The Australian Journal of Agricultural and Resource Economics

Journal of the Australian Agricultural and Resource Economics Society

Australian Journal of Agricultural and Resource Economics, 58, pp. 519–537

Food insecurity and its determinants*

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Expansion of aggregate food supplies within developing countries themselves is strongly associated with reduced undernourishment. It is not sufficient to rely solely on aggregate economic growth or reductions in poverty incidence to deliver improved food security. But the evidence also shows that higher food prices significantly increase the rate of undernourishment. It is therefore important to stimulate agricultural output without raising domestic food prices. Improvements in agricultural productivity achieve that, but agricultural protection aimed at food self-sufficiency does not, because the objective of reducing imports is achieved through an increase in domestic food prices. Although this process delivers benefits to those food insecure people who are net sellers of food, in most poor countries their number is exceeded by the food insecure people who are net buyers of food. Increased food prices make the latter group more food insecure. Food self-sufficiency does not imply food security.

Key words: agricultural productivity, food prices, food security, poverty incidence, undernourishment.

1. Introduction: global food insecurity

Food security, or more correctly its opposite – food insecurity – is back on the global agenda, triggered by alarm over the international food price surges of 2007–08. The international price of rice temporarily tripled, and wheat and maize prices more than doubled (Timmer 2008). Food price fluctuations like these are worrying, raising the prospect that for some period at least large numbers of people may be unable to obtain the food they need (Heady and Fan 2008). A central policy issue for food-insecure regions of the world, concentrated in Asia and Africa, is how best to respond to the reality of food insecurity. In this paper, I want to present and analyze some recently available data on undernourishment that I think are useful for addressing this and other related questions. I think the key underlying research questions are what drives changes in food security; and what does this imply for agricultural and food policy?

Section 2 briefly reviews the definition of food insecurity, including the possibility of developing quantitative measures for it. Section 3 summarizes

* This is a revised version of the Presidential Address to the Australian Agricultural and Resource Economics Society, Port Macquarie, NSW, 5 February 2014. Dung Doan, Huy Quynh Nguyen and Ramesh Paudel provided excellent research assistance but are not responsible for any errors. The paper also benefited from the comments of two anonymous referees.

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doi: 10.1111/1467-8489.12073

recently available data from FAO on one such measure, undernourishment and discusses its meaning and limitations. Section 4 uses data from this source on changes in undernourishment across countries to analyze, in turn, the effects of economic growth, relative food prices and the impact of changes in the aggregate availability of food within individual countries. Section 5 concludes.

2. The meaning of food insecurity

2.1. Why food is different

Food is not a 'normal' commodity, in that it has no substitutes. If we are unable to obtain adequate food we suffer, and soon die, regardless of how much we possess of other things. Moreover, because our bodies lack the capacity to store large amounts of energy and other essential nutrients, for active lives, we must have adequate food intake almost continuously. This applies most especially to children, whose development may be impaired permanently by prolonged dietary inadequacy. But for large numbers of poor people, the reliability of food supplies cannot be assumed. The prospect of genuine food insufficiency is frightening for anyone, even if the probability is small and even if the expected duration of inadequate intake is not long. For these reasons, it makes sense to speak of 'food insecurity' in a way that we do not speak of, say, 'clothing insecurity' or 'entertainment insecurity'. We can survive for a long time without a reliable supply of these things, but not food.

Food is different, but is it *uniquely* so? Clean drinking water, shelter, access to basic medical care and education for children are similarly essential, in addition to adequate nutrition. There are no substitutes for any of them. The cruel nature of poverty is that it compels households to make choices among these items, all of which are essential for a minimally adequate standard of living. It is therefore important that a focus on food insecurity does not mean that other requirements for a decent life can be ignored. Still, there remains a basic difference between the requirement for food and most other 'essentials'. Whereas there is usually scope for temporary postponement of acquisition of other essentials, there is very limited scope to postpone consumption of food, particularly in the case of children (Timmer 2010).

2.2. Defining food insecurity

At the 1996, World Food Summit food security was defined as existing 'when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life'. The World Health Organization (WHO) adds to this definition a description that has been widely cited and drawn upon in subsequent studies. It says that food security rests on three pillars:

food availability (sufficient quantities existing);

food access (households are able to obtain the quantities required); and *food utilization* (appropriate nutrition and hygiene).

The first component of the WHO definition, food availability, is generally understood to relate to the national level (aggregate supplies). The second, food access, relates to the household level (capacity to purchase). But there is another way of interpreting these two categories. Food availability may be thought of in terms, not of aggregate quantities of food, but of its dual: the prices at which food is available. This in turn depends on productivity in the production and distribution of food within the domestic economy, the capacity of international trade to augment domestic food supplies, and supplementary measures to provide food to those otherwise unable to purchase it.

Food access, the capacity of households to obtain the food they require, depends on the level of household incomes relative to the price of food. But as mentioned above, food is not the only requirement for a decent life. The poverty line is a measure of the amount of expenditure (or income) required to purchase the goods and services needed for a minimally adequate standard of living, and because of its importance food necessarily forms a large component of the poverty line. Poverty incidence measures the proportion of households whose expenditures (or incomes) fall below this poverty line. Food access is therefore inversely related to poverty incidence. The lower the level of poverty incidence, the higher the proportion of households possessing adequate access to food. But is reducing poverty incidence enough? Many households may continue to be food deficient even though poverty incidence falls, and unexpected disasters can also lead to temporary but widespread hunger. Improving food access is about making food more affordable, supplemented by appropriate social safety nets.

A problem with both the WHO and World Food Summit definitions is that they are nonquantitative. It is not enough to know merely whether food security does or does not exist. Our interest is motivated by the reality of food *in*security, but there are degrees of that, some more severe than others. It is not obvious how varying degrees of departure from full food security could be quantified, based on either the World Food Summit or World Health Organization definitions. An operational definition of food security must support quantification (United States Department of Agriculture 2000). In contrast, poverty incidence has been defined quantitatively, making it possible to study systematically the causes of changes in poverty incidence over time and across environments. We need to be able to do this for food (in) security as well.

It is helpful to distinguish between four levels of food security.

1. *Global level* food security relates to whether global supplies are sufficient to meet aggregate global requirements. There are roughly 1 billion hungry people in the world, heavily concentrated in poor countries, and also a

similar number of obese people, located especially in richer countries but increasingly in poor and middle-income countries as well. The amount of food currently produced is seemingly enough for everyone, leaving 'only' a problem of distribution across individuals. But while arithmetically correct, this simplistic description does not necessarily provide a practical means of reducing hunger in poor countries.

2. *National level* food security is based on a similar comparison of aggregate supplies and aggregate requirements at the national level. Of course, international trade can influence these national outcomes without necessarily changing global balances.
3. *Household level* food security refers to having access to adequate food at all times, roughly along the lines of the World Food Summit definition. But 'security' implies more than just the adequacy of food intake today. It implies something forward-looking, involving *expectations* of future circumstances and not simply present ones. It is an inherently probabilistic concept because it relates to the expected availability of sufficient food in the future, which necessarily involves uncertainty.
4. *Individual level* food security is about the distribution of food within the household. When the household is short of food, individual members may be affected differently. The importance of this matter is beyond doubt, but few of the available datasets address it, focusing on consumption per person at the household level.

Data about current levels of food intake are useful as indicators of what expectations may be. Figure 1 uses the above concepts to show a hypothetical cumulative distribution function of food consumption per person, measured, say, in calories per person per day. Caloric intake levels are displayed on the horizontal axis. The vertical axis shows the cumulative number of people whose observed intake is less than the quantity shown on the horizontal axis.

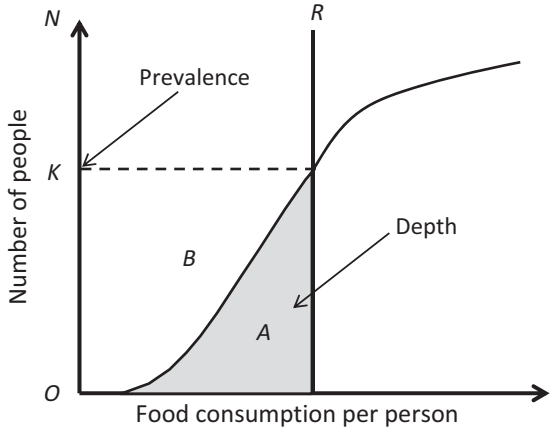

Figure 1 Prevalence and depth of food insecurity: cumulative distribution function (CDF).

Below starvation levels, no individuals are recorded. As the level of intake per person increases, moving from left to right on the horizontal axis, the total number whose recorded intake is less than this amount increases until the highest intake per person is reached, beyond which the entire population consumes less than this amount.

If the caloric requirement per person is R, the number of persons with intake less than R is given by K. The proportion of the population whose intake is expected to be inadequate is therefore K/N, corresponding to the *prevalence,* or incidence, of undernourishment. The total amount of food that these K persons would need to consume for their intake to be adequate is given by the rectangle KR. Their actual consumption is the area B. Area A is therefore a measure of the degree to which actual consumption falls below the requirement, indicating the *depth* of undernourishment, or alternatively the magnitude of the food security gap. A measure that can be compared across countries is the magnitude of this gap relative to the amount of food required for all K persons to consume R, given by the ratio of areas $A/(A+B)$. Readers familiar with the literature on poverty measurement will recognize that the prevalence of undernourishment is mathematically analogous to the head-count measure of poverty incidence, and the depth of undernourishment is analogous to the poverty gap. In the case of poverty measurement, income or expenditure per person replaces food consumption per person and the poverty line replaces the food requirement per person, R. The diagram is otherwise similar, except that the shape of the cumulative distribution function (CDF) will be different, a point that will be important for subsequent discussion.

2.3. Quantifying food insecurity: the FAO undernourishment data set

Considerable progress in the quantification of food security was made in a recent joint report of the Food and Agriculture Organization, the International Fund for Agricultural Development and the World Food Program, *The State of Food Insecurity in the World, 2012* and *2013* (FAO/IFAD/WFP 2012, 2013). The report presents improved estimates, for most countries of the world, of average availability of dietary energy supplies and average protein supplies. The report contains important information on nutritional outcomes, including the prevalence of undernourishment, meaning the proportion of the population whose average daily intake of calories over a year is below the nutritionally determined minimum daily caloric requirement, and the 'depth of the food deficit', meaning the degree to which caloric intake of the undernourished falls below minimum dietary requirements. All of these data are available in downloadable form.[1]

[1] The report also provides downloadable data on physical access to food in the form of paved roads relative to total roads, road density and the density of rail lines, and economic access in the form of food prices, though these prices are not related in the report to incomes, as is done in measures of poverty incidence.

The FAO prevalence of undernourishment data set is the flagship food security measure produced by FAO. These data are used by the United Nations system in monitoring progress towards Target 1 (Hunger) of the Millennium Development Goals and are used together with other data in both the IFPRI Global Hunger Index and the Economist Intelligence Unit's Food Security Index. The meaning of the undernourishment indicator is not that people below the minimum level of caloric intake are starving (most are not), but that they are receiving insufficient caloric intake to sustain a normal, active and healthy life.

FAO reports the prevalence of undernourishment for each country annually, but over a three-year moving average, apparently computed from the skew-normal distribution function.[2] This function involves three parameters: the mean, the coefficient of variation and a coefficient of skewness. The values of these parameters are reported for each country, for each three-year moving average period, on the FAO's website. The mean is computed from FAO's national food balance sheets, updated annually. It calculates average caloric availability from data at the commodity level, recording national production plus imports minus exports minus usage other than direct final consumption such as processing, seed, feed to livestock, wastage, net addition to stocks and so forth. It then converts these commodity-level calculations into caloric availability using nutrient composition tables. The coefficients of variation and skewness are estimated from the food consumption component of household income and expenditure surveys conducted by the statistical agencies of individual countries, though the methods used to estimate these parameters from the survey data are not reported. Because these surveys are seldom conducted on an annual basis, annual update of these two parameters would be impossible. Unlike the data for the mean, the FAO data for these two parameters are revised only intermittently. The calculation of the prevalence of undernourishment combines the above information with the country-specific minimum daily requirement, R, which reflects the demographic composition of the population and is also published.

It is possible for researchers to check the FAO calculations, but it requires a good deal of work. The method actually used to compute estimates of the prevalence of undernourishment is not reported, but it can be inferred. It is illustrated, through the specific example of Indonesia, in Figure 2. The figure shows the cumulative distribution function implied by the skew-normal distribution using the three parameters mentioned above and the value of R, each as reported for Indonesia by FAO. This is done for two illustrative intervals, 1999–2001 (labelled 2000) and 2009–2011 (labelled 2010). The value of the prevalence of undernourishment for each of these two intervals derived

[2] The FAO documents seemingly never explicitly identify the distribution function actually used, but the skew-normal distribution is a function of the three parameters whose values are provided and the calibration exercise for Indonesia, described below, confirms that this distribution fits the calculations reported. It is described at <http://en.wikipedia.org/wiki/Skew_normal_distribution>.

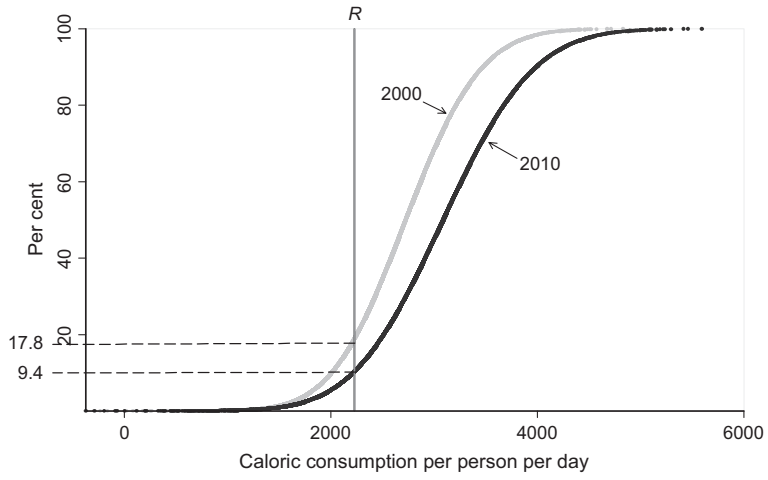

Figure 2 Prevalence of undernourishment, Indonesia, 2000 and 2010. Note: The years 2000 and 2010 refer to the averages for the intervals 1999–2001 and 2009–2011, respectively. Source: Author's calculations based on data reported by FAO *Food Security Indicators*, 2013.

from the diagram replicates the values reported by FAO, 17.8 and 9.4 percent, respectively.

The publication of the FAO measure in downloadable form, along with the data on which it is based, is a valuable contribution. The prevalence of undernourishment measure has many self-evident limitations, as FAO recognizes. The annualized nature of the data may exclude many people who are hungry only in certain seasons, even though their caloric intake is adequate when calculated over the full year. The measure looks at caloric consumption per person at the household level and ignores distribution within the household, a point that could be very important in the case of children. It looks only at people below the minimum daily intake of calories; people above but close to this level of caloric intake are vulnerable to negative shocks that might reduce their intake to welfare-reducing levels, but their numbers are ignored. The measure ignores the degree to which consumption falls below the minimum, but the depth of undernourishment data also published in the same source do address this issue. The measure looks only at caloric intake, ignoring other important nutritional requirements, on the grounds that caloric adequacy is primal (Ecker and Breisinger 2013). Finally, daily energy requirements are sensitive to the level of physical activity. FAO also publishes estimates that attempt, imperfectly, to take this matter into account.

Undernourishment, as measured by FAO, is a potentially useful indicator of nutritional status, at the most basic level, but only one such indicator. There is ample scope for errors in the estimates. The fact that FAO publishes the results only in the form of a 3-year moving average indicates a lack of confidence in the year-to-year variations in the annual calculations on which these moving

Table 1 Number of undernourished people (millions)

Region	1990–92	2000–02	2010–12
World	1015.3	957.3	853.6
Asia	751.3	662.3	560.0
Central Asia	NA	11.6	6.1
East Asia	278.7	196.6	166.8
South Asia	314.3	330.2	297.4
South East Asia	140.3	113.6	69.7
Oceania	0.8	1.2	1.1
Latin America	57.4	53.8	41.1
Sub-Saharan Africa	173.1	209.5	224.6

Source: Data from FAO Food Security Indicators, 2013.

averages are based. Changes in the resulting measure over extended time periods of a decade or so might be reliable, but presumably not the short-term (annual) changes (in 3-year moving average form) that are reported.

3. The prevalence and depth of undernourishment

Globally, undernourishment remains a serious problem, but impressive progress has been made. According to the FAO estimates summarized in Tables 1 and 2, over the two decades from 1990–92 to 2010–12 the total number of undernourished people in the world declined from a little over one billion to 854 million, a decline of 162 million. *All* of this decline occurred in Asia, in that the number of undernourished people in Asia declined by 191 million, implying an increase in the rest of the world of about 29 million. In Latin America and the Caribbean, the number of undernourished people fell by 16 million, but in Sub-Saharan Africa undernourishment increased by 52 million people. Within Asia the largest decline was in East Asia (112 million), followed by Southeast Asia (71 million) and South Asia (17 million).

Despite the progress, food security remains a major concern for Asia. The first reason is the sheer size of Asia's undernourishment problem. Of all undernourished people in the world today, 560 million, or 66 percent of the global total, reside in countries of Asia, a reduction from 74 percent two decades before. Undernourished people still constitute 14 percent of the population of Asia, compared with 12 percent of the world population (Table 2). While the prevalence of undernourishment in Asia is only half that of Sub-Saharan Africa (at 27 percent), the population of Asia is so much larger that the absolute number of undernourished people in Asia is still more than double (at 563 million) the number in Sub-Saharan Africa (at 234 million). Of Asia's malnourished people, 297 million, 35 percent of the global total, are in South Asia alone, itself exceeding the total number, 225 million, in Sub-Saharan Africa.[3]

[3] The problem is particularly significant in relation to children. World Bank data suggest that among several Asian countries the incidence of childhood stunting exceeds 40 percent, a proportion comparable with Sub-Saharan Africa, though in Asia the total number of children affected is larger.

Table 2 Prevalence and depth of undernourishment (percent of population)

Region		1990–92	2000–02	2010–12
World	Prevalence	18.9	15.5	12.3
	Depth	128	106	85
Asia	Prevalence	24.1	18.3	13.8
	Depth	165	126	96
Central Asia	Prevalence	12.8	16.2	7.8
	Depth	NA	109	54
East Asia	Prevalence	22.2	14	11.5
	Depth	161	95	76
South Asia	Prevalence	25.7	21.1	17.2
	Depth	167	156	123
South East Asia	Prevalence	31.1	21.5	11.7
	Depth	218	150	83
Oceania	Prevalence	13.5	16	12
	Depth	82	99	74
Latin America	Prevalence	13.8	11	7.4
	Depth	87	70	51
Sub-Saharan Africa	Prevalence	32.7	30.6	25.6
	Depth	221	213	179

Note: *Prevalence* means the percentage of the population with average daily caloric intake over the year less than the minimum daily requirement. *Depth* means the mean difference between intake and minimum daily caloric requirement, in kcal per person per day, among those whose intake is below the minimum daily requirement.Source: Data from FAO *Food Security Indicators*, 2013.

A second reason is the dependence of much of Asia on a single crop. Rice is the staple food of most of Asia.[4] For the majority of Asia's poor people, expenditure on this one commodity accounts for a large proportion of their household budgets, a much larger proportion than for the nonpoor. This, together with the first point above, explains why Asian countries were so greatly alarmed by the huge increases in the international price of rice in 2007–08. The global market for rice is particularly thin, making international price volatility more pronounced than for most other staple foods. In recent decades, both supply and demand conditions for food have changed rapidly in Asia (Timmer 2014). A growing middle class has diversified its diet away from staple cereals such as rice and towards fruit, vegetables and livestock products. But at the same time rapid urbanization and accelerating nonagricultural demands for land have placed greater pressure on agricultural resources. Finally, agricultural production in much of Asia is especially vulnerable to climate change, requiring greater policy attention to the requirements of agricultural adaptation (Nelson 2010).

A feature of the data is the variation in the rates at which undernourishment has declined in different parts of the world. To illustrate, Figures 3 and 4 show the time path of the FAO undernourishment data for twelve individual Asian countries: six in Southeast Asia (Figure 3) and six in South

[4] The most important exception is that wheat is the major staple in some parts of North India and Pakistan.

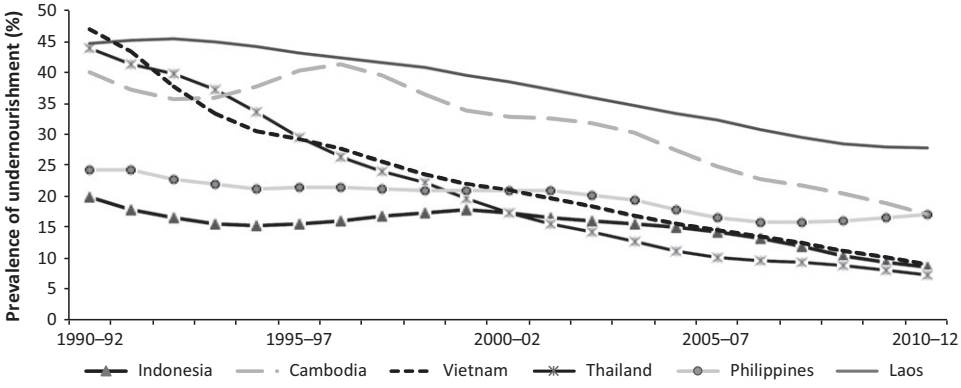

Figure 3 Prevalence of undernourishment: Southeast Asia. Source: Data from FAO *Food Security Indicators*, 2012.

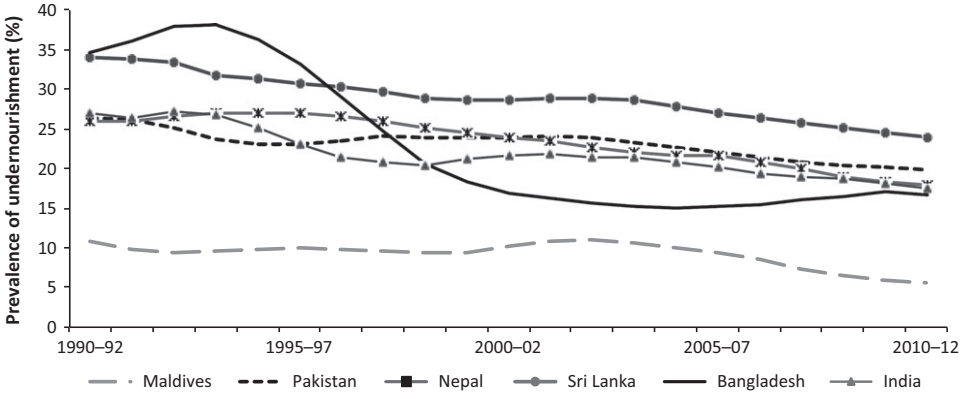

Figure 4 Prevalence of undernourishment: South Asia. Source: Data from FAO *Food Security Indicators*, 2012.

Asia (Figure 4). In Southeast Asia, the absolute number of undernourished people declined over the last two decades by more than 50 percent and East Asia was not far behind, at 36 percent. But the decline was much lower in South Asia, at 7 percent. There may be many reasons for the variation but the differences seemingly correlate with rates of poverty reduction, themselves correlating with rates of economic growth. These relationships need to be studied more systematically and we turn to that in the following section.

4. Determinants of undernourishment

4.1. Economic growth

The FAO's landmark report, *State of Food Insecurity in the World 2012*, stresses the importance of economic growth, stated in the report's subtitle

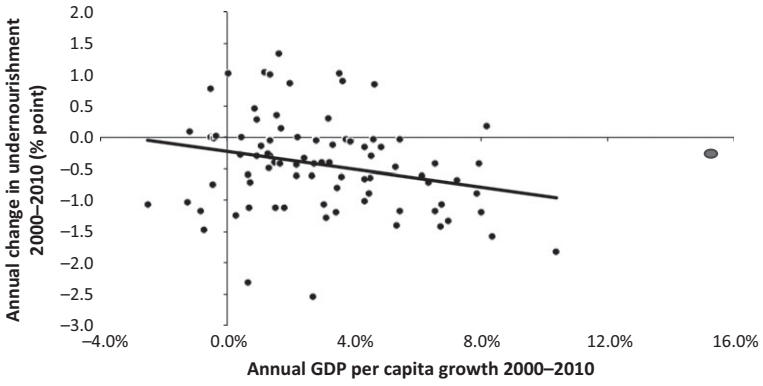

Figure 5 Reduction in undernourishment and economic growth: Developing countries. Note: The large dot to the far right is China, which was excluded from the data used in the regression on the grounds that China's growth rate data may be unreliable. Source: Author's calculations using data from FAO *Food Security Indicators*, 2012 and World Bank, *World Development Indicators*, various issues.

to be 'necessary but not sufficient' for reductions in hunger and malnutrition – exactly what the World Bank says about poverty reduction. The relevance of economic growth is weakly supported by Figure 5. The change in undernourishment is calculated as the annual average difference between FAO's 2000 and 2010 levels of that variable, for each country, and the annual GDP growth rate per capita is calculated for each country as the annual average growth rate over the same decade using World Bank data.[5] The 85 countries included are those not classified as 'advanced countries' in either data set.[6]

The chart also shows a regression line fitted to these data, with statistical details provided in Table 3.[7] The estimated equation is seemingly the simplest possible for testing the hypothesis that reductions in undernourishment are driven by economic growth:

$$\Delta H^i = a + by^i + e^i, \tag{1}$$

where ΔH^i denotes the change in measured undernourishment (hunger) as a percentage of the population of country i over the period 2000–2010, y^i

[5] The link for the FAO data is http://www.fao.org/economic/ess/ess-fs/fs-data/en/#.U839pFeK0pQ. The link for the World Bank data on economic growth is http://databank.worldbank.org/data/views/variableSelection/selectvariables.aspx?source=world-development-indicators.

[6] All data used in Figure 5 and the regressions reported in Tables 3–5, along with a full list of the countries covered in each case, are available on the journal's website.

[7] The data for China are shown by the dot on the far right of Figure 5. China is an extreme outlier and was excluded from the regression shown in Tables 3 and 4 on the grounds that its growth data may be suspect. If it is included, the relationship between changes in undernourishment and aggregate growth becomes even weaker.

Table 3 The weak relationship between undernourishment and economic growth: 2000–2010

	Developing countries	Asia	Africa	Latin America
Real GDP growth per capita	−7.068** (2.969)	−13.744** (5.789)	−4.958 (4.731)	−7.929 (8.207)
Constant	−0.223* (0.118)	0.157 (0.330)	−0.252 (0.176)	−0.303 (0.242)
N	85	17	42	23
R^2	0.064	0.273	0.027	0.043
adj. R^2	0.053	0.225	0.002	−0.003
F-stat	5.666	5.637	1.098	0.934
p-value for *F*-statistic	0.020	0.031	0.301	0.345

Note: *indicates $P < 0.10$, **$P < 0.05$, and ***$P < 0.01$. The regressions for 'Developing countries' and 'Asia-Pacific' exclude China on the grounds that its GDP data may be unreliable. Standard errors are in parentheses. Source: Author's calculations using data from FAO *Food Security Indicators*, 2012 and World Bank, *World Development Indicators*, various issues.

Table 4 Undernourishment, poverty and economic growth: 2000–2010

	Change in undernourishment		Change in poverty	
	Prevalence of undernourishment	Depth of undernourishment	Poverty incidence	Poverty gap
Agriculture	−0.445* (0.231)	−4.711** (2.006)	−0.998*** (0.346)	−0.593** (0.242)
Industry	−0.175 (0.191)	−1.595 (1.657)	−0.258 (0.286)	0.056 (0.200)
Services	0.168 (0.105)	1.839* (0.914)	0.029 (0.157)	0.041 (0.110)
Real price of food	4.815** (2.349)	36.342* (20.415)	7.495** (3.519)	1.867 (2.461)
Constant	−5.355** (2.415)	−39.973* (20.983)	−8.148** (3.617)	−2.372 (2.530)
N	41	41	41	41
R^2	0.252	0.289	0.368	0.182
adj. R^2	0.169	0.210	0.298	0.091
p-value for model	0.0299	0.0133	0.0020	0.1144
p-value for null	0.0259	0.0058	0.0217	0.0565

Note: See notes to Table 3.Source: Author's calculations using data from FAO, World Bank and ILO.

denotes the average growth rate of real GDP per capita of country *i* over the same period, *a* and *b* are estimated parameters and e^i is an error term. Country observations are unweighted by population. The use of ordinary least squares to estimate the relationship assumes that changes in undernourishment do not cause changes in the rate of growth. Otherwise, the endogeneity of economic growth would lead to biased estimates of *b*.

According to these results, reduced undernourishment is weakly associated with economic growth per capita.[8] The relationship is statistically significant for the developing countries as a whole and for Asia, but not for Africa or

[8] A positive/negative coefficient in Table 3 means that an increase in the independent variable concerned is associated with an increase/reduction in undernourishment.

Table 5 Undernourishment, food availability and food access

Dependent variable: change in undernourishment				
	Prevalence	Prevalence	Depth	Depth
Independent variables				
Food *availability* (change in aggregate supplies)	−0.410*** (0.152)	−0.464*** (0.107)	−3.838*** (1.134)	−4.154*** (0.973)
Food *access* (relative price of food)	–	4.175*** (1.657)	–	25.029** (9.697)
Constant	−0.265 (0.105)	−4.425*** (0.108)	−1.057 (0.938)	−25.591** (10.127)
N	49	48	49	48
R^2	0.339	0.540	0.403	0.500
adj. R^2	0.325	0.519	0.390	0.478
p-value for F-statistic	0.010	0.000	0.000	0.000

Note: See notes to Table 3, except that China is included in the countries covered. Source: Author's calculations using data from FAO (food availability) and ILO (relative price of food).

Latin America. The quality of fit is poor. Figure 5 shows that there are numerous instances of positive economic growth coinciding with increased undernourishment, so economic growth is certainly not sufficient for reduced undernourishment. But there are also several instances of negative economic growth coinciding with reduced undernourishment. Evidently, economic growth is neither necessary nor sufficient for reduced undernourishment and the statistical relationship between them is weak. A better explanation for changes in undernourishment is surely possible.

4.2. The composition of growth and the price of food

Table 4 shows the relevance of disaggregating GDP growth per capita into its major sectoral components: agriculture, industry and services. The 41 countries used in this analysis are those developing countries for which FAO data on undernourishment, World Bank data on poverty incidence (see below) and International Labour Office (ILO) data on consumer prices (also see below) are each available. Country observations are again unweighted by population.

The estimated equation is

$$\Delta H^i = a + \sum\nolimits_s b_s G_s^i y_s^i + cP^i + e^i. \tag{2}$$

The treatment of economic growth in this equation draws upon the identity that $y^i = \sum_s G_s^i y_s^i$. The growth rate of GDP per capita is equal to the sum of the sectoral growth rates per capita, y_s^i, each multiplied by its share of GDP, G_s^i. The value of this decomposition of GDP is that if the composition of GDP growth matters for the reduction in undernourishment, the coefficients

estimated for the various sectors, b_s, will be significantly different. It is thus possible to study whether the sectoral composition of growth is important for undernourishment by testing the null hypothesis that the true sectoral coefficients are the same. An *F*-test for this restriction is provided in the final row of the table (*P*-value for null).

Equation (2) also includes a variable for the real price of food, constructed from ILO consumer price data.[9] The variable is the ratio of the food component of the CPI to the overall CPI, averaged over the ten-year period. The relevance of this variable is that whereas GDP and its sectoral components relate to incomes, undernourishment surely also depends on the consumer price of food relative to other goods. Undernourished people are likely to have higher budget shares for food than the national average, implying that their consumption of food may be particularly sensitive to the level of food prices relative to other prices. In estimating this equation, it is assumed that changes in undernourishment do not drive changes in the components of GDP or food prices.

The null hypothesis that the sectoral coefficients are the same is strongly rejected for both the prevalence and depth of undernourishment. Growth of agriculture is not only more important for reduced undernourishment than growth of industry or services, it is the only component of GDP growth for which a significant effect can be found. The negative and significant coefficient for agriculture means that higher growth of agricultural output is associated with larger reductions in undernourishment. The results also strongly confirm the importance of the food price variable. On average, higher food prices mean higher levels of undernourishment. Table 4 shows, in the last two columns, that very similar results are obtained for the same 41 country sample if changes in poverty (the headcount measure of poverty incidence and the poverty gap measure) are used as the dependent variables, instead of the undernourishment variables. The poverty data used are from the World Bank's 'Povcal' database and relate to the $1.25 per day poverty line at 2005 purchasing power parity.[10] Growth of agriculture and lower food prices are strongly associated with reductions in both undernourishment and poverty.

4.3. Availability and access

The food security literature emphasizes the distinction between the *availability* of food, meaning aggregate supplies available for final consumption, per capita, and *access* to food, meaning the capacity of households to purchase that food. These two variables are used in equation (3) as explanatory variables for changes in undernourishment. Availability of food is measured by FAO data on domestic supplies of available food (output plus imports

[9] Source: http://laborsta.ilo.org.
[10] Source: http://iresearch.worldbank.org/PovcalNet/index.htm.

minus exports minus nonfood uses minus wastage minus net storage), measured in calories per person. Access to food is measured as the relative price of food using ILO consumer price data, as above. The equation estimated is

$$\Delta H^i = a + b\Delta F^i + cP^i + e^i, \tag{3}$$

where the variables are as before except that ΔF^i denotes the change in food availability per person. The results are summarized in Table 5. When changes in poverty incidence (either the headcount measure or poverty gap) are included as explanatory variables, they have the expected positive coefficients but they are not significantly different from zero. These results confirm that both expanded aggregate availability of food per person and a lower level of food prices are strongly associated with reduced undernourishment. We now explore the reasons for these two results.

4.4. Mean food availability

Why is undernourishment so sensitive to changes in mean food availability? Since the food availability variable, calculated from food balance sheets, is used as an input into the estimation of undernourishment, it is likely that its strong correlation with undernourishment partly reflects this. Nevertheless, I want to argue that we should expect changes in measured undernourishment to be highly sensitive to changes in availability. Availability can be understood as the mean of the distribution of caloric consumption per person. How do changes in this mean affect changes in measured undernourishment?

Referring to Figure 1 above, holding R constant, changes in measured undernourishment result from shifts in the CDF. In the local neighbourhood of the initial intersection between R and the CDF, only two kinds of shifts are possible: shifts in the horizontal position of the CDF, reflecting changes in the mean, and shifts in its slope, reflecting the concentration of the population or, equivalently, the degree of equality in the distribution – the more equal the distribution, the steeper the slope. Now consider each of these in turn. Changes in the mean, holding the slope constant, produce a horizontal shift of the CDF. The effect on measured undernourishment, the vertical intercept with R, depends on the magnitude of the slope. The steeper the slope, the greater the change in the vertical intercept for any given change in the mean. This geometric point is illustrated by Figure 6, which depicts a magnification of the intersection of R with the CDF and shows a mean-increasing horizontal shift from CDF^0 to CDF^1, which reduces undernourishment from H^0 to H^1.

Now contrast the measurement of undernourishment with the measurement of poverty incidence. The diagrammatic representation is identical in the two cases, except that in place of caloric intake poverty measurement uses household expenditure (or household income) and in place of the minimum

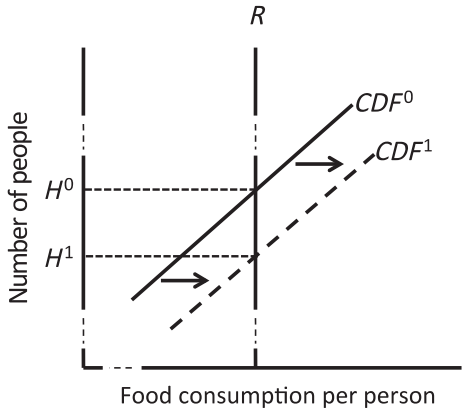

Figure 6 The effect on undernourishment of a change in mean food availability.

daily requirement of calories, *R*, poverty measurement uses the poverty line. But in the neighbourhood of the intersection point the slope of the distribution of caloric intake is much higher (a steeper curve) than the distribution of expenditures because caloric intake is much more equally distributed across individuals than total expenditures. Because the slope is steeper, the sensitivity of measured undernourishment to changes in mean availability of food should be much greater than the sensitivity of poverty incidence to changes in mean expenditures.

Next, consider a change in the slope of the CDF, holding the mean constant. The impact on the vertical intercept will now depend on the horizontal distance between the mean of the CDF and the minimum requirement, *R*. For any given change in the slope, the impact on the vertical intercept will be larger the greater the difference between these two quantities. Figure 7 illustrates this point, again depicting a magnification of the intersection of *R* with the CDF. Holding the mean constant entails rotating the CDF around this mean, denoted *M* in the diagram. As shown, a reduction in the slope of the CDF (increased inequality) increases under-

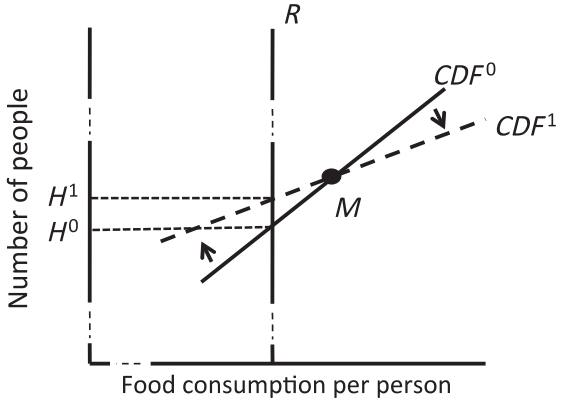

Figure 7 The effect on undernourishment of a change in the distribution of food consumption.

nourishment from H^0 to H^1. If the mean is distant from R, the change in the vertical intercept may be large, but as the mean becomes closer to R, the same change in the slope will produce a smaller change in the vertical intercept. If the mean is equal to R, a mean-preserving change in the slope will not affect measured undernourishment at all.

How do the measurement of undernourishment and poverty differ in this respect? For the sample of 41 countries used in the regressions for Table 4, the simple average of the ratio of mean caloric intake to the minimum daily requirement is 1.07 but the simple average of the ratio of mean expenditure to the poverty line is 3.63. Comparing the determinants of changes in undernourishment and poverty incidence, undernourishment should be much more sensitive to changes in the mean and less sensitive to changes in distribution across households.

4.5. Food prices

Why are higher food prices associated with higher levels of undernourishment and poverty?[11] At the simplest level, higher food prices harm households who are net purchasers of food but benefit net sellers, including many undernourished and poor farmers (Ivanic and Martin 2008).[12] The net effect of a change in food prices therefore depends on the sizes of these two groups and the amounts by which consumer and producer prices each change. To illustrate the first issue, data for Indonesia on the distribution of net sales of the staple food, rice, are summarized in Figure 8. The data come from the Indonesian Family Life Survey 2007, which has the advantage of capturing both household level production and consumption of food items.[13]

Urban areas contain many land-owning households who are net sellers of rice, as well as many net buyers. Rural areas include many net buyers of rice, including producers of agricultural commodities other than rice, households involved in nonagricultural activities and landless workers who sell labour and buy rice, as well as many net sellers. But net buyers outnumber net sellers in both urban and rural areas. It could not be asserted that all countries necessarily resemble this pattern, but the regression results suggest that the Indonesian story is not atypical.

5. Conclusions

The evidence indicates that expansion of agricultural output within developing countries themselves is associated with reductions in both the rate of

[11] See also Warr (2008) and Warr and Yusuf (2014), who use general equilibrium modelling to arrive at the same conclusion, regarding poverty, for Thailand and Indonesia, respectively.

[12] Ivanic and Martin study nine poor countries, not including Indonesia, and find that net food purchasers outnumber net food sellers in most but not all cases. See also Anderson *et al.* (2012).

[13] Available at: http://www.rand.org/labor/FLS/IFLS.html.

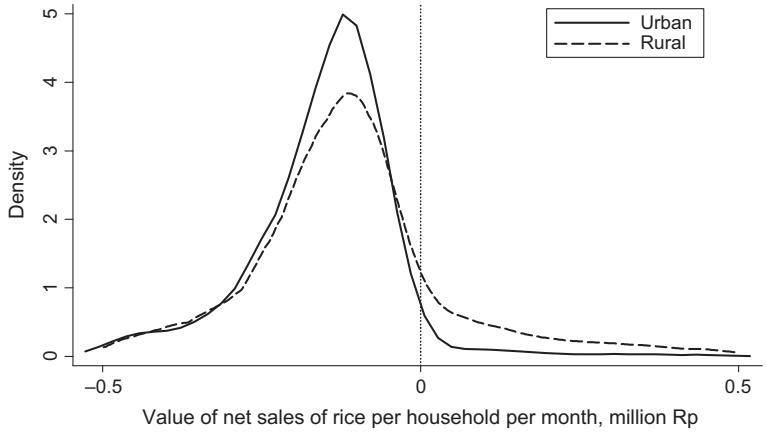

Figure 8 Probability density function (PDF) of household net sales of rice, Indonesia, 2007. Source: Author's calculations using data from *Indonesia Family Life Survey*, 2007.

undernourishment and the rate of poverty incidence. It is not sufficient to rely solely on aggregate economic growth or reductions in poverty incidence to deliver improved food security. But the evidence also shows that higher food prices worsen both undernourishment and poverty. Agricultural output must be increased without at the same time raising food prices.

Two policy strategies are available for stimulating agriculture and both are currently used, to varying degrees. The first is investment in the infrastructure and knowledge required to raise agricultural productivity. The second is policy interventions that raise agricultural product prices. In food importing countries, this is frequently associated with a policy drive for food self-sufficiency. Both policies are capable of increasing agricultural output. But the first does so without raising food prices (Alston and Pardey 2014), while the second uses increased food prices as its central instrument (Warr 2005, 2011).

Agricultural protection aimed at achieving food self-sufficiency is often described as a policy for improving food security. It is not that. It delivers benefits to many people who are net sellers of food, but these numbers are exceeded, on average, by the number of net buyers who are made more food insecure by increased food prices. The policy implication is that food insecurity can be reduced most effectively by raising agricultural productivity through investments in infrastructure and research, supplemented by food safety nets to assist those unable to benefit from market-based economic development.

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