Structural Transformation, the Changing Role of Rice, and Food Security in Asia: Small Farmers and Modern Supply Chains

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INTRODUCTION

Food security is not a viable social objective unless it is also a profitable undertaking for input suppliers, farmers, and marketers of output. Consumers must then be able to afford to purchase food, secure in the knowledge that it is safe and nutritious (Reardon and Timmer 2007). Achieving food security within these constraints of a complex economic system is a challenge because both poor consumers and small farmers must be effective participants.

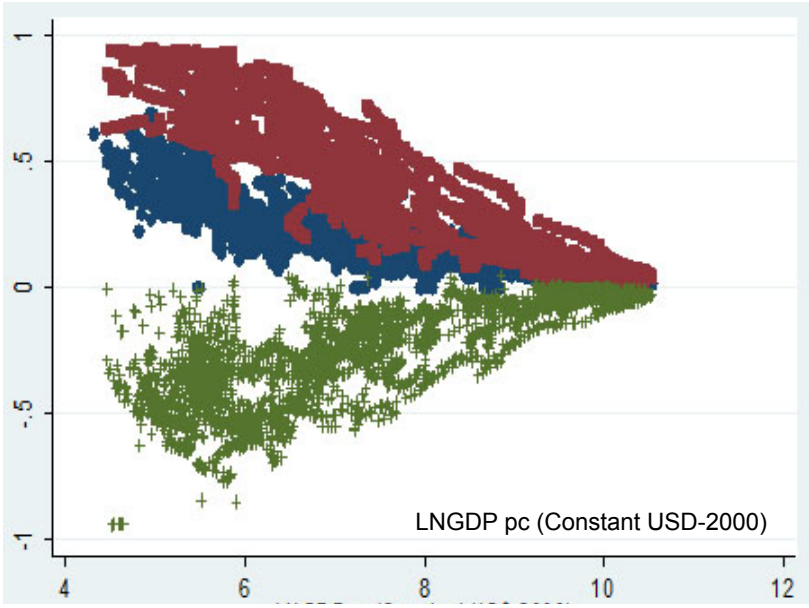
This paper aims to set this challenging task in the context of the long-run dynamic evolution of food systems, especially the rice-based systems in Asia. The emphasis is on both "long-run" and "dynamic" because the Asian food economy has very deep historical roots (and accompanying resistance to change); at the same time it is changing extremely rapidly, driven by the pace of economic growth and technological innovation. It is a very fast-moving target. A robust analytical framework with deep historical roots is needed to put it clearly in focus.

The structural transformation of an economy during the long-run process of economic growth is the appropriate analytical framework for this task (see Figure 1). Rising productivity in the agriculture sector stimulates overall economic growth, which then leads to the relative decline of agriculture in both the gross domestic product (GDP) and the labor force (Timmer 2009). The apparent paradox has quite real ramifications. Many countries have mistaken the relative decline of agriculture in successfully growing economies as a signal to ignore the sector and starve it of investment resources and policy attention (Timmer 1988, 2002). The subsequent costs have been very high: stagnation and worsening poverty. History tells us that the *only* sustainable pathway out of poverty is higher agricultural productivity coupled with a dynamic non-agricultural economy—a structural transformation. It is a general equilibrium process intimately linked to what is going on in the rest of the economy. As China's Chairman Mao once put it, "the only way out for agriculture is industry."

There are four basic patterns to a successful structural transformation and these have been remarkably uniform across more than two centuries of modern economic growth:

1. A declining share of agriculture in value added in the economy (share of GDP) and employment (share of the labor force);
2. A commensurate rise in the share of urban/industrial/modern service activities;
3. Migration of rural workers to urban settings;

Figure 1. Structural transformation in 86 countries from 1965–2000



4. A demographic transition with rapidly falling mortality rates, slowly falling fertility rates, and a subsequent period of rapid population growth, which offers a "demographic bonus" when dependency rates drop to low levels for several decades.

The basic cause and effect of the structural transformation is the rising productivity of agricultural labor. Labor productivity in agriculture can be raised in three basic ways:

1. Use new technology to produce more output for a given amount of labor.
2. Let agricultural workers migrate to other occupations without lowering output, thus, sharing the output with fewer rural people (the classic Lewis model of development).
3. Have higher prices for agricultural output (make it worth more in real economic terms, which may well be happening in the current economic era, but is a reversal of historical trends).

There are also stresses on the poor during the structural transformation. Even when absolute poverty is falling, as it typically does during rapid economic growth, the distribution of income—especially between rural and urban areas—usually worsens, challenging policymakers to take corrective actions. Such actions—agricultural protection and widespread subsidies to farmers—often worsen urban and rural poverty because most of the poor must purchase their food. A dynamic rural economy stimulated by genuine growth in productivity is pro-poor in all circumstances. In contrast, a rural economy with farm profits stimulated by protection tends to hurt the poor in both the short and long-run. Many are left in pockets of poverty.

Why should Asia have these pockets of rural poverty when most of the rest of their economies are highly dynamic? At a meeting last year sponsored by the Bill and Melinda Gates Foundation to address the issue of lagging

regions, three basic hypotheses were advanced as explanations:

1. Lagging regions have poor connections to the surrounding dynamism because of *geographic isolation* and *poor infrastructure*.
2. Lagging regions suffer from *behavioral isolation* due to cultural or ethnic reasons.
3. Lagging regions have *poor governance*, which keeps key public goods from being provided.[1]

Of course, determining that any one of these reasons is the "answer" for why rural poverty persists just pushes the question deeper. Why? Fundamental answers are likely to lie in the realm of political economy, not just economics.

These deeper questions require two others to be first asked: Where have we come from (historically and structurally)? Where are we headed in terms of the future structure and dynamics of the food system?

The brief answer is that the Asian food system has been shaped over the past half century or so by (1) a broad political mandate in Asia to feed both urban and rural populations (a mandate not seen as clearly in much of Africa); (2) a technological revolution in rice and wheat coupled with (reasonably) good policies and public investments in rural infrastructure to make this mandate (largely) possible; and (3) rapid inclusive economic growth resulting largely from (1) and (2), which gave (most) Asian households access to food in their fields and markets. The structural transformation has been driven by these processes (and the changing role of rice in the economy). Asia is now richer, more urban, better connected both within each country and across borders, and it is much better fed.

These changes have dramatic implications on the role of rice in Asia's food security:

1. Rice is increasingly becoming the food of the poor. This has significant implications for poverty if countries use "high" rice prices as a mechanism to guarantee "macro" food security (often equated with stable rice prices in key urban markets) and a high level of self-sufficiency in rice.

2. The share of rice in caloric (energy) intake is falling rapidly.
   - Asia now has a strongly negative income elasticity of demand for rice.
   - Rapid rural to urban migration lowers quite sharply per capita rice consumption.
   - Better connected food systems mean that rural households can be less self-sufficient in food production and consumption, especially rice.
   - On the average, Asia obtained about 40 percent of calories from rice in the early 1970s at the peak impact of the Green Revolution; that share is now below 30 percent and falling.
   - The budget share spent on rice is falling even faster. Now, only 10 percent of the food budget goes to rice (on the average—it is higher for the poor), so 90 percent of the food budget is spent on other commodities and value added from processing and convenience.

3. Following the changing patterns of rice consumption, the share of rice in agricultural output and in the overall economy is also falling rapidly.

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1 This particular rationale is the subject of an extensive research and training program being proposed by the Crawford School of Economics and Government at the Australian National University.

A Framework For Understanding Food Security

This historical lesson opens a wide door for policymakers to use the modernizing potential of new technologies to integrate three areas of connected concern—the *sustainability* of agricultural practices that form the foundation of *food security*, both of which must be compatible with the long-run process of *income convergence*, a process that integrates both rural and urban economies as well as poor and non-poor households (especially in rural areas through the enlargement of farm size) (see Figure 2). Technology is the key integrator of these three arenas because it facilitates sustainability through yield growth rather than area expansion, raises productivity and marketed surpluses as farm sizes increase, and affects all three determinants of farm income—area, yield, and price of output—during the process of income convergence.[2]

Connecting Short-run to Long-run and Macro to Micro

The triangular objectives in Figure 2—sustainability, food security, and higher incomes for the rural poor—need to be put within a policy framework. Especially when a long-run perspective is needed because of the structural transformation, having an organizing framework is useful to understand how the essential components of food security relate to each other. In what is otherwise an extremely complicated food system, this framework should be as simple as possible (but no simpler, to quote Albert Einstein). The framework used here divides the world into issues facing policymakers in the short-run (1–2 years) versus the long-run (5–10 years or longer), and at the macro, economy-wide level versus at the household or individual level (see Figure 3).

The policy objective in this simple framework is the same as in Figure 3—for all households to have reliable and sustainable access to nutritious and healthy food. Thus, the triangular objectives are achieved by ending up in the bottom right box of the matrix. The starting point, however, is the upper left box of the matrix, where policymakers deal primarily with macro-level issues in the short-run. To the extent they are concerned about the welfare of poor households, in the short-run, the best they can do is to stabilize food prices and send transfer payments—via safety net mechanisms—to those households most affected during a food crisis when prices rise sharply.

In an ideal world, policymakers could use economic mechanisms under their control to shift households directly to the long-run objective (the lower right box where sustainable food security is achieved). In return, policymakers would receive political support for this achievement, hence, the two-way diagonal arrow connecting the upper left and lower right boxes. The diagonal arrow reflects a technocratic view of the world where policymakers take informed actions on behalf of public objectives and are rewarded when they succeed.

In fact, market economies—and politics—do not work that way. Policymakers at the macro level must implement long-run measures to

2 An important debate is going on in food security and agricultural development circles over the sustainability of modern, high-input agriculture, especially the energy intensity of those inputs. Historically, agricultural technologies have reflected the factor price environment in which they were developed—high labor costs lead to mechanization, high land costs lead to yield-enhancing innovations (Hayami and Ruttan 1985). High energy costs are likely to lead to energy-saving technologies, although it is unclear how to fix nitrogen without using a lot of external energy. Urea, for example, is just a solid form of atmospheric nitrogen made with natural gas and electricity.

Figure 2. Three objectives during the structural transformation

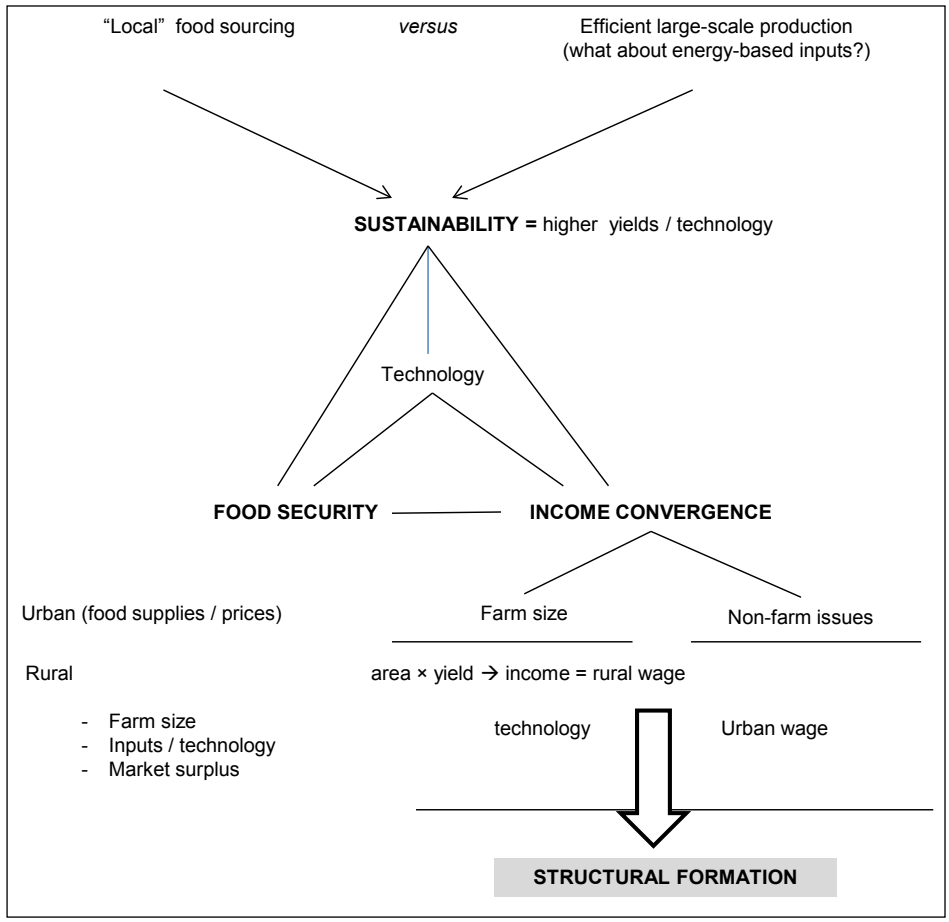
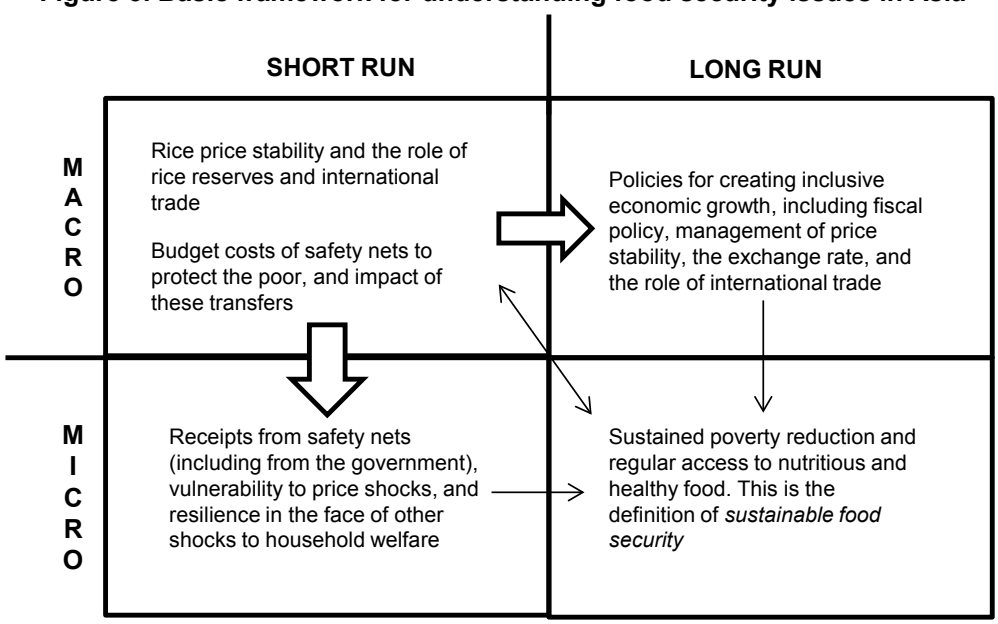


Figure 3. Basic framework for understanding food security issues in Asia



stimulate inclusive, pro-poor economic growth and sustain that growth for decades in order to have a measurable impact on poverty (via the small vertical arrow connecting the upper right box to the lower right box). These long-run measures are reflected in the broad horizontal arrow from the upper left to the upper right. It is hard, however, to concentrate the political and financial resources needed to make this arrow an effective mechanism to stimulate economic growth if most policy attention and fiscal resources are being devoted to short-run crises.

Simultaneously, albeit creating tensions for policies favoring long-run growth, policymakers must also find enough resources and efficient transfer mechanisms to ensure that the poor do not fall into irreversible poverty traps during times of economic crisis, including food crises. These transfers can impose substantial fiscal costs and hence challenge the necessary investments for long-run growth. Design and implementation of these transfers involve human and political capital that also has real opportunity costs to the growth process. Thus, a focus on the broad downward arrow is necessary to ensure the continued viability and participation of poor households, although these activities have opportunity costs in terms of economic growth.

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; 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. 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 country has then managed the "escape from hunger" that Fogel documented for Europe and America in the late 18th and early 19th centuries, and which a number of Asian countries have managed in the 20th century (Fogel 1991, 1994; Timmer 2004, 2005a).

By contrast, a world of heightened instability—in global finance and the world food economy—forces policymakers to concentrate resources in the upper left box in their attempt to stabilize domestic food prices and keep the poor from slipping deeper, irreversibly, into poverty. Important as it is, this effort clearly comes at the expense of significant progress out of the short-run box on the upper left, both to the right and from top to bottom. From this perspective, instability is a serious impediment to achieving long-run food security. In a world of greater instability—induced by climate change, new financial arrangements, and even pressures from new political voices—food security is likely to suffer.

How can this be fixed? Any successful approach will need to recognize that Asia's food marketing system is being transformed right now, as modern supply chains and supermarkets change the nature of farm-market-consumer interactions (Reardon 2010). Further complicating the analysis, climate change really does seem upon us, with greatly increased uncertainty about weather patterns and corresponding increases in instability of production. Both the spread of modern supply chains and climate-induced production instability have the potential to be a real problem for food security.

The Dynamics of Modern Food Supply Chains in Asia

The changing food marketing system influences food security in Asia in direct and indirect ways. The analysis here builds on the "10-wheeler" framework developed by Reardon (2010) as an operational model for connecting policy concerns about food security (and the changing role of rice) to the rapid dynamics of modern food supply chains (see Figure 4). Much is impressionistic and speculative in this discussion, as the hard data from recent surveys are still being analyzed or have not even been collected. Nevertheless, enough is known to lay out the basic story.

Food security in Asia has traditionally been defined as having stable prices for rice in the major urban markets of a country. The large Asian countries, especially China, India, and Indonesia, had to rely primarily on domestic production to achieve this goal. The world market was only used as an instrument at the margin, with imports and exports controlled by government authorities tasked to defend stable prices (Timmer 1996). That approach to food security made sense when a third of the economy was dependent on rice production, marketing, and consumption as well as when well over half of daily caloric intake in many Asian countries came from rice. Policy discussions on food security focused almost entirely on rice production—the second "wheel" on the left of Figure 4.

Except for a few important exceptions (for example, Bangladesh and Vietnam still get about half their calories from rice), that world no longer exists. Indeed, the contribution of rice to total caloric intake in Asia has dropped from its peak in the 1970s of almost 40 percent to less

Figure 4. Modernizing food supply chains in Asia: The "10-wheeler" model

	Rice Economy (Starchy staples)	**Non-rice Commodities** (Fruits and vegetables, meat/ dairy, processed foods, wheat)
Farm inputs/supplies	Smaller area possible Higher yields; stress tolerance Consumer quality	More value/hectare, but what role for small farmers? (what "assets" do they need to stay in?)
Farm production (management and knowledge)	Very knowledge intensive for good management practices; Access to inputs by farm size	Knowledge intensive; can there be effective extension for new technologies? Role of farm assets
Procurement/logistics and wholesalers	Less rural consumption as workers leave; more transportation and storage; greater production instability with climate change	High transaction costs of dealing with small farmers; issues of quality control and product traceability
Processing and value added	Milling technology How to add value; branding	Large share of consumer food expenditure is spent in this box
Retail/consumer welfare and health dimensions	Supermarkets as suppliers of rice? Increased price stability through private actions? Problems of access by the poor?	Modern supply chains are funneling consumers back up the system. The food system is less supply driven.

than 30 percent currently (see Table 1). Yet the mindset still exists; most discussions on food security in Asia even in 2011 still focused on rice (Timmer 2010a). It is time to update that mindset, and the other components in Figure 4 are a good starting point.

Part of the updating requires a clearer recognition of who consumes rice. Increasingly, rice is consumed by the poor, who usually must buy most of their rice in rural and urban markets. Almost by definition, having a surplus of rice to sell to the market raises a family above the poverty line in most Asian countries.[3] This reality makes rice more, not less, important to food security in Asia. On the other hand, it also makes a mockery of most Asian countries' strategy of keeping rice prices stable by keeping them high, well above long-run levels in world markets.

When *food security* is equated with *food self-sufficiency*, this strategy may make sense, because it is easier to stabilize domestic food prices using domestic production—stimulated by high prices—than to follow and depend on the world market for rice, with its great price volatility. But this strategy forces poor consumers to pay high prices for rice, thus, increasing considerably the degree of poverty in a country (Warr 2011). Self-sufficiency in rice is a political strategy, not a poverty strategy. If countries were more open to rice trade, they would be richer, not poorer. The big question is how to make such openness possible when policymakers and the general public distrust the world rice market, for reasons that are easy to understand (Timmer 2010b).

Consumers in Asia get about 30 percent of their calories from rice and 70 percent from other commodities, increasingly from animal products, fruits and vegetables, and wheat products. On the average, they spend only 10 percent of their food budget on rice (although the figure is roughly double for the poor), which means that 90 percent of food expenditures are for non-rice commodities and for the value added to those commodities beyond the farm. Modern supply chains produce that value added at the same time that they coordinate the transactions, investments, and technologies that generate it.

Increasingly, modern supply chains are transmitting demand signals from consumers who shop in supermarkets back up the food system, level by level, to processors, farmers,

Table 1. Changing role of rice in food consumption in Asia

Year	Total Calories	Calories from Rice	Rice as % of Total
1961	1805	656	36.3
1970	2069	790	38.2
1980	2200	797	36.2
1990	2443	848	34.7
2000	2606	803	30.8
2007	2668	783	29.3
	Average Annual	**% Increase or (Decrease)**	
1961–1970	1.53	2.09	0.57
1961–1990	1.05	0.89	(0.25)
1970–2007	0.69	(0.03)	(0.71)
1990–2007	0.52	(0.47)	(1.00)

Source: Data from FAO Food Balance Sheets
Note: Calories-daily per capita energy available

3 Many rice surplus farmers in China may still be officially classified as poor and higher farm prices would probably reduce poverty in the country. In the rest of Asia, higher rice prices seem to raise poverty significantly (Timmer 2005b).

and input suppliers. Traditionally, each cell in the food system depicted in Figure 4 was connected locally by small traders operating with minimal capital and primitive technology (Reardon and Timmer 2007). Modern supply chains are far more integrated into the farm-level procurement systems of supermarkets and are coordinated by these firms as they seek to "drive costs out of the system."

Three important trends emerge from the "10-wheeler" perspective when it is overlaid with changing food consumption patterns in Asia. First, the vertical boxes are increasingly connected by market and non-market forces. One key conclusion for technology suppliers in the private sector is that there can be no effective demand for inputs unless farmers are able to sell surpluses into the market. This market is increasingly controlled by procurement officers for supermarket chains, and their tendency to consolidate suppliers may counter the effort by governments seeking to include small farmers. On the other hand, successful efforts to reduce the transaction costs of incorporating small farmers into modern supply chains may simultaneously pay dividends by making these same farmers more accessible to input suppliers.

Second, there is a clear and rapid shift from the left side column (the rice sector) of Figure 4 to the right side (the non-rice sector). This shift reflects Bennett's Law, which argues for an inherent desire among consumers for diversity in their diet. This dietary diversification tends to improve the nutritional quality of the diet, although more processed foods and highly industrialized meat production raise nutritional, environmental, and food safety concerns.

Third, today's increasingly diversified, market-driven food economy is more reflective of supply chain dynamics and consumer demand than in the past, which makes it more sensitive to rapid income growth and somewhat less sensitive to population growth. Especially in Asia where population growth is slowing quickly and income growth continues to accelerate, understanding the "Engel elasticities" of the various items in the food shoppers' baskets (i.e., how demand for individual items responds to income growth), as well as other factors shaping consumer demand for food such as advertising, age structure, urbanization, and globalization of tastes, will be necessary for effective planning all the way back the chain—to input supply.

As many of these broad consumer changes are being driven by changing demand for (and supply of) rice, a brief review of these dynamics is useful to put in context the broader changes in the food system.

The Changing Role of Rice

Asia is much more dependent on agriculture than the rest of the world, reflecting its historical structural dependence on smallholders and the need to keep them profitably employed in agriculture even as the industrial sector is expanding rapidly. According to the World Bank's data for East and Southeast Asia combined, the share of agricultural value added in overall GDP declined from 36 percent in 1961 to 12 percent in 2007.[4] The share of agriculture in South Asia's economy is higher, starting at 42 percent in 1961 and declining to 18 percent in 2007.

4 If the major agricultural producers of Southeast Asia (Indonesia, Thailand, the Philippines, Vietnam, and Malaysia) are examined separately as a regional aggregate, the share of agricultural value added to GDP would be 40.9 percent in 1961, 38.6 percent in 1970, 26.9 percent in 1980, 21.9 percent in 1990, 16.4 percent in 2000, and 14.5 percent in 2007. Most of the remainder of the World Bank's regional aggregate of "East Asia and the Pacific" is then composed of China. The share of agriculture in China's GDP from 1961 to 2007, by decade, was 36 percent, 35 percent, 30 percent, 27 percent, 1 percent, and 11 percent.

The contrast between Asia and the rest of the world is sharp: in 1961 agriculture was 3.7 times as important to Asian economies (taking the simple average of East Asia and South Asia) as to the world as a whole. This ratio had climbed to 5.2 times as important in 2007. Despite the rapid transformation of Asian economies, agriculture remains very important. This is mostly because Asian economies remain very poor, on the average, as well as because the huge number of small farmers in Asia cannot be moved to urban industrial and service jobs in just a few decades. The structural transformation takes generations to bring about.

Rice in Production

At the global level, the share of rice in total cereal production has not changed a lot between 1961 and 2007, starting at 24.6 percent and rising gradually to 28.1 percent. But the regional patterns have changed quite dramatically. Asia relies far more heavily on rice than the rest of the world, even as East Asia's share of rice fell steadily from 56.2 percent in 1961 to 43.0 percent in 2007. A similar but slower decline from a higher base occurred in South Asia. Southeast Asia is very heavily dependent on rice; it accounted for 90.6 percent of cereal production in 1961 and rice still accounted for 85.9 percent of cereal production in 2007.

The role of rice in the overall economy has also changed significantly. At the world level, rice accounted for just over one-half of 1 percent of GDP in 1961. Over the next half century, the share of rice in GDP for the entire world fell to just 0.174 percent of GDP. In terms of overall economic output on a global scale, rice is a very small factor.[5]

Despite the high importance of rice in Asia, however, its share in national economies is not as large as many observers think. Even in 1961, rice accounted for just 6.8 percent of GDP in East Asia, 8.4 percent in South Asia, and 14.5 percent in Southeast Asia. Naturally, because of the structural transformation, the declining role of agriculture in successfully growing economies, and the agricultural transformation, where farmers diversify out of low-valued rice production, the share of rice in Asian economies (share of GDP) has declined very rapidly. In 2007, it was just 1 percent in East Asia, 2.7 percent in South Asia, and 3.8 percent in Southeast Asia. So, even in Asia, rice is less important *economically* than livestock, construction, transportation, or even banking, although total employment in the rice economy may still rival these other sectors. This is because the economic returns to working in the rice sector are so low—a failure of the structural transformation to absorb rural workers fast enough.

Rice in Consumption

Momentous changes are also underway in rice consumption, especially in Asia. New data, extensive econometric analysis, and a historical perspective help us understand the underlying dynamics of these changes (Timmer, Block, and Dawe 2010). The result is surprising, as the projections suggest a significant decline in global rice consumption in the next four decades, starting as soon as 2020. The main drivers of this decline are rapid income growth in Asia and a massive shift of labor from rural to urban areas. The sharp negative trend with respect to incomes and between urban and rural households is striking.

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5 It should be emphasized that these are production shares of rice to value added and do not include the value of processing and marketing. The share of rice at the level of consumption is probably about half again as large. See the following discussion of the role of rice in consumption.

With more open trade and the globalization of tastes, a shift to more balanced diets in Asia (less rice and more wheat, animal products, fats and oils, and vegetables and fruits) means a decline in rice consumption. The foundations of this decline have been apparent in the global data since the early 1990s, when the aggregate income elasticity of demand for rice turned negative. Per capita consumption of rice peaked about the same time. Projecting forward, global rice consumption is expected to rise from the 441 million metric tons (mmt) consumed in 2010 to about 450 mmt in 2020, before declining to just 360 mmt in 2050.

From a food security perspective, the changing role of rice in Asian diets has three clear implications. First, the overall importance of rice to Asian consumers as a source of calories is gradually declining (see Table 1). Rice as a share of calories for all of Asia (as defined by FAO, with data from its food balance sheets) peaked in 1970 as the Green Revolution got under way, with 38.2 percent of the average Asian household's calories coming from rice. That share has steadily declined, falling to 29.3 percent in 2007. What is particularly striking about this decline is its acceleration. The share fell by 0.25 percent per year between 1961 and 1990, but increased to 1 percent per year from 1990 to 2007. If Asian policymakers are worried about where their constituents get their daily food, the answer is that over 70 percent of it comes from the non-rice economy.

Second, the total size of rice demand is important because rice remains the largest single source of calories for a significant majority of Asian consumers. This point returns the discussion to the production situation, where yield growth has stagnated and many key rice-growing basins are threatened by short-run environmental degradation and long-run impacts from climate change (Thapa and Gaiha 2011). Precisely because rice production is facing serious challenges and is likely to be more unstable in the future, most countries in Asia need to increase their participation in the world rice market and trade, not seek localized self-sufficiency. Fortunately, declining consumption will mean less pressure on rice production systems, with the potential to concentrate rice production in highly productive environments and spare fragile ecological settings.

Third, the role of rice in Asian food consumption and how that role is changing greatly vary across countries. On the average, India consumed just 703 kilocalories (kcal) of rice per capita per day in 2007, a sharp contrast with Vietnam's 1,629 kcal consumption. Still,

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Source: Data from FAO Food Balance Sheets
Note: Calories - daily per capita energy available

rice consumption in Vietnam accounted for "only" 57.8 percent of total caloric intake (and has fallen below 50% by 2010), whereas the share in Bangladesh was 69.8 percent in 2007. Excepting only the Philippines, that share has been falling since 1970 or 1980, and especially rapidly in South Korea (from 49.8% in 1980 to 26.8% in 2007) and China (from 38.7% in 1970 to 26.8% in 2007). The drop is also noticeable in Bangladesh (from 75.2% in 1990 to 69.8% in 2007) and Indonesia (from 56.1% in 1980 to 48.8% in 2007). In all of these countries (except Bangladesh and again the Philippines[6]), the drop in share of rice has also been accompanied by at least a modest fall in its total consumption. Only population growth continues to drive rice consumption upward in Asia, and population growth is slowing in most countries.

POLICY IMPLICATIONS

When historical experience is overlaid on these frameworks, a number of policy implications can be seen for food security strategies.

First, the implications depend very much on *which* historical experience is examined from the perspective of these frameworks. The experiences of Europe, North and South America, East, Southeast and South Asia, and Africa have been sharply different, especially from the perspective of modern input suppliers. The focus here has been mostly on the rice-consuming parts of Asia because that is where the intersection of modern inputs, food security, and small farmers provides both the most opportunities and significant challenges.

Second, farm size affects everything. The dynamics of farm size determine the pace of income convergence, the achievement of the Millennium Development Goals for food security, and the sustainability of agriculture going forward because it depends so heavily on technological innovations (and the ability to get them to farmers). The present tendency in much of the developing world for farm size to continue shrinking is cause for great concern because micro farms almost certainly do not have the scale to use most modern inputs, have high transactions costs in both input and output markets, and are difficult to reach with the knowledge needed to efficiently manage farming.

From a historical perspective, farm size tends to increase as agricultural laborers leave for more productive jobs in urban (or rural non-farm) areas. This trend accompanies rising real wages in both the rural and urban economies; it tends to mean an increasing reliance on new mechanical technologies that save on labor. However, in many parts of Asia and Africa farm size continues to decline. In these settings, reliance will increase on biological and chemical innovations that raise yields and reduce crop vulnerabilities.

Third, the agricultural transformation that reflects higher on-farm productivity seems increasingly to be driven by the intensive use of integrated technologies, where a package of inputs addresses yield potential, control of diseases, pests and weeds, and improved water utilization. Three important characteristics of these integrated technologies are crucial to the success of food security strategies going forward:

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6 The Philippines' case is interesting and hard to explain. The share of rice in the average Filipino diet had declined steadily from 1961 to 1990 under the pressures of rapid population growth, slow growth in domestic rice production, and a lagging economy. The share has since increased 9 percentage points to 2007, with daily rice intake rising 1.7 percent per year since 1990. Substitution away from corn, sharply higher rice imports to support political campaigns, apparent success in the domestic rice production program, and increased rice consumption among the poor because of extensive subsidies may account for these trends.

1. A lot of science tends to be built into these inputs by the suppliers.
2. Successful use of these inputs is very knowledge-intensive on the part of the farmer.
3. Better management techniques (in addition to the scientific understanding required) are needed to optimize the use of integrated packages.

It is not at all clear how farmers, in general, and small farmers, in particular, will gain access to the knowledge and management skills needed to use modern integrated input packages. "Learning by doing" is expensive and takes a long time. Modern extension systems, mostly developed by the private sector and using information and communication technologies (ICT), offer more hope, but such extension systems have a clear bias in serving larger and better-informed farmers.

Fourth, concerns for food safety, bio-security, and traceability also seem to grow along with economic complexity of the society and rising consumer awareness, made possible through higher incomes and exposure to modern media. Clearly, the transaction costs of incorporating small farmers into secure procurement systems that address these challenges will be significant, although the use of ICT may also be the answer in this arena.

Fifth, the connections between output markets and input markets are becoming stronger; thus, it is no longer useful to think about "market development" and the provision of rural infrastructure for the two markets separately. The implications for both the public and private sectors are stark: they need to be engaged with the *basics* of market development, not just programs that develop demand for inputs or outputs. This reality almost certainly means being engaged with modern supermarket chains as well as government-sponsored market development programs.

The Big Challenges to Food Security in Asia

In conclusion, a brief list of the big questions going forward can summarize the arguments here.

First, farm size continues to decline, with an especially worrisome rise in the number of "micro farms"—those under 0.2–0.3 ha. Can such small farms survive? The structural transformation has long-run implications on their changing role, but the reality of the short-run is quite challenging. Finding innovative ways to reach small farmers in both input and output markets will be key to rural food security over the next several decades.

Second, what will be the impact of the changing role of rice on the Asian food economy? The impact of dietary diversification on food consumption is sure to feed back to the production side, where the big uncertainty is how fast rice yields can be raised in the already-productive rice basins in Asia. Two-thirds of the world's poor depend on how this question is answered.

Third, integrated technologies combining new genetics, agro-chemicals, and management techniques will increasingly be the route to higher crop (and livestock) productivity. But these integrated technologies may have important scale economies in total, even when the individual components appear to be scale neutral. Part of the possible scale effect will arise because reaching small farmers with modern inputs and buying their increasingly diversified outputs will require a new, information-intensive marketing system—a supply chain if you like. Supermarkets, because they have access to the consumers who are buying these outputs, will drive these new supply chains.

Fourth, what is the right strategic approach for governments and donors to enhance food security? Typically, the approach uses "diagnostics" (research and analysis) to design "projects" (which involve both design and

implementation) in order to develop a "proof of concept" (that requires honest and tough evaluations, with direct feedback to the research and analytical teams, ideally by having at least some members of those teams involved in the entire cycle). The big and tough question is how to make this approach "scalable." That is, how do donors and policymakers learn what works for small farmers? How can farmers' output get to demanding consumers? And how can these tasks be accomplished on an economy-wide scale? Historically, only market processes have managed to be scalable, but these market processes do not necessarily care whether small farmers survive or poor people get enough to eat. Scalability is the holy grail of development assistance, and the World Bank, IFAD, the Bill and Melinda Gates Foundation, and many others would like to know the answer.

Finally, one advantage of a longterm perspective is the realization that food security challenges are never fully met and they can change radically in a short period. Food security is all about understanding what is happening to the food economy in both the short-run and the long-run as well as translating that understanding into effective policy action.

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