Agricultural Transformation and Nutritional Outcomes in Africa

Prepared for the African Economic Research Consortium Collaborative Project on the Impacts of Agricultural and Food Policies on Nutrition Outcomes in Africa

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I. Introduction

There exists a strong connection between the process of structural transformation in an economy and the nutritional status of the population. In the case of the food and agricultural sector, structural transformation involves technological change and innovation that leads to increased efficiency and productivity. The structural transformation in the agricultural sector will not only affect food output and markets, but is also a crucial driver of the growth in other sectors of the economy, such as the manufacturing and services sectors, and thus, all aspects of the modern economy. Simply stated, structural transformation in agriculture is needed to ensure the availability of plentiful and low-costs wage goods, particularly food, which enable the process of urbanization and industrialization, thereby achieving the goals of income growth and poverty alleviation. Although economic growth and poverty alleviation are certainly the main motivations of economic policy that promote structural transformation in the agricultural and food sector, this framework paper takes a slightly narrower perspective and will instead examine the role of structural transformation in agriculture in terms of its relationship to improving nutritional status.

Five central characteristics of successful structural transformation are (1) a declining share of agriculture in the gross domestic product (GDP); (2) increased capital intensity, which enables and encourages population movements from rural to urban areas, as agriculture sheds low productivity jobs; (3) the growth of employment and output in other sectors, particularly in the service sector, but more importantly, in manufacturing and industrialization; (4) improving health and nutritional status; and (5) a decline in early mortality, and subsequently, birth rates, which are key to the demographic transition and the social and economic benefits that, in turn, result from this process. There are many important caveats and qualifications to these five

processes; perhaps, of most importance is that agriculture's decline in terms of GDP is not to be confused with the notion that agriculture does not remain a leading sector of economic growth in both the transition to and sustainability of fully modern economies. In fact, quite to the contrary, the success of the transformation process is predicated on productivity increases in agriculture, such that the sector is increasingly competitive with non-agricultural enterprises.

The importance of the evolution of the agricultural sector and overall food system goes beyond the general equilibrium effects that ripple across the economy and include the concern over impacts on nutrition, as patterns of production and systems of food processing and marketing evolve. This is the central concern of this paper and is particularly relevant during the transitional process from more traditional, low productivity labor-intensive agriculture dominated by smallholders and weak market linkages, to a more capital-intensive, technologically advanced agriculture. Inevitably, there are winners and losers as a result of the process, both in the short- and long-term, as measured in terms of nutritional risk. Understanding who these nutritionally vulnerable groups are requires an appreciation of the agricultural and food system as a source of income and employment, as well as its effects on food availability and prices. And, in particular, this paper is concerned with the critical role of policy in terms of guiding the structural transformation in agriculture to help realize multiple goals, including the affordability and availability of a diverse low-priced food supply, a safe diet of high quality, and rural income growth and time savings of a highly constrained population, especially vulnerable groups like women and their children. And superimposed on this analysis is the imperative of minimizing the stress on fragile ecosystems in Africa and fostering the goal of environmental sustainability and resilience.

The evidence of transformation in Africa is compelling, albeit, occurring at a slower pace than has been observed in other regions of the world. Commensurate with more disciplined fiscal and monetary policy and the progress in terms of reducing hyperinflation and accompanying overvalued exchange rates and parallel markets, foreign investment is increasing, and many African countries are among the most rapidly growing economies in the world. Although GDP growth has accelerated, as predicted, agriculture's share is on the decline. Specifically, the share of agriculture, forestry and fishing, as a share of GDP, has been between 16 and 17 percent in the 2010s, in contrast to being between 20 and 25 percent in the last decade of the previous millennium. Also, the share of the labor force in agriculture is on the decline, as economies throughout the continent are diversifying and labor is rapidly moving to cities and towns. Employment in agriculture as a percent of the total is around 26 percent, down from around 44 percent in 1990. The urbanization rate is currently around 40 percent, up from around 20 percent in 1980, and this rate is expected to reach 70 percent by 2050. Although agricultural growth in Africa lags behind many other regions of the world, it has been more robust since the turn of the millennium, markedly exceeding rates of the previous decades (World Bank Group 2017). In fact, between 2005 and 2010, agricultural growth averaged around 4 percent per year. Consequences of the improved economic performance, especially the agricultural GDP, are that poverty rates are falling and other non-monetary measures of well-being, such as levels of education, are increasing rapidly. Likewise, infant and child mortality rates are witnessing dramatic declines. For example, infant mortality fell by more than half, from 108 in 1990 to 51 in 2017, per 1,000 births. The rate of improvement in these health indicators accelerated. For example, the rate of decline in under-five mortality more than doubled between the last decade of the 20th century and the first decade of the current millennium.

There is also evidence that fertility rates are beginning to fall, in keeping with expectations that economic development contributes to the demographic transition accompanying structural transformation. The fertility rate fell from 6.8 in 1980 to 4.9 in 2015 (UNDP 2017). This gives rise to the potential for a large demographic dividend, similar to what has been previously observed in Asia. This potential is predicated on enlightened policy, however, including food production, marketing and trade policies that foster the availability of moderately priced wage goods, particularly, in terms of a diversified food supply. Additionally, while fertility rates are declining globally, Africa's population continues to grow rapidly and will likely do so for decades. In 1980 there were 376 million Africans and over 1 billion in 2015. Projections are that Africa's population will be nearly 2.5 billion people by 2050. This clearly represents a formidable challenge in terms of feeding the rapidly expanding population and has important implications for both the level of investment and technological progress, as well as related trade and economic policies that will be required to forestall large food shortages.

Another important consideration is that the cautious optimism concerning the process of transformation of Africa as a whole is tempered by the fact that statistics about the continent overall mask the poor performance of many individual countries on the continent, most prominent of which are those that have been mired in conflict and adversely affected by failed governance and acute economic distortions. The heterogeneity in performance is to be expected, given the size and diversity of the continent and its large number of nation states. In fact, that heterogeneity exists not only between countries but within countries, where the process of structural transformation is characterized often by large differences between regions and communities. Innate geographic and natural resource endowments are partially the explanation

for within country inequalities in the pace of structural transformation, there is still an important role of policy to address these regional inequalities.

It is with this broad perspective in mind that the remainder of this paper aims to provide a better understanding of and guidance on addressing the challenges associated with structural transformation, with a focus on the agriculture sector's role in the transformation process and the relationship to nutrition outcomes. The intent is to inform the channels through which agriculture and related food systems policies impact nutritional outcomes in Africa, and provide both provide guidance and context for the research papers that will be prepared as part of the AERC collaborative project.

II. Structural Transformation and Undernutrition: The Evidence

We next turn to a discussion of the evidence from Africa, first, on the extent of progress in terms of reducing malnutrition in Africa, and second, on the relationships between GDP per capita, agricultural growth, and poverty alleviation with nutritional outcomes in the population. Of particular interest are issues such as whether the evidence suggests that economic transformation and, more specifically, the agricultural and food system has and will contribute to improvements in the nutritional status of the population.

A quick perusal of the most recent statistics suggests that stunting among children under the age of five in Africa is on the decline, from 38.3 to 30.3 percent prevalence between 2000 and 2017 (Table 1). While progress is noted in all regions of Africa, it is slowest in southern Africa and most rapid in eastern Africa. More noteworthy is that improvements in nutritional status in Africa has been substantially slower than in Asia, particularly, but by no means in only Eastern Asia, where levels of stunting fell from 19.2 percent to 5.3 in 2017.

Table 1. Stunting—Regional numbers of children affected and share of total number

	2000		*2017*	
Region	millions	*Share of total*	*millions*	*Share*
Africa	50.6	38.3	58.7	30.3
Eastern Africa	21.5	45.7	23.9	35.6
Middle Africa	7.1	40.2	9.3	32.1
Northern Africa	4.9	23.8	5.0	17.3
Southern Africa	2.0	33.1	2.0	29.1
Western Africa	15.1	36.9	18.6	29.9
Asia	134.6	38.1	83.6	23.2
Latin American and the Caribbean	9.7	16.9	5.1	9.6
Oceania	0.4	36.8	0.5	38.1
Australia and New Zealand	0.0	--	--	--
Europe	--	--	--	--
North America	0.7	3.0	0.5	2.3

Source: UNICEF, WHO, and World Bank (2018, 12)

The qualitative story in terms of magnitudes and changes is similar for other nutritional indicators, such as the prevalence of underweight and wasting (low weight-for-height). As observed throughout the world, wasting prevalence, a measure of acute episodes of malnutrition, among children under five years of age is much lower, afflicting approximately one-quarter as many children as stunting or chronic malnutrition. Similarly, there are some differences in the regional dimensions of the problem, most notably that wasting prevalence is half the magnitude in Southern Africa as in West Africa, while prevalence rates are very similar for stunting. As I will discuss further, this is expected given the differences in the nutrition production function for different types of malnutrition.

There are, however, myriad other types and indicators of malnutrition that go beyond what are regarded as the best indicators of overall health, as particularly captured by stunting. Of

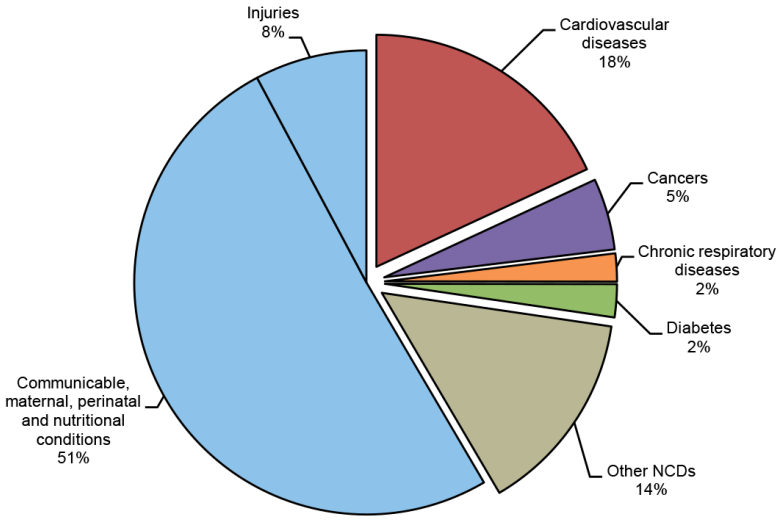
particular concern are micronutrient deficiencies, which have profound functional implications and potentially devastating impacts. Much of the early attention to micronutrients was focused on European populations; as various policies and interventions reduced the severity of these micronutrient deficiencies in higher income countries, the sense of urgency about their global dimensions receded. Thus, although much has been learned regarding the relationship between micronutrient deficiencies and disease and disability, as far back as the 19th century, a renewed sense of urgency has emerged during the past couple of decades when advocates, concerned with the health of low income populations, have branded widespread micronutrient deficiencies, especially of vitamin A, iodine and iron, as "hidden hunger." I find this label an odd one insofar as the physical manifestation of several of these deficiencies, especially when more acute, such as goiter from iodine deficiency and blindness or Bitot's spots[1] from Vitamin A deficiency, are often quite manifest. Of course, the overt signs of these deficiencies are not always present; this can also be said of stunting and other forms of chronic malnutrition. Thus, any discussion of the relationship between the transformation of the agricultural and related food system and its impact must accord attention to the devastating toll in of common afflictions, such as iron deficiency, which affects more than one and a half billion people worldwide (WHO 2008). Hardest hit are preschool-aged children, for whom prevalence rates are estimated at 47 percent. Forty-two percent of women worldwide are also iron deficient. Regional estimates indicate an even worse picture in Africa where two-thirds of preschoolers suffer from anemia. The prevalence rate of anemia among pregnant women is 57 percent. Vitamin A deficiency similarly affects 250 million preschool-aged children, resulting in blindness estimates of between 250,000 and 500,000

[1] Bitot's spots are the buildup of keratin located superficially in the conjunctiva of human eyes.

children; and among them, half die within a year of losing their vision (WHO 2016). Iodine deficiency disorders, which contribute to cognitive impairment among children, afflict nearly 30 percent of children, or around 240 million children worldwide. Among these children, around 5 percent have intakes that are severely deficient (Andersson and Zimmermann 2012).

While the persistence of various types of undernutrition continue to challenge policymakers in Africa, one of the consequences of prosperity and a globalized food system that accompanies structural transformation is the marked change in the availability, prices, and preferences for food. This in turn has contributed to the global epidemic of overweight and obesity. Over 2 billion people over the age of 18 are estimated to be obese or overweight; this problem, in sheer numbers, afflicts more than two times the number of people suffering from insufficient calorie intake. The number of obese and overweight individuals has more than doubled between 1980 and 2014. Although this problem is still largely concentrated in middle- and upper-income countries, low-income countries and the poor are not immune to this affliction, which is strongly associated with the growing epidemic of noncommunicable diseases (NCDs), such as cardiovascular disease, diabetes, and cancers. Similarly, although the problem of overweight and resulting deaths is concentrated in adults, the problem cuts across all demographics, including children under the age of five. In Africa, the number of overweight and obese children increased from 5.4 to 10.6 million between 1990 and 2014 (WHO 2017). Globally, one in four obese children live in Africa. Certain countries have been particularly hard hit by this growing epidemic. For example, in Southern Africa there has been a 33 percent increase in the share of overweight children, from 10.3 to 13.7, between 2000 and 2017 (UNICEF, WHO, and World Bank 2018). Consequently, throughout the continent, noncommunicable disease, much of which is related to nutrition, is increasingly the cause of

mortality. Figure 1 for Ghana illustrates this well—in 2014, 42 percent of deaths were a result of noncommunicable disease.



Total deaths: 210,000
NCDs are estimated to account for 42% of total deaths.

Figure 1. Causes of Mortality, Ghana, 2014.

Source: Sahn (2015).

For policymakers, the challenge of addressing overweight and obesity is complicated. Perhaps. most important is that overweight and undernutrition are linked in complex ways. For example, there is compelling evidence that early childhood undernutrition contributes to later life obesity, as explained by the expression of the thrifty phenotype hypothesis (Barker 1992, 1998a,b). This has been widely discussed in the literature and provides the biological explanation for how the same *in utero* and early childhood stress may lead to stunting as a child and an increase in the risk of overweight and obesity as an adult. Thus, there are strong links between undernutrition and overnutrition, providing evidence on the role of early childhood experiences and their deleterious impacts across the life course. As such, all the dimensions of malnutrition

that I discuss in this paper are part of a complex etiology, often with competing agents, interest groups, and constituencies, as well as conflicting goals and policy prescriptions. And more specifically, this complexity sets up difficult challenges in how the underlying process of structural transformation, as related to the agricultural and food sectors, can be better understood and made to contribute to improvements in the nutritional status of the population.

III. The Role of Economic Growth

Two fundamental questions underlie concerns with the role of agriculture in improving nutritional outcomes. The first is about understanding the relationship between economic growth and nutritional outcomes. And the second is whether there is anything distinguishing the impact of growth and structural transformation in the agricultural sector from that of growth in general. That is, does the source of growth, at least in terms of agriculture versus non-agriculture matter?

To address these questions, we can begin with some stylized facts from cross-country evidence. Figure 2 shows a strong relationship between gross national income (GNI) per capita and levels of malnutrition.

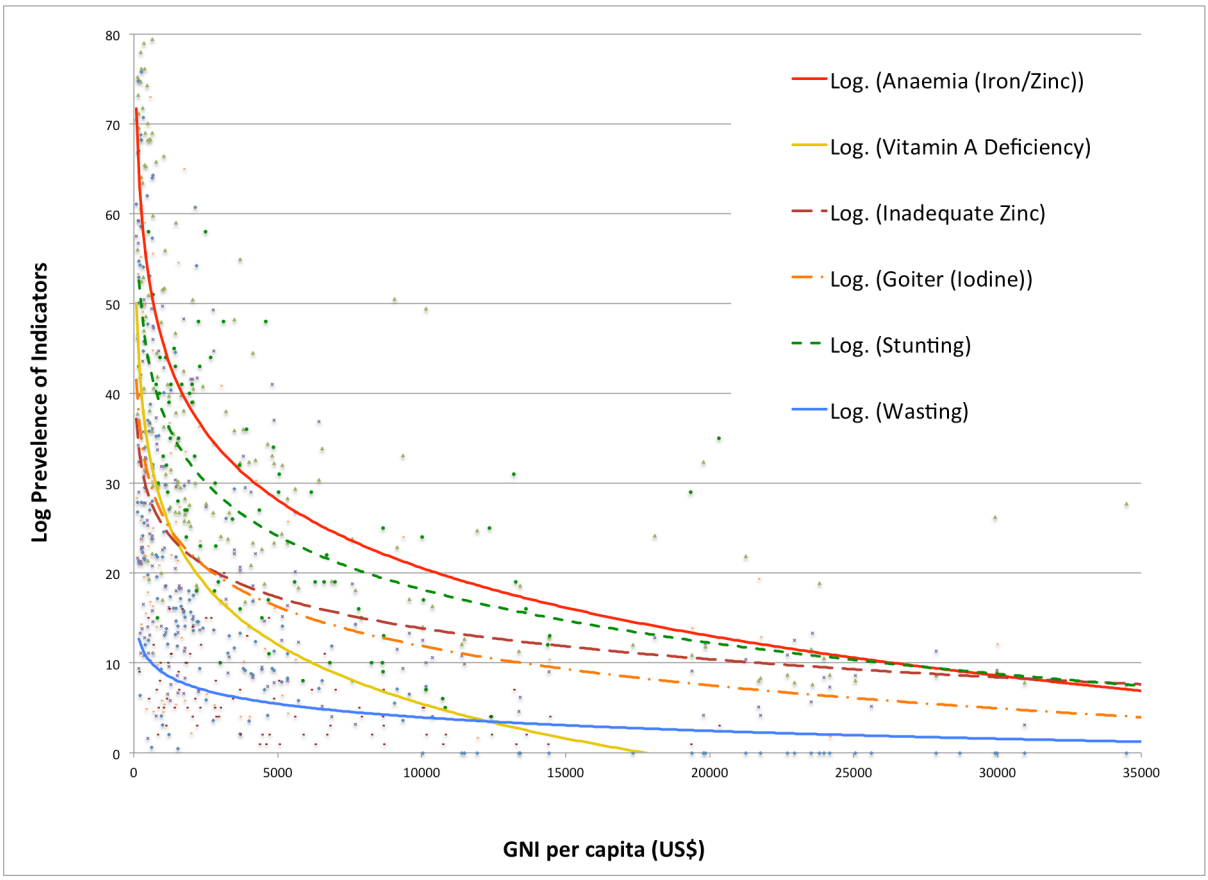


Figure 2. Associations among income and malnutrition indicators

Source: Barrett and Bevis (2015, 63).

Data sources:

GNI data from World Bank (2014).

Anemia, vitamin A, and zinc indicators from United Call to Action (2009)

Goiter data from World Health Organization's *Iodine Status Worldwide 2004* (WHO 2004)

Stunting and wasting data from UNICEF (2013)

As can be readily seen for countries in Africa, this relationship is strong and consistent for stunting, wasting, and a range of micronutrient deficiencies. Similar studies that incorporate data from other regions of the world show the same pattern.

This association, however, cannot be interpreted causally. It is possible that the same factors that promote GDP growth also co-determine nutritional outcomes. If economic growth and nutrition are jointly determined by other exogenous variables, then it is not increasing incomes that is causally determining these improvements in nutritional status. Additionally, there is the prospect that causality runs from better nutrition to economic growth. This would be consistent with the large literature, discussed further later in this paper, about the productivity-enhancing power of improving nutritional status. That is, there are a range of pathways through which better nutrition can impact economic growth, most important of which are mechanisms related to improved cognitive outcomes and physical stamina and strength.

Several studies have endeavored to explore the extent to which increases in incomes are causally related to nutrition, over what time horizon and through which mediating variables. The findings of this research paints a conflicting picture. Some studies, such as Haddad, Masset, and Smith (2015); Ruel et al. (2013); and Headey (2013), suggest that growth will contribute greatly to the reduction in malnutrition over the long-term. For example, Haddad, Masset, and Smith (2015) reported the long-term elasticity of stunting with respect to growth in GDP per capita to be 0.63. This high elasticity may in fact find explanation if the expectation that, over the long-term, structural transformation and high GDP contribute to a range of changes are occurring in terms of education, infrastructure, government revenue, spending on social services, and so forth, which are expected to contribute to better nutritional outcomes. In fact, the curve shown nearly captures this long-term picture, but it says little about the impact of short-term improvements in materials levels of living.

One way to illustrate the complexity of these expectations is with a similar graph, but in this case, I show the curves estimated by decade. Figure 3 illustrates how there is a secular

improvement in infant survival for any given level of real GDP per capita. That is, the relationship between real GDP per capita and the level of stunting is not constant, meaning other factors not captured by GDP affect infant survival, and these factors have contributed to improvements over a constant level of real income. These improvements may be explained by a range of factors, including health technology, access and quality of services, the impact of improved education, cognitive skills and knowledge, and even the distribution of income and related services provided by the state and non-state actors.

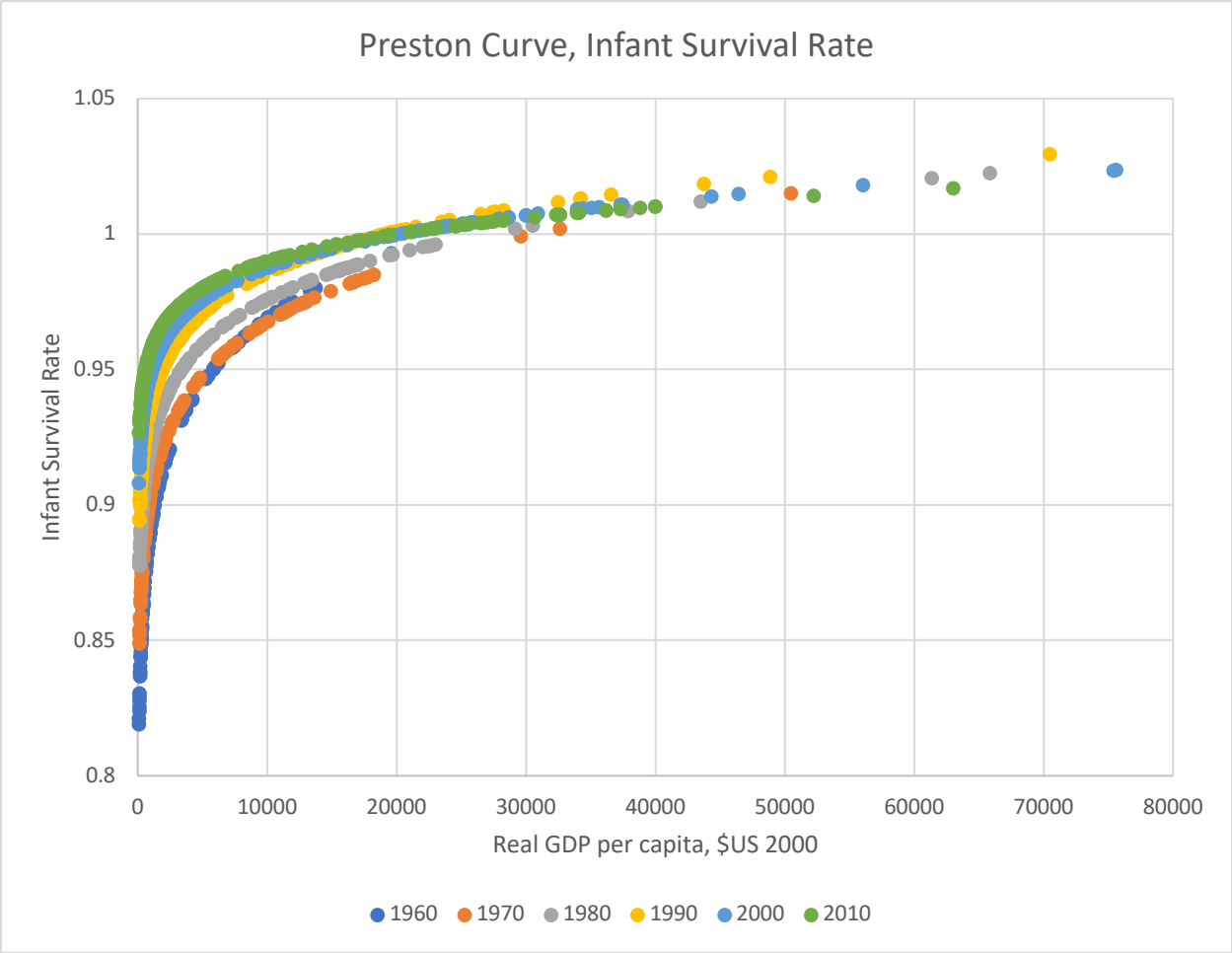


Figure 3. Preston Curve of infant survival rate vs. real GDP per capita

Source: Author's calculations using World Bank Indicators data set

This raises the question as to what are the short-term elasticities of health improvements with respect to increases in economic growth. Clearly, it is difficult to infer the impact of short-term economic growth on nutrition from long-term elasticities. Therefore, a number of recent studies have set out to determine shorter-term impacts. Here, the evidence is much more modest in terms of the benefit of economic growth. A recent paper by Smith and Haddad (2015) estimated a short-term elasticity of 0.17, which is quite close to the work of Alderman et al. (2013) that reported a doubling of GDP per capita would reduce stunting by 14.8 percentage points and reduce the share of children who are underweight by only 11.4 percentage points, implying an elasticity of only 0.11. Alderman et al. (2013, 52) concluded, "The overall takeaway finding from this analysis is that growth has in and of itself little impact on reducing chronic malnutrition," which is consistent with the report of Subramanyam et al. (2011), who found that state-level rates of malnutrition are only weakly related to economic growth.[2]

This finding can be explained partially by the absence of inclusive, or pro-poor, growth, now well documented in the literature (AfDB 2012; Ravallion 2004). Quite simply, the benefits of economic growth have often left behind those at the lower end of the welfare distribution.

Another potentially related explanation for the sobering estimates of how growth will impact nutrition has to do with the pattern of growth; specifically, the question is whether economic growth in certain sectors, particularly agriculture, is more likely to lead to reductions in malnutrition. Indications here are at best ambiguous, as discussed by Headey (2012), who

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[2] Neeliah and Shankar (2008) came to the same conclusion and argue for the importance of targeted interventions.

pointed out that many factors will affect the strength of the relationship between agricultural growth and malnutrition. These include the extent to which food insecurity is a problem and agricultural growth increases food availability. If such circumstances exist, it increases the likelihood that growth in the agricultural sector may be more strongly related to reductions in malnutrition than is the case with nonagricultural growth. This makes sense to the extent that low-income households have deficits in calorie consumption and that the malnourished live in households that are disproportionately reliant on domestically produced food. The countervailing possibility is that, as Headey (2012) pointed out, non-agricultural growth may have a larger impact on dietary diversity through, for example, the increasing of reliance on food markets with a greater range of products than in markets with primarily locally grown, foods.

There is also reason to expect that underlying economic conditions, such as the extent of income or land inequality, are important in terms of determining how sector-specific growth patterns affect nutritional outcomes. Similarly, Fan and Brzeska (2012) pointed to the fact that it is not whether growth is in the agricultural sector per se; it is the subsector that matters. For example, growth in staple crops will have a different impact on nutrition than livestock. And depending on the nature of the nutrition problems that are prioritized, it may be that subsectors like fruits and vegetables, that supply micronutrients such as vitamin A, may be of greater importance that more calorie-rich crops, which may be more important when stunting and underweight are the main nutritional problems.

Another consideration in terms of nutritional impact of the subsector is whether growth is concentrated in export crops versus those grown primarily for domestic consumption. Also, the impact of growth on nutrition may differ, depending on whether it is poor or rich farmers, or the region of the country, that enjoy the direct benefits of productivity growth. Even if there is a

focus on crops commonly produced and consumed domestically by the poor, there are other considerations that impact the extent to which agricultural growth will improve nutritional outcomes. These include the nutritional value of the food, the nature of food processing, and safety along the entire value chain. These considerations highlight the importance of policies designed to guide the process of agricultural transformation just beyond the narrow objectives of raising productivity, but also to agricultural research that prioritizes nutritious staple crops, fosters consumers' abilities to make informed choices about healthy foods, and even study of related issues, such as the impact of technology on water resources, including diseases such as hookworm, and the more general issue of environmental sustainability.

These types of differences in the nature of agricultural growth are also strongly correlated with gender-specific roles in agriculture. The literature suggests that the gender-specific analysis of benefits from different types of growth is lacking in most instances. As I will expand upon below, there has been a serious neglect of attention to issues such as gender control of income and time use, including constraints presented by income, both of which are powerful determinants of nutritional status of young children and vulnerable groups. And, of course, compounding this complexity is that, as noted above, malnutrition itself is multidimensional and will be differentially affected by different sector and subsectoral patterns of growth.

The finding that there is a weak link between economic or income growth and nutritional outcomes can be viewed in two lights. One is a rather sobering and implies that, even despite Africa's economic progress and increases in agricultural GDP, problems of malnutrition are going to persist. The other is that despite the absence of economic progress, policymakers need to explore more fully the short-term scope for reducing malnutrition—even in the absence of robust economic growth, including in agriculture.

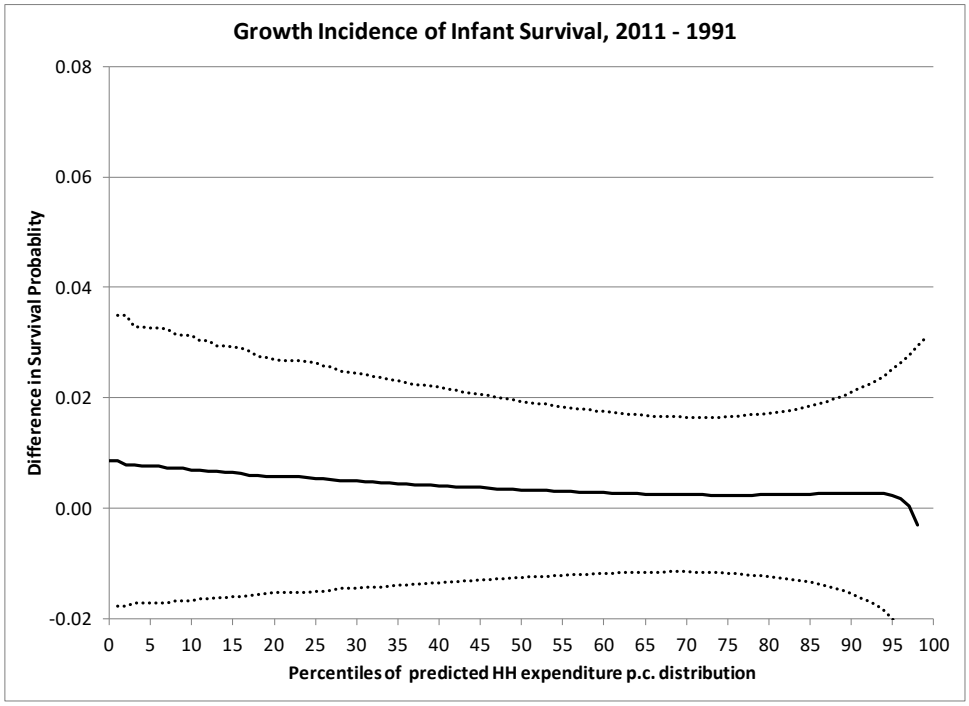
Much of the literature on improving living standards, of which health and nutrition are clearly priorities, has been focused on one paramount goal: poverty reduction through improving material resources of the poor. This quest has focused attention of policymakers increasingly on looking beyond economic growth, and addressing instead the issue of the extent to which the economic growth is inclusive or pro-poor growth. Research suggests that despite the variation across countries, there is appreciable evidence that growth does lead to commensurate reductions in poverty (Ravallion 2001; Dollar and Kraay 2002; Ravallion 2013; Dollar, Kleineberg, and Kray 2015). As Amartya Sen (1979, 1985, 1987) articulated in his seminal writings nearly four decades ago, poverty must be understood as deprivations in multiple dimensions of well-being, which has given rise to a wide-ranging literature on the multiple dimensions of poverty (Duclos, Sahn, and Younger 2006 a, b; Alkire and Foster 2011a, b). Although income growth is instrumentally important, and pro-poor growth even more so, broad measures of improvements in living standards must consider welfare in multiple dimensions, such as nutritional status, which are intrinsic to the human condition. This raises the question of whether there is a similar pattern in terms of how economic growth translates into nutritional improvements, as it does for improvements in poverty and related measures of material wealth. That is, will structural transformation lead to similar improvements in terms of the reduction in poverty and malnutrition? This would be expected if there is a strong and static correlation between income and nutrition. Even if this correlation is strong, however, this does not necessarily say much about whether there is a similar correlation between the distributions of *improvements* in income and nutrition across the population.

Sahn and Younger (2017) addressed this question in the African context using a technique originally proposed by Ravallion and Chen (2003) to examine the extent to which economic growth is pro-poor—the growth incidence curve. Klasen (2008) later adapted this tool to non-income measures of well-being. Sahn and Younger (2017) went one step further to address whether height gains are larger for children in poorer or richer households? That is, where in the income distribution are heights improving, and by how much? We can answer that question with a "gradient health improvement incidence curve":

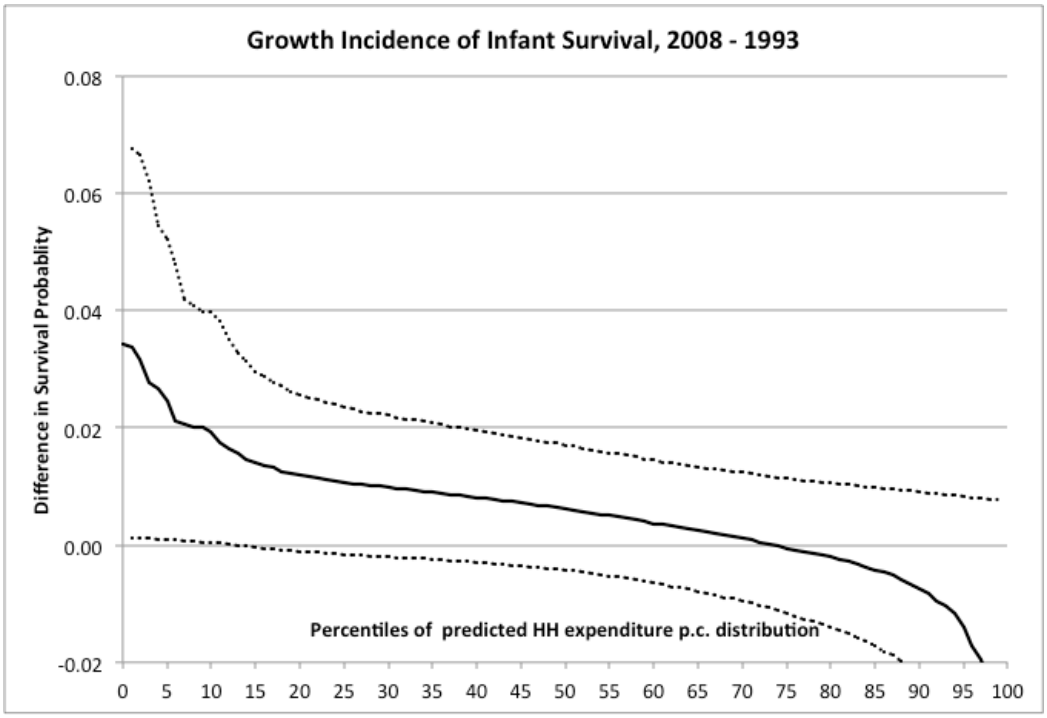
$$dgh_t(p) = h_t(y_t(p)) - h_{t-1}\big(y_{t-1}(p)\big) \ , \tag{1}$$

where $h_t(y_t(p))$ is the height associated with the pth quantile of the income distribution rather than the height distribution. Estimation of $h_t(y_t(p))$ requires a regression, Sahn and Younger (2017) do nonparametrically, using local linear regression.

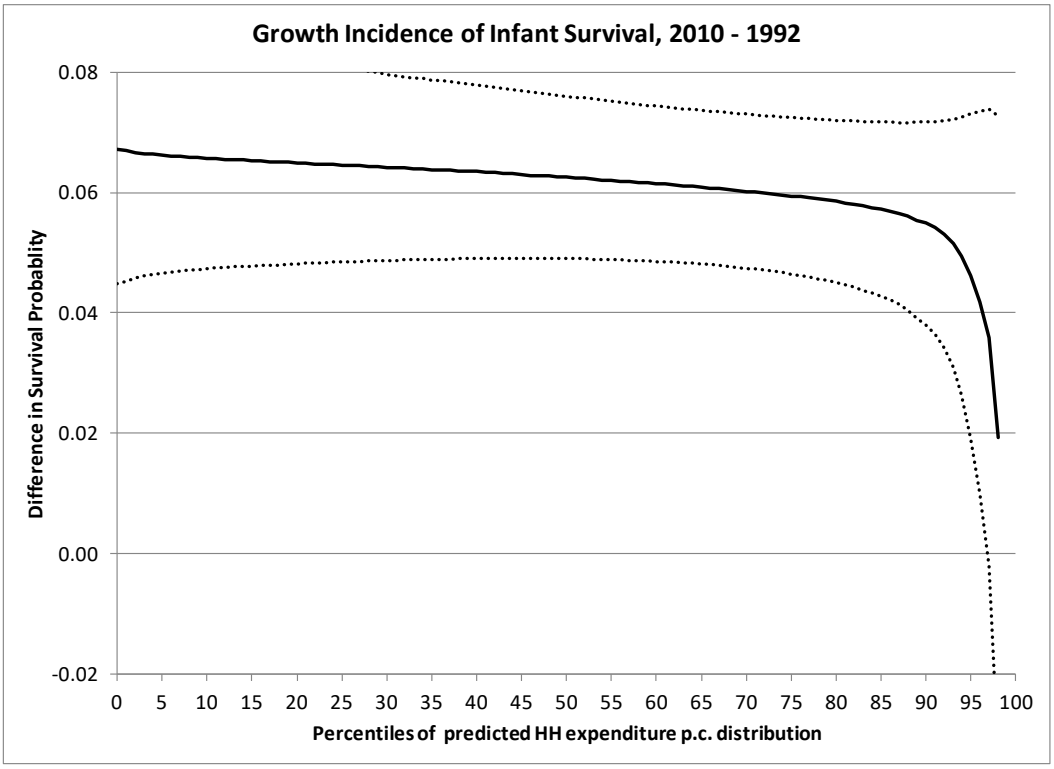
Four examples of gradient health improvement incidence curves (GHIIC) are shown here in Figure 4.



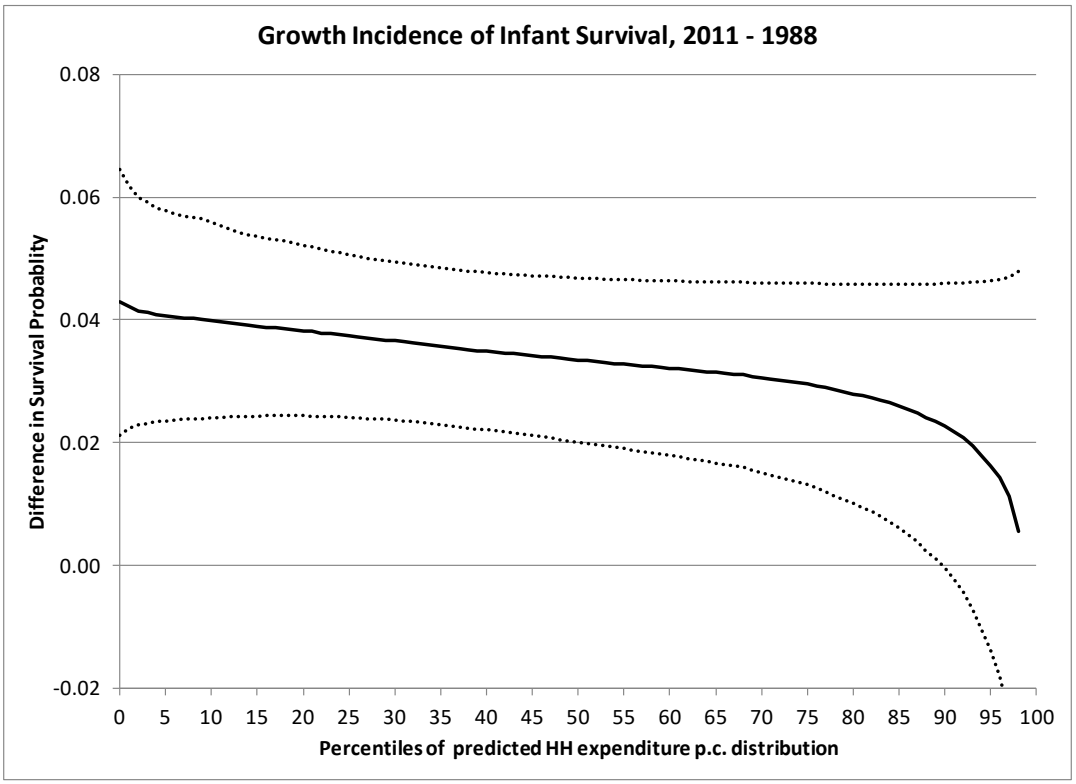
Cameroon



Ghana



Malawi



Uganda

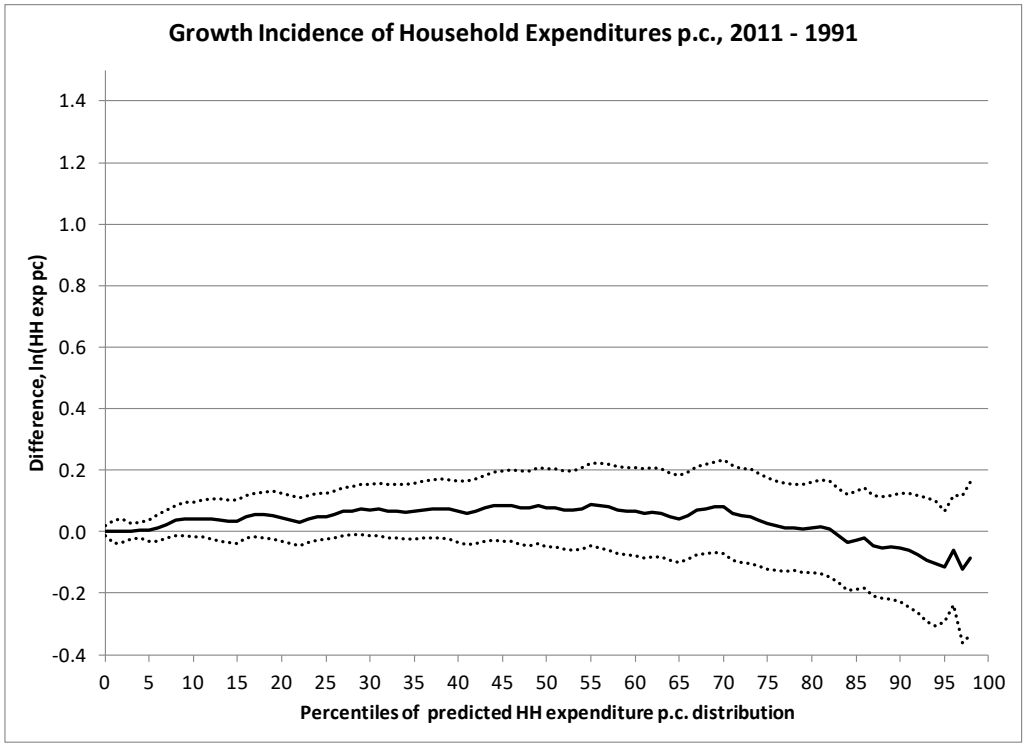
Figure 4. Gradient Health Improvement Incidence Curves (GHIIC): Cameroon, Ghana, Malawi, Uganda

Source: Sahn and Younger (2017, Fig. 5, 315–316)

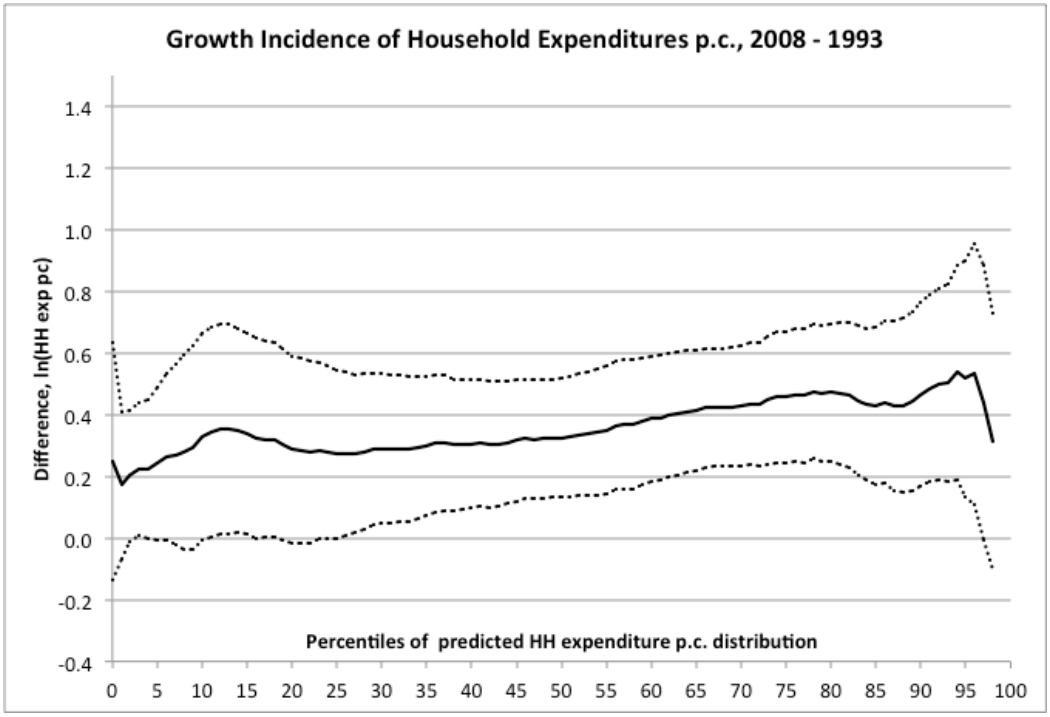
For Cameroon and Madagascar, there is a clear upward slope in this curve, implying that the health improvements are concentrated in the upper end of the health distribution, while for Malawi and Uganda the curve is flat. What is of equal interest, however, is how these curves compare with the more widely estimated and understood growth incidence curves (GICs) of the type estimated by Ravallion and Chen (2003), based on income improvements, where for a cumulative distribution of incomes F(y), let p be the quantile associated with a given income, so that p = F(y). Then, p ranges from 0 (the poorest quantile) to 1 (the richest). Inverting this gives a quantile function, $y(p) = F^{-1}(p)$. The growth incidence curve (GIC) is:

$$g_t(p) = \frac{y_t(p)}{y_{t-1}(p)} - 1 \tag{2}$$

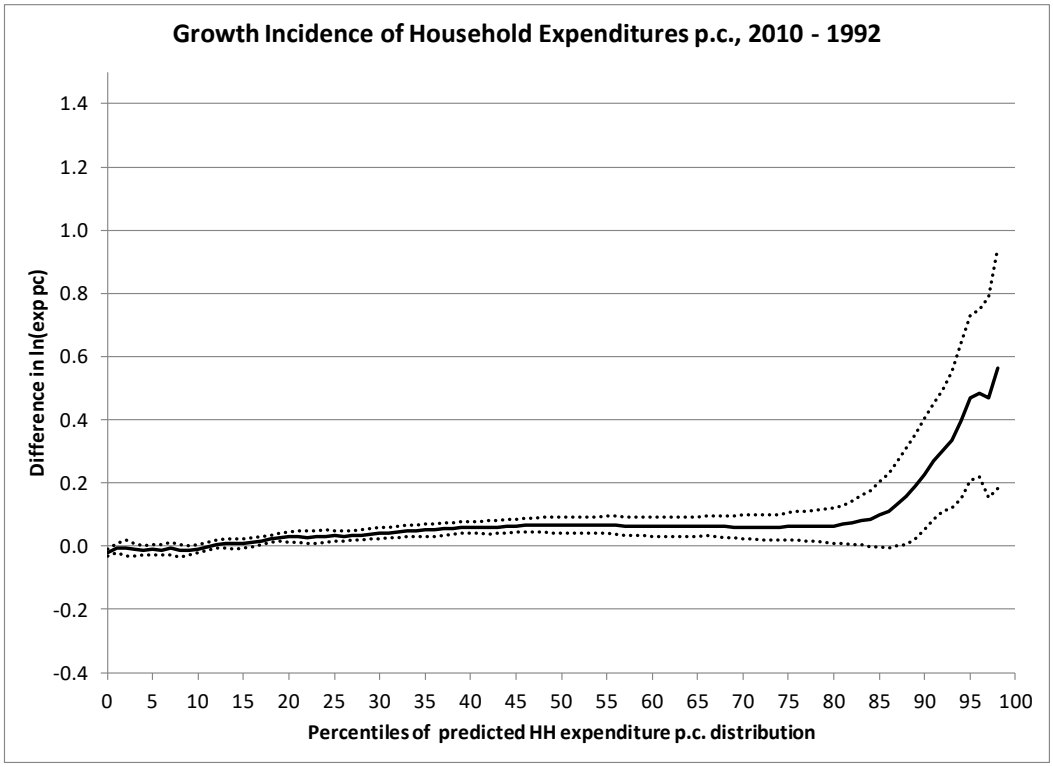
This curve shows how much income at the pth quantile has grown at time t, graphing it for all values of p.



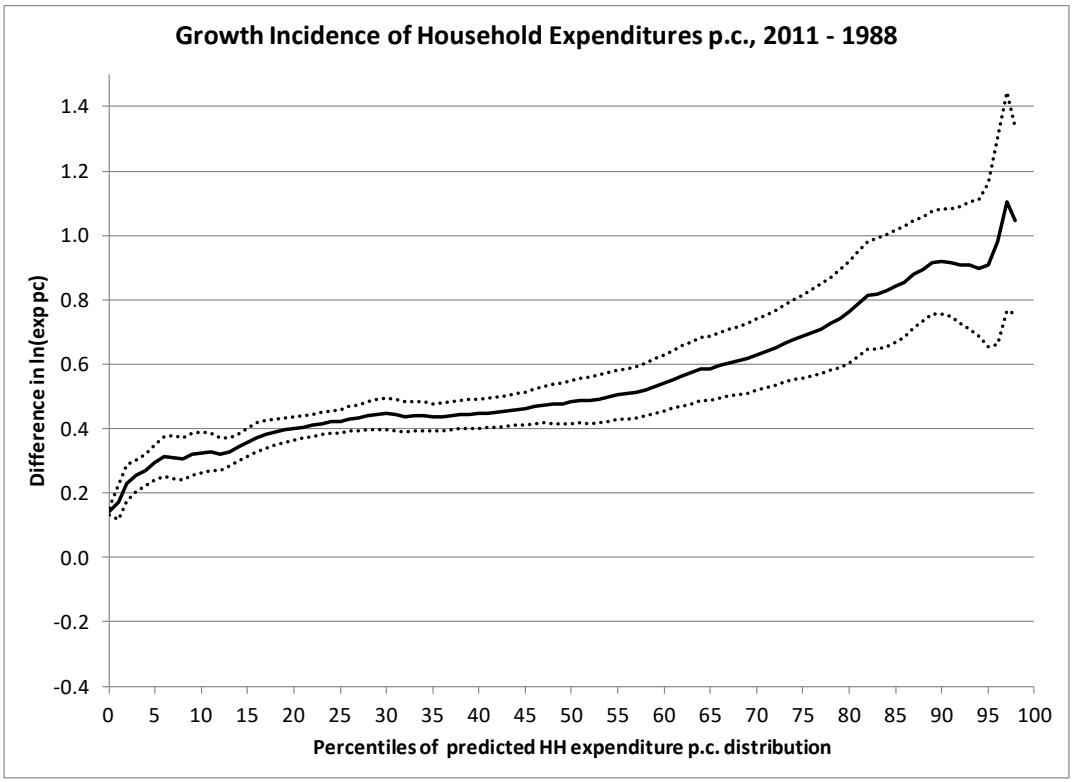
Cameroon



Ghana



Malawi



Uganda

Figure 5. Growth Incidence Curves (GIC): Cameroon, Ghana, Malawi, Uganda

Source: Sahn and Younger (2017, Fig. 4, 314),

These curves for the same four African countries are shown in Figure 5, and we compare them with the gradient health improvement incidence curves. The highest level of growth in per capita expenditure distribution across the two periods was in Uganda. Incomes improved among those in the lower end of the expenditure distribution, and thus there was what may be referred to as weakly pro-poor growth, where there is growth in absolute terms. It is not pro-poor, however, in a "strong absolute" definition, which requires that income increases in currency value for the poor be greater than those for the rich. The economic growth in Uganda is additionally not pro-poor in a relative sense, where we define relative pro-poor growth as the case that the growth rate of the poor's incomes is greater than that of the non-poor. Growth is much slower in the other three countries, and in all of these countries it is not pro-poor in relative terms.

In Cameroon and Malawi, there is no pro-poor growth in weakly absolute terms. In the cases of Madagascar and Malawi, the limited growth that occurred is concentrated in the upper end of the per capita expenditure distribution. In Malawi, for example, there is virtually no growth in per capita expenditures across 80 per cent of the expenditure distribution; then, there is a sharp upward slope of the curve, indicating that there was measurable growth in expenditures among the wealthiest quantiles of the population.

Comparing the GICs and GHIICs suggests, first, improvements in stunting in a population have a different distribution than income/expenditure growth, and that distribution is usually more hopeful in the sense that it is more likely to be strongly pro-poor than the

distribution of income growth. Thus, it is really not sufficient to look at poverty and income growth, which, of course, is a more meaningful metric of well-being that economic growth. Second, we have yet to see clear patterns in terms of the within-country relationship between the distribution of improvements in income over time in growing economics and improvements in nutrition. This suggests that the economic development process that contributes to pro-poor growth is not the same as the process that defines the inclusiveness of improvements in nutrition. It is therefore not possible to assess the impact of structural transformation only in terms of the benefits measured by material measures of well-being; we must also think about income alone—the distributional benefits of income growth differ from those for health gains. In particular, although Ravallion and Chen (2003) found that even when economic growth is not pro-poor, the opposite is true for stunting. This only reinforces the observed weak relationship between the process of structural transformation, including in the agricultural sector, and nutrition outcomes, raising the question as to why, and what this implies for policy.

In addressing this question, we inevitably are directed to considering the role of direct agricultural policies, such as promoting investments in research on nutrient-rich staple crops and outreach policy initiatives that are targeted to poor areas or producers. The range of policy initiatives spans a wide spectrum, however, from those concerned with promoting environmental resilience, nutrition-informed fiscal and monetary policies, and promoting nutrition-sensitive infrastructure development. So, although there is a strong case to push for structural transformation in agriculture and robust economic growth, such developments will not be sufficient to realize quick or acceptable rates of improvement in nutrition. Instead, agricultural transformation is not a panacea in terms of improving nutrition, especially in the absence of other investments, such as investments in health, education, physical infrastructure, and so forth. Their

importance is highlighted in the next section that provides an analytical framework for focusing on the most salient programs and policies to achieve nutritional goals.

IV. Nutrition Production Function

While broad policy prescriptions focus attention on myriad channels that link agriculture and nutrition, understanding the relationship between the process of agricultural and food sectors and nutrition can be facilitated through consideration of the underlying nutrition production function, which links nutrition outcomes to various inputs, including those that are related to the structure and functioning of the agricultural sector. The underlying nutrition production function provides insight into the role of inputs in determining nutritional outcomes. More specific to the concerns of this paper, the nutrition production function represents a conceptual framework for how structural transformation in agriculture, and specifically, short- and medium-term improvements in food production and agricultural productivity contribute to reductions in malnutrition. The intent is also to provide the framework for further consideration of the types of investments and policies that help realize the goal of reducing undernutrition without waiting decades for GDP growth to do so, while at the same time, proving insights into how to mitigate the deleterious effects of structural transformation in terms of the growth of noncommunicable disease.

As a point of departure, consider the simple nutrition production function that builds upon Grossman (1972), where current nutritional status, $N_{it,}$ is a function of the nutrition N_{it-1}, of the prior period, as well as a series of inputs, notably the vector of nutrients consumed from food; nutrients from other sources such as supplements; time inputs in the form of self-care or care of the mother/father or other provider, which can include breastfeeding and weaning practices for young children; the general health environment, including housing conditions, the availability

and quality of water and waste facilities such as latrines; health behaviors such as smoking, alcohol consumption, and engaging in risky sex practices; use and consumption of preventative and curative health services; and genetics, which affect the initial health endowment and mediate the impact of other inputs on nutritional outcomes.

There are several important factors in considering the nutrition production function and how it informs the issue of the relationship between agriculture and nutrition. First, is that the relative importance of the parameters in this production function are likely to differ dramatically, based on the type of malnutrition we are concerned with. For example, supplements are clearly going to be paramount in determining micronutrient nutrition, while having little impact on obesity. It is also the case that other inputs, such as water and latrines, may have an important impact on certain micronutrient deficiencies, such as iron status, as mediated through hookworm infection, but not on others, such as iodine deficiency. Similarly, certain nutrients will be important in determining the level of stunting (e.g., consumption of calories), but not micronutrient status (where dietary diversity and consumption of green leafy vegetables or iron-rich foods may matter more). And, of course, in the case of overweight and underweight, the sign on the coefficient of a nutrient is expected to have an opposite effect on those outcomes.

While the different role of inputs in the production of the different types of nutrition is intuitive, the challenges of empirically understanding these relationships is far from straightforward. More vexing is that, even if the parameters in the production function are fully understood, the appropriate policy response to addressing the problems of malnutrition are complicated and involve formidable trade-offs in terms of which type of malnutrition to prioritize. Quite simply, both the characteristics of the population most vulnerable to different forms of malnutrition and the policies to address those needs of different populations groups

(e.g., pregnant women and children under the age of two years in the case of stunting and water, and adults in the case of obesity) are potentially contradictory, or at least would imply a different ordering in terms of importance and relevance.

Following from this realization is that the particular role of agriculture and food policies may have complex, and often, more important indirect pathways which impact nutritional outcomes. Take, for example, the paramount concern with malnutrition early in the life course, particularly, for the period *in utero* to 24 months of age. A consensus has emerged over the past decade that this is the most critical period for intervention in terms of stunting and wasting, and that nutritional deficits during this period are unlikely to be compensated for, in terms of their functional implications, later in life. Damage is permanent, in terms of growth, higher risk of mortality and morbidity, and related deleterious outcomes such as reduced cognitive and physical abilities. So, it is during these critical 1,000 days, from conception to a child's second birthday, that reversible damage can occur from nutritional deprivation. This point, perhaps, is easiest understood by looking at the simple Figure 6, showing the association between age and growth faltering. It is in the early months of life that this slowing of growth occurs, and there is little evidence of catch up. In this sense, the problems of stunting and wasting (and the composite indicator of low weight-for-age) mirrors the disturbing evidence for certain micronutrient deficiencies, such as folate and iodine, that have serious consequences if they occur during pregnancy, resulting in irreversible damage to the newborn child. A similar story applies to deficiencies of Vitamin A and D, as well as iodine, where long-term irreversible consequences are particularly devastating early in life.

Although this high-risk window is now widely accepted in policy circles, the question arises as to the policy measures in response to this reality. The nutrition production function

represents an important construct to consider policy options in response to these deficits. First and foremost, the production function highlights the importance of the temporal dimension, as indicated by the subscripts in the functional relationships. As a result, there is considerable discussion in the literature of time-sensitive interventions. This is relatively straightforward in terms of targeting programs, such as prenatal folate supplementation. In that case, the issue of timing is all the more challenging, because between by the time a woman is aware she is pregnant and/or seeks out prenatal care, it can be too late in terms of damage done from folate deficiency. This is in contrast, for example, to iron deficiency where the time-sensitive period is later in pregnancy, and the consequences for fetal development less urgent. Thus, in the case of folate, the target population is all women of childbearing age, unlike iron supplementation.

This illustration, however, is for nutrition-specific interventions, in contrast to the focus of this paper on broader agricultural policies. The challenge is that policies are often more complicated to formulate in terms of addressing nutritional goals, as the lags and the mediating mechanisms between policy changes and their impact on vulnerable groups are inherently less direct and often involve unanticipated delays.

Another issue that the production function highlights is that there are a large number of inputs that affect nutrition. Noteworthy, however, is that nutrient intake is only one of the many inputs that matter, and of course, intake is a far step away from issues of production. Mediating factors include the supply chain, and related issues of price and income that affect food demand. Likewise, when consumption is measured at the level of the household, it obfuscates the issue of intrahousehold dynamics, which is a critical issue in terms of who consumes what nutrients, which is what we want to capture in the production function.

In the case of children under the age of two years, the nutrient requirements are of course modest, at least in terms of their quantity. And for the first six of the 24 months, these are ideally supplied exclusively through breastfeeding. Even with the introduction of weaning, breastmilk is still a crucial source of nutrients, and likewise, the food-based diet provided to the infant and young child involves the provision of modest amounts of calories, proteins and other vital nutrients. Thus, nutrient consumption from food, Z_{it}^{f}, is only a small part of the equation that will affect nutritional status, and given that, the likely direct role that food prices and availability play is less important than several other parameters in the production function. These include those that affect the likelihood of infection and disease, as well as the types of preventative and curative health services accessible by the mother and child. Thus, it would be a great simplification to conflate the issue of food consumption, availability and prices, let alone agricultural output and production, with nutritional outcomes, especially among young children. That being said, it is likely that agriculture and food systems play a crucial role in the availability, quality, and diversity of the diet, which is an important complement to other inputs in the nutrition production function.

It is also the indirect role of the agriculture and food system, in terms of affecting other inputs in the nutrition production function, that should be the focus of policymakers. There are many mechanisms by which agricultural policy affects nutritional outcomes indirectly. First and foremost is as a source of employment and livelihoods for rural households. Second is that agricultural transformation has important implications for time availability and related constraints faced by what is often scarce, seasonal labor. This is especially an acute issue for women who often have conflicting time demands in terms of food production and marketing, on the one hand, and their role as mothers and care providers of young children, on the other. The

time demands of these productive and reproductive roles are altered through the process of structural transformation. Labor-saving technologies reduce labor demand, and also, the demand for more children among households falls as rural incomes rise and infant and child mortality rates drop. These changes are expected to allow women more time to care for their children, and also, to reduce the health risks and stress on them directly, contributing to their improved health and nutrition.

Further, of the paramount importance is the contribution of the process of agricultural transformation to robust rural economies, which can source schools, clinics, and other public infrastructure vital to nutritional well-being. As depicted in the nutrition production function, these elements of social infrastructure are important inputs, and the paucity of such services has been an important constraint to reducing levels of malnutrition.

Another important but indirect impact of structural and agricultural transformation that will affect nutritional outcomes is mediated through the challenges associated with the environment and natural resource management—promoting environment resilience and lessening climate change, soil degradation, water pollution, shortages, and related concerns of sustainability. Although environmental concerns are of greater importance to households living in rural areas, they are relevant to urban households also. For example, access to clean and plentiful water is a prerequisite to preventing infection and disease that can contribute to malnutrition. Related concerns, such as the generation of hydroelectric power instrumental to the structural transformation of more energy-intensive agricultural practices and, of course, a robust urban economy, is yet one more of many examples of how environmental concerns can affect key inputs in nutrition production.

In terms of the relationship between agricultural transformation and nutritional outcomes in urban areas, again, the production function makes clear that there are a wide range of mechanisms through which this process will affect nutritional outcomes. To highlight a few, the most basic is that the agricultural sector and related food system is the essential provider of a plentiful, diverse, and safe food supply in urban areas that enables the large population movements to urban areas that is occurring throughout Africa. Of course, it is in this environment that the demand for agricultural products changes, as tastes and lifestyles evolve, and likewise, the role of and nature of the food processing and market systems becomes increasingly prominent. As the supply chain becomes more distant between producer and consumer, including an increasing role for imported goods, the issue of the challenges associated with noncommunicable diseases from obesity gains prominence. Note that in the context of the nutrition production function, the inputs that contribute to the various types of malnutrition in urban areas, from severe cases of wasting to the rise in obesity, are often very different and operate through opposite signs on the parameters in this model. This represents a formidable challenge to policymakers trying to formulate agricultural and food policies to address the diversity of nutrition problems.

V. Labor Markets and Employment Linkages with Food and Nutrition Policy

Employment and labor market-related linkages between agriculture, the food system, and nutrition are complex and bidirectional. On the one hand, the agricultural and related food processing and marketing sectors are not only the main food producer, but also the largest employer and source of economic output. Thus, the agricultural sector is instrumental to both providing employment and thus, economic growth, and also a source of wage goods necessary to

lift rural but, more importantly, urban households out of poverty. Quite simply, without the surpluses from farms, non-farm households will not have access to an adequate, diverse and reasonably priced food supply, an essential input into good nutrition. And, in turn, good nutritional status is an important input into a productive agricultural sector and food system, reflecting the role that health plays in human capital development and productive work.

Employment and Wages

Structural transformation will inevitably reduce the share and the number of workers employed in the agricultural sector. This process has long been recognized and, in fact, was written about as far back as the 1930s and 1940s by Fisher (1939), and elaborated on in many seminal articles, including the by Clark (1957), Chenery (1960), and Johnston (1970).

This transformation has historically been driven largely by advances in agricultural technology, which affects numbers of workers engaged in agriculture, but also by the nature of skills required for successful farming and related food processing and marketing. The reduction in agricultural employment is not only being driven by technological change in agriculture that lowers demand for workers per unit of land and other inputs, but structural transformation also increases the demand and opportunities for non-farm work, particularly in urban areas, as well as in rural areas.

In Africa, this process of transformation has begun, albeit at a slow pace. Table 2 shows the share of workers engaged in agriculture. Although the decline can be clearly seen and corresponds to expectations based on experiences in other regions of the world, agriculture still employs well more than half of Africa's labor force. So, the process of transformation of the

labor force is quite clearly in its early stages. However, some important warning signs are emerging.

This movement of workers out of agriculture has been accompanied, as expected, by a declining share of agricultural value added as a share of GDP. This process is in keeping with the movement of labor away from low productive agricultural work. The low productivity of farmers in Africa has been highlighted by Gollin, Lagakos, and Waugh (2014) who pointed to the fact that the productivity among African farmers lags behind those in other sectors. By implication, the movement of labor out of agriculture is, on balance, a positive step in the modernization of African economies in keeping with the process of structural transformation. The alternative would been continued lagging productivity in the agricultural sector, as workers struggle to grow sufficient amounts of food to feed themselves and their families and as land becomes increasingly scarce and degraded through over-exploitation of natural resources. Yet, productivity remains

However, there are several important distinguishing characteristics of this shift away from low productivity agricultural activities. One is that there is emerging evidence that instead of labor moving into productive manufacturing activities, it is largely destined for services-based activities. Around one-third of workers are employed in the service sector and just over 10 percent are industrial workers. The failure of African economies to follow the East Asian model of manufacturing-led structural transformation is a source of concern that has been discussed, for example by Page (2018); Bhorat, Rooney, and Steenkamp (2016).

Although much has been written on the subject, there are some important considerations over how agricultural transformation has related to the nutritional status of rural as well as urban populations. In particular, nearly 30 years into this process of structural transformation, a large

share of Africa's workers is still engaged in agriculture, despite have agriculture having declined, and the share of agricultural value added still remains high in most countries, decreasing from 20 percent in the 1990s to around 15 percent currently (World Bank Group 2015). More importantly, the concern over nutrition is that poverty remains concentrated in households primarily engaged in agriculture (Shimeles 2014), contributing to malnutrition being higher in rural than urban areas (WHO 2002). This reflects in part the low capital intensity of African agriculture. By implication, the process that can raise earnings of those engaged in agriculture, increasing capital intensity and productivity will, however, lead to the sector shedding jobs. These two realities of the transformation in agriculture—to higher productivity with a reduced demand for labor—needs to be managed appropriately, so as to not contribute to transitional loss of livelihood, food shortages, and other negative outcomes such as instability in food prices, all of which imperil nutritional status.

There are many perils to nutritional status that are potentially associated with the structural transformation, which leads to labor shedding in the agricultural sector. The first that is of considerable concern in the African context is that those who are displaced in the agricultural sector labor market end up migrating to cities and towns only to be unemployed or engaged in low productivity informal sector work. These newly urbanized workers are at heightened risk of not only poverty, but often lack the type of social safety nets, social networks, and community-based mutual assistance arrangements that they left behind when leaving their places of origin.

The process of agricultural transformation also runs risks, if not properly managed, for workers who remain employed in the modernizing agricultural sector on which they rely for their livelihoods. In this regard, there are two paradoxes that confront policymakers. First, technological innovation is essential to a long-term strategy to feed the poor and ensure

improved nutritional outcomes, both through its direct impact on food availability and indirect impact in terms of raising wages and time savings, especially for women. However, the process of technical change is enabled in part by higher and more stable food prices. The former can be a risk to the nutrition of low-income net food consuming households; although, the latter is certainly good for consumer and producers. Simply, if prices fall, farmers have lower incentive to produce more. And if prices rise, and wages rise in the non-farm sector, this will impede structural transformation.

The appropriate response to this food policy dilemma is to design short-term policies to that provide low-income households access to food and below market prices in this transitional phase toward a more productive and modern agricultural sector, which offers workers higher returns and raises living standards of farmers. So, efforts to create safety nets for the poor and promote food price stability cannot become an excuse for subverting markets and their role in price formation. The transitional process that characterizes structural transformation can put considerable pressure on policymakers, especially if employment falls, wages are stagnant, and the process is considered a threat to food security and nutrition. This may encourage ill-advised policies, ranging from agricultural protection to input subsidies, that only serve to promote rent-seeking and retard the rate of transformation. Concerns over nutritional impact during this transition are certainly warranted and merit a serious policy response, but this must be done in a way that does not create more market failures and impede market efficiency.

The second and related paradox is that, as the agriculture sector's contribution to employment and GDP falls, it is necessary to increase investment in order to raise worker productivity and increases wages, especially relative to the non-agricultural sector. This imperative is often not a policy priority, and agriculture is neglected, especially as governments

look toward cheap imports as an alternative to domestic agriculture for a source of low-cost wage goods for the growing urban population. These low food prices in turn serve to enable policymakers to neglect investments that, over the longer term, are essential to technological change, higher rural wages, and a reliable supply of food products to fuel the growth and productivity of the urban labor market. Especially important in this regard is avoiding the food price instability that has plagued Africa, representing considerable nutritional risk for lower income households. Instead of investing in agriculture to raise productivity and wages and adopting related policies that stabilize food markets, the response of governments has been to neglect agriculture.

Women, Production, and Reproduction

African women play a unique role in African agriculture, and improving their employment prospects and productivity is perhaps the single highest priority of policymakers who are focused on nutrition-sensitive policies. This importance reflects women's dominant role in food production and markets and their special vulnerabilities related to reproductive health, as well as unique responsibilities in the home, particularly in terms of child care.

Although the role of being a productive worker can conflict with demands of biological reproduction, particularly in terms of binding time constraints, there is ample scope for policymaking to bridge this divide in the quest to improve nutritional outcomes of women and their children. In fact, there are several areas of investment that both bolster the productivity of women in the labor market and enhance their roles as mothers and caregivers. The most obvious is raising educational opportunities. Women in Africa are catching up in terms of school attainment, but still lag behind men in many countries, particularly in West African francophone

countries. Additionally, improving access to maternal and child health services, as well as providing for modern contraception and even child care alternatives, are all critical to improving the employment opportunities of women. These policy measures work through improving women's health status and raising productivity, an issue I address further later in this paper, as well as by altering time allocation. Healthier children mean more opportunities for women to work. Likewise, the available of day care facilities and other similar options for caring for young children are important. And likewise, access to modern contraception reduces unwanted pregnancies and enables women to more fully engage in productive work (Almanza and Sahn 2018).

Structural transformation also brings greater capital intensity to farming, reducing some burdensome tasks associated with many activities, from gathering water to harvesting and milling grains.

In combination, labor-saving technologies, fewer children, more education, and better health directly enter into the production function to improve nutritional outcomes of women and their children. Rural women—who are overwhelmingly dependent on agriculture for employment, income, and food—need to be the focal point in terms of examining the link between agriculture and nutrition. Rarely, however, are agricultural interventions defined or driven by nutritional goals, particularly, with a focus on rural women and children. Agriculture is a key sector of employment and opportunity for women, providing for improved gender dynamics. Since women have traditionally had limited access to technology, inputs, extension, and output markets, as structural transformation occurs, it will alter investment in basic rural infrastructure and labor-saving technologies. In this section, I will examine the extent to which such investments impact women's special vulnerabilities and opportunities. For example, since

women are the primary food producers in sub-Saharan Africa, identifying opportunities for reducing the labor burden in preharvest and postharvest operations would contribute significantly to their health. Given the continued importance, and the large share of staple crops in the diets of the poor, identifying mechanisms for enhancing the micronutrient density of grains through biofortification can potentially be a high return strategy. Policymakers need to consider the importance of the gender dimension of research and investment in agriculture and related food systems in pursuing food security and dietary diversity (both production and consumption diversity) at the household level.

Nutrition and Productivity

While the role of structural transformation in promoting increased efficiency and productivity in agriculture is essential, there is an equally important relationship that recognizes the importance of improved nutrition of workers as an input into raising output in the agricultural sector. The literature on the impact of nutrition on productivity is vast[3] and falls into two broad categories: the macroeconomic literature showing that nutrition and health have contributed in an important way to increases in productivity and economic growth, and the microeconomic literature that involves actually individual-level studies that show the impact of better nutrition on outcomes, such as schooling, cognition, and the ability to do physical work.

In regard to the macro literature, some of this work is from economic historians such Robert Fogel, who estimated that 50 percent of Britain's growth since 1800 was attributable to the increases in dietary energy available for work, and to the improvements in the efficiency in

[3] See Strauss and Thomas (1998) for an excellent review.

the transformation of nutrients, particularly calories, into work (Fogel 2004).[4] These estimates are in line with other studies such as the World Health Organization report showing that that 30 percent of the per capita growth between 1780 and the middle of the 20th century can be directly explained by improvements in nutritional status (WHO 2002).

Various macro-econometric cross-country models, which have similarly examined how economic performance has been affected by health and nutrition of the population, include the work by Barro (1997); Bloom and Sachs (1998); Arora (2001); Gallup, Sachs, and Mellinger (1999); Gallup and Sachs (2001); and Bloom, Canning, and Sevilla (2004). They all show large health-induced increases in productivity It is also the case that this literature has been criticized for not showing definite causation, as identification of the models is challenging, and for problems with the reliability of data, especially from Africa (Weil 2007).

Other macro simulation techniques have also been employed to evaluate the impact of health on economic growth, including the research of Weil (2007); Young (2007); and Ashraf, Fink, and Weil (2008). This literature reports far more modest effects than cross-country regressions.

The challenges of identification and causal inference in all these techniques focuses attention on the micro literature, which is more compelling and where a combination of experimental and non-experimental evidence shows a large impact of nutrition on productivity,

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[4] Fogel (2004) argued that nutrient intake was so constrained that 20 percent of the labor force was unable to engage in productive work, and it was increases in agricultural productivity in the 19th century that improved health and productivity of workers, leading to more rapid economic growth.

particularly in the agricultural sector. The fact that malnutrition prevalence is higher in rural areas and that work on farms is labor intensive, requiring strength and stamina, makes the sector particularly vulnerable to any functional consequences of malnutrition.

One strain of the literature on the productivity effects of better nutrition shows that taller workers in agriculture have higher earnings (Deolalikar 1988; Haddad and Bouis 1991; Glick and Sahn 1997; Schultz and Tansel 1997; Thomas and Strauss 1997). This result is presumed to capture the mechanisms that taller and better nourished adults are more able to conduct physical work, but it is certainly possible that causation is running through other intermediating factors such as better nourished children growing up to be taller adults, with higher cognitive skills. Recent papers have addressed this possibility. LaFave and Thomas (2013) use data from the Philippines and reported a 1 percent increase in height as related to a 1.9 percent increase in hourly earnings, when controlling for both cognition and education. Similar findings were reported by Bossavie et al. (2014), who conducted a study with workers in Pakistan that included both Raven's scores as well as an index of non-cognitive skills. Vogl's (2014) findings showed that earnings among those working in a "brawn"-intensive occupation were increased by 0.63 percentage points for each additional centimeter of height, although, the effect declined by more than half when other covariates and Raven's score was added to the regression. Kaila, Sahn, and Sunder (2018) also show an independence of height on productivity, even after controlling for cognitive ability.

There is also research that shows how low body mass index (BMI) contributes to lower productivity in poor countries (Glick and Sahn 1997; Schultz and Tansel 1997). Additionally, productivity has been shown to be affected by nutrient intake: Strauss (1997) estimated a farm production function for Sierra Leone and found that calorie intake had a significant positive

effect on the marginal product of agricultural labor; Sahn and Alderman (1988) instrumented per capita household calories using prices, and the results from Sri Lanka indicated that there was a positive effect on market wages for rural men but not women. Behrman and Deolalikar (1989) found calories impact productivity in the peak agricultural season for men. The positive effect of intake on productivity is not a universal finding, as shown in studies by Haddad and Bouis (1991) and Deolalikar (1988).

Much of this research focuses on the role of iron status in affecting aerobic capacity (Haas and Brownlie 2001). Noteworthy among these studies is the causal effects of iron supplementation on the output of rubber workers in Indonesia (Basta et al. 1979), cotton mill workers in China (Li et al. 1994), and tea plantation workers in Sri Lanka (Edgerton et al. 1979) Additionally, several studies have demonstrated how cognitive development of children was impaired by iron deficiency (Pollitt 2001). Another interesting field experiment was the "Work and Iron Status Evaluation" (WISE) study that provided iron supplements to adults in Central Java, Indonesia, and demonstrated that iron deficiency had a causal impact on time allocation and economic productivity (Thomas et al. 2006).

Randomized food supplementation of sugarcane cutters in Guatemala indicated that those living in treatment villages were not more productive than the control villages (Imminck and Viteri 1981); and another study in Kenya found a limited impact of food supplementation on the productivity of road workers (Wolgemuth et al. 1982).

In addition to this evidence on the importance of nutrition for labor productivity of adults, there is equally important evidence that nutrition affects schooling and enhances cognitive skills through both the timing and amount of schooling, as well as the learning per year of schooling (Glewwe and Jacoby 1995; Alderman, Hoddinott, and Kinsey 2006; Yamauchi 2008). Going one

step further, Alderman and Behrman (2006) used the association of low birthweight and cognitive capacity in childhood to estimate the impact on wages. Alderman, Hoddinott, and Kinsey (2006) and Hoddinott et al. (2013a, b) showed the impact of nutritional supplementation in childhood on later life productivity.

VI. Nutrition, the Demographic Transition, and the Rise of Obesity

From the end of the 18th century through the middle of the 20th century, the concerns of demographers and related social scientists were with population growth, focused on the apocalyptic fears of food shortages and famine. As Malthus articulated in "An Essay on the Principle of Population" (Malthus, 1798), famine was seen as inevitable on a massive scale, a sentiment echoed over the next two centuries, including by Ehrlich (1968), following a drought in North India in 1965 and 1966. Indeed, Malthus failed to foresee the remarkable increase in agricultural productivity, resulting from technological change and embodied in the Green Revolution and, more recently, the development of biotechnology.[5]

While famine continues to plague small areas of the world, particularly in failed states where civil conflict and egregious policy failures are prominent, the primary demographic discussion is about the broader process known as the demographic transition. This process whereby fertility rates fall in response to declines in infant and child mortality, which result from investments in health and social services and improved nutrition, is early in its development in

[5] In addition, Malthus failed to anticipate the reductions in marketing and related transactions costs due to progress in transportation and communication that allowed for intercontinental trade in grain, as well as relatively rapid relief efforts on a global scale.

sub-Saharan Africa, as contrasted with other regions, such as Latin America. See Figure 7. (Lam 2011). A corollary of this process is the movement of populations from urban to rural areas, especially among the youth. This does not mean that rural populations will decline quickly or dramatically in Africa, as the overall rate of population growth will continue for decades, but it does present several challenges in terms of the nutritional implications of these demographic trends, especially as the share of the population on farms decline. Therefore, increased output per worker and per unit land, the key characteristics of structural transformation in agriculture, will be a corollary of success in managing this demographic change.

Another equally apparent aspect of this transition that invariably accompanies population movements off farms and to the cities and towns, is an increase in obesity and overweight, contributing to a rapid increase in the burden of chronic disease. This is a result of changing patterns of food consumption and lifestyles, including the nature of work. To date, the increase in overweight and obesity in Africa has been modest, compared to other regions of the world. Likewise, in comparison to other regions of the world where structural transformation is further advanced, especially in Latin America, the Middle East, North Africa, and parts of Asia, the prevalence of overweight and obesity is relatively low in Africa. This is expected since the demographic and related nutrition transition is in the early stages in Africa. There is little doubt that as GDP per capita increases, however, and the structural transformation of the economy and agriculture, in particular, accelerate, the disease burden in Africa will shift along with nutrition transformation.

Understanding the factors underlying the changing patterns of consumption and activity in the nutrition transition can assist policymakers trying to dampen the inevitable trend toward the shifting burden of disease that accompanies urbanization. At the core of the factors that

contribute to an increasing prevalence of obesity is the movement toward foods being marketed and purchased through a commercialized food sector that offers different products than consumed on farms and in rural areas. More specifically, there has been a widespread shift toward consumption of high-fat, high-sugar, high-salt, and highly refined and processed foods and beverages, at the expense of fruits, coarse grains, legumes, vegetables, and other plant based products. This reflects both changes in the supply chain and food markets commensurate with structural transformation in agriculture. The availability of less healthy food choices, however, is not just a consequence of food producers, processors, and marketing institutions conspiring to increase their earnings at the expense of unwitting consumers, who are being manipulated through advertising and coercion. Indeed, these considerations, especially given the effectiveness of advertising and ineffectiveness of nutrition education efforts, may be an important part be the explanation for turning to less healthy consumption choices. So, too, are changes in consumer preferences, as time constraints and lifestyles interfere with more traditional forms of food processing and preparation.

Another dilemma for policymakers is that the growing tide of overweight is not replacing undernutrition, but instead, co-existing in the same countries, communities, and even households. This so called double burden of malnutrition, may seem contradictory, but is really not surprising after consideration of the nutrition production function previously discussed. For example, infectious diseases, which are especially debilitating for vulnerable groups such as women and children, will continue to contribute to the downward spiral of disease and malnutrition. These diseases may be especially problematic in more densely populated urban areas where clean water is scarce, sanitation facilities absent, and maternal and child health facilities strained, unable to meet the expanding needs of the burgeoning population. These problems are exacerbated by the

simultaneous demand from the better-off households, who demand access to secondary and tertiary curative care, and the political economy that enables elite capture of government budgets.

Obesity and overweight, however, result not only from adverse consumption behaviors, but additionally, from the increasingly sedentary lifestyles of urban dwellers. Simultaneous with increasing consumption of energy-dense, sugar, and fat-laden foods, people living in cities take up more sedentary work, rely on new modes of transportation, and are less physically active than their rural counterparts. Thus, both sides of the energy balance equation are contributing to overweight and obesity.

Having identified the more proximate causes of obesity only provides limited policy guidance, particularly in terms of how agricultural and related food policies can tackle this issue. Indeed, while observations that the "supermarketization" of Africa, as a source of processed and unhealthy food, is at the core of the problem, an inextricable march into the modern supply chain that bridges agriculture to consumers defies easy solutions. Several policy prescriptions have been widely discussed. These include:

1. Using tax and related fiscal policy to reduce sugar in food, and particularly, consumption of sugar-sweetened beverages, as well as alcohol.
2. Introducing incentives to manufacturers and retailers to develop and distribute products with lower sugar and fat content.
3. Requiring consumer food labeling, both in supermarkets and eating establishments.
4. Instituting food standards for meals and beverages that are provided and sold in institutions, particularly schools and daycare facilities.

5. Increasing availability and use of sports and recreational facilities in communities, and especially, in schools to increase physical activity.
6. Limiting marketing practices, by legislation, of such as advertising directed at children for sugar-filled food and beverages.
7. Promoting nutrition education and literacy that focuses on healthy eating behaviors, body size, and levels of physical activity through a variety of avenues, ranging from public service announcements to school curriculums and other healthcare-related facilities.
8. Providing more direct guidance to women, especially in antenatal settings, for infant nutritional needs, and to women who are pregnant and lactating regarding the relationship between food choices and pregnancy risks, such as hyperglycemia and gestational hypertension.
9. Encouraging breastfeeding, including through maternity leaves and making the workplace compatible with breastfeeding.
10. Creating initiatives to increase availability of and access to healthy food choices in poor and disadvantaged communities.

It is worth noting that most of these policy prescriptions, while they will certainly affect agriculture through, for example, affecting consumer demand, are not agricultural policies per se. Instead, agriculture will certain be impacted by changes in the regulatory environment, trade policies, fiscal policies, and effective nutrition education and behavioral change initiatives. Thus, farmers are expected to respond to market signals to the extent that these direct measures listed here affect demand, but, they are not the focus of policy initiatives to reduce obesity and

overweight. Nonetheless, there is no question that agriculture and the broader food system is integral to any effort to reduce overweight and obesity. Coordinating with other sectors, ranging from commerce and industry, health, education, transport, finance, and trade, will be essential. This process will only prove successful, however, if coordination takes place at various levels, from communities to transnational corporations. Although government clearly occupies a central role in the effort to slow the rapid increase in noncommunicable disease related to obesity and overweight, private industry, nongovernmental organizations, and other non-state actors must work together in order to ensure success. Quite simply, government's paramount role in policymaking and setting the incentive and regulatory framework will only prove as successful as their ability to bring along the private sector and civil society in pursuit of this agenda. This is particularly the case for the agriculture sector. Prices will be impacted, whether from trade policies or direct subsidies or tax policy on certain foods, and private sector producers will be expected to respond. There is a complementary role, however, that the public sector needs to play. Whether in terms of agricultural research, extension programs to promote production of a new or more diverse set of food options, or investments in infrastructure to facilitate the marketing of healthier products, government will have a continued and important role to play in transmitting those incentives into profitable production increases on the farm.

VII. Complementary Nutrition-sensitive and Nutrition-specific Interventions

Structural transformation that brings about changes in the agricultural and food systems has its limits in terms of expectations for contributing to declines in malnutrition. Therefore, in this section of the paper, I will discuss interventions or programs that address the underlying determinants of fetal and child nutrition—food security; adequate caregiving resources at the

maternal, household, and community levels; access to health services; and a safe and hygienic environment that incorporates specific nutrition goals and actions. These interventions include programs in sectors such as agriculture, water, and sanitation, as well as social protection. In addition, these programs are generally intrinsically targeted to the poor and often contain design features that can empower women. Still, the nutrition-sensitive sector that has the most potential to address constraints to nutrition is agriculture and related food policy. This should include generalized food subsidies to increase food security, conditionally or unconditionally targeted cash transfers, biofortification and food supplementation, home gardens, and more generally, preventative and primary healthcare interventions.

Although these programs hold considerable potential, to date, they have been largely implemented outside of Africa. And many, such as generalized food subsidies to increase food security, while once widespread (Pinstrup-Andersen 1988) are less common, given their expense and the comparatively low share of total expenditures accruing to the malnourished. Similarly, food rations and in-kind distribution on quotas have become less common, in part due to the tendency for leakage (Alderman 1988; Mehta and Jha 2014). Conversely, targeted cash transfers, either conditional or unconditional, have become a widespread means of increasing access to food. While such cash transfers have long been recognized as less distortive than subsidies, the current focus builds upon the evidence from PROGRESA, a well-documented, large-scale pilot in Mexico, as well as improved technology for delivering and tracking cash. Nevertheless, nearly two decades after the introduction of PROGRESA, large in-kind food distribution programs remain active in diverse settings, mainly from outside of Africa, as in India, Egypt, and Indonesia.

Biofortification is another nutrition-sensitive agricultural intervention. It involves breeding of staple crops to increase the availability of micronutrients and essential amino acids to improve the quality of protein. While breeding may prove successful, adoption by farmers is often more problematic (Saltzman et al. 2013). And likewise, there have been major challenges in terms of acceptance by consumers.

The most well-documented example of biofortification is orange-fleshed sweet potatoes (Hotz et al. 2012). And from Africa, one of the most successful stories is of sweet potatoes, and iron-rich beans released in Rwanda. Over 500,000 households adopted these crops by 2014, and there is evidence that these crops have begun to spread to neighboring countries with little outreach.

Biofortification can also be achieved through other channels, such as applications of fertilizers that increase zinc and selenium concentrations in crops and soils. Iodine has similarly been added to water systems used for agriculture.

Many challenges remain with these types of interventions, most prominent is enlarging the scale of such efforts. In the absence of doing so, the potential for highly targeted programs, such as home gardens, is inevitably quite limited (Pinstrup-Andersen 2013).

VIII. Conclusions

The nutrition impact of structural transformation in agriculture is part of a larger nexus of development challenges and opportunities. Africa is at the early changes of this transformative process, and evidence-based policy will be crucial to exploiting the opportunities and limiting the potentially deleterious effects of the complex of changes in the economy and agricultural and food system that are taking place simultaneously. In this paper, I have discussed the broad

contours of structural transformation, including the acceleration of economic growth, the declining share of agriculture in GDP, the increase in productivity in the agricultural sector, and the movement of labor off the farm to urban areas and smaller towns and into services and manufacturing. These processes are well underway in many, but not all African economies. The continued success of this transformation is predicated on enlightened policymaking, including reducing economic distortions, responsible fiscal and monetary policies, and fostering an economic climate that is attractive to foreign investment, including trade policies that encourage an outward looking, exported-oriented economy. Meanwhile, there is an emerging consensus that Africa is facing a debt crisis that could derail much of the economic progress that has been made in the past decade.

Even with enlightened domestic macroeconomic policy, this will not be sufficient to promote the continued structural transformation of African economies. Other factors, many of which are out of the direct control of policymakers, present challenges. These range from instability and adverse conditions in world commodity prices, as well as the threats posed by increased trade tensions and barriers being imposed by developed countries. Additionally, the implications of climate change and related environmental challenges will prove perilous, especially for Africa where agricultural still remains the leading sector of economic activity. Thus, any discussion of structural transformation needs to be cognizant of the alarming process of resource degradation due to overexploitation of resources, global warming, and climate instability.

While these transformative processes in the economy are essential to economic development and raising living standards, the closely related demographic and nutrition transitions have important implications for the role of agricultural policy. These transitions are

occurring simultaneous with changes in the supply chain and food markets, as well as food choices and preferences. Stunting, wasting, and micronutrient deficiencies are beginning to decline during this transitional process, but will not quickly disappear. And at the same time, these forms of malnutrition are increasingly accompanied by a rapid increase in overweight and obesity. Conflicts inevitably arise in terms of priority setting. These are particularly salient in terms of how to invest public resources efficiently, simultaneously incorporating nutritional considerations into those decisions, but there are also difficult choices in terms of policymaking itself. This includes a range of policy dilemmas such as: price policy that is inherently conflicted in terms of supplying low-cost wage goods to a growing urban population and remunerative prices to farmers; increased reliance on modern agricultural technologies that may come at the cost of sustainability and resilience in the agricultural sector and food system; food and other related transfers that, while designed to assist the poor, may in fact exacerbate the growing problem of obesity and overweight; agricultural policies that focus on productivity-increasing and labor-saving technologies that will displace small farmers and small-scale producers who are unable to find good jobs in the nascent manufacturing sector and low-productivity service sector; increasing the efficiency of the supply chain and availability of a reliable, safe and diverse food supply that could lead to dominance of large-scale retailers and the related risks to nutrition associated with the supermarketization of the food supply; trade policy that promotes engagement in world markets, at the risk of externally induced market failures that lead to food price shocks and represent a serious risk to nutrition.

Dealing with these policy dilemmas requires strong government institutions and cooperation among a range of stakeholders, from international organizations, commercial interests, and local organizations, including women's groups and farmers' organizations.

Perhaps, the biggest challenge is strengthening and fostering joint engagement among these stakeholders. This can only occur if there is a common priority accorded to nutrition when designing a broad range of policies. Consensus on such a priority, however, has proven elusive in Africa, not unlike other regions of the world, including Western and wealthy countries that have left many nutritional challenges unmet, as narrow interests are advanced at the expense of social welfare.

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