0</td>
<td>11,756</td>
</tr>
<tr>
<td>Northern</td>
<td>68.3</td>
<td>31.7</td>
<td>102,751</td>
</tr>
<tr>
<td>Northwestern</td>
<td>96.0</td>
<td>4.0</td>
<td>151,992</td>
</tr>
<tr>
<td>Southern</td>
<td>33.6</td>
<td>66.4</td>
<td>6,321</td>
</tr>
<tr>
<td>Western</td>
<td>23.3</td>
<td>76.7</td>
<td>1,877</td>
</tr>
<tr>
<td>Zambia</td>
<td>44.1</td>
<td>55.9</td>
<td>398,560</td>
</tr>
</tbody>
</table>


Note: The survey covered 7,264 households and is statistically representative at the province level.

The responses in Table 5 initially suggest that many households in Zambia perceive that there is unallocated land available in their villages. This view is particularly strong in the sparsely populated areas of Northwestern and Northern provinces, which incidentally also have the biggest portions of arable and available land, and to a lesser extent in Central province. Central province is third in terms of available arable land. However, in the major agricultural provinces of Eastern and Southern provinces, less than 40 percent of respondents reported that unallocated arable land was still available in their areas. These two provinces have, other than Western province, the lowest amount of unutilized arable land.

One might expect that the “no” responses would be concentrated in the most densely populated provinces, and the “yes” responses would be concentrated in sparsely populated areas. This is not uniformly the case in Zambia. For instance Western province has the second lowest population density in Zambia but it contained the greatest proportion of respondents indicating that no additional land was available. This result is most likely because many parts of Western province are unsuitable or only marginally...
suitable to crop cultivation, hence population density underestimates the degree to which population is concentrated in a few productive areas.

Because 94 percent of Zambia’s land is in the customary tenure system, it is often implied that there should be great scope for area expansion by African farmers. Metcalfe (2005) and others, however, feel that this conclusion should be heavily qualified:

"Although it is sometimes stated that 94 percent of Zambia falls under customary tenure from that proportion must be deducted the 8 percent of the country designated as national parks and further 8 percent designated as forest reserves. From the remaining 76 percent must be deducted two percent for urban areas and 12 percent as unspecified areas (e.g., state farms, property, military, research stations, etc.). Finally, from the remaining 64 percent the Game Management Areas (GMAs) that make up 23 percent of Zambia’s land area must be considered" (p. 7).

These figures put into context the generally held notion that 80 percent of arable land in Zambia remains uncultivated, and that 94 percent of its land is under customary tenure, implying that it is available for smallholder agricultural development. According to Chizyuka et al. (2006), land falling under customary administration is 62 percent of the country territory or 46,500 square kilometers, but this includes mountainous areas, marshes and swamps, areas that are permanently flooded, infested with tsetse flies, and/or too arid to be suitable for intensive crop production. We conclude that, in reality, a much smaller amount of viable arable land is available for future generations of Zambian smallholders than is often thought.

A paradox of land pressures amid land abundance?

Several conclusions emerge from the evidence presented so far. First, while many parts of sub-Saharan Africa are very sparsely populated, often leading to relatively low population densities when computed over all rural area; a growing proportion of its population reside in fairly densely populated areas of 500 persons per km² or greater. These data may resolve the apparent paradox of land constraints amid the appearance of land abundance and massively under-utilized land.

However, the major disparities in the population densities of 1km² grid cells within each country examined raises questions about how such extreme differences have arisen and why hasn’t migration tended to equilibrate these differences over time? Why is much of Africa’s rural population concentrated tightly in particular areas while vast areas potentially suitable for agriculture remain largely unutilized? This question requires more intensive investigation but for now, we forward three major factors explaining the observed great variation in rural population densities:

1. **Natural clustering of population to the most hospitable and fertile areas.** These areas include the highlands of eastern and southern Africa, the humid tropics of West Africa, and coastal areas near natural ports and river confluences. This historical clustering of the population, when combined with the common
usufructory or “use rights” system of land tenure, introduces rigidities in land markets that would otherwise reduce spatial differences in population density over time. Land assets cannot generally be sold by the family (customary land officially belongs either to the chief, president, or state), and hence a decision to migrate out of the area means that the household will lose its access to land in its home area without compensation. Households with sufficient means have been able to acquire new land in other areas while retaining some members on their original homestead, but in general the usufructory land system tends to inhibit population shifts over time from land-constrained to land-abundant areas (Low 1986).

2. **Pattern of prior public investment.** Potentially arable land can remain underutilized because it has yet to receive the requisite public investment in physical infrastructure (e.g., roads, electrification, irrigation), water, schools, health facilities and other services required to raise the economic value of land and thereby attract migration and settlement in these areas (Govereh 1999). Several governments have shown a willingness to devote state resources to develop land for large-scale commercial investment but much less so for smallholder-led agricultural development.

3. **Colonial segregation of Africans into reserves.** A major factor in countries with a colonial settler history such as Kenya, Malawi, Zimbabwe, and Zambia, has been the historical and post-independence continuation of colonial tenure systems separating “customary lands” from “state lands” (Basset and Crummy 1993; Binswanger et al. 1995). Many areas under customary tenure are facing emerging land constraints borne of steady rural population growth since independence. By contrast, much of Africa’s unutilized arable land is under state authority, which is not readily accessible for settlement by smallholder populations under prevailing land allocation institutions. Post-independence governments have often allocated land to non-farming elites in exchange for political support, contributing to land underutilization while nearby farming areas exhibit signs of land pressures and degradation (Kanyinga 1998; Mbaria 2001; Stambuli 2002; Namwaya 2004). It is perhaps not surprising then that median farm sizes are quite small and declining for the vast majority of the farming population, as indicated in Table 4, while large tracts of land in other parts of the country remain unutilized. This dual land-tenure structure has impeded natural migration from processes 1 and 2.

Many of the “state vs. traditional chiefs” conflicts that have featured prominently in post-independence Africa (Herbst 2000) have centered on attempts by the state to wrest control of customary lands. Politicians’ arguments for converting customary land to state land normally focus on the need to allocate land to commercial entrepreneurs and capitalized “emergent” farmers with the ability to use it productively; although as shown earlier there is very little evidence to suggest that large-scale farms are more efficient than small-scale farms (Binswanger et al. 1995). In areas where traditional authorities have succeeded in retaining control over customary land, there are still numerous reports
of land being allocated to local elites having no legitimate claim to land in that area under
traditional norms (Deininger and Byerlee 2011).

Regardless of whether land is retained under customary or state control, several scholars
argue that African farmland is facing an “enclosure” process in the absence of efforts to
reverse it (Woodhouse 2003; Stambuli 2002). Woodhouse argues that much of Africa is
facing increased commodification and individualization of land driven by population
growth and increased pressure on remaining arable land regardless of land tenure regime.
This process is being intensified by the post-independence continuation of converting
unutilized customary land into titled property or state land. While one might be tempted
to regard this as evidence of emerging land markets in Africa, in most cases the processes
of allocation are opaque; little public information about land transaction prices have
emerged in any country that could serve as a basis for price discovery more broadly.
Meanwhile, many customary (i.e., smallholder) farming areas are facing intensifying land
constraints borne of steady rural population growth since independence, which is only
made more acute by transfers of land from customary to state control (Colin and
Woodhouse 2010). An important literature in Kenya has documented the rapacious
disempowerment of local communities from their traditional lands, first by colonialists
and later by successive post-colonial governments (Juma 1996; Kanyinga 1998; Okothe-
Ogendo 1976). Post-independence Kenyan governments have largely retained the same
institutions despite recognizing the importance of land rights and even elevating it to a
crucial post-independence challenge (Republic of Kenya 1965). While the modes of land
access were primarily through inheritance and the market, access to state land (and land
converted from customary to state land) has been a major instrument of patronage
favoring the political elite. For these reasons, it is perhaps not surprising that median
farm sizes are quite small and declining for a large proportion of the smallholder
population, while large tracts of land in other parts of the country continue to be allocated
by the state to local elites and foreign investors.

When do agricultural growth and poverty reduction converge and when do they
diverge?

Returning now to several debates discussed earlier on the role of land in affecting
development trajectories, some scholars and a growing number of African governments
believe that greater support for investment in large-scale agriculture may be the best use
of public funds for poverty reduction. Other analysts have argued that overcoming
Africa’s food security and poverty problems is primarily a challenge of improving the

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20 For example, in a recent study of “emergent” farmers (10-100 hectares) in Zambia, Sitko and Jayne
(forthcoming) found that most of the 186 farmers interviewed purchased or obtained a 99-year lease from
local authorities in customary lands. Of these, the majority entered into farming later in life after earning
enough money from urban (often civil service) employment to purchase land. These farmers are cultivating
an average of 27 percent of the land obtained, while over 90 percent of the surrounding small-scale farmers
in the area own less than 5 hectares.

21 Namwaya (2004) reports that over 600,000 hectares of land, or roughly one-sixth of Kenya’s total land
area, are held by the families of the country’s three former presidents, and that most of this land is in
relatively high-potential areas.
uptake of productivity-enhancing Green Revolution technologies. Consider, for example, Roger Thurow’s (2010) conclusion:

“Thus, more and more eyes are turning to Africa, agriculture's final frontier. Africa was largely left out of the green revolution, the postwar movement to push up crop yields in the hungriest parts of the world by promoting the use of new seeds and new farming technology. And so agricultural production on the continent could jump quickly if farmers there simply used existing seed, fertilizer, and irrigation technology. And if more efficient networks were developed to distribute and sell the harvests, boosting agricultural yields in Africa could be a major step toward feeding not just the continent but also the rest of the world.”

This section explains why the uptake of improved technology may indeed boost agricultural yields and yet do very little to address rural poverty that is associated with pervasive constraints on access to land and other productive assets. The recent experiences of Zambia and Malawi illustrate how agricultural growth that is not broad-based may have very little effect on rural poverty. Both countries have succeeded in doubling maize production between the early and late 2000s. In both countries, the marked increase in maize production coincides with the scaling-up of government input subsidy programs. The national use of fertilizer and hybrid maize seed in both countries has roughly doubled between 2004 and 2010, and yield growth in both countries has been the primary source of the production booms (Mason et al. 2011; Ricker-Gilbert et al. 2011). In Zambia’s case, farmers have benefited from the purchase of maize at above-market prices (roughly $275 per ton) through the Food Reserve Agency (FRA). Together the input subsidy and maize price support programmes in Zambia accounted for over 60 percent of the Ministry of Agriculture’s public budget over the past five years and over two percent of the country’s GDP in 2010. These two programs also accounted for 90–96 percent of the total budget allocated to the ministry’s Poverty Reduction Programmes (PRPs) during the 2006–2011 budget years. In Malawi, the input subsidy program alone has exceeded 10 percent of the national budget in at least two of the past five years.

In spite of the impressive growth in grain yields and production, rural poverty in both countries has declined very little over this time span. In Zambia, the rural poverty rate was 77.3 percent in 2004 and 76.8 percent in 2006; while official poverty rate estimates for 2010 have not yet been released, preliminary estimates suggest that the rural poverty rate remains in the range of 74–78 percent. So, why is it that maize production has increased so impressively without making a serious dent in rural poverty?

Table 6 shows data from the nationally representative 2011 Crop Forecast Survey to show how maize production has varied according to farm size. Column A of Table 6 shows the number of farmers in five farm size categories. Overall Zambia has an estimated 1,471,221 small- and medium-scale farmers (‘smallholder’ farmers), defined as farmers cultivating between 0.1 and 20 hectares. Approximately 42 percent of them are cultivating less than one hectare of land; 33.3 percent of the smallholder farms are cultivating 1–2 hectares; 2.9 percent are cultivating 5–10 hectares, and 0.5 percent are cultivating over 10 hectares (column B). Farmers cultivating less than two hectares
accounted for 75 percent of the total number of farmers in Zambia’s smallholder farm sector.

Table 6. Smallholder maize production growth from the baseline period (2006-2008 harvest years) to 2011, by farm size category

<table>
<thead>
<tr>
<th>Total area cultivated</th>
<th>Number of farmers, 2006-08 to 2011</th>
<th>% of farms</th>
<th>Annual mean during 2006-2008 baseline period (MT)</th>
<th>2011 harvest (MT)</th>
<th>Absolute change (D-C) (MT)</th>
<th>Increase in maize output per farm (E*1,000/A) (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.99 ha</td>
<td>616,867</td>
<td>41.9%</td>
<td>212,335</td>
<td>309,324</td>
<td>96,989</td>
<td>157.2</td>
</tr>
<tr>
<td>1-1.99 ha</td>
<td>489,937</td>
<td>33.3%</td>
<td>381,293</td>
<td>707,438</td>
<td>326,145</td>
<td>665.7</td>
</tr>
<tr>
<td>2-4.99 ha</td>
<td>315,459</td>
<td>21.4%</td>
<td>490,102</td>
<td>1,130,527</td>
<td>640,425</td>
<td>2,030.1</td>
</tr>
<tr>
<td>5-9.99 ha</td>
<td>42,332</td>
<td>2.9%</td>
<td>196,848</td>
<td>494,719</td>
<td>297,871</td>
<td>7,036.6</td>
</tr>
<tr>
<td>10-20 ha</td>
<td>6,626</td>
<td>0.5%</td>
<td>103,156</td>
<td>144,888</td>
<td>41,732</td>
<td>6,298.4</td>
</tr>
<tr>
<td>Total</td>
<td>1,471,221</td>
<td>100%</td>
<td>1,383,735</td>
<td>2,786,896</td>
<td>1,403,161</td>
<td>953.7</td>
</tr>
</tbody>
</table>


Column C shows the estimated total maize production within each of the farm size categories over a ‘baseline’ period (the three years covering the 2005/06 to 2007/08 crop seasons). Column D shows the estimated maize production for these five farm size categories in the 2010/11 crop season. Overall, maize production increased from an average of 1,383,735 tonnes in the baseline period to 2,786,896 tonnes in the 2010/11 season.

Column E shows the change in maize production over this period for each farm size category. Farmers cultivating less than one hectare contributed an additional 96,989 tonnes to national maize production in 2010/11 compared to their average maize production during the three-year period 2005/06-2007/08. By dividing the additional maize production in column E by the number of farms in each category as shown in Column A, we derive the additional maize production per farm for each of the farm size categories, as shown in Column F. When expressed on a per farm basis, it is apparent that farmers cultivating less than one hectare produced 157.2 additional kilograms of maize per farm in 2011. Farmers cultivating one to two hectares contributed 326,145 additional tonnes of maize in 2010/11, which amounts to 666 kilograms of additional maize per farm. Farmers cultivating two to five hectares contributed an additional 640,425 tonnes to national maize production in 2010/11, or 2.03 additional tonnes per household. The 2.9 percent of the farmers cultivating five to 10 hectares contributed an additional 297,871 tonnes to national maize production in 2010/11, which amounted to 7.04 tonnes of additional maize production per farm. And lastly, the 0.5 percent of farmers cultivating
10–20 hectares increased their maize production in 2010/11 by 6.3 tonnes per household compared to the earlier baseline period.

The data in Table 6 show that very little of the increase in national maize production in 2010/11 came from the bottom category of farmers (less than one hectare cultivated) even though they account for over 40 percent of the smallholder farms in Zambia and are among the poorest of the rural poor. Given that their maize output increased by an average of just three 50-kg bags per household between 2005/06-2007/08 and 2010/11, the national maize bumper harvest is unlikely to have resulted in significant reductions in hunger and poverty among this group of farmers. The main increase in national maize production (column E) came from farmers in the 1–2, 2–5 and 5–10 hectare cultivated area categories. When expressed in per farm terms, however, the major increases in maize production were enjoyed by farmers cultivating over five hectares—farm households that constitute only 3.4 percent of all the smallholder farms in Zambia. Table 6 clearly shows that the increase in maize production per farm is strongly related to farm size. However, even the relatively small increases in average maize production among the smallest farms is likely to have improved their food security status substantially as a result of their harvesting even a few more 50-kg bags of maize in 2010/11 than in the earlier period.

Table 7 uses the same Crop Forecast Survey data to examine the amount of subsidized FISP fertilizer received during the 2010/11 crop season by farmers within the same five categories. The number and percentage of farms in each category in 2010/11 are shown in columns A and B, respectively. The percentage of farms receiving FISP fertilizer in each category is presented in column C. Slightly over 14 percent of the farmers cultivating less than one hectare received FISP fertilizer in the 2010/11 crop season. The average quantity of fertilizer they received was 168 kg. Across all 596,334 households in the category, the average household received 24.1 kg of FISP fertilizer (column D). By contrast, over 50 percent of farmers in the 10–20 hectare cultivated category received FISP fertilizer in 2010/11, receiving 657 kg per farm. The average amount of FISP fertilizer received by farmers in the 10–20 hectare category was 346 kg, about 14 times more per farm than those in the less than one hectare category.
Table 7. FISP fertilizer received (2010/11 crop season) and maize sales, 2011, by farm size category

<table>
<thead>
<tr>
<th>Total area cultivated (maize + all other crops)</th>
<th>Number of farms</th>
<th>% of farms</th>
<th>% of farmers receiving FISP fertilizer</th>
<th>Kg of FISP fertilizer received per farm household</th>
<th>% of farmers expecting to sell maize</th>
<th>Maize sales (kg/farm household)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.99 ha</td>
<td>596,334</td>
<td>39.6%</td>
<td>14.3%</td>
<td>24.1</td>
<td>22.2</td>
<td>135</td>
</tr>
<tr>
<td>1-1.99 ha</td>
<td>499,026</td>
<td>33.1%</td>
<td>30.6%</td>
<td>69.3</td>
<td>47.7</td>
<td>609</td>
</tr>
<tr>
<td>2-4.99 ha</td>
<td>354,116</td>
<td>23.5%</td>
<td>45.1%</td>
<td>139.7</td>
<td>64.0</td>
<td>1,729</td>
</tr>
<tr>
<td>5-9.99 ha</td>
<td>49,410</td>
<td>3.3%</td>
<td>58.5%</td>
<td>309.7</td>
<td>82.1</td>
<td>6,613</td>
</tr>
<tr>
<td>10-20 ha</td>
<td>6,999</td>
<td>0.5%</td>
<td>52.6%</td>
<td>345.6</td>
<td>86.8</td>
<td>15,144</td>
</tr>
<tr>
<td>Total</td>
<td>1,505,885</td>
<td>100%</td>
<td>28.6%</td>
<td>77.1</td>
<td>42.7</td>
<td>950</td>
</tr>
</tbody>
</table>


Column E shows the percentage of households selling maize. This ranges from 22.2 percent among the smallest farm size category to 86.8 percent among the largest. In terms of quantities of maize expected to be sold, column F shows that, on average, about 135 kg of maize will be sold for every farm in the less-than-one hectare category, compared to 1.7 tonnes per household in the two to five hectare category, and over 15.1 tonnes per household in the 10–20 hectare category. Clearly, the benefits of the FRA maize support prices are disproportionately enjoyed by the relatively large farmers over five hectares, even though they constitute only 3.8 percent of the smallholder farm population.

The smallest farmers in Zambia—those cultivating less than two hectares who account for over 70 percent of all the smallholder farms in the country—participated only marginally in the maize production expansion of 2010/11. These farmers received relatively little FISP fertilizer and sold very little maize, hence they were unable to benefit from the FRA producer price of 65,000 kwacha per bag. The farmers benefiting the most from the government’s expenditures on supporting maize prices were clearly those selling the most maize. In contrast, about 30 percent of the relatively poor smallholder households actually had to purchase more maize and maize meal than they produced to meet their families’ food needs and hence were adversely affected by a support price policy that raised maize prices in the countryside. This disaggregated picture of Zambia’s maize production expansion may reveal why rural poverty rates remain so high despite the record maize harvests in the past several years. Similar conclusions emerge from Malawi (Ricker-Gilbert et al. 2011).

The composition of the Zambian government’s public spending on agriculture reveals that the lion’s share of its budget was devoted to maize price supports and input.
subsidies, which as shown below were captured primarily by larger farmers (Figure 5). The types of scale-neutral public investments that can promote productivity even on one-hectare farms, e.g., improved seed and agronomic research, farmer education and extension, physical infrastructure, etc., receive only about 20 percent of the public budget to agriculture across all ministries.

Figure 5. 2010 budget allocation to agriculture, Government of Zambia

Source: Ministry of Finance published budget figures including supplemental spending.

Notes: Expenditures to agriculture accounted for 15.3 percent of total government budget in 2010. Other Ministry of Agriculture programs included the Zambia Agricultural Research Institute (0.3 percent of total agricultural budget), Veterinary and Tse Tse Control programs (1.0 percent), seed control and certification (0.2 percent), provincial agricultural research stations (0.1 percent), Policy Analysis Unit (0.7 percent). Agricultural programs in other ministries include feeder roads, Central Statistical Office, Forestry, farm block, and resettlement programs.

This disaggregated picture of the distributational effects of growth – at least how it was achieved in Zambia and Malawi – demonstrate the limitations of current approaches for achieving Green Revolutions in Africa. Conventional approaches such as those focusing

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22 The sampling frame for the CFS survey covers farms cultivating 0.1 to 20 hectares. Anecdotal reports indicate that African farmers cultivating well over this amount of land are perhaps the biggest recipients of the government fertilizer subsidy program. Hence the findings presented in this section may underestimate the skewed distribution of public agricultural expenditures to relatively large farmers.
largely on farm price supports and input subsidy programs may increase aggregate farm output but have tended to produce concentrated benefits that are correlated with farm size and asset wealth (Jayne, Mather and Mghenyi 2010). This form of (mis)targeting has therefore lost valuable opportunities for public expenditures on agriculture to reduce rural poverty rates in the process of raising agricultural production. The Zambia and Malawi experiences stress the need not only to promote the use of improved technology but to do so in a way that reaches – directly or indirectly – farms in the bottom half of the asset distribution. Taking action to expand access to land for smallholder farm production, as a complement to input promotion and farm productivity programs, may be fundamental to effective national agricultural development and poverty reduction policies.

Hertel (2011) concludes that there is substantial scope for endogenous intensification of production in response to higher product prices, particularly in Africa, where fertilizer application rates are low. Higher farm prices may indeed provide incentives for profitable intensification to close the high yield gaps observed in the region (Fisher, Byerlee and Edmeades 2009). The findings reported here for Zambia confirm previous evidence that the African farming sector can quickly and robustly respond to higher food prices, but that the response is likely to be greatest according to which type of farmers receive the greatest public support to respond to price incentives. Some analysts promoting a prioritization of large-scale agriculture based on conclusions of dismal past performance of smallholder agriculture seem unaware of how public funds and policies have consistently been allocated (often unintentionally) to benefit larger farms at the expense of small farms. Governments and development partners concerned with reducing poverty and food insecurity can therefore take advantage of the scope for endogenous intensification of production in response to anticipated higher food prices by allocating public budgets to agriculture and erecting policies in ways that enable the rural poor to be part of the growth process. Land allocation policies and land taxes are obvious entry points for achieving these goals.

Moreover, there are likely to be severe food insecurity problems if farm intensification in Africa is driven by higher food prices alone, because of the large proportion of resource-poor farmers who have insufficient access to land and other assets to produce a surplus through either intensification or extensification, and are likely to remain net buyers of food even under a high food price regime (Jayne, Mather and Mghenyi 2010). Policy strategies to broaden the base of farms that can respond to future price signals and agricultural growth opportunities may increasingly require explicit consideration of egalitarian approaches to expand and broaden access to unutilized arable land in the region.

This conclusion raises questions, therefore, about the potential impact of promoting large-scale investment in farmland in response to heightened global demand for food. The advocacy of a large-scale commercial farm approach (e.g., Collier and Dercon 2009) seems unable to address how the majority of Africa’s rural population could be integrated into such an approach. Large-scale farms are capable of absorbing an exceedingly small fraction of the rural labor force, and unskilled farm labor in most cases pays very little above poverty-line wages. Moreover, there is little evidence that the non-farm sectors in sub-Saharan Africa will be capable of rapidly absorbing more than a small fraction of
labor force into skilled or semi-skilled non-farm employment. The region’s longstanding infrastructural and educational disadvantages relative to other regions translate into relatively high production costs of non-farm goods and services. Hence, under the most plausible scenario of a continued slow transition of the labor force from agrarian to non-farm sectors, a public investment and policy orientation explicitly biased in favor of large-scale agriculture raises major questions about how governments will address the livelihood challenges for a major fraction of the region’s underserved population remaining in rural areas.

The recent World Bank report on land issues by Deininger and Byerlee (2011) provide a more nuanced argument that the promotion of large commercial agriculture could complement a small farm-led development approach, or at least co-exist with it, without choking off the prospects for the latter. They are guardedly optimistic that new investment in large-scale farming can be promoted for areas of Africa that have abundant unutilized land. They stress that due diligence must be exercised to ensure that investment in farmland by outside interests does minimal disruption to local interests and conclude that there is good potential for mutually beneficial outcomes especially in land abundant areas with low population densities.

The main risk with this World Bank position is that an explicit promotion of new large-scale farm investment might encourage scarce public expenditures to be allocated in ways that are even more distributionally regressive and skewed in favor of large-scale and “emergent” farm interests than they currently appear to be in many countries. Findings earlier in this section from Zambia (and more broadly as described in Jayne et al 2010) attest to the extent to which programs ostensibly designed to support smallholder agriculture are actually channeled to medium- and large-scale agriculture. An explicit focus on large-scale agriculture could easily exacerbate the distributionally regressive use of public funds. Already, several African governments appear poised to devote substantial public resources in support of large-scale commercialized agriculture in the form of irrigation, electrification, and road development, based on little consideration or analysis as to whether the same magnitude of public support for smallholder agriculture might produce even greater benefits to productivity and poverty reduction. Perhaps most importantly, allowing the discourse on agricultural development in Africa to be cast in terms of how best to exploit the continent’s unutilized land has arguably diverted attention from the more central and enduring challenge of implementing agricultural development strategies that effectively address the continent’s massive rural poverty and food insecurity problems, which require recognizing the growing land constraints faced by much of its still agrarian-based population.

**Conclusions and policy implications**

Despite the fact that sub-Saharan Africa in 2012 contains much of the world’s unutilized and underutilized arable land, a significant and growing share of Africa’s farm households are living in densely populated areas. These areas are characterized by small and declining farm sizes for the majority of people living in them. Ironically, inadequate access to land and inability to exploit available unutilized land are issues that almost
never feature in national development plans or poverty reduction strategies. There has been seemingly little recognition of the potential challenges associated with increasingly densely populated and land-constrained areas of rural Africa, despite the fact that a sizeable and increasing share of its rural population live in such areas.

Nationally representative farm surveys consistently show the following regularities: First, there are great disparities in landholding size within smallholder farming areas. While the top 10 percent of the rural population reside on farms ranging from five to 25 hectares, half or more of Africa’s smallholder farms are below 1.2 hectares in size, and a quarter of the farms are below 0.5 hectares, with limited or no potential for area expansion (Jayne et al. 2003). Second, because of this pattern of landholding size distribution, farm production and marketed surplus are similarly skewed. In most nationally representative surveys in the region that the authors analyzed, the top five percent of farmers (not counting large-scale commercial farmers) account for 50 percent of the marketed grain surplus (Jayne et al. 2010). Third, and in stark contrast, half or more of rural farm households are unable to produce enough grain to feed themselves and are either buyers of grain or go hungry because they are too poor to afford to buy food. Most of the households owning less than one hectare of land fall into this category regardless of their agro-ecological or market access conditions, and their incomes tend to be below the poverty line. After controlling for agro-ecological conditions, small farm size is highly correlated with income poverty (Jayne et al. 2003). Fourth, a high proportion of farmers in densely populated areas perceive that it is not possible for them to acquire more land through customary land allocation procedures, even in areas where a significant portion of land appears to be unutilized (Stambuli 2002; Yamano et al. 2009; Jayne et al. 2008). Land markets, both formal and informal, appear on the rise (Woodhouse 2003; Holden et al. 2009). In Kenya, roughly a quarter of young men and women born in rural areas start their families without inheriting any land from their parents, forcing them to either commit themselves to off-farm employment or buy land from an increasingly active land sales market (Yamano et al. 2009). And fifth, survey evidence points to increasing concentration of landholdings over time as well as declining mean farm size (Jayne et al. 2003).

These concerns lead to policy questions about appropriate and feasible smallholder-led agricultural strategies in the context of land-constrained farming systems and limited off-farm employment opportunities to absorb redundant labor in densely populated rural areas. Associated issues for research revolve around whether many farms are becoming, or have already become, “too small” to generate meaningful production surpluses and participate in broad-based inclusive agricultural growth processes given existing on-shelf production technologies. Evidence presented earlier about population density being inversely related to soil fertility and farm size might suggest the presence of threshold effects in the relationship between population density and farm productivity, especially labor productivity, as the intensification of labor and capital per unit of land may lead to diminishing returns to labor and capital beyond some point. Other reasons for declining agricultural productivity beyond some threshold level of rural population density may include reduced fallows leading to soil fertility depletion, and the tendency to produce little or no surplus production on very small farms with many residents; leading to difficulties of purchasing needed cash inputs in the presence of incomplete rural financial
markets. All of these dynamics may be mutually reinforcing in the threshold relationships between population density, farm sizes, and farm productivity. These relationships are likely to be strongly conditioned by variables such as agro-ecological and market conditions. Future empirical research is needed to investigate these conditioning influences.

Certainly, most of sub-Saharan Africa’s land area is not characterized by such dilemmas. Most of the continent is sparsely populated. However, based on two alternative spatial databases capable of estimating populations at the level of one square kilometer and distinguishing between arable and non-arable land, a high proportion of rural people nevertheless live in densely populated areas. This apparent paradox is resolved when the unit of observation is shifted from land units to people. In at least five of the 10 countries analyzed, 25 percent of the rural population resides in areas exceeding 500 persons per square kilometer, which, by at least one account (Henao and Baanante 1999), is estimated to be the maximum supporting capacity for areas of intensive crop cultivation in the region.

The evidence presented here suggests that there tends to be a fallacy in concluding that most of the people in rural sub-Saharan Africa live in land abundant conditions. This has created the false perception that the development challenge for the region is how to productively utilize the continents’ underutilized land resources. In the past several decades, and especially since the rise of world food prices, there have been concerted efforts to transfer land out of customary tenure (under the control of traditional authorities) to the state or to private individuals who, it is argued, can more effectively exploit the productive potential of the land to meet national food security objectives. Such efforts have nurtured the growth of a relatively well-capitalized class of “emergent” African farmers, most of whom did not start out in agriculture but rather bought land earned from salaried employment in the towns (Sitko and Jayne forthcoming). These farmers are well represented in many African countries’ powerful farm lobbies, disproportionately enjoy the benefits of input subsidy and price support programs due to their relatively large farm sizes, and become major forces lobbying for the continuation of such programs.

Moreover, some African governments are increasingly receptive to devoting state resources to develop land for large-scale commercial investment (e.g., investments in irrigation, electrification, and road infrastructure). Ironically, policy debates in the region seldom address whether similar public investments in customary tenure areas could generate even greater payoffs in terms of agricultural productivity growth and poverty reduction. Instead, rural poverty is increasingly being viewed as a problem to be addressed through social safety net, food assistance, and drought recovery programs.\(^23\) Increasing reluctance of ministries of agriculture to view poverty reduction as part of their mandate is consistent with land policies currently transferring land out of customary systems, where it is reserved for future generations of smallholder farmers, into private titled and state land.

\(^{23}\) Ironically, even programs explicitly created to reduce rural poverty are also often disproportionately captured by the rural non-poor (Morris et al 2007; Xu et al. 2009; Ricker-Gilbert et al. 2011; Banful 2011; Mason et al. 2011).
Widespread anecdotal evidence suggests that potentially the greatest threat to broad-based agricultural growth is the process of customary lands being sold or leased to a small but growing class of African elites. These processes of elite capture of the political process appear to be moving quite rapidly in a number of African countries. Before his assassination in 2003, the Economic Advisor to the President of Malawi, Kalonga Stambuli, wrote that:

I have seriously deplored the social injustice and economic marginalization associated with land conversion from communal tenure to leasehold tenure mostly enjoyed by the elite who also enjoyed a monopoly in the production of export crops. Most deplorable is the fact that the abundance of idle land among estates explains much of the low equilibrium trap to which our countries have been subjected. The economic hegemony of the agricultural elite was compounded by state enterprise expansion into the private sector, over-regulation, a stifling bureaucracy, and totalitarian politics. Inadequate amounts of land available to farmers remain a major constraint to supply response.24

These anecdotal reports are consistent with research pointing to the growing commodification and individualization of land in customary areas (e.g., Woodhouse 2003).

The growing focus on how best to exploit Africa’s unutilized land has arguably diverted attention from the more central and enduring challenge of implementing agricultural development strategies that effectively address the continent’s massive rural poverty and food insecurity problems, which require recognizing the growing land constraints faced by much of the rural population. It may be increasingly relevant to ask whether structural transformation processes may be retarded in situations in which the distribution of rural assets are so highly skewed that a large strata of the rural population may be unable to benefit from agricultural growth incentives that would otherwise generate broad-based growth multipliers. In most of the national household surveys from Africa reviewed in this paper, the distribution of land and other productive assets within the smallholder sector is at least as skewed as in much of Asia at the time of their Green Revolutions. Estimates of land concentration would certainly be worse if the authors accounted for the large-scale farm sectors in these countries.

The literature on growth linkages indicates that the first-round beneficiaries of agricultural growth generate important multiplier effects by increasing their expenditures on a range of local off-farm and non-farm activities that create second-round benefits for a wide-range of other households in the rural economy (Johnston and Mellor 1961; Mellor 1976). In much of Africa, the consumption growth linkages have been found to be especially important (Delgado and Minot 2000). The extent and magnitude of these second round effects depend on how broadly spread the first-round growth is. The initial distribution of land and other productive assets will clearly affect the size of these multipliers. If dynamic labor and services markets can be developed, then other employment opportunities should be easier to create in the very locations where the

24 Email from K. Stambuli to Professor Michael Weber, Michigan State University, February 13, 2003, subject: “Elitist Land and Agricultural Policies”.
larger smallholders are investing and raising their output and productivity. Pro-active public sector investment and policy support in developing these labor and service markets will be a key determinant of the magnitude of the growth linkages to be derived from agricultural growth.

Viewed in a static way, one could conclude that the only way out of poverty for the severely land-constrained rural poor is to increase their access to land. Viewed within a dynamic structural transformation framework, this group’s brightest prospect for escape from poverty will most likely involve being pulled off the farm into productive non-farm sectors. Farming will be increasingly unable to sustain the livelihoods of people born in rural areas without substantial shifts in labor from agriculture to non-farm sectors. Education, which played a crucial role in Asia by allowing households to exit agriculture into more lucrative off-farm jobs, is relatively low in most areas of rural Africa by world standards. Investments in rural education and communications are likely to become increasingly important to facilitate structural transformation.

Therefore, while greater equity in landholdings is important to kick-starting inclusive rural growth processes in the short- and medium run, an important long-run goal will be to pull the rural poor out of agriculture and into skilled off-farm jobs through investments and policies that support the processes of structural transformation.

Implications for development strategy

1. *African governments and international donors could greatly relieve Africa’s growing land problems (and related food security and poverty problems) by focusing on efforts to sustainably improve crop and animal productivity.* Closing the “yield gap” through productivity growth can relieve the severity of land pressures in densely populated areas and buy needed time for longer-run investments such as education and health improvements to enable more rural people to integrate into gainful off-farm employment. Higher food prices are likely to provide greater incentives for intensification of input use and contribute to yield growth. Peak oil projections may also fundamentally change the economics of global food production in ways that are difficult to predict with accuracy now.\(^{25}\) Despite skepticism in some quarters about the prospects for achieving smallholder-led development (Collier and Dercon 2009), this path has been the way out of hunger and poverty for much of Asia and, historically, most other areas of the world (Lipton 2005). Successful small farm intensification will also help to conserve the world’s remaining forestland and biodiversity. For all of these reasons, it would seemingly be in governments’ and donor agencies’ interests to redouble their efforts to support small farm productivity growth.

\(^{25}\) Peak Oil projections are based on the summation of individual producing nations’ petroleum production over time. In its *State of the World 2005*, Worldwatch Institute observes that oil production is in decline in 33 of the 48 largest oil-producing countries. See [http://en.wikipedia.org/wiki/Peak_oil](http://en.wikipedia.org/wiki/Peak_oil) for a review of over 150 reports.
2. **However, closing the yield gap will in many cases require a reallocation of public expenditures from price supports and input subsidies targeted to relatively large and capitalized farms to investments that can support productivity growth on one hectare farms.** While the long-term strategy is to effectively shift marginal farms out of agriculture and into productive non-farm jobs, this cannot happen by pushing farmers out of the sector; broad-based rural productivity growth will be required to pull households from the farm into non-agriculture. Hence the need to provide greater public funding for activities that can achieve productivity growth on one hectare farms. These include farmer extension programs that effectively transfer improved technologies and agronomic practices onto farmers’ fields: planting on time, the use of conservation tillage practices, scouting for appropriate use of herbicides and pesticides, right plant population, soil testing to identify the nutrients that need to be added back to the soil, appropriate fertilizer cocktails for addressing soil nutrient deficiencies, including lime where acidic soils lock up phosphorus, use of coated nitrogen to reduce leaching, improving soil structure and organic content, investing in drainage, and of course public investments to generate improved seed varieties. Widespread adoption of these practices will raise the response rates of fertilizer application and are necessary to meaningfully close the wide yield gaps observed in the region (Fischer, Byerlee and Edmeades 2009).

3. **Commission comprehensive land audits in each country:** Current land allocation decisions are being made in an information void. Very few, if any, African countries keep accessible databases on the amount of unutilized and underutilized arable land available in each country’s customary and state lands. Nor has there been any government report showing the amount of customary land that has been transferred into private title or leasehold tenure in the past several decades. A comprehensive and transparent land database would raise public awareness and provide the means to assess the costs and benefits of alternative approaches to guide future land policy decisions.

4. **Consider applying a land tax or user fees,** with the lowest (or zero) rates being put on farms under five hectares (which would exempt 90 percent of smallholder farms in most countries) or farms in customary lands, and a flat tax rate per hectare on farms over five hectares. Similar taxes could be considered for water use to support the efficient use of these scarce resources.

5. **Especially because land appears to a relatively abundant resource in many parts of Africa, an extensification strategy of pulling more land into productive use by the existing farm population that currently lack adequate access to land is likely to be part of the solution to addressing Africa’s food and hunger challenges.** In many parts of the region, governments may be able to improve access to land for rural households through a coordinated strategy of public goods and services to raise the economic value of customary land that is currently remote and under-utilized. This would involve investments in infrastructure and service provision designed to link currently isolated areas with existing road and rail infrastructure and through allied investment in schools, health care facilities, electrification and
water supply, and other public goods required to induce migration, settlement, and investment in these currently under-utilized areas. Such investments would also help to relieve population pressures in areas where the carrying capacity of the land has been exceeded. The approach of raising the economic value of land through public investments in physical and marketing infrastructure and service provision was pursued successfully by Southern Rhodesia and Zimbabwe starting in the 1960s with its “growth point” strategy in the Gokwe area, once cleared of the tsetse fly. Public investments in this once desolate but agro-ecologically productive area induced rapid migration into Gokwe from heavily populated rural areas, leading to the “white gold rush” of smallholder cotton production in the 1970s and 1980s (Govereh 1999).

6. **Input subsidy programs**, currently in vogue, could be more effective in reducing poverty while raising aggregate food supplies by explicitly targeting the 70 percent of smallholder farms under two hectares, where rural poverty is concentrated.

*Some areas for future research*

1. How are land-constrained farming systems evolving differently from more land-abundant farming systems? Is there evidence of changing relative factor prices and factor proportions in densely vs. sparsely smallholder production systems? How does this affect the programmatic implications for rural development and poverty reduction strategies?

2. Can the general equilibrium effects of intensifying land access problems in sub-Saharan Africa be quantified? For example, to what extent are urban migration and the attendant problems of slums, health and sanitation problems, congestion, etc., exacerbated by the new generation’s declining ability to access sufficient land to earn a livelihood in agriculture? To what extent do land access problems account for the growing emigration of young Africans from densely populated areas (e.g., Ethiopia, Kenya, Malawi) to the Middle East, South Africa, and Europe?

3. What kind of farming systems lie beyond the continuum defined by Boserup (1965), andBinswanger and Pingali (1998), where population density has reached not only the level required to induce sedentary agriculture, land intensification, and the substitution of capital and labor for scarce land, but where population density has continued to rise well beyond this point? How would a scenario of higher world food prices affect land intensification incentives and the potential supporting capacity of rural lands disaggregated by agro-ecological potential and market access conditions?
## Appendix 1

<table>
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<th>Period</th>
<th>Ethiopia</th>
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Biofuels, Rural Development, and the Changing Nature of Agricultural Demand

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Abstract

Policies promoting ethanol and biodiesel production and use in the U.S., Europe, and other parts of the world since the mid-2000s have had profound and largely unintended consequences on global food prices, agricultural land values, land acquisition, and food security in developing countries. They have also created regional opportunities in the form of agricultural investments, crop yield growth, and prosperous farm economies. This paper reviews the main policy initiatives behind the 21st century biofuels boom—with specific attention to renewable fuel mandates—and describes how these policies influence food price levels and stability in international and national markets. It also explores the implications of an expanding biofuels industry for development policy and food security in countries with persistently high rates of hunger, including virtually all sub-Saharan African countries and India. The paper ends by suggesting three themes surrounding the debate over crop-based biofuels: 1) the dominant role of uncertainty in energy and agricultural markets, especially in light of new energy investments, financial instability, and climate change; 2) the importance of government policies and well-developed supply chains as pre-requisites for profitable biofuel industries; and 3) the need to weigh opportunity costs to biofuels development in terms of fiscal expenditures, land and water resources, and political capital. These issues are particularly important for food insecure countries as they chart their development strategies for the future. Policies that appear promising for food and energy security at the macro-scale today might have major shortfalls for poor communities and households over the longer run if food availability, access, stability and nutrition are seriously compromised.
Biofuels, Rural Development, and the Changing Nature of Agricultural Demand

Many of the core lessons on food policy for low-income countries have endured since the early writings of Arthur Mosher (*Getting Agriculture Moving* 1966) and Timmer, Falcon and Pearson (*Food Policy Analysis* 1983). But two more recent trends have become defining features of the world food economy: globalization in trade and capital flows, and increased integration between the agriculture and energy sectors via the expansion of biofuels. Global and regional demands for food, animal feed, and fuel now play a dominant role in the behavior of agricultural commodity markets, contributing to rising food price levels and volatility since 2005. The burgeoning biofuel industry, in particular, is reshaping the nature of agricultural demand. What makes the 21st century biofuels boom an interesting topic for this volume is that it is propelled largely by U.S. and EU policies, which in turn stimulate new policy initiatives in developing countries. The questions for this chapter are: 1) What are the key policies behind the recent surge in biofuels production and use worldwide? 2) How does the expansion of biofuels affect agricultural markets, food prices, and food security on a global basis? And 3) What does a growing biofuels market mean specifically for development policy and food security in countries with persistently high rates of hunger, including virtually all sub-Saharan African countries and India?

The current commercial biofuels sector is comprised of ethanol and biodiesel produced from agricultural crops such as maize (corn), sugarcane, cassava, sorghum, rapeseed (canola), soybeans, and palm oil, and are commonly referred to as “first-generation” biofuels.¹ These liquid fuels are used mainly in the transportation sector. They are distinct from biomass fuels, which are comprised of renewable materials such as crop or forest residues, animal dung, and municipal solid wastes and are used widely in the developing world for regional or small-scale heating, cooking, and electricity.²

Liquid biofuel production has increased by more than five-fold since 2000 on a global scale, topping 100 billion liters (27 billion gallons) in 2010 (Figure 1). Ethanol accounts for most of the global total (86 billion liters or 22.4 billion gallons), but biodiesel production, at 19 billion liters (5 billion gallons) has also grown significantly in recent years. One of the most striking differences between the two fuels is that ethanol remains largely a story of the U.S. and Brazil—accounting for 57 percent and 33 percent of the global total, respectively, in 2010, while biodiesel is produced by numerous countries around the world. The large market shares of the U.S., Brazil, and the EU shown in

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¹ Recycled cooking oils and processed animal fats are also used as biodiesels. “Second generation” biofuels are derived from cellulosic residues (e.g., maize stover), fast-growing trees (e.g., poplar), or dedicated energy plants (e.g., switchgrass, elephant grass). “Third generation” biofuels are produced mainly from algal-based materials. At present, second- and third generation biofuels are in the development stage and are not yet economically viable at a commercial scale. See IEA 2011; Gerasimchuk et al. 2012.

² Renewable energy sources supplied 16.7 percent of global energy consumption overall in 2010, and biomass energy was half of the renewable total. Biomass comprises a much larger volume of energy than liquid biofuels, which provide only 2-3 percent of global road transport fuels today (REN21 2012; IEA 2011).
Figure 1 are indicative of major biofuels policy initiatives that have encouraged domestic investments and consumption.

**Figure 1: World biofuel production, 2000-2011**

![World Biofuel Production, 2000-2011](Figure1.png)


What these policies and the resulting growth in the biofuels sector imply for global food security and food policy is the central focus of this paper. By creating a substantial new layer of demand for crops for use as a transportation fuel, the development of first generation biofuels reduces the availability of crop production for human consumption and animal feeds in the absence of significant area expansion or productivity growth. In so doing, it also bolsters crop prices, farm revenues, land values, and farm wages. How biofuels affect food security via access, stability, and nutrition thus depends on the net production versus consumption status of households, the volatility of food prices, the transmission of prices from international to national and local markets, and the extent to which crop production for biofuels displaces local food production, particularly if the latter provides important nutritional benefits to households. At a macro scale, the development of biofuels can also affect food security through domestic investments in the rural sector, trade-offs in fiscal priorities with respect to other social developments (e.g.,...
education, health), and water and land allocations for large-scale biofuel estates versus smallholder agriculture.

The stakes of biofuels development for low-income countries are high given the potential impacts on food security. The chapter begins by reviewing the current policy incentives underpinning 21st century growth in ethanol and biodiesel production and consumption at the global scale, and then describes how these policies influence food price levels and stability in international and national markets. The final section explores how biofuels investments in developing countries might affect food security over both the short- and long-run, and identifies some areas of future study and focus for emerging food policy leaders in sub-Saharan Africa, South Asia, and other regions with high rates of hunger. The chapter highlights, but does not exhaustively review, the vast literature that has developed on biofuels during the past decade.

The political economy of the biofuels boom

The U.S. and the EU have led the global expansion of ethanol and biodiesel production, respectively, since 2005 (Figure 1). Other large countries in the world food economy, including Brazil, Argentina, China, Indonesia, and India, have also played a significant role. What are the political and economic motivations behind this growth? The most obvious explanation is that policies promoting biofuels production, particularly in the U.S. and EU, reflect a continued response to the process of structural transformation, defined by the declining relative share of agriculture in aggregate income and employment. More than a century of agricultural investments and policy incentives that opened frontiers, enhanced crop productivity, and generated growth in rural incomes and food supplies in the U.S. and Europe have resulted in surplus production and strong political constituencies formed around agricultural interests. Even with post-World War growth in agricultural trade, global grain prices trended downward (with some major spikes) over a 50-year period leading into the 21st century due to gains in crop production that exceeded increases in global demand (Figure 2). A long history of dual-purpose farm legislation has thus been established, in which production incentives and rural welfare goals go hand-in-hand (Kennedy 2007).

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3 For further discussion on structural transformation, see papers by Badiane and Timmer in this series.
Figure 2: Real wheat and maize prices, $US/MT, January 1970-February 2012

Declining real cereal prices helped to induce the development of the grain-fed livestock sector and the corn-fructose sweetener industry, and more recently the ethanol industry in the U.S. (Naylor and Falcon 2011). Enzyme production, distilling processes, and supply chains formed around the corn-fructose industry set the stage for corn-ethanol production, and distiller by-products from ethanol production for use in livestock feed became a key element of the sector’s profitability \( (\text{ibid}) \). Production gains in oilseed crops (rapeseed, soybean), combined with developments in co-products (meal-oil) and supply chains, also fostered growth in the biodiesel industry. Despite these market trends, however, the ethanol and biodiesel industries would not have flourished as they did since 2005 without strong policy incentives in the U.S. and EU. The objectives for supporting biofuels have been numerous and include, at the core, the desire to support rural economies and agricultural constituents. In addition, creating incentives for biofuels development has allowed governments to reduce direct subsidies to farmers, and as a result, to come closer to meeting the targets of the Uruguay and Doha Rounds of the World Trade Organization (WTO). But there have been few savings for government budgets. Direct agricultural subsidies have been replaced by biofuel tax credits and exemptions, and high and volatile food prices related to biofuels growth have led to additional government spending on consumer subsidies (e.g., the SNAP program in the U.S.) and farm insurance safety nets.\(^4\)

\[^4\] Expenditures on the USDA Supplemental Nutritional Assistance Program (SNAP) benefits more than doubled between 2007 and 2011, from about $30 billion to $72 billion. Almost two-thirds of the growth in spending on SNAP benefits between 2007 and 2011 stemmed from the increasing number of participants due to the economic recession; in 2011, one in seven Americans (roughly 45 million people) received...
Although rural revitalization offers one explanation for policies supporting the biofuels boom, it is certainly not the only one. Global economic growth has generated rapid increases in energy demand worldwide, particularly in emerging economies, and in turn to higher crude oil prices. The jump in crude oil prices from $60/barrel in mid-2005 to $140/barrel in mid-2008 certainly helped justify government expenditures on biofuel development at the time. In addition, dependence on foreign oil sources that are controlled by unstable governments, or on governments hostile to OECD (especially U.S.) interests, has encouraged a greater reliance on domestic sources of energy and on renewable energy. Investments in renewable energy have been supported further by commitments to curb greenhouse gas emissions (GHGs) in the face of global climate change. The extent to which biofuels policies result in GHG reductions remains hotly debated, however, particularly in light of agricultural land use change, intensive production practices on existing cropland, transportation requirements for liquid biofuels, and subsidies to energy companies that support biofuel and fossil fuel consumption. Legislation within the U.S. and EU has been implemented to address these issues directly, although accounting accurately for GHG emissions, particularly with respect to indirect land use change, is a difficult task.

U.S. biofuel policies

Policies surrounding the U.S. ethanol industry illustrate how these objectives played out between 2005 and 2012. The U.S. policy setting warrants special attention given the country’s dominant contribution to global biofuels production during the past decade and its large role in international agricultural markets, particularly maize and soy. Ethanol policies in the U.S. have taken three main forms: tax exemptions and credits, tariff protection, and mandates (Naylor and Falcon 2011). The first two have their origins in earlier legislation dating back to the 1970s and 1980s, but it is the third element—mandates—that are critical to the recent biofuel boom. Mandates for ethanol and biodiesel fall under the Renewable Fuels Standard (RFS), first established by Congress through the Energy Policy Act of 2005, and then bolstered through the Energy

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SNAP benefits. The rising cost of the SNAP program was also due to higher food prices. For more information, see: Congressional Budget Office, “The Supplemental Nutritional Assistance Program” (April 2012), http://www.cbo.gov/publication/43173 (Accessed July 10, 2012).

There is a large literature surrounding this debate. See, for example, de Gorter and Just (2007); Searchinger et al. (2008); Fargione et al. (2008); Campbell et al. (2009); Tilman et al. (2009); Loarie et al. (2011); and Gerasimchuk et al. (2012).

Indirect land use change (ILUC) is the change in land use induced by commodity price movements related to biofuels production, within or outside of the country where the biofuels are produced. For further information on modeling efforts, see USDA (2011).

In 2009-10, the U.S. accounted for over one-third of global maize and soy production, and for almost half of world exports in both commodities. See FAOSTAT: http://faostat.fao.org/.

The tax and tariff policies are defined under the Renewable Fuels Reinvestment Act of 2010 and were phased out completely on December 31, 2011. They included a $0.45/gallon blender credit (volumetric excise tax credit), a $0.54/gallon tariff on imported ethanol, and a 2.5 percent ad valorem tariff (Naylor and Falcon 2011). Also included was a $1.00/gallon blending tax credit on biodiesel established initially under the American Jobs Creation Act of 2004, which provided a tax credit regardless of biodiesel source (domestic or foreign) or amount (up to 99.9 percent biodiesel blend) (de Gorter et al. 2011).
Independence and Security Act of 2007. The RFS currently requires that the amount of conventional (corn- or other first generation)\(^9\) ethanol used in gasoline blends in the U.S. reach a minimum target of 15 billion gallons by 2015, and that advanced biofuels (made from agricultural, cellulosic, and algal materials) reach a minimum of 21 billion gallons by 2022 (Figure 3). Within the advanced biofuel mandate, at least 1 billion gallons must be comprised of biodiesel (made largely from soy oil), and a small but rising share must come from non-cellulosic fuels that include, by definition, sugar-based ethanol. The RFS mandates, which are enforced through the Environmental Protection Agency (EPA), also have a greenhouse gas stipulation: conventional biofuels satisfying the 15 billion gallon target must be 20 percent lower in GHGs than petroleum-based transportation fuels, and advanced biofuels must be up to 50 percent lower for non-cellulosic material and 60 percent lower for cellulosic material than gasoline and diesel (calculated through a life-cycle analysis).\(^{10}\) Corn-based ethanol produced in modern natural gas fired plants already meets the first criterion, and sugar-based ethanol from Brazil meets the advance fuel target of 50 percent GHG reductions.

**Figure 3: U.S. renewable fuels mandates**

![Graph](image)


On the consumption side, a key policy measure encouraging the use of ethanol in the U.S. was the phase-out of MTBE (methyl tertiary butyl ether) as a gasoline additive in 2005 due to environmental and health risks. Ethanol quickly emerged as the preferred MTBE substitute as part of a 90%/10% (E10) gasoline blend, and as a result, the demand for

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\(^9\) Maize and corn are used interchangeably throughout this paper; because “corn” is a word widely used in the U.S., it is used predominantly when discussing the U.S. ethanol sector.

\(^{10}\) For further information on the RFS see: [http://www.epa.gov/otaq/fuels/renewablefuels/index.htm](http://www.epa.gov/otaq/fuels/renewablefuels/index.htm) (accessed June 21, 2012).
ethanol became tightly linked to growth in transportation fuel demand overall. Herein lies the opportunity for, but also the constraint on, future expansion of corn-based ethanol. Presently, Americans consume about 135 billion gallons of gasoline per year (IEA 2012), and thus the amount of ethanol consumed in E10 blends is 13.5 billion gallons—close to the conventional fuel mandate (Figure 3). Without setting a blending mandate above E10 (e.g., at E15 or higher) the U.S. ethanol industry faces a ceiling on demand, commonly known as the “blending wall”. In 2011, the U.S. exported over 1 billion gallons of ethanol, over one-third of which went to Brazil—historically the world’s leading ethanol producer and exporter. Ironically, because there are limited domestic supplies of advanced biofuels to meet the current RFS mandate, the U.S. also imported ethanol from Brazil!

In order to circumvent these types of inefficiencies, the EPA has three options. First, the agency has the authority to waive one or more sub-mandates depending on potentially harmful economic or environmental outcomes. Waivers are possible, for example, if the projected volume of cellulosic biofuel production is inadequate to meet the mandate or if a major disruption in biodiesel feedstock production is likely to cause fuel prices to rise above acceptable levels. According to current legislation, corn-based ethanol cannot fill the gap for advanced biofuels, although this regulation could change in the future if advanced biofuels remain commercially unviable. The second option is that the EPA can expand its system of mandate compliance certificates (referred to as Renewable Identification Numbers, or RINs), which allows for the banking and trading of renewable fuels compliance among energy refiners over space and time. Finally, in June 2012 the EPA provided final approval for the use of E15 blends in gasoline for all cars and light trucks manufactured since 2001. Although E15 is not yet generally available at pumping stations, this policy measure will likely expand the demand for corn-based

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11 The blending arrangement has been particularly important for the pricing and profitability of ethanol. Ethanol contains only about two-thirds the energy (BTUs) of gasoline. To be competitive as a direct energy source, its per gallon price must therefore be two-thirds the cost of gasoline.

12 In practice, the current blending wall in the U.S. is below 13 billion gallons, because infrastructure and other constraints prevent 10 percent blending in all gasoline. Although some E85 pumps exist, the volume of use is small. Most of the residual ethanol production in the U.S. is exported. For further details, see Abbott et al. (2011).


14 Under the Energy Independence and Security Act of 2007 (EISA) and the preceding Energy Policy Act of 2005, the EPA Administrator, in consultation with the U.S. Secretary of Agriculture, may waive individual biofuels mandates if “the implication of the requirement would severely harm the economy or environment” (http://www.farmdocdaily.illinois.edu/2011/09/epa_mandate waivers_create_new_1.html, accessed June 22, 2012).

15 For further information on RINs see McPhail et al. (2011) and Farmdoc Daily: http://www.farmdocdaily.illinois.edu/2012/03/is_the_ethanol_mandate_truly_a.html (accessed June 22, 2012).

16 Ethanol blends above E10 can erode catalytic converters, especially in older car models, because ethanol burns hotter than gasoline. To avoid this barrier on ethanol demand, the EPA approved in October 2010 the use of E15 for cars and light trucks manufactured after 2007, and in January 2011 approved an extension for vehicles made since 2001. The latest approval ensures that E15 will not be mislabeled and will thus comply with the Clean Air Act (see http://www.epa.gov/otaq/regs/fuels/additive/e15/, accessed June 22, 2012).
ethanol in the U.S. beyond the current 15 billion gallon target. Whether or not EPA waivers will allow conventional ethanol to meet a larger share the total RFS mandate in the future is a key question for the industry’s growth, and in turn for agricultural commodity markets.

**International policy initiatives: the rising role of mandates**

Like the U.S., Brazil and the EU also adhere to mandates as a guiding policy tool. Brazil developed its sugar-ethanol sector early on with public support through direct budgetary spending, subsidized credit, tax relief, and provision of government-owned assets (especially land and water) at below-market value. With these early investments and abundant land resources, Brazil has been able to attract foreign investment for its biofuels industry, and to establish a well-integrated sector with flex fuel cars since 2003 (Schmidhuber 2007; Valdez 2011a,b; Rabobank 2012). Brazil eliminated its import tariffs in 2007 and has reduced its use of tax exemptions for ethanol blending and exports; however, it still relies on subsidized credit for sugar planting and for ethanol refining and storage (Gerasimchuk et al. 2012). More importantly, it uses an aggressive set of mandates, set at E20-25 and B5,\(^\text{17}\) to ensure a market for its expanding sugar and ethanol output. It has been difficult for Brazil to meet its ethanol mandates with domestic supplies in recent years, however, because international sugar prices have escalated and spiked several times since 2009, creating incentives to shift the use of sugar from fuel to food production and exports (Barros 2011). In addition, domestic sugar yields have been afflicted by adverse climate. In 2010-11, Brazil imported almost 400 million gallons of ethanol from the U.S. and cut its exports. To meet mandates in the future, Brazil is expanding its sugarcane production into the cerrado (grassland) region—a move that is effectively pushing soybean production up into the Amazon and creating tradeoffs with environmental objectives related to biodiversity protection and GHG emissions (Loarie et al. 2011). By expanding its sugar and ethanol production targets, Brazil is also positioning itself to capture a greater share of the U.S. market given the composition of RFS mandates and the elimination of ethanol import tariffs in the U.S. in December 2011.\(^\text{18}\)

The EU has similarly transformed its policy approach, from an earlier emphasis on tax and trade incentives and indicative consumption targets to a more recent focus on blending mandates (Kutas et al. 2007; Swinbank 2009; Blandford et al. 2011). In 2009, the EU passed legislation through its Renewable Energy Directive (RED) that required 10 percent of all transportation fuel to come from renewable resources by 2020 (EU 2009; Flach et al. 2011). Implementation of the EU mandate is in the hands of individual member states, most of which now have legislation in place to meet the targets. A key issue related to the EU directive is the sourcing of feedstocks to meet its mandate via biofuels according to its sustainability criteria. These criteria require that biofuels use under the mandate lead to a 35 percent reduction in GHG emissions relative to fossil fuel

\(^{17}\) A blending mandate of E20 implies 20 percent ethanol and 80 percent gasoline. For B5, the target is 5 percent biodiesel blended with 95 percent fossil fuel diesel.

\(^{18}\) Sugar ethanol qualifies as an advanced non-cellulosic fuel in the RFS (Figure 3).
sources (gasoline and diesel) upon implementation, and that the reduction in GHGs be
toscaled to 50 percent for existing plants by 2017 and 60 percent for new installations. The
directive also provides a double mandate credit for the use of second-generation biofuels,
and restricts the use of palm and soy oils due to their direct and indirect impacts on
tropical deforestation. The use of biodiesel from rapeseed is expected to account for most
of the RED mandate in the near term, and electric cars are anticipated to play an
increasing role over time.\textsuperscript{19}

Beyond these core production regions, over 50 other countries also support biofuels
currently through some combination of tax incentives, trade protection, and blending
mandates (IEA 2011). The global cost these biofuels subsidies, calculated on the basis of
direct budgetary spending, tax relief, and import duties, and indirect market price transfer
was estimated at $22 billion in 2010 (IEA 2011; Gerasimchuk et al. 2012). Mandates, in
particular, have become the preferred instrument of support as a result of worsening
public sector deficits worldwide.\textsuperscript{20} The rising use of mandates worldwide has transferred
the burden of costs from governments to consumers through fuel and food markets. But
mandates still come at a high cost to many governments, especially in countries where
public investments are required to develop agricultural supply chains or refining and
transportation infrastructure in order to meet the targets. Moreover, if mandates are set
sufficiently high (e.g., at blending rates of 10 percent or more), they have the potential to
_distort prices more than conventional subsidies or tariffs and can thus have a significant
impact on food security.

\section*{Agriculture-energy linkages}

Biofuel subsidies and blending mandates have created a tighter connection between
energy and agricultural markets, with major implications for global food prices. Energy
has always been an important input into agricultural production, particularly in more
advanced systems where nitrogen fertilizers and machinery are widely used and where
transportation plays a major role in tradable inputs and outputs in the farm sector (as
reviewed in Naylor 1996). However, agriculture-energy market linkages have become
stronger in recent years as evidenced by high correlations for monthly prices of crude oil
and key biofuel feedstocks (Abbott et al. 2008, 2009, 2011).\textsuperscript{21} What do these connections
imply for both the level and stability of food prices as the demand for transportation fuel
continues to grow, especially in emerging economies?

\textsuperscript{19} In 2010, the EU biofuels sector was comprised of 80 percent biodiesel and 20 percent ethanol (Flach et
al. 2011).

\textsuperscript{20} For more information on specific mandates and targets throughout the world, see IEA 2011.

\textsuperscript{21} For example, the correlation between maize and crude oil prices was insignificant (r=0.12) between
1980-2005 and rose to 0.77 between 2006-2011 when the U.S. introduced its renewable fuels standard
(author’s calculations based on crude oil prices from the U.S. Energy Information Administration, see
prices were from the USDA National Agricultural Statistics QuickStats online database:
To answer this question, there are three key points to keep in mind. First, the size of the energy sector is vastly greater than the size of the biofuels sector, and as a result, energy prices have a direct affect on biofuel production but not vice versa. Second, the profitability of ethanol and biodiesel production is a function of crude oil and diesel prices (which determine the amount and type of fuel demanded), the price of natural gas (for refining ethanol and as a competitive fossil fuel in energy use), and the price of biofuel feedstocks (Cassman et al. 2006; Schmidhuber 2007). With mandates for biofuel consumption, agricultural commodities used as feedstocks tend to fluctuate between a floor price determined by the mandated demand, and a ceiling price above which biofuel refining is no longer profitable (also known as the “parity price” or the breakeven price for biofuel producers). Feedstocks typically account for 50-80 percent of variable costs in biofuels production, and therefore an endogenous cap on crop prices is set by the profitability criteria of the biofuels sector (Schmidhuber 2007; Mitchell 2010). Finally, alternations in the price of agricultural commodities used as feedstocks, such as maize and rapeseed, influence prices of other crops that are used as substitution in production and consumption at local to global scales. Given these relationships, it is not surprising that agriculture and energy prices have moved together, as have major agricultural commodity prices since 2006.22

The tight linkage between agriculture and energy prices introduces substantial uncertainty into the biofuels market, and into agricultural markets on which biofuels depend. Petroleum prices have historically been more volatile than the prices of agricultural commodities used as feedstocks (Naylor and Falcon 2010); large swings in energy prices can thus lead to major fluctuations in biofuel demand when the mandate is not binding. Recent experience in the U.S. raises additional questions about energy price volatility. Natural gas prices in the U.S. have plummeted since 2008 with rapid development and deployment of horizontal drilling and fracking technologies for shale gas (Greenstone et al. 2012). The gap between crude oil and natural gas prices has been increasing since the beginning of 2009, but this trend is unstable. During the 12-month period from the beginning of July 2011-2012, the price of light crude oil fluctuated from under $80/barrel and to over $110/barrel.23 Declining natural gas prices have helped to lower costs of ethanol refining, but ethanol’s competitive edge as a transportation fuel will be diminished if crude oil prices, which are strongly correlated with gasoline prices, were to remain under $80/barrel. Moreover, if natural gas-based transportation infrastructure is widely developed in the U.S. in response to rising natural gas supplies and declining prices, investments in new ethanol-based technologies such as flex-fuel cars or E85 fleets could be crowded out.24

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22 The correlation between crude oil prices and selected agricultural prices (maize, wheat, and soy) for the period 2006-2011 was above 0.7 for all three commodities. The correlations between commodities over the time period were 0.87 for maize-soy, 0.77 for wheat-soy, and 0.73 for maize-wheat (author’s calculations based on IMF financial statistics deflated by IMF U.S. GDP deflator, 2005=100).

23 These prices are for light crude WTI (West Texas Intermediate). Brent crude has similarly fluctuated within a higher range, peaking at almost $130/barrel in March 2012 and then falling by more than 30 percent to $88/barrel in June 2012. See www.oil-price.net (accessed July 10, 2012).

24 The replacement of oil for natural gas in transportation fleets can occur with: 1) the conversion of natural gas to methanol, an alcohol with similar properties to ethanol; 2) the use of compressed natural gas (CNG)
The major state of flux in energy and agricultural commodity prices in the first half of 2012 is indicative of the type of market uncertainty that is likely to prevail in the years ahead. One could easily imagine a different scenario, in which crude oil prices were to soar due to political disruptions in the Middle East (e.g., the blockage of the Strait of Hormuz). In the absence of widespread natural gas technology or other transportation fuel alternatives, such an event would cause the demand for biofuels to shoot up and stay on a perfectly elastic course; that is, at a constant (high) price despite continued growth in supply. This sort of reliance on biofuels—particularly first generation biofuels—would have serious implications for agricultural demand and food prices. How large the shock would be, and how long it would last, are highly uncertain.

**Biofuel mandates and crop prices**

A more predictable scenario is that the implementation of mandates for first generation biofuels will lead to high and volatile prices for key feedstock commodities irrespective of political disruptions. Rapid growth in the biofuels sector since the turn of the century has broken the long-term downward trend in real agricultural prices that was caused mainly by surplus production in advanced economies. Much of this surplus is now being taken up directly or indirectly through the mandated use of biofuels. Enforced mandates essentially create an additional and inelastic level of demand for crops used as feedstocks, up to the point where the mandate is binding (Figure 4). With this new demand, any supply shock (e.g., drought) will be amplified in the market, causing a larger price hike than would be the case without the mandate. Moreover, if agricultural stocks decline as a result of the expansion in biofuel mandates, price spikes will be even higher.

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in light- to medium-duty vehicles using existing engine technologies; and 3) the use of CNG or liquefied natural gas (LNG) in medium- to heavy duty vehicles. For more information, see Knittel (2012).
Figure 4: Biofuels mandates create an added and inelastic level of demand for agricultural commodities used as feedstocks*

* Adapted from Abbott et al. (2009)

Growth in the U.S. corn ethanol market, spurred largely by mandates, illustrates this point (Naylor and Falcon 2011; Hertel and Beckman 2012). Between 2000 and 2010, U.S. corn ethanol production grew by a factor of eight, and by the end of this period, 40 percent of domestic corn consumption went to the ethanol industry—surpassing use in animal feeds for the first time on record. Domestic stocks-to-use for corn fell to 14 percent in the beginning of 2012, far below the levels for soy (22 percent) and wheat (31 percent). Low stock levels have fueled expectations in commodity markets associated with speculative and, more important, non-speculative activity (Wright 2011). As a result, corn prices have been highly volatile since 2006 and rising in real terms despite continued growth in corn production. Allocating a greater share of corn to ethanol has played a key role in international price movements, amplifying shocks caused by climate and China’s recent entry into global corn market. Extreme heat and drought throughout the U.S. in 2012, coupled with low stock levels and ethanol mandates, has driven corn prices to an unprecedented peak, highlighting once again this pattern of volatility (Babcock 2012).

26 Given the short time series by which to test the interaction between energy and agricultural price volatility in the recent biofuels era, Hertel and Beckman (2012) apply stochastic simulation techniques and use a general equilibrium model, GTAP (Global Trade Analysis Project), to assess the global economic impacts of the U.S. renewable fuels mandate and blending wall.
Price transmission and price-income effects

Understanding the food security implications of a global agricultural system linked to energy markets requires both macro- and micro- analyses. At the macro level, fluctuations in international agricultural prices affect food producers and consumers within any country only to the extent that prices are transmitted from global to domestic and local scales. Price transmission depends on a country’s exchange rate (which in turn is a function of its macro-economic policy and financial capital flows), its trade policy, and transportation costs (Naylor and Falcon 2010). Relative to three decades ago when Food Policy Analysis was first published (Timmer, Falcon, and Pearson 1983), the magnitude and rate of global capital flows have exploded, and the majority of countries have transitioned from fixed exchange rates to some sort of flexible exchange rate regime. Trade policies have also changed course. Progress on opening agricultural trade through the WTO has proceeded slowly, and during the past decade, many developing countries have sought to insulate their domestic economies from global food price volatility. Several African nations have resorted once again to government-run marketing boards (Jayne et al. 2010a), and other countries throughout the world have implemented a variety of tariffs and quantitative controls in an attempt to protect domestic agricultural producers or consumers (Naylor and Falcon 2008; Martin and Anderson 2012). Unfortunately, policies aimed at stabilizing domestic markets typically result in greater instability in international markets, particularly when such policies are implemented by countries that account for a large share of global trade (Timmer 2009; Timmer 2010; Naylor and Falcon 2010; Martin and Anderson 2012).

Transportation costs have also factored into trade strategies. Global freight costs have been relatively high and volatile since the mid-2000s due to fluctuations in crude oil markets. In addition, poor infrastructure and high fuel costs in many developing countries have resulted in wide CIF (import) and FOB (export) price bands that effectively insulate domestic markets and stifle governments’ ability to drive food policy off of their trade policy (Timmer, Falcon and Pearson 1983; Naylor and Falcon 2010). Generalizations about price transmission across countries do not come easy. But understanding domestic price dynamics is key for assessing economic behavior at the household and firm levels in response to the expansion in global biofuels.

At the micro level, a set of own-price, cross-price, and income effects characterize the nature of food security outcomes with respect to changes in agricultural commodity prices. In addition, growth in the biofuels sector affects factor markets, as evidenced most clearly through changes in land values. Following from the U.S. ethanol discussion above, these price and income effects can be traced through an analysis of the corn market. Corn is often considered to be a lynchpin commodity in the world food system because of its multiple end uses in food, feed, fructose, and fuel, and because of its substitutability with other commodities in these end uses (Naylor and Falcon 2011). In an era of high prices, low-income households that are dependent on corn as a primary staple food either eat less or allocate more of their incomes to food and away from other

27 Government attempts to stabilize domestic prices for key staple crops in sub-Saharan Africa have not succeeded, particularly when the role of the private sector has been subordinated (Jayne et al. 2010a, b).
Since food comprises up to 80 percent (and sometimes more) of household expenditures for the world’s poorest households, a jump in staple food prices can have a devastating effect on nutrition, especially for girls and women who are fed last in many cultures when food supplies are short. Corn is a primary staple in eastern and southern Africa and in Central America, and most of the poorest households are net consumers (Jayne et al. 2010b; Naylor and Falcon 2010). Their ability to substitute into other low valued food commodities is limited, and thus price hikes for corn often translate directly into increased hunger.

Because corn is used as feed, fructose, and fuel in the global economy, a variety of cross-price responses also occur when corn prices rise. On the demand side, livestock producers and feed companies substitute away from corn and into wheat and other substitute ingredients. Ethanol blenders and food processors dependent on fructose (e.g., the soft drink industry) similarly adjust their inputs to use sugar over corn at certain price ratios. On the supply side, higher expected prices for corn linked to RFS mandates induce area expansion and investments in technology, inputs, and capital that are reflected in yield gains over time (Box 1). These partial-equilibrium dynamics become much more complicated in the real world when supply chains, macro prices (exchange rates and interest rates), trade policies, biophysical and nutrient constraints, factor markets, and financial markets come into play. As a result, computable general equilibrium (CGE) models have been developed to assess the economy-wide impacts of biofuels. The bottom line with both approaches is that rising prices for corn due to the expansion of the ethanol industry have far-reaching effects on other agricultural commodity markets through substitutions in production and consumption, and on rural incomes and assets. Similar analyses could be done for other first generation biofuel systems, such as rapeseed-based biodiesel in the EU and its affects on the global vegetable oils market, or sugar-based ethanol in Brazil and its effects on land and labor markets.

**Box 1: Direct and indirect effects of biofuels growth - the U.S. corn-ethanol case**

Growth in first generation biofuels alters prices of staple food crops through direct and indirect channels, as illustrated by the hypothetical example of U.S. corn-ethanol (Figure B-1). Creating a new level of demand for corn as an energy crop leads to price increases for corn, wheat, and soy in the short run in the absence of significant yield growth or crop area expansion. The ripple effects are seen in pristine land areas cleared for agriculture (e.g., conservation land in the U.S. or rainforests in Brazil), on the livestock sector, and on consumers of these staple food commodities—and they depend importantly on yield growth.

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28 The theoretical foundation of this behavior is based on the Slutsky equation (which shows that the own-price response is a function of a pure substitution and an income response), and Timmer’s Law (which shows that poor households are affected more than wealthier households by staple price increases because their budget shares for food are higher). See Timmer, Falcon, and Pearson (1983).

29 There is a wide body of literature focused on economic assessments of biofuels using computable general equilibrium models, which is reviewed only partially in this chapter. For a broader review of the CGE studies, see Timilsina et al. (2012) and Zivin and Perloff (2012).

30 Adapted from Naylor et al. (2007).
responses to rising prices over time. The magnitude of impact depends on adjustments in grain, oilseed, and livestock markets, and on price transmission domestically and internationally.

The food security implications of biofuels expansion must be considered in the context of food-feed-fuel linkages. Corn designated for ethanol in the U.S. returns roughly 30 percent of its volume to the livestock (mainly cattle and dairy) sector. Distiller grains are thus important by-products of the ethanol industry, contributing 15-20 percent of total revenue from ethanol processing. Similar livestock feed by-products are produced from other forms of ethanol and biodiesel production worldwide. If these by-products are ignored in the analysis of biofuels, the implications for price consequences will be overstated, and the profitability of the biofuel sector will be understated (Taheripour et al. 2010).

Figure B-1. Dynamics of a biofuels-induced increase in demand for corn in the US

Notes: Y-axis = price; x-axis = quantity. D = demand curve; S = supply curve. Panel (1) – rising demand for corn leads to growth in supply along the curve that includes production at higher marginal costs. Panel (2) – longer run shift in supply due to technical change induced by higher prices. Panel (3) – higher corn prices increase demand for wheat in livestock markets, causing wheat prices to rise. Panel (4) – greater area sown to maize reduces area planted to soy, causing soy prices to rise.

31 Approximately 40 percent of ethanol plants in the U.S. produce wet distiller grains and 60 percent produce dry distiller grains. For more information on the role of by-products for livestock feeds, see Taheripour et al. (2010), Mitchell (2010), and Naylor and Falcon (2011).
Factor market effects

The rising demand for agricultural crops for food, feed and fuel has caused land to become an increasingly scarce factor of production at national and global scales. Over the short term, rising land scarcity and limited supply chains servicing land that is available suggests more inelastic agricultural supply (Abbott et al. 2011). The agricultural sector is unique relative to other sectors of the economy (with the exception of forestry) in its fundamental dependence on land. Creating additional value from agriculture through its use as fuel is thus reflected in greater marginal returns to land and higher land values, both for land dedicated to feedstock crops and for land planted with substitute crops. With well-functioning land markets, marginal returns to land are equated across crops, raising land values across the board (ibid.). In the U.S., for example, higher corn prices have been capitalized into high farmland values that mirror the record-breaking farm real estate spike of the early 1980s (Duffy 2011).32

Several CGE models have been developed to capture the effects of biofuels growth on land markets (as reviewed in Timilsina et al. 2012). These models differ in their treatment of crop yields, biofuels feedstocks and policies, land use, and trade, but generally show increased land values over the longer run. Yield growth in response to higher commodity prices and land values is critical to keeping land use change in check over the longer run (ibid.).33 However, as Lobell points out in his paper for this series, ensuring future growth in crop yields will become increasingly challenging in the face of global climate change.

Using recent history as a gauge, biofuels are likely to have a major impact on global land use. Abbott et al. (2011) show that farmers have responded to the new agricultural demand since 2005/2006 by bringing new land into production, and by shifting away from crops that are not directly or indirectly related to the biofuels sector and into high-demand crops (Figure 5). For 13 of the world’s major food crops, harvested area increased by 38 million hectares (three percent of current global agricultural land use) between 2005/6 and 2010/11. Only 30 percent of this land came from crop substitution, and 70 percent resulted from new area expansion. The major first-generation biofuels crops and their substitutes in staple food production and consumption accounted for most of the growth (sugar was not included as a staple food). In the U.S., land area for major food crops has remained fairly constant since 2005; most of the growth in corn area has come from substituting out of other crops and out of land dedicated to conservation. By

32 Farm real estate values in the U.S. corn-belt rose from an average of $2500/acre in 2005 to $3500/acre in 2010 (with the top state, Illinois, surpassing $4000/acre). These values are almost identical to the highest values recorded during the 1980 land value spike in the U.S. (Farmdoc.com). The difference between the two periods is that interest rates in the current period have been hovering close to zero, reinforcing the fact that land is an excellent investment in the U.S., especially with expected high returns stemming from the RFS mandates.

33 The CGE model developed by Timilsina et al. (2012) uses an explicit land use module and detailed biofuel sectors and targets for countries throughout the world; it suggests significant reductions in pasture and forest land by 2020 in some key countries, but only moderate price increases for food commodities (with the exception of sugar) due to yield responses over time.
contrast, sub-Saharan Africa has experienced widespread acquisitions of undeveloped land during the past decade, a topic that is discussed further in the following section.

**Figure 5: Change in global harvested area for 13 major food crops (2005/6 to 2010/11)**

![Chart showing change in global harvested area for 13 major food crops](image)

Source: FAS (2011) USDA FS&D online database

Source: Abbott et al. (2011)

The increased value of agricultural production related to biofuels also feeds back to higher wage rates in agricultural production and processing, with potential spillovers to other sectors of the economy depending on the size of the biofuel industry (Ewing and Msangi 2009). For example, wages in the sugarcane and ethanol industries in Brazil have risen with the expansion of ethanol over the past few decades (Smeets et al. 2008), as have human development indicators in regions where sugar and ethanol processing have become major activities (Martinelli et al. 2011). The degree to which agricultural commodity prices influence rural wages, and in turn poverty alleviation and food security in the developing world depends on the share of agriculture and biofuels processing in the region’s economy, labor mobility, employment conditions and contracts, and the rate of food price increase affecting inflation-adjusted earnings and food access for low-income households. Although biofuels growth can enhance rural incomes, it can also decrease food supplies and access for the poor (Rosegrant et al. 2008; Timilsina et al. 2012).

**Biofuels development in food insecure countries**

There are clearly pros and cons to biofuel expansion in countries that have persistently high rates of hunger, virtually all of which are agrarian economies. On the one hand, high and volatile prices hurt low-income net consumers in rural and urban areas who spend the
majority of their income on food. In addition, high agricultural prices in international markets create fiscal challenges for governments in net grain and oilseed importing countries. On the other hand, developing a domestic biofuels sector can help countries achieve greater energy security, and can promote rural development, agricultural employment, and income growth. The main problems with an agricultural development strategy based on domestic biofuels growth are: 1) it can displace crop production for direct food consumption; 2) it can increase local food prices and land values, and induce speculative activity in domestic land markets (“land grabs”); and 3) it can create opportunity costs with respect to development spending on alternative objectives such as health and education, and it can alter current account balances with wide-reaching macroeconomic effects (Arndt et al. 2010; Mitchell 2010).

Any welfare assessment of biofuels in food insecure countries should thus consider both micro- and macroeconomic aspects of development, and clearly identify the strategy of development that is being pursued. Mitchell (2010) outlines three distinct phases of biofuel development in low-income countries, each of which requires different levels of policy support, institutional capacity, trade activity, and regulatory oversight. The first phase entails the production of agricultural feedstocks for export and for limited use in local transportation and small-scale stationary energy uses. For example, countries might invest in sugar production for export to ethanol refiners, or in jatropha production for export as straight (unprocessed) vegetable oil (SVO) for the biodiesel industry or for local energy use. Projects at this stage are focused mainly on export crop promotion, rural income enhancement, and seasonal risk management of incomes; however, such projects might impose tradeoffs in local resource use (land, water, nutrients) with food crops for domestic consumption. The second phase of development revolves around the production and export of processed biofuels, with the aim of filling gaps in renewable fuels mandates in other countries, and taking advantage of preferential trade access that might be available to U.S., EU, and other markets. A portion of the biofuels production, most likely in the E5-10 and B5 range, might also be allocated to domestic fuel use. Projects at this stage require more direct involvement of the private sector and more thorough development of supply chains, fuel quality regulation, and infrastructure than in the case above. The third stage includes the production and retail sale of biofuels for domestic transportation use at larger scale, and requires significant institutional capacity, infrastructure development, and government support. In order to promote domestic fuel security and rural agricultural investments, the blending target might be set at E85 and B85 depending on domestic resource availability.

How do these different strategies play out in terms of food security and rural income growth? Arndt et al. (2010) present a useful framework for evaluating biofuels projects in developing countries, with a specific eye on sub-Saharan Africa (Table 1). Starting at the household level, the consequences of biofuels development on human welfare depend on trade-offs between feedstock and food production, seasonal income earning opportunities for families engaged in the biofuel sector, and household labor allocation—particularly for women who dominate the farm sector and play a pivotal role in household food production (UNDP 2012; Arndt et al. 2012). At the farm or firm level, successful investments in biofuel feedstock and refining activities depend on production costs
(including the value of family or hired labor), seasonal labor requirements and constraints, market profitability, international competitiveness, and price volatility. These variables, in turn, are a function of infrastructure, supply chain development, and agricultural policy.

### Table 1: Framework for evaluating biofuels investments

<table>
<thead>
<tr>
<th>Level of analysis</th>
<th>Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household</td>
<td>Income, poverty, labor allocation, and food security</td>
</tr>
<tr>
<td>Farm or Firm</td>
<td>Production costs, international competitiveness, Profitability, price volatility</td>
</tr>
<tr>
<td>Macroeconomic</td>
<td>Taxes, public investments, and fiscal balances, Employment, resources, and growth linkages</td>
</tr>
<tr>
<td>Environment</td>
<td>Water use, wildlife corridors, GHG emissions</td>
</tr>
</tbody>
</table>

Source: Adapted from Arndt et al. (2010)

Moving from the micro- to the macro-level, interest rates, exchange rates, and factor mobility (labor, credit) play a key role in the success of biofuels investments, as do public investments in infrastructure (e.g., roads and ports), fiscal policy (tax exemptions and budget balances), and trade agreements. For example, attracting international investments in the biofuels industry is likely to entail large public sector investments, as well as tax exemptions on fuels and exports—all of which could deplete government revenues that might otherwise be used for the smallholder agriculture sector, domestic water infrastructure, health clinics, and other development priorities. Finally, at the local to national scale, the ability to meet land and water requirements is critical for the success of biofuels development. How access rights are designed and enforced for land and water use have major implications for production capacity and income distribution. Moreover, the structure and enforcement of wildlife corridors and environmental regulations (e.g., water pollution from refining, air pollution from burning) are important for human health, ecosystems, and tourism revenues. Given these wide-ranging consequences for human welfare, government budgets, and the environment, strategies to promote rural development and energy security through the biofuels industry must be analyzed with great care, particularly for food insecure countries.

**Biofuels development in sub-Saharan Africa**

The biofuels sector may be an attractive target for development in sub-Saharan Africa for several reasons. There are large untapped land holdings available for further agricultural development throughout the continent, and there is a desire by many countries to promote export crops for foreign exchange earnings. More generally, the biofuels sector provides

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34 Fiscal balances are an important component of the welfare outcome. In many countries, transportation fuel is taxed heavily and adds to government revenue, but biofuels investors often demand tax exemptions for blending and distributing fuel, as has been the case in the U.S.
an opportunity to enhance agricultural investments and develop supply chains for rural income growth and improved food security. It also provides an avenue for countries to meet their large and rising fuel needs. Much of sub-Saharan Africa remains energy insecure for transportation, cooking, lighting, heating and cooling, and production activities (Nussbaumer et al. 2012). Fuel prices throughout the continent are roughly double those in other competitive regions (and even higher for landlocked countries), and the demand for transportation fuel is expected to grow by more than 5 percent per annum through 2020 with continued population and income growth (Mitchell 2010).

Several African countries have adopted biofuels blending targets or mandates, and provide subsidies at different stages in the value chain (IEA 2011; Gerasimchuk et al. 2012). There are a wide variety of crops that can be used for biofuels in the region, including sugar (cane and molasses), maize, cassava, sweet sorghum, jatropha, castor beans, and palm oil. Some of these crops, especially maize and cassava, have large tradeoffs with food consumption and are not widely used as fuels. The two leading biofuel feedstocks in the region are molasses and jatropha, neither of which is a staple food commodity (jatropha is toxic for human consumption). Africa has a long history of sugar production with supply chains already in place in several countries, and investments in sugar-based ethanol benefit from decades of technological development in Brazil. Sugar tends to be a water-intensive crop, however, which limits production and imposes major opportunity costs with respect to staple food production given that less than five percent of agriculture in sub-Saharan Africa is currently irrigated. Jatropha, on the other hand, can be grown under marginal, drought-prone conditions by smallholders. The drawbacks are that there is no history of crop breeding in jatropha, very little experience in jatropha-based biodiesel production, and no human consumption value to the crop if the fuel market fails. Moreover, although the crop can be grown under marginal conditions, yields are substantially higher when fertilizers, irrigation, and other inputs are used (Ewing and Msangi 2009; Altenburg 2011). Labor requirements for jatropha production are also very high because the seeds ripen throughout the year and need to be picked by hand. As a result, labor availability and costs are often the major constraint on growth of the jatropha industry (Mitchell 2010).

The implications of biofuels development for food security in sub-Saharan Africa revolve around a few key issues. First, the level of government support needed to attract foreign investments for commercial-scale growth in feedstock and biofuel production often involves commitments to build infrastructure and provide tax exemptions or subsidies that diminish budget revenues for other development priorities that might enhance food security. A related issue is that large-scale expansion of feedstocks requires land and water, which raises a series of thorny questions about property rights and access to resources. Much of the unoccupied land on the continent is state-owned, and individual countries have different statutes related to customary land rights and the ability to own or lease real property on crown land. The ambiguity in and high potential value of land

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35 Molasses is one of the lowest-cost commodities that can be used as an export or in domestic production of ethanol, but it is not as high yielding as sugarcane. The latter has higher trade-offs as a food commodity and also higher production costs. See Mitchell (2010) for further details on production practices and costs of alternative feedstocks and biofuels in Africa.
ownership has led to widespread land acquisitions (also referred to as “land grabs”) by foreign companies, global financial companies trading land-based assets, and individuals within and outside of Africa who see land as a lucrative investment—especially since other financial investments have lost value since 2008 (Kugelman and Levenstein 2012). The International Land Coalition estimates that over 31 million ha of land was sold in sub-Saharan Africa between 2000 and 2011; the largest regional purchaser was Asia (38%), followed by Africa and Europe (each ~20%) and North America (~10%).

During the past five years, the main targeted use for this acquired land (~40%) has been biofuels (Schoneveld (CIFOR) 2010), although only a portion has been cultivated to date. There is clearly a speculative component to land transactions in Africa that differs from the more structural factors influencing land market sales in the U.S. and other fully developed agricultural systems. How these land acquisitions affect smallholder production in Africa—and particularly the ability of poor households to secure land assets, water, and other inputs such as fertilizer relative to larger landholders coming into the region—is a critical factor influencing food security in the region (as discussed in the paper by Jayne et al. in this series).

Despite the focus on land acquisitions in sub-Saharan Africa, there are many opportunities for smallholders to engage in biofuel activities, either as outgrowers selling their product to a central processing firm, or as employees on larger estates. In some locations, farmers also lease their land to biofuel producers, or grow and process small amounts of oil from jatropha or other oil seeds such as castor beans for small-scale local use. There are several case studies of biofuel operations in eastern and southern Africa showing the outcomes of various value chain arrangements (see for example, Ewing and Msangi 2009; Mitchell 2010; Arndt et al. 2010; Negash and Swinnen 2012). In virtually all cases, these operations are foreign owned, and they either employ agricultural workers or have some sort of contracting arrangement with smallholders. The latter can provide additional income on a year-round basis and thus reduce seasonal risks of income loss; they can also lead to the creation of supply chains that have positive spillover effects on local staple crop systems (Negash and Swinnen 2012). One of the main lessons from these studies, however, is that supply chains are commonly the limiting factor for success. It is often difficult to achieve sufficient expansion for economies of scale, and the ability of outgrowers to remain profitable is frequently constrained by their lack of credit and other inputs (Mitchell 2010). Although government support is usually strong for these projects, the institutional capacity is often insufficient to manage risks, ensure stable prices, and enhance smallholder productivity. But the industry is at a nascent stage, and some of these constraints could be overcome in the future.

**Biofuels development in India**

Like sub-Saharan Africa, India continues to experience widespread food and energy insecurity despite rapid income growth. In order to encourage the production and use of

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37 For a discussion on the structural features of U.S. farmland values, see Gloy et al. (2011).
renewable fuels as the demand for transportation fuel escalates, the Government of India approved a National Biofuels Policy in December 2009 (Aradhney 2011). This policy establishes an indicative blending target of 20 percent for both ethanol and biodiesel by 2017—it is suggestive (not a hard mandate) because the country has struggled to supply sufficient feedstocks to meet its target in the past (ibid.). The policy also includes a suite of support prices for feedstocks and biofuels, as well as various tax exemptions. Given the state of food insecurity in India (as discussed by Binswanger and Banziger in this series), the aim of the policy is to develop non-edible feedstocks—mainly sugar and jatropha and other native tree-based oilseeds.

Despite good intentions, the country faces some major challenges in meeting its biofuels targets over the next five years. India is the world’s second largest sugar producer after Brazil (Aradhney 2011), but its production has been highly volatile during the past two decades (Landes 2010). Sugar production is dominated by small-scale producers who often have limited access to inputs and thus variable yields. Land ownership laws in the country prevent vertical integration (e.g., refining mills cannot own land or invest directly in feedstock production), and prices offered by blenders are often too low to cover feedstock production costs. At the same time, the sugar industry (and the molasses sub-industry) is heavily regulated, with government controls on prices, mill capacity, domestic consumption, and trade. The combination of production volatility and widespread inefficiencies in the sector has limited India’s ability to meet its ethanol targets to date (Raju et al. 2009). Moreover, the share of sugar area that is irrigated is between 90-100 percent in most regions where it is grown (Landes 2010), which raises serious questions about the allocation of scarce water supplies for fuel versus food. If sugar remains the target feedstock for ethanol production in the future, its drain on available water resources could have large impacts on the nation’s food security, particularly in light of climate change (see Lobell’s paper in this series).

In addition, growth in India’s biodiesel sector has been dependent in the past on imported soy and palm oil from Southeast Asia and South America, which has implications for the country’s foreign exchange reserves, as well as for tropical deforestation and climate change. Foreign investments are now being encouraged to support domestic jatropha production as a feedstock. However, most of the production is occurring under marginal conditions, and as in the Africa case, producers experience poor yields, low prices, and high labor costs. It is unlikely that jatropha will become cost-competitive with fossil diesel or imported vegetable oils in the future. As a result, the prospects for commercial jatropha-based biodiesel to generate rural economic growth and improve food security are limited.

Finally, and perhaps most important, the National Biofuels Policy was approved at the federal level, but it must be implemented at the state level. Political and institutional

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38 Jatropha is also commonly planted as a boundary hedge crop to protect crops and prevent soil erosion, which provides modest additional income to farmers without tradeoffs to agriculture and livestock systems. More dispersed plantings of jatropha in forest systems or along rail lines have not contributed much to feedstock production, because even very poor households find the labor requirements too high and the returns too low to collect the seeds (Altenburg 2011).
conditions vary highly among states, as do socioeconomic variables and the nature of biofuel value chains (Altenburg 2011). Individual states also have different norms and goals surrounding the biofuels sector, varying sets of favored constituencies, and distinct realms of political power and organization. These factors result in a wide array of prices and tax structures, and complications in interstate trade of feedstocks and biofuels (ibid.). At the federal level, regulatory oversight of the biofuels industry is complex, involving at least five ministries (Raju 2009; Evans 2010). India’s success in meeting its renewable fuel targets through first generation biofuels—to say nothing about enhancing rural incomes and food security—hinges in large part on resolving these inconsistencies between state and federal directives. Even if they were resolved, the complicated socio-political context underpinning biofuel activities at the state level is still likely to constrain biofuel expansion in the future (Altenburg 2011).

Conclusion

The wide range of food security and policy issues reviewed in this paper suggest that the global expansion of liquid biofuels (ethanol and biodiesel) is indeed changing the nature of agricultural demand and rural development. Three main themes emerge from the chapter. The first theme surrounds the issue of uncertainty that dominates any discussion of future biofuels growth. Given the tight linkages between the agriculture and energy sectors, the realm of uncertainty is vast. It includes, for example, fluctuating trends in energy supplies and prices, particularly in light of natural gas investments in the U.S. and political tensions in the Middle East; uncertainties in global financial systems, economic growth, and energy demand; unclear trajectories for the commercial viability of advanced (second and third generation) biofuels; and extreme heat waves and droughts that cause crop prices—and hence first-generation biofuel feedstock prices—to spike. Volatility in crop and energy prices creates additional uncertainties in the policy domain. In the case of the U.S., the world’s largest biofuel producer and supplier of grains to the international market, such volatility could lead to important changes in renewable fuel mandates, blending requirements, waivers, and regulations on biofuel production—all of which would affect global food prices and food security.

The second main theme relates more specifically to government policies and the development of supply chains that such policies have supported. One of the key lessons from the U.S. ethanol and EU biodiesel examples is that there is no such thing as a “clean slate” when it comes to agricultural policy. Biofuel subsidies and mandates have created new price dynamics in international grain and vegetable oil markets, but they follow from an already distorted global food economy that has been characterized by subsidized production, surplus dumping, and high levels of trade protection in many industrialized countries. The downward trend in real prices that dominated international agricultural markets during the second half of the 20th century—viewed by many analysts as the leading disincentive for global agricultural investment in developing countries—was reversed in the first decade of the 21st century with rapid growth in biofuel demand (Swinnen 2011). Whether this shift is good or bad for global food security remains hotly contested and depends largely on the time frame of analysis and assumptions on
agricultural investments and yield growth in response to changes in crop prices. But one underlying condition is clear: the 21st century biofuel boom would not have occurred without substantial government subsidies and without the prior existence of supply chains that could support the ethanol and biodiesel sectors in the U.S., EU, and Brazil. In particular, policies that led to the emergence of strong private sector involvement in the agricultural and energy sectors were critical for the successful development of biofuel industries that were capable of capturing potential economies of scale.

The third and final theme draws on these points and addresses the question: Given the uncertainties and public sector costs surrounding the development of liquid biofuels, should developing countries facing high rates of food and energy insecurity invest in the industry? There is no universal answer to this question; each country must evaluate its own economic and resource situation, and its institutional capacity. This evaluation must be done with skill and great care, because the stakes for rural development, hunger, resource depletion, and inequality are high. Adopting a strategy for biofuel growth as a means of stimulating the agricultural economy, addressing domestic transportation fuel needs, and enhancing foreign exchange reserves will require the creation of well-functioning supply chains that can generate economies of scale. To date, small isolated plants with new sources of feedstocks (e.g., jatropha) have thus far been too costly. Public investments in agricultural productivity and infrastructure, as well as fuel mandates and tax exemptions for private companies that are needed to build supply chains and ensure long-run demand for biofuels, will have large opportunity costs in terms of fiscal expenditures, land and water resources, and political capital.

Arguably the most prominent opportunity cost related to biofuels development is the trade-off with domestic food supplies that support local and regional markets. This trade off involves land and water resources as well as labor allocation. In many cases, the reallocation of family land, domestic water supplies, and women’s labor (which constitutes the majority of agricultural labor in sub-Saharan Africa) from food crops into biofuel feedstocks leads to a reduction in household food production and deteriorating health for family members. The sum of losses at the micro-level could thus erode well-intentioned development targets at the macro-scale. Increased biofuel production and improved food security will be a very delicate marriage for most developing countries. There are already many signs—highlighted by worsening resource inequality in several nations—that the marriage may not be blissful and lasting.
References


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Core literature on Biofuels, Rural Development, and the Changing Nature of Agricultural Demand


This paper provides technical details and economic analysis of the modern crop-based biofuels boom in its early stages of growth. Written by an interdisciplinary team of scholars from Stanford University and the University of Nebraska, it explores the food security and environmental dimensions of the biofuels industry around four case studies: U.S. maize production for domestic ethanol; Chinese cassava imports for domestic ethanol; expansion of Brazilian sugarcane and soy for global ethanol and biodiesel; and Indonesian palm oil growth for global biodiesel. The paper also provides analyses of cellulosic biofuels potential, and of energy yields and greenhouse gas mitigation potential of leading biofuels. Although the biofuels industry has continued to develop since the publication of this piece, it provides a solid framework for evaluating food security and environmental impacts of the sector.


Also published at the early stage of 21st century biofuel expansion, this paper provides a European perspective on the implications of crop-based ethanol and biodiesel for agricultural markets, prices and food security. The paper is written by a senior economist at FAO and covers both the theoretical and empirical aspects of agriculture-energy linkages via biofuels. It is particularly useful in describing the process of price transmission and how renewable fuel mandates and energy prices can create a floor and ceiling price for biofuels feedstocks. The economic analysis throughout this report is excellent.


This series of economic reports written for the Farm Foundation by Philip Abbott, Christopher Hurt, and Wallace Tyner at Purdue University provide a comprehensive overview of how the biofuels sector—and the U.S. ethanol industry in particular—have
affected international food prices and land markets since the turn of the century. The reports discuss biofuels in a broader context of factors influencing the dynamics of the world food economy, including agricultural stock adjustments, feed demand, macroeconomic policy and exchange rates, and speculation. The reports provide excellent economic analyses of the issues at a basic level that does not require advanced modeling skills. The Farm Foundation series is thus a “go to” location for up-to-date analyses and insights on biofuels and agricultural markets.


This series of papers by Rosamond Naylor and Walter Falcon at Stanford University’s Center on Food Security and the Environment (FSE) provides a sequential analysis of the chaotic nature of global food markets since the early period of the 21st century biofuels era. The first paper describes the 2008 global food crisis, when energy and agricultural prices spiked, causing food riots and agricultural trade restrictions. It is followed by a more in-depth economic analysis of the subsequent drop in prices and ensuing volatility caused by the global financial crash. The third paper discusses the continuing role of U.S. ethanol policy in influencing food price levels and variability throughout this period. The collection of papers is useful in presenting a political economy perspective and providing specific details about policy changes in industrialized and developing countries that accentuate volatility stemming from the biofuels sector. The 2010 piece, in particular, provides a comprehensive economic analysis of food price volatility and its impacts on global food security, moving from international markets to local markets in poor countries.


This paper provides an excellent grounding for understanding the potential economy-wide impacts of biofuels growth on developing economies. It outlines the key energy-agriculture linkages that affect economic growth and food security, and discusses the policy context of biofuel development. The paper is most useful in its construction of an economic framework that provides the intuition for general equilibrium modeling. The authors have subsequently contributed to a series of biofuels papers based on computable general equilibrium (CGE) model analysis (cited in references).

This report by Donald Mitchell at the World Bank represents the “book” on biofuels in Africa. In addition to providing a general understanding of the issues (which is synthesized beautifully in the beginning of the report), it provides detailed analyses on feedstock and biofuel production costs, global and regional demand for biofuels, biofuel policies, and excellent case studies from an African context. The report also provides selected demographic and sectoral data for African countries and is filled with interesting figures and information boxes.