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THE NEXUS BETWEEN AGRICULTURE AND NUTRITION

DO GROWTH PATTERNS AND CONDITIONAL FACTORS MATTER?

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1. Introduction

ADEQUATE NUTRITION IS A BASIC HUMAN NEED. INDIVIDUALS MUST CONSUME sufficient amounts of not only calories, but also protein, fats, vitamins, and minerals to support growth and development throughout their life cycle. Although tremendous progress has been made in meeting the world's food demand, many parts of the developing world continue to suffer from undernutrition—that is, deficiencies in energy, protein, and essential vitamins and minerals. A number of indicators can be used to measure nutritional status (Box 1). Although undernutrition can occur at any time during a person's life cycle, nutrition deficiencies among children (particularly those under 24 months) can lead to particularly severe and even permanent damage (Ruel and Hoddinott 2008).

BOX 1 — Indicators of nutritional status

Nutritional intake: Deficiencies in consumption of calories (hunger) and vitamins and minerals (hidden hunger) based on food purchased or consumed.

Nutritional outcome: Body mass index for adults, and stunting (low height-for-age), wasting (low weight-for-height), and underweight (low weight-for-age) for children.

Economic growth, which many assume naturally has a positive impact on nutritional status through increased incomes and food expenditures, has not translated into improved nutrition in a number of developing countries. For example, despite India's impressive economic growth in recent years—with gross domestic product (GDP) growing at an annual rate of about 7–10 percent—it is still home to approximately 42 percent of the world's undernourished children. The disconnect between growth and reduced undernutrition is often referred to as the "Asian enigma."

Inadequate nutrition can be caused by an array of dynamic and interactive factors at the international, national, regional, community, household, and individual levels. The pattern of growth—that is, which sector or subsector is driving growth—matters a great deal. As part of overall economic growth, agricultural growth has an important role to play in reducing and preventing undernutrition through a number of channels. Its impact extends from increasing household ability to purchase and produce more nutritious food to economy-wide effects such as increasing government revenues to fund education, health, infrastructure, and nutrition intervention programs. However, questions remain about the effects of different patterns of agricultural growth on nutrition. Furthermore, factors such as infrastructure, the status of women (including their educational level), and land distribution also contribute to how well agricultural growth translates into nutritional improvements.

This paper seeks to provide an overview of the complex and dynamic relationship between nutrition and growth, examine how different growth patterns lead to different nutritional outcomes, and identify the factors that influence the magnitude of this relationship. It aims to offer researchers insights on areas for future research and analysis and to provide policymakers with knowledge regarding potential development strategies and investment policies that will increase the likelihood of positive nutritional outcomes.

2. Does Growth Matter?

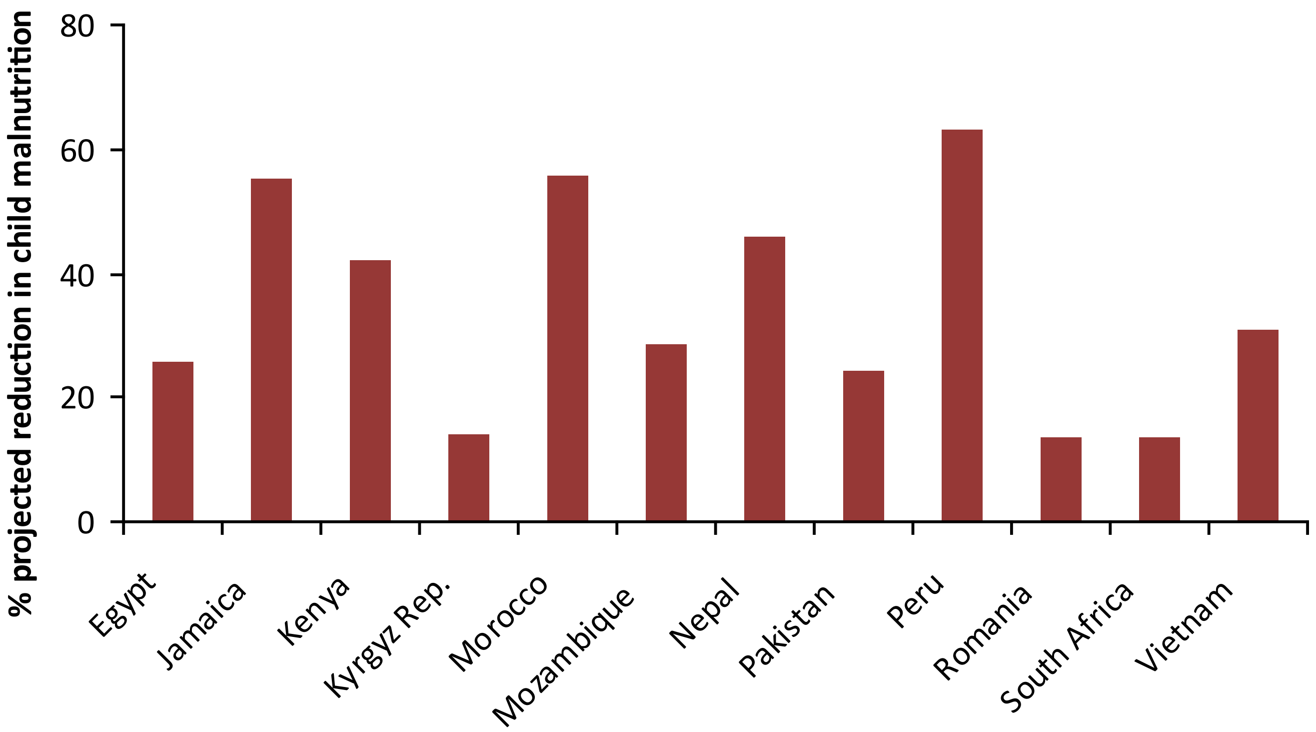
Although many studies have analyzed the impact of nutrition on overall economic growth—including the influential work by Fogel (1994)—few studies have tried to explain and quantify how economic growth contributes to reducing undernutrition. One reason could be the assumption that economic growth will ultimately lead to improved nutrition and that this line of reasoning does not need empirical evidence for support. It is true that economic growth has the potential to contribute to improved nutrition through a variety of channels. Increased household or individual income from agricultural growth, for example, will enable households or individuals to purchase not only more food, but also food that is potentially more nutritious. For agricultural households, higher incomes could also allow them to consume a greater quantity of nutritious food from their own production. Few studies quantify these effects satisfactorily, and the limited studies available offer either inconclusive or conflicting results on the link between growth and nutrition.

A number of studies argue that overall economic growth—usually represented by GDP, per capita GDP, and per capita income—is weakly associated with indicators of nutritional status (Neeliah and Shankar 2008; Bouis and Haddad 1992). These studies assert that the relatively tenuous link between economic growth and reduced child malnutrition warrants the use of supplementary interventions that aim to improve child health and nutrition directly. Furthermore, some studies have found that despite a positive relationship between income and nutrition, economic growth may not necessarily lead to a reduction in undernutrition since other economic factors—including changes in relative food prices, spending on nonfood necessities, and an increase in savings—may have a negative impact on nutritional status, as was the case in China during the 1990s (Meng et al. 2004).

In contrast, another group of studies has found a positive and significant link between increased economic and nutritional status—either unidirectional or bidirectional (Subramanian and Deaton 1996; Dawson and Tiffin 1998; Alderman, Hoogeven, and Rossi 2005; O'Donnell, Nicolas, and Doorslaer 2009). For example, data from rural areas in Maharashtra, India, show a positive relationship between calorie consumption and total expenditures, with an elasticity of 0.3–0.5 that slowly decreases with rising incomes (Subramanian and Deaton 1996)—which is consistent with the long-standing principle that the proportion of income spent on food falls as income rises (Engel's law).

Using cross-country and household data, Haddad et al. (2003) measured the anticipated reduction in malnutrition as a result of economic growth over a period of approximately 25 years in a cross-section of countries. The study found that sustained income growth could produce a sizable projected reduction in undernutrition through 2015 (Figure 1). Household-level results project that an increase in per capita income

Figure 1—Projected reduction in child malnutrition rate with 2.5 percent annual growth in per capita income from 1990s to 2015 (%)



Source: Haddad et al. (2003).

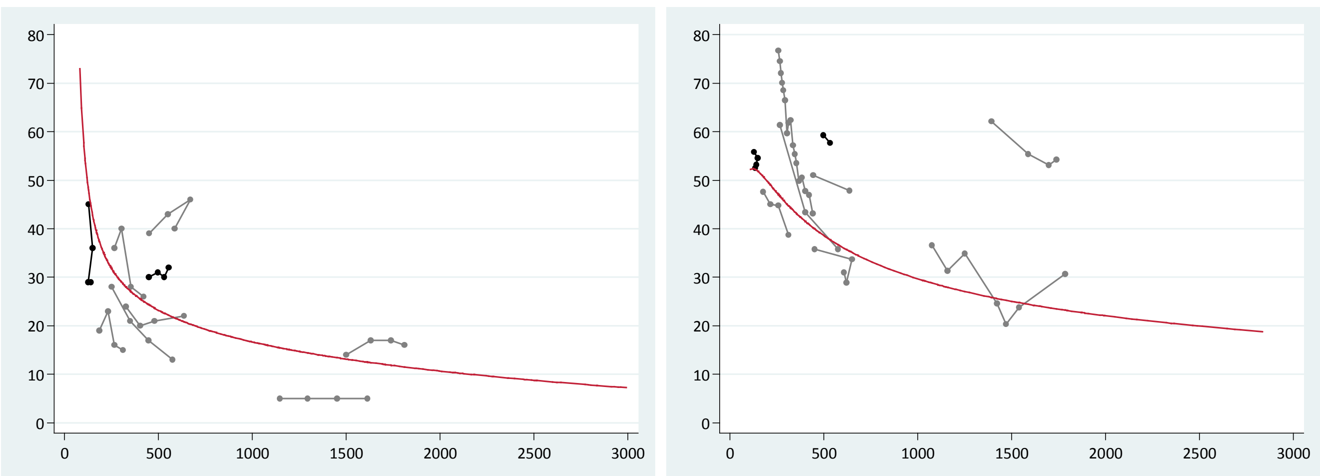
of 2.5 percent between the early 1990s and 2015 results in an average annual decline in the malnutrition rate of (1) 27 percent if community and household infrastructure are held constant, and (2) 34 percent if changes to household and community infrastructure are incorporated. A cross-country analysis by the authors reveals similar findings. However, few of these countries included in the household analysis had been able to sustain annual per capita income growth greater than 2.5, and even if they had sustained growth at this level, it would not have been enough to meet the Millennium Development Goal (MDG) target of halving malnutrition rates. Consequently, the authors argue that a more balanced strategy is needed to reduce malnutrition, whereby income growth and cost-effective health and nutrition interventions—including vitamin supplementation and nutrition education—are used simultaneously. Similarly, evidence from Tanzania shows that although income growth and direct nutritional interventions are each positively associated with improved nutritional status among children, alone they are insufficient to meet the MDG target of halving the prevalence of underweight children under five years of age (Alderman, Hoogeven, and Rossi 2005).

These studies have a number of shortcomings, especially in terms of data, measures, and econometric issues. First, long time-series data on nutrition are sparse and vary in definitions, quality, and sampling across countries (Smith and Haddad 2000). The indicator used to measure nutrition as a dependent variable has a large impact on the results of these studies. For example, if nutrition is measured by calorie intake, then initial rapid growth can have a large impact. If nutrition is measured by outcome, however—prevalence of underweight, wasting, or stunting—the immediate impact of initial growth might be small or nonexistent. Even different measures of calorie variables, ranging from calories purchased to calories prepared, have been found to result in different calorie-expenditure elasticities (Ohri-Vachaspati et al. 1998). Moreover, the common use of average calorie deficiency as a measure of general undernourishment has been criticized because it is often based on unreliable and conceptually flawed data that, for example, disregards variations in both calorie distribution and calorie requirements across different countries, population groups, and seasons; the reliability of child undernutrition indicators has also been questioned because this measure does not take into account small genetic differences in growth potential between populations (Klasen 2008).

Second, many past studies have failed to recognize that there is a nonlinear relationship between growth and nutrition outcomes. Moreover, in this relationship there is also a threshold, which implies that the nutritional impact of growth diminishes or disappears after crossing a certain economic level, requiring the use of other interventions to reduce undernutrition. Another potential explanation for discrepancies in past studies on the relationship between economic growth and nutrition is that many studies treat economic growth as a homogenous process across countries and time. However, recent evidence has shown that factors such as a country's stage of economic development can significantly influence the size of the growth-nutrition correlation. For example, Ecker et al. (2011) use cross-country regressions to show that the potential for economic growth to reduce undernutrition among the general population and children varies according to a country's economic status (Figure 2).

According to this study, undernutrition levels decline rapidly in response to additional income during the early stages of a country's growth, when levels of annual per capita GDP are low. As a country moves up the

Figure 2—Undernutrition-growth trends in selected developing countries



Source: Ecker et al. (2011).

economic development ladder the relationship between growth and nutritional status becomes much weaker, with the impact of growth declining when the annual GDP per capita exceeds approximately US$500 (in constant 2000 U.S. dollars). The study found a similar pattern for agricultural growth. The relationship between growth and child malnutrition is found to be more modest, with child malnutrition less responsive to growth even during the early stages of a country's economic development. The authors hypothesize that non-income factors such as health and education matter more for reducing child malnutrition than for reducing hunger.

Another shortcoming of past growth-nutrition analyses is the disregard of diet quality. Subramanian and Deaton (2001) argue that the low calorie-income elasticity found by some studies is not because the overall quality of the diet remains unchanged with income, but because calorie intake is a poor indicator of diet quality. The authors find that although the intake of nutrients such as vitamin A and iron are poorly correlated with income, the intake of fat, calcium, riboflavin, and vitamin C appear to rise steadily with income. A similar study by Skoufias et al. (2009) in Mexico examines the effect of increases in household income on micronutrient consumption at the household level. Income is found to have an especially high and positive impact on the consumption of nutrients—primarily fats, vitamins A and C, iron, and calcium—that have high deficiency rates among the population. The relationship is larger for poorer percentiles of the population, and although it decreases at higher percentiles, it remains sizable in magnitude. The effect of income on other micronutrients is statistically significant but quite small.

The continued existence of divergent opinions on the exact relationship between economic and nutritional outcomes calls for more empirical research on the growth-nutrition relationship in specific settings. More specifically, the "economic growth" variable needs to be dissected into contributing components of growth.

3. Do Sectoral Growth Patterns Matter?

3.1 The Agricultural Sector

Past development experiences have shown that the agricultural sector has been the engine of growth in many countries and that a successful economic transformation vitally depends on agricultural development and increased agricultural productivity, especially during the initial stages of a country's development (see, for example, Johnston and Mellor 1961). In fact, the early withdrawal of public support from agriculture has been shown to slow down economic transformation and create inequalities that pose persistent development challenges (Tiffin and Irz 2006; Breisinger and Diao 2008).

A number of studies have found that growth originating from agriculture is often more effective at reducing poverty than growth in other sectors, such as industry and services (Christiaensen, Demery, and Kühl 2006; de Janvry and Sadoulet 2009; Ravallion, Chen, and Sangraula 2007; Nin Pratt and Diao 2008). Growth in the agricultural sector promotes overall economic development mainly through backward and forward links in production and consumption between agriculture and the rest of the economy. Furthermore, the poor participate more in growth from the agricultural sector, not only because of the continued rural nature of poverty—with approximately three-quarters of the developing world's poor living in rural areas (Ravallion, Chen, and Sangraula 2007)—but also because the sector typically accounts for a large share of the poor's income, expenditures, and employment in many developing countries. However, the full potential of agricultural growth linkages varies between regions and with the structural features of the rural economy. For example, because of higher agricultural incomes, better infrastructure, and greater use of farm inputs, the agricultural growth multipliers in India's Green Revolution states of Punjab and Haryana are more than two times higher than those in low-income states such as Bihar and Madhya Pradesh (Hazell and Haggblade 1991).

Now the question is to what extent agricultural growth—and growth in particular subsectors of agriculture—can be a springboard for nutritional improvement through such channels as increased agricultural production and lower food prices. The conventional hypothesis is that agricultural growth is likely to have a larger impact on improving nutrition levels than growth in other sectors. There are a number of potential pathways through which agriculture can have an impact (see, for example, Kennedy and Peters 1992; World Bank 2007). On the one hand, agricultural growth can have a positive impact:

- Increased household production leads directly to higher and more diversified food consumption.
- Increased agricultural production for markets raises household income, thereby increasing ability to purchase food and gain access to health and education services.

- Lower and less volatile food prices from rising agricultural productivity benefit urban poor and rural net food buyers, while also freeing additional household resources for other (productive) expenditures.
- Increased government revenue can be used to finance investments in health, education, rural infrastructure, and nutrition intervention programs.

On the other hand, its impact can also be negative:

- Agricultural growth led by intensified use of modern inputs (including fertilizers, pesticides, and herbicides) and irrigation practices may also have negative consequences on human health and nutrition.
- Intensification of agriculture may reduce women's time for childcare and their own health.

Empirical evidence on the nutritional impacts of agricultural growth is limited. One of the few studies was conducted by Headey (2010), who finds that the impact of economic growth—both overall and agricultural—on undernutrition varies across a number of factors. Agricultural growth, in particular, not only is associated with a reduction in underweight, but also leads to reduced stunting in more food-insecure countries, with the exception of India. Moreover, agricultural growth is positively and significantly linked with calorie intake (especially at lower levels of calorie consumption), although evidence from the analysis also suggests that the effect on dietary diversity—used as a rough proxy for micronutrient consumption—is minimal. As a final point, the study finds that pro-nutrition growth—namely, "transformative" growth that places emphasis on poverty reduction and improvements in education and health outcomes—has the capacity for larger and more significant reductions in undernutrition than regular economic growth. This finding underscores the need to integrate policies and programs to reduce undernutrition across different sectors and ministries. Additional evidence from Ecker (2011) shows that the impact of agricultural growth is variable across measures of undernutrition. A study on Yemen shows that while agricultural growth can lead to large reduction in undernutrition, its impact on stunting is only 10 percent of its impact on calorie deficiency. This result suggests that other interventions in addition to agricultural growth are needed if the final objective is to improve children's nutritional status.

3.2 Agricultural Subsectors

Within the agricultural sector, individual subsectors, like staple crops or livestock, have different impacts on development outcomes. Whether growth in a subsector is pro-poor (and pro-nutrition) depends on (1) its linkages with rest of the economy, (2) its initial size and geographic concentration, (3) its growth potential, and (4) market opportunities. A number of recent studies in several Sub-Saharan African countries have shown the differential impact of various agricultural subsectors (for example, Diao and Pratt 2007; Pauw and Thurlow 2010).These studies simulated the contribution of growth in different agricultural subsectors to the country's economic and agricultural growth, poverty reduction, and calorie intake. The authors assessed the relative impacts by increasing the growth rate of one subsector, while holding the growth of the other subsectors constant. A recent study of households in East Africa, for example, found that the effects of income on dietary diversity—based on the assumption that dietary diversity is highly correlated with dietary quality and nutrient content—varied according to source of income (Villa 2010). Income from livestock trade and crop value, specifically, appears to have a relatively strong positive effect on dietary diversity, whereas income from wages and salary appears to have a negative effect.

A recent study by Pauw and Thurlow (2010) finds that the apparent disconnect between Tanzania's growth, poverty reduction, and nutrition outcomes is due to the composition of the country's recent agricultural growth. More specifically, Tanzania's rapid growth in recent years has failed to translate into significant improvements in poverty and calorie availability—what can be dubbed the "East African enigma." Using a regional and dynamic computable general equilibrium model of Tanzania, the authors find that the country's high agricultural growth did not benefit all farmers equally because it was driven primarily by crops that are only grown in specific parts of the country or by larger-scale farmers who are less likely to be poor.[1] A comparison of alternative sources of agricultural growth reveals that the largest effect on poverty reduction and calorie intake is derived from growth led by maize, followed by sorghum and millet, and root crops (Table 1). These crops not only are important expenditure items for poor households, but are also grown more intensively by

[1] Various analyses related to the impact of different composition of agricultural growth all used computable general equilibrium (CGE) models. The advantage of a CGE model is its ability to model the impact through different economywide channels such as income, prices, employment, and wages. The weaknesses lie in its inaccuracy of parameters and inability to validate the model using empirical data.

Table 1—Poverty-growth and calorie-growth elasticities, Tanzania (2000–07)

Product	Calorie-growth elasticity	Poverty-growth elasticity
Maize	-1.9	-1.5
Sorghum and millet	-1.5	-1.5
Pulses and oilseeds	-1.8	-1.4
Roots	-1.1	-1.5
Horticulture	-1.0	-1.4
Livestock	-0.7	-1.3
Export crops	-0.8	-1.4

Source: Pauw and Thurlow (2010).

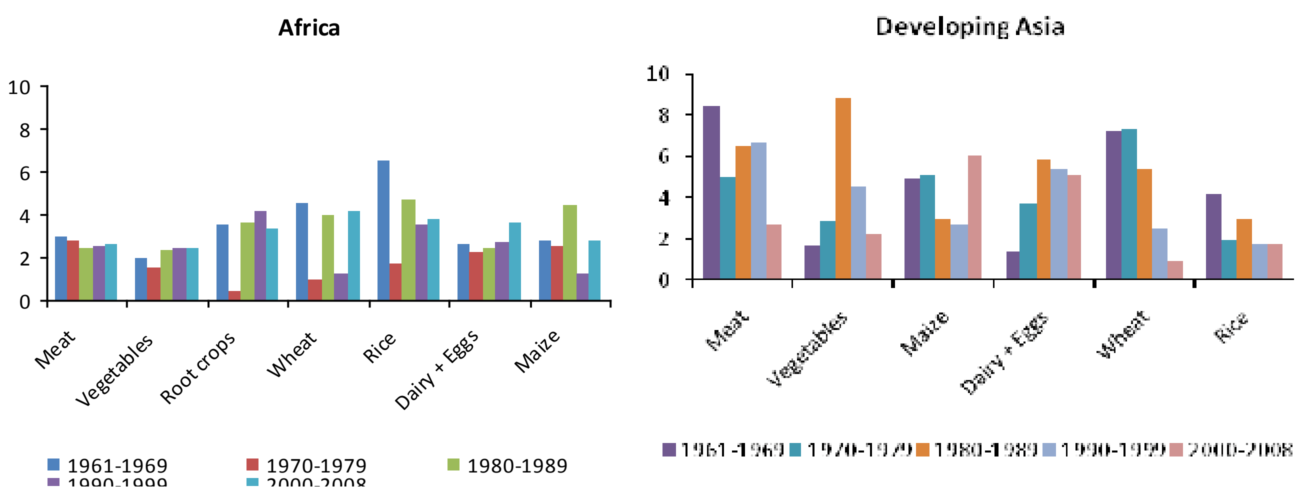
poorer farmers. In contrast, rice and wheat are grown in specific parts of the country and, in the case of wheat, by larger-scale farmers. The effectiveness of growth—in terms of both poverty reduction and improved calorie intake—can thus be enhanced by accelerating growth in subsectors with stronger links to poorer households and regions.

A similar study by Diao and Pratt (2007) in Ethiopia also finds that the contribution of growth in staple crops to poverty reduction and calorie intake is greater than the contribution of any other agricultural or nonagricultural sector modeled. The authors argue that cereals and other staple crops are the most important income source for the majority of small farmers and account for the largest share of their dietary calories. On the other hand, the modest impact of exportables on household incomes and consumption, for example, results from the fact that poor famers often lack the financial resources and technologies required to cultivate these crops. Evidence from Pakistan suggests that the impact of income growth on calorie consumption varies according to different stages of agricultural production (Behrman, Foster, and Rosenzweig 1997). Income increases during the planting stage have an especially large impact on calorie consumption among smallholders, whereas the nutrition effect of higher incomes is relatively small during the food- abundant harvest stage, especially for poorer households.

The differential impact of agricultural subsectors is further amplified by the regional variation in natural resource and economic conditions within many developing countries. For example, the study of agriculture's role in decreasing poverty and increasing growth in Ethiopia shows that similar growth rates within agricultural subsectors have different effects on the associated poverty rates across the regions (Diao and Pratt 2007). Although growth in staple crops will be the dominant driver in the food-surplus area, growth in staples alone will not be not be sufficient to reduce poverty and increase nutrition intake significantly in food-deficit regions, necessitating a more balanced agricultural growth strategy that combines growth in a number of subsectors. The study thus emphasizes the need for regionally differentiated strategies to maximize the potential of specific agricultural subsectors to improve nutritional status and poverty reduction, taking into account how subsectoral growth priorities vary across regions and how the priorities interact and contribute to national development objectives. The policies and interventions planned as part of an agricultural development strategy should especially be integrated with specific interventions targeted toward lagging regions.

The results just described may not hold, however, when the definition of nutrition goes beyond calorie intake to include diet quality, micronutrients, or even wasting, underweight, and stunting among children. Research on the effects of different growth patterns on nutrition need to go beyond calorie intake to include a range of indicators of nutritional status, including micronutrient intake and wasting, underweight, and stunting among children. Indeed, in the past several decades, the structure of agricultural growth has changed

Figure 3—Production growth, 1961–2001 (%)



Source: FAOSTAT database (2011).

dramatically because of different growth rates among subsectors (Figure 3). In general, growth rates of meat, egg, and dairy production have increased in Asia. In Africa, production of rice, wheat, and root crops has grown faster than that of meat, dairy, and eggs. In many parts of the developing world, changing production patterns will be difficult in the short run and may also involve trade-offs between diet quantity and quality. Innovative programs such as HarvestPlus can be used to add nutrients to staple crops through modern breeding. This biofortification will allow consumers to increase their intake of micronutrients such as vitamin A, iron, and zinc even if their diet patterns remain the same.

4. How Do Conditional Factors Affect the Link between Growth and Nutrition Outcome?

Many factors related to underlying conditions within developing countries affect the link between growth and nutritional outcomes. In other words, given the same economic growth or agricultural growth, improvement in these factors will result in better nutrition outcomes.[2]

4.1 Land Distribution

Access to productive assets such as land is associated with both poverty and nutrition status in many developing countries through a number of channels. Justification for land reforms has been based on the assumption that land is one of the most valuable productive resources in agriculture-based economies because it is vital to securing a sustainable livelihood and has a strong welfare-improving effect (Agarwal 2002; Finan, Sadoulet, and de Janvry 2002). Not only do land endowments provide individuals and households with a source of income, but they also facilitate farm households' access to a cheaper and more secure source of food from own production relative to the market—especially in areas with high market prices due to underdeveloped or inefficient markets. When land distribution is more egalitarian, income and nutritional benefits from growth are more widely shared.

The positive relationship between access to land and nutrition beyond the effects on poverty reduction has been documented in a number of studies. Preliminary results from India show that land reforms, especially the abolition of intermediaries and the imposition of ceilings on landholdings, have had a positive impact on nutritional outcomes, which was measured using women's height (Ghosh 2007). Similarly, an analysis of the nutritional effects of land distribution in China found that the redistribution of land trumps the redistribution of output or income from that land (Burgess 2001). The author thus argues that the redistribution of land can have a greater nutritional impact than targeted social assistance (such as cash or in-kind transfers) because improved land access provides the beneficiaries with a cheaper and more secure source of food over time. In fact, among the main features distinguishing China from other developing countries with higher malnutrition rates but similar economic growth—such as India—are China's virtual lack of landlessness and its relatively egalitarian distribution of land.

However, the link between land distribution and nutrition is not completely straightforward. On the one hand, evidence from Kenya shows that tenants of settlement schemes are better off in terms of income, food consumption, and nutritional status than the rest of the rural population (Hoorweg et al 1996). The incorporation of farm size into the analysis reveals, however, that larger farm size translates into increased incomes but not higher food consumption nor better nutritional status—because of larger household size and less off-farm employment among larger farms. The authors conclude that the incongruity between increased income and lower nutritional outcomes among larger farms underscores the need to include indicators that measure economic as well as social and nutritional outcomes, since a country can excel in one indicator but fall far behind in another. Furthermore, before access to land can be translated into improved nutrition, agrarian reforms need to include a comprehensive package of support services that enable beneficiaries to obtain other resources, such as credit, capital, technology, and marketing information (Guardian 2003).

4.2 Women's Status

Gender inequality in nutritional status has been widely documented, with South Asia showing especially alarming trends (Klasen 1996; Dey and Chaudhuri 2008; Dancer, Rammohan, and Murray 2008). Constraints to woman's roles include weak land rights; lower levels of education; and lack of access to credit, extension

[2] In an econometric sense, these variables (or factors) have a direct impact on the independent variable (nutrition) and an interactive impact with the growth variable.

services and technologies. Women's access to land, for instance, can increase their empowerment within the household and hence the consumption of certain goods that improve the nutritional status of children (Agarwal 2004).

Nonetheless, many past growth-nutrition analyses have overlooked the potential impact of gender-based variables despite ample evidence that men and women often have divergent priorities and patterns of consumption. A number of studies have found that children's nutrition is higher when women have more control over household resources. For example, cross-country evidence from Smith et al. (2003) clearly shows that women's higher status—as measured by women's relative decisionmaking power and the degree of equality between women and men—is a significant and positive determinant of children's nutritional status. The strength of the relationship between women's status and child malnutrition differs across regions, with the largest impact in South Asia: the region would have 13.4 million fewer malnourished children if men and women had equal status. The authors assert that South Asian malnutrition rates are significantly higher than those in other regions not only because women's status is lower in South Asia, but also because the effect of women's status on child nutrition is higher in the region.

Furthermore, households in which women have more resources often spend more on household and child nutrition—improving diet quantity and quality—than male-dominated households (see Hoddinott and Haddad 1995; Rogers 1996; Thomas 1997). For example, holding income constant, members of female-headed households in Rwanda and The Gambia consumed 377 and 322 more calories daily (per adult equivalent), respectively, than those of male-headed households (Kennedy and Peters 1992). Evidence from Brazil shows that the effect of women's income on nutrition is four to eight times that of men's income (Thomas 1997). Studies in Côte d'Ivoire and Ethiopia found that women's income and assets brought into marriage, respectively, have a positive effect on food expenditures, whereas men's income increased expenditures on clothing, alcohol, and cigarettes (Quisumbing and Maluccio 2000). In fact, low-income, female-headed households often exhibit better nutrition than higher-income male-headed households (Kennedy and Peters 1992). However, while agricultural growth that benefits women can lead to improved household and child nutritional status through higher incomes among women, it can also have a negative impact on nutrition by changing time and labor allocation patterns, reducing women's time for childcare and the quality of food provided by the mother.

4.3 Rural Infrastructure

A large body of evidence has closely linked investment in infrastructure—including roads, water, sanitation, and electricity—with growth in agricultural productivity and poverty reduction. Infrastructure is positively related to better health and nutrition through a variety of channels. First, infrastructure can promote income growth by raising agricultural productivity, lowering production and transaction costs, and removing bottlenecks to the participation of the poor in the development process, thereby facilitating increased access to, availability of, and consumption of food among larger segments of the population. Although a number of studies have compared the poverty reduction impact of infrastructure with other types of public spending, evidence on the relationship between different public investments and nutrition is more limited. The importance of infrastructure for nutrition is not surprising given the large body of evidence that has closely linked investment in infrastructure with growth in agricultural productivity and poverty reduction (Fan et al. 2009; Pardey et al. 2000). Rural transport, for instance, is important for the livelihoods of the rural poor, with inefficient transport systems hampering development in rural areas, both by raising the costs and effectiveness of inputs in the production process and by delaying the sale of harvested crops. In China and India, government expenditures on research and roads have among the largest positive impacts on poverty reduction and agricultural productivity, making them win-win development strategies (Fan, Hazell, and Thorat 2000; Fan, Zhang, and Zhang 2004). Recent evidence from India shows that the impact of income growth on malnutrition is substantially smaller when infrastructure is incorporated, implying that a fair share of what has been attributed to the impact of income growth on nutrition is actually due to investments in infrastructure (Headey et al. 2010).

Infrastructure also improves access to more and better health, water, and sanitation services. The provision of infrastructure—including safe drinking water, health facilities, and sanitation—in developing countries such as India, Peru, and Sudan has been shown to reduce the incidence of stunting and underweight (Borooah 2005; Merchant et al. 2003; Checkley et al. 2004). Similarly, cross-country evidence shows that improved sanitation is a statistically significant determinant of child undernutrition, with the difference in access to sanitation accounting for 20 percent of the difference in malnutrition between the richest and poorest quintiles (Leipziger et al. 2003). However, the provision of infrastructure does not affect all population groups evenly. On the one hand, improved infrastructure in the form of increased access to water and health facilities in India and Senegal is especially important for child nutritional status at the lower end of the distribution of child nutritional status (Borooah 2005; Bassole 2007). On the other hand, access to electricity and piped water has been shown to have a larger and more significant effect on child weight and height at the higher end of the child weight and height distribution (Aturupane, Deolalikar, and Gunewardena 2006). Similarly, the expansion of health care infrastructure in Peru has been shown to have an especially large and significant impact on child nutritional status (height-for-age) in poor urban areas, whereas the link between health facilities and nutrition in rural areas is insignificant. These studies thus emphasize the importance of complementing indirect policy interventions (such as improved infrastructure) with direct nutritional interventions (such as food supplementation programs) that target at-risk children.

4.4 Health Status

Health and nutritional status are directly linked through a synergistic relationship. Undernutrition is one of the major causes of immune deficiency, and illness impairs nutritional status by reducing both appetite and the body's ability to absorb nutrients, which in turn lowers the individual's resistance to further illness (Scrimshaw 2003). Individuals with HIV/AIDS, for example, have higher nutritional and energy requirements than the general population—10–30 percent higher among adults and 50–100 percent higher among children. Yet the loss of appetite associated with the illness means that their dietary intake is reduced at the very time when requirements are higher.

Health status can have a significant impact on nutritional outcomes by affecting a household's ability to take part in productive activities that generate food or income to purchase food. Poor health potentially contributes to undernutrition through a number of pathways (FAO 2002; UN 2004), including the following:

- decreased work productivity resulting from ill or deceased household members;
- increased medical and health care costs for households and villages, especially with the return of many sick urban dwellers and migrant laborers;
- increased household dependency ratios through loss of productive adults and addition of orphans of dead relatives into households; and
- loss of local intergenerational knowledge and skills.

Working through these pathways, sickness and death have been shown to result in a reduction of cultivated land, yields, and crop varieties (UN 2004; Gillespie and Kadiyala 2005). Results from Mozambique, for example, show that agricultural households that suffer from male illness or death (most likely attributed to HIV/AIDS) experience a significant reduction in food production. This decline results in decreased nutritional welfare since these households are dependent on own-food production to obtain their food for consumption. Absenteeism and the loss of labor resulting from poor health can lead to changes in cropping patterns and declines in crop diversity, with affected households switching to less labor-intensive crops—such as roots crops—that are often lower in nutritional value (UN 2004; Barnett and Rugalema 2001). However, it is important to remember that the impact of health on the link between agriculture and nutrition is heterogeneous and depends on a variety of factors such as the length of an illness, the degree of disability, and who is infected or dies (age, gender, and position in household) (Gillespie and Kadiyala 2005).

5. Strategies and Investments for Pro-Nutrition Growth

Given the dynamic relationship between agricultural growth and nutritional status, nutritional improvements can be addressed in a number of ways. The question is how to set priorities and allocate limited public resources. This section pays special attention to the question of how we can make growth more pro-nutrition and set priorities for public spending to reflect this extension.

5.1 Growth Strategy

Recently, changing attitudes among both researchers and policymakers on "one-size-fits-all development strategies" have led to increased demand for research to understand the heterogeneity and country-specific conditions of development experiences. Understanding alternative economic and agricultural growth options is a key component of any development strategy. As shown in the previous section, the relationship between growth—nonagricultural and agricultural—and undernutrition is not straightforward, and more solid research is needed to support evidence-based policymaking and strategy formulation. For growth strategies to maximize their impact on nutrition, the differential impacts of specific economic and agricultural policies and conditional factors on growth-nutrition links need to be taken into account.

So far, nutrition has not been widely used as an objective of economic growth and agricultural growth strategies. A review of national agricultural investment plans under the Comprehensive Africa Agricultural Development Program (CAADP) shows that the food and nutrition component is either weak or nonexistent. This is often the case because food and nutrition fall under several government entities (such as ministries of agriculture, social affairs, and health), a situation that makes it difficult to incorporate nutrition within the main agricultural strategy mostly led by the ministry of agriculture. The multisectoral nature of nutrition often has the result that nutrition is a "political, administrative, and institutional orphan" (DFID 2009).

Growth strategies should be designed with a nutritional lens and take into account what type of sector and subsectoral practices and policies can enhance nutrition. Agriculture growth strategies, for example, could contribute to increasing demand for and access to nutritious foods along the entire value chain. Nutrition-sensitive value chains can be built through various interventions, including consumer knowledge and awareness campaigns that increase demand for nutrient-rich foods and new tools that improve the nutritional value of foods along the value chain. In addition, strategies need to mitigate the health and nutrition risks associated with agriculture, such as water-borne, food-borne, and zoonotic diseases as well as occupational injuries and health hazards. Biofortification—the development and release of staple crops that are enhanced with bioavailable nutrients—also has great potential to improve nutrition. More specifically, biofortification has the potential to increase the micronutrient content of staple crops, especially among undernourished populations who are living in remote areas where access to commercially marketed fortified foods and supplementation programs is severely limited. The HarvestPlus CGIAR Challenge Program, for example, breeds more nutritious varieties of staple food crops that are consumed by poor people in developing countries. However, biofortification will not work in all places or for all crops. Growth strategies that incorporate biofortification programs should thus be based on rigorous assessment of the nutritional and economic impact of biofortified crops in the context of other food-based interventions. Setting priorities and sequencing these interventions as part of a pro-nutrition growth strategy should depend on country-specific conditions such as stage of development and level of institutional capacity. In order to maximize the nutrition impact of growth strategies, more focus also needs to be placed on the role played by conditional factors.

5.2 Investment Strategy and Fiscal Policies

Public investments in rural infrastructure and agricultural research have been shown to have one of the largest impacts on poverty reduction and economic growth in a number of developing countries (Fan, et al., 2008). There is no empirical evidence, however, showing how different types of public spending affect nutrition. Nutrition intervention and nutrition education efforts not only face resource mobilization constraints, but also confront the challenge of allocating such resources effectively and efficiently. Since public resources in most developing countries are scarce and the opportunity cost is high, decisionmakers should allocate public resources more efficiently, taking into account positive and negative spillover effects on nutrition. Research on the effects of public investments should be expanded to include nutrition to give policymakers information on how to prioritize public spending according to nutritional and other development outcomes. The fiscal burden of a pro-nutrition growth strategy can also be reduced through improved efficiency in fiscal management and implementation.

Fiscal policies, like taxes on unhealthy foods and subsidies on nutrient-rich foods, can also be used to maximize positive and minimize negative spillover effects on nutrition. The potential impacts of food taxes and subsidies on diets in developed countries have been a subject of research interest of various studies (Marshall 2000; Allais, Bertail, and Nichele 2008; Salois and Tiffin 2010). Taxes on foods that are rich in saturated fats can be useful in generating government revenue, but the studies show that these taxes need to be complemented by interventions that discourage the consumption of these foods. Such interventions include subsidies on nutrient-rich foods such as fruits and vegetables. More research is needed on the impact of similar fiscal policies to support consumption of more nutritious food in developing countries

6. Conclusion

This paper has sought to give an overview of the nutritional impact of changing growth patterns and the influence of conditional factors on the nutrition-growth relationship. Paying attention not only to the relationship between subsector agricultural growth and nutrition but also to the role of conditional factors is an important step to ensure pro-nutrition growth. The question facing many developing countries remains how to set priorities and sequence interventions in order both to promote growth and to improve undernutrition. A new paradigm for agricultural development is needed, whereby agricultural growth leads not only to increased production and reduced poverty, but also to improved nutrition. To summarize, in this paper, we argue the following:

- Economic growth matters in many developing countries, but the impact varies across both countries and time and there is a nonlinear and dynamic relationship between growth and nutritional outcomes. Economic growth has a bigger impact on malnutrition during early stages of development when the economy is still relatively small.

- Different sectoral and subsectoral growth patterns have differential impacts on nutritional outcomes. It does matter whether growth comes from the agricultural or the nonagricultural sector. Within the agricultural sector, it also matters whether growth comes, for example, from staple or nonstaple crops.

- Conditional factors, such as land distribution, women's status, rural infrastructure, and health status, have an impact on the growth-nutrition linkages. For example, there is a positive relationship between access to land and nutrition as well as gender equality and nutrition.

- Growth alone is not sufficient to address malnutrition, other complementary interventions (such as targeted nutrition programs) are needed. Interventions that directly aim to improve women and child health and nutrition are particularly important.

- Growth strategies and investment policies need to be designed with a nutritional lens, identifying the likely trade-offs between implementing pro-nutrition growth strategies, pursuing other objectives such as poverty reduction, and using other instruments such as targeted nutrition programs.

- More research is needed on the impacts of different sectoral patterns and public investment policies on nutrition, and how these impacts vary across different economic, geographic, and social conditions. This research needs to be based on more comprehensive nutrition data—including micronutrient intakes across different segments of the population.

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