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Global Nutrition Impacts of Rapid Economic Growth in China and India[1]

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Overview and Motivation

Despite record global economic growth in past decade – malnutrition remains a serious problem in many parts of the world. According to the United Nations' Food and Agriculture Organization (FAO), about 800 million people (17% of the world's population) remain malnourished. For these households at a subsistence level of income, changes in commodity market conditions, as may arise from changes in global economic growth and/or trade policy can have serious consequences for nutritional intake. Even a small decline in diet quality can have substantial adverse impacts on health status. On the other hand, a modest income boost, or lower food prices, could have extremely positive impacts. Previously, the links between changes in the global economy and nutritional outcomes have been explored by a relatively wide range of authors (e.g., Fang et al., 2006; Rosegrant et al., 2005).

The goal of this paper is to offer modest extensions of this previous work in three directions. First of all, unlike many of the papers in the nutrition area, we seek to account for the behavioral response of low income households in the face of changing prices and incomes. Clearly when households are faced with a rise in the price of food products, they cannot afford to consume as much, *ceteris paribus* so consumption much adjust. The extent of this adjustment will depend on the change in real income and the Engel elasticities for each good. In addition, consumers are likely to substitute away from higher cost food items. All of these factors could have an advese impact on nutritional attainment. By estimating and incorporating a demand system into our analysis, we are able to take these factors into account. In so doing, we draw on the work of Rimmer and

Powell (1996) and Cranfield et al. (2003a; 2003b) in order to characterize consumer demands across the income spectrum.

A second important extension embodied in this work relates to the impact of changes in factor earnings on household nutritional attainment in the wake of globalization. Most economic analyses of this issue have tended to focus on the commodity price impacts of globalization. If they have taken into account the earnings-side impacts, they have typically done so in a simplistic way. In this paper, we seek to capture the earnings-heterogeneity of poor households and thereby shed light on the differential impact of global economic growth on different household groups. We do so using the framework developed in Hertel et al. (2004), and further refined in Hertel et al. (2007a).

The final contribution of this paper is to imbed this framework for analysis of nutritional issues into a widely used, global general equilibrium model (GTAP: Hertel, 1997) in order to permit nutritional outcomes to be routinely reported as part of standard economic analyses of global economic growth and trade liberalization.

We illustrate this approach to the analysis of nutritional impacts of global economic growth through a series of globalization shocks, focusing on the impacts in Bangldesh. We begin by considering solely the impact of an exogenous rise in the consumer price rise for food products. This permits us to illustrate the mechanisms through which low income consumers respond to changing economic conditions in our framework. We then turn to an analysis of the impact of economic growth in India and China, respectively, on the poor in Bangladesh, and in particular on their nutritional attainment. Our findings indicate that the nutritional impacts of globalization depend importantly on the source of the globalization shock, and the resultant earnings effects on the poor.

Analytical Framework

Consumption Behavior: The analytical approach used here builds on that of Hertel et al. (2004), which employs a sequential, macro-micro modeling strategy whereby results from the global model are passed on to a series of micro-simulation models in order to evaluate the impact of a given change in trade policy on a variety of households, including those at the poverty line. At the core of the framework is a utility function, and the associated consumer demand system. As with Hertel et al. (2004) we employ Rimmer and Powell's (1996), AIDADS system to represent consumer preferences, due to its capability to capture expenditure patterns across the global income spectrum. AIDADS has now been widely estimated on international cross section data, and it performs well out of sample, when compared to other demand systems – particularly for food products (Cranfield et al., 2003a). This functional form may be viewed as a generalization of the popular, but restrictive, Linear Expenditure System (LES). Unlike the LES, AIDADS allows for non-linear Engel responses, while maintaining a parsimonious parameterization of consumer preferences (see also Cranfield et al., 2000).

The following equation gives the budget share form of AIDADS:

$$\lambda_n = \frac{p_n \gamma_n}{y} + \frac{\alpha_n + \beta_n \exp(u)}{1+\exp(u)}\left(1 - \frac{p'\gamma}{y}\right) \quad \forall\ n \qquad (1)$$

where λ_n is the budget share of good *n*, α_n, β_n, and γ_n are unknown parameters, u represents utility, p_n is the price of good *n*, and *y* is income. The following parametric restrictions are used to ensure well-behaved demands: $0 \leq \alpha_n, \beta_n \leq 1$ for all *n*, and

$$\sum_{n=1}^{N} \alpha_n = \sum_{n=1}^{N} \beta_n = 1.$$

Estimation of this demand system is undertaken using the 80 country, per capita consumption data set offered by GTAP, version 6.1 (Dimaranan, 2007).[3] The resulting parameters are reported in the first part of Table 1. The demand system is regionalized in order to permit it to precisely reproduce per capita demands in each country, as illustrated for our focus country – Bangladesh -- in the second part of Table 1.[4]

The AIDADS demand system is particularly attractive for poverty analysis, since it devotes two-thirds of its parameters to consumption behavior in the neighborhoood of the poverty line. In particular, γ_n is the estimated subsistence level of demand for commodity *n*, and α_n is the marginal budget share at the subsistence level of income, while the remaining *n*-dimensional parameter vector, β_n, is the marginal budget share at very high income levels. So, in the case of staple foods (i.e. crops), we observe non-zero (relatively large) values for both γ_n and α_n, whereas the value of β_n is zero (see Table 1 – where the subsistence estimate is reported as a share of expenditure at mean prices and subsistence income). Therefore, from (1), we expect that the budget share for crops at low income (and hence low utility) levels will be high, whereas it will be very low (trending to zero) at high levels of per capita income and utility.

Figure 1 charts the budget shares for the ten goods in the Bangladeshi aggregate demand system across the lower income spectrum, beginning with the subsistence level

[3] Note that all expenditures are at producer prices, so there is a separate category of final demand for wholesale/retail/trade services.

[4] This country-specific calibration technique is detailed in Golub (2006), and is based on the general ideas laid out in Hertel et al. (2004).

of income, as defined by our international demand system, and extending past the $1/day international poverty line all the way to the national per capita average income in Bangladesh. Figures along the x-axis are based on the natural logarithm of per capita expenditure, with units reported here in multiples of the subsistence level of income. Thus, the $1/day poverty line in Bangladesh is about 2.5 times the subsistence level of income. And national average income is 8.4 times subsistence income. From this figure we can see that the crops and other food expenditure shares fall with rising income, whereas the livestock expenditure share rises at low income levels, then falls at higher per capita incomes. Taken together, total expenditures on food are estimated to account for three-quarters of household budgets at the subsistence level and over half at the $1/day international poverty line. At higher income levels, the largest expenditure item is housing and other services, the demand for which rises strongly at modest income levels.

Figures 2 and 3 decompose the staple foods shares in Figure 1 into their two component parts: subsistence and discretionary shares (recall equation (1)). This decomposition is useful in understanding how households at very low income levels respond to a price shock. By definition, subsistence quantities do not respond to changes in prices, whereas discretionary expenditures are responsive to economic conditions. From Figure 2 we see that, at the lowest income levels, crop expenditures are dominated by the subsistence requirement. Since the subsistence quantity is fixed, the subsistence share falls as income and total expenditure rises. At an income level slightly above the $1/day international poverty line, the subsistence share is overtaken by the discretionary component of expenditure on crops. From that point on, the discretionary share dominates; and this share continues to rise, before eventually falling at higher income levels. Figure 3 charts the same curves, only this time for other food products. In this case, the subsistence share is overtaken by the discretionary share a bit before the international poverty line.

Given our focus on the nutritional impacts of globalization, it is useful to consider how food consumption is predicted to change in response to a price change. Cranfield et al. (2007) explore the implications for the change in average budget share of a commodity where γ_n and α_n are non-zero and β_n is zero, i.e. a staple commodity. They break this down into the change in the subsistence share and the change in the discretionary share, respectively. Inspection of (1) shows that the subsistence share (the first term on the right hand side of this equation) will rise for any price shock to an individual subsistence commodity, since the numerator increases linearly in price, whereas the demoninator is unaffected. On the other hand, the discretionary share may increase or decrease, depending on the relative size of change in $(1\text{-}\mathbf{p}'\boldsymbol{\gamma}/y)$ versus $\alpha_n/(1+\exp(u))$ (Cranfield et al., 2007). In general, they find that, at very low income levels the price impact on the subsistence share dominates the total impact. As incomes rise, the impact of a price rise on the discretionary share becomes more important. The latter effect is non-linear, reaching a maximum at moderate income levels, thereafter declining.

Figure 4 shows the response of aggregate consumption of crops, livestock and other food products to a 10 percent rise in the price of crops. At very low levels of income, there is little change in consumption, since household demands are dominated by subsistence requirements. However, as income rises, the quantity response is more pronounced. Table 2 converts these demand changes into nutritional attainment for households at the poverty line. In the first column we see the "baseline" or nutritional attainment prior to the price shock. With a total nutritional intake of 1900 kcal per day, these households are on the verge of being malnourished. In the face of a crops price shock, crops consumption and nutrition falls by 5%, and livestock and other food consumption falls as well. Overall nutritional intake is predicted to fall to 1,838 kcal. The drop in caloric consumption is somewhat less under the livestock price shock; while livestock demand is more price elastic, the share of expenditure on livestock products is lower at the poverty line so the overall impact is smaller. The 10% price rise in other food products falls in between. It has a negligible impact on crops and livestock consumption, but this is the largest source of caloric intake for households at the poverty line and so the 5% reduction in consumption reduces nutritional intake to 1848 kcal/person/day.

Adding earnings and endogenizing nutritional intake: With the parameters from (1) in place, we can now specify a well-defined household micro-simulation model in which households maximize per capita utility, subject to a per capita budget constraint, based on the households' overall endowments:

Choose $\left(x_{1k},...,x_{ik},...,x_{nk}\right)$, where *i* indexes the commodities and *k* households, to maximize u_k

subject to: $\sum_{i=1}^{n} U_i\left(x_{ik}, u_k\right) = 1$, (2)

$$U_i\left(x_{ik}, u_k\right) = \varphi_{ik}\left(u_k\right)\ln\left(\frac{x_{ik} - \gamma_i}{A\exp(u_k)}\right) \quad \forall\, i \tag{3}$$

$$\varphi_{ik}\left(u_k\right) = \left[\alpha_i + \beta_i \exp\left(u_k\right)\right] / \left[1 + \exp\left(u_k\right)\right], \text{ and} \tag{4}$$

$$\sum_{i=1}^{n}\left(p_i x_{ik}\right) = Y^k = \sum_j W_j \bar{E}_j^k + T^k Y \tag{5}$$

In this formulation, (2) – (4) define the implicitly additive AIDADS utility function with parameters $\alpha_i, \beta_i, \gamma_i$ and *A*, and marginal budget share as given in (4). Equation (5) is the *per capita* budget constraint, with income computed as the product of W_f, the wage paid to endowment *f*, and $\overline{E}_f^k$ corresponding to the (fixed) endowment owned by household *k.* To this we add any transfer payments, which are assumed be a constant share, T^k, of net national income, *Y*. Trade reform changes factor earnings, net national income, and thereby household income. When combined with the changes in commodity prices, utility maximizing households vary their mix of consumption, x_{ik}, and attain a new level of utility. By estimating the nutritional content of the food items in the consumption bundle at the poverty line, ξ_i, we can then predict the change in nutritional well-being of an individual in household *k*, along dimension *j* (e.g., caloric intake), as follows:

$$N_{jk} = \sum_i \xi_i x_{ik} \qquad (6)$$

A key finding in the work of Hertel et al. (2004) is the importance of stratifying households by their primary source of income. For example, in Bangladesh, it is estimated that 22% the $1/day poor reside in households that rely exclusively on rural wage earnings (Table 3, Rural Labor column). A further 15% of these poor are in households that earn virtually all of their income from farming, and 13% are in nonfarm enterprise specialized households (Table 3, Agriculture and Nonagriculture, respectively). Less than half of the poor households have diversified earnings (final two columns of Table 3). Given the very different earnings sources, we expect the impacts of global economic growth to differ substantially across poor households. Accordingly, we follow those authors in stratifying the popoulation into seven groups, the first five of which have specialized earnings patterns: agricultural self employment, non-agricultural self-employment, rural wage labor, urban wage labor, or transfer payments. The remaining households are grouped into rural and urban diversified strata, leading to seven total strata.[5]

Table 4 reports the shares of earnings at the poverty line. The poor in Bangladesh command relatively small endowments of land, with correspondingly small earnings shares from this income source (column one). For the poor, self-employed farm households (row 1), most of their earnings come from their own labor endowment, and similarly for the poor, self-employed non-farm households (row 2). Indeed, apart from the transfer-dependent households, labor income dominates the earnings profile of poor households – the poor are poor because their only asset is their own labor.

Global General Equilibrium Model: Our starting point for the global, general equilibrium analysis of globalization on nutritional attainment is the modified GTAP model developed by Hertel et al. (2007a) using the GTAP version 6.1 data base (Dimaranan, 2007). The modified model focuses on features that enhance analysis of trade changes on the poor. For example, on the demand-side of the model, the global model is modified to incorporate the demand system given in equation (1). Thus, aggregate market outcomes are consistent with the preferences used to evaluate the impact of price changes on poor and malnourished households. The other modifications relate to the factor markets where the authors introduce farm/non-farm factor market

[5] A clear limitation of this approach stems from the rigidity of a given households' classification by earnings specialization. Obviously households my be induced to specialize or diversify in response to changing relative factor returns. We believe that the relatively broad definition of strata circumvents this problem for the majority of households in the fact of modest earnings changes. However, this important qualification will be further considered below in the results section.

segmentation based on the OECD's (2001) survey of agricultural factor markets. As is common in such analyses, assume a constant aggregate level of land, labor, and capital employment reflecting the belief that the aggregate supply of factors is unaffected by trade policy. This is not the 'full employment' assumption sometimes ridiculed by advocates of structuralist models of development, rather it assumes that aggregate employment is determined by factors such as labor market norms and regulation that are largely independent of trade policy in the long run.

The income sources in Table 4 must be mapped to factor earnings in the general equilibrium model in order to make inferences about the nutritional impacts of trade reform. Agricultural labor and capital receive the corresponding farm factor returns from the general equilibrium model, as do non-agricultural labor and capital. Wage labor reported in the survey presents a problem, since we don't know how much of this is employed in agriculture vs. non-agriculture activities. For this reason, we simply assign to it the economy-wide average wage – a blend of the farm and non-farm wages. Finally, transfer payments are indexed by the growth rate in net national income according to equation (5).

Since the AIDADS demand system in (1) predicts consumption at any point on the income spectrum, we can readily evaluate it for the household at the $1/day poverty line. This is where we focus our analysis and discussion. Obviously the nutritional impacts will vary slightly for households with lesser or higher income levels; however, it should give us a good idea of the nutritional impacts of these globalization shocks on the poor. Specifically, we solve (2) – (4) for seven different households. These represent the households who are initially at the poverty line in the seven different strata. Once we have obtained the new level of consumption x_{ik}, we take an estimate of the nutritional content of food items in the consumption bundle at the poverty line, ξ_i, and predict the change in nutritional well-being of an individual in household *k*, along dimension *j* (e.g., caloric intake), as follows:

$$N_{jk} = \sum_i \xi_i x_{ik} \tag{6}$$

Globalization Scenarios

In this paper we consider two alternative globalization scenarios, focusing on growth in China and India, respectively. These are the two largest, and most rapidly growing, economies in the region. In order to isolate the impact of growth in each of these economies, we strip away all other economic growth and simply evaluate the impact of growth in each of these economies individually on nutritional attainment in Bangladesh.

Table 5 reports the key assumptions made about annual rates of growth and the changes in the fundamental drivers of supply and demand in these two economies. These estimates have been taken from Hertel et al. (2007b) who develop a global economic baseline, for the 1997-2025 period, using a dynamic GTAP model, which has been modified to incorporate the demand system given in (1). This dynamic model takes population, labor force and total factor productivity growth as exogenous and produces capital accumulation and GDP endogenously.

There are several important points to note about this baseline. Firstly, we see very little cumulative population growth in China over this entire 28 year period. This is reflected in slow growth in unskilled labor. However, the skilled labor force is expanding strongly. On the other hand, the population in India is still growing fairly rapidly, with even higher growth in skilled labor than China. This higher rate of labor force growth attracts additional capital, with the percentage growth in capital stock in India projected to outperform that in China. However, China still shows comparable GDP growth over the period, due to higher TFP growth (5%/year in the non-agricultural economy, as opposed to 3.5% in India).

Globalization Results

India's Growth: In this section, we introduce China and India growth as separate simulations and contrast their impact on the poor in Bangladesh, specifically focusing on nutritional attainment. We begin with India's growth impacts. The first column of Table 6 reports the impact of India's growth on the global price index for internationally traded goods and services, by sector. The strongest price increases come in forest products, followed by petroleum and then cotton. This is consistent with the boom in primary commodity prices that has recently been observed. On the other hand, there are *relative* price declines in most manufactured products and some of the agricultural products, as supply-side growth in India outstrips the growth in demand for products such as rice and wheat.

For Bangladesh, the key consideration is how this pattern of world price changes interacts with her net supplies to the world market. Bangladesh's main exports are textiles and apparel products. And India's growth depresses world prices for this sector, so Bangladesh registers a negative contribution to its terms of trade in the first column of Table 7 in the row corresponding to textiles and apparel. On the other hand, she is a net importer of other manufactures, and the price decline here benefits Bangladesh. Cotton also registers a large gain, which is odd since Bangladesh is currently a net importer of cotton and world cotton prices are rising. However, we project that, if India were to grow dramatically, and *the rest of the world, including Bangladesh, were not to grow at all*, then Bangladesh would reduce its cotton usage, reduce imports and expand production so that it would actually become a net exporter of this product. This is, of course, an extremely hypothetical – indeed unrealistic – scenario. But it does permit us to isolate the impact of India's growth on Bangladesh.

The remaining columns under the "India grows" subheading in Table 7 report the export price and import price effects on Bangladesh. Since products are differentiated by origin, Bangladeshi prices diverge from the average world price (as do Indian export prices). With Indian manufactures prices pulling down the world average, Bangladeshi export prices tend to rise relative to that same average, resulting in a positive export price effect for most goods. The import price effect reflects deviations in the mix of Bangladeshi imports from the world average. To the extent that products (e.g., heavy manufactures) are disproportionately sourced from India, Bangladesh will benefit from strong supply-side growth in India and the associated decline in import prices. Summing across columns and down rows, we find the overall impact of India's growth on Bangladesh to be quite favorable for her terms of trade, with the index of export prices, relative to import prices, rising by 5.72%. Therefore, we expect average welfare in Bangladesh to rise.

The rise in Bangladeshi welfare is clearly in evidence in Table 8A, which reports the change in aggregate consumption, by broad commodity group. With the exception of crop and livestock products, which see relative price rises, per capita national consumption of goods and services rises strongly. As we have seen previously, however, there is a sharp difference between consumption patterns at the national average income level and at the poverty level. Furthermore, depending on the source of earnings of the poor, the income effect of India's growth may differ rather substantially. This point is illustrated in the subsequent columns of Table 8A. The higher agricultural prices benefit the self-employed farm households more than average, while relatively lower non-farm prices tends to hurt the self-employed non-farm households. Consumption changes for the labor- and transfer-dependent households are more similar to the national average, as are the consumption changes for the diversified households.

These changes in consumption have nutritional implications, as determined by equation (6). These changes are reported in the bottom row of Table 9A, which reports baseline nutritional attainment, caloric intake following the India growth shock, and finally, the difference in nutritional intake as a result of this growth. Nutrition improves for all households excepting the self-employed, non-agriculture households. The largest gains are for the self-employed farm households, who see the largest income rise as a result of India's growth.

China's Growth: Now we turn to the impact of China's growth on nutritional attainment in Bangladesh. Again, we begin with the impact on world export prices in Table 6. The first point to note is that China's growth generally has a larger impact on world markets. Petroleum prices rise by twice as much as under the India-grows scenario. And forest products rise by about eight times as much. Strong growth in agricultural TFP (recall Table 5), coupled with a diminishing expenditure shares on food in China result in declining agriculture prices – particularly for pork and chicken where China has shown particularly strong productivity growth. Textiles and apparel prices drop by more than

50% as a result of China's supply side growth, and other manufactures prices also fall sharply as China expands her exports.

The second panel in Table 7 reports the impact of China's growth on Bangladeshi terms of trade. The final column reports the total terms of trade impact, by commodity. The overall terms of trade gains to Bangladesh from China's growth are roughly four times as large as the gains from India's growth. Scanning down the total column, we see that forest products, textiles and apparel, other manufactures and petroleum all stand out, with the first three contributing positively, and petroleum contributing negatively to Bangladeshi terms of trade. The forest products and petroleum totals are dominated by the world price effects, whereas textiles and apparel gains are driven by rises in the relative price of Bangladeshi apparel (world prices are falling). Other manufactures show an important import price component as Bangladesh benefits due to cheaper imports from China.

Next, turn to Table 8B, which reports consumption of aggregate commodities in the baseline and the counterfactuals due to China's growth. Consider first the change in consumption at the per capita income level. The combination of a high price elasticity of demand for textiles and apparel, and a strong price decline due to cheap imports from China, fuels a boom in consumption of these goods. The consumption of services also increases strongly, with agricultural consumption increasing more modestly in this average household. However, the consumption of manufactures falls sharply, since this sector contains natural resource-based products – particularly wood, paper, lumber and furniture, and those prices rise sharply.

Moving across to the consumption impacts at the poverty line, we see adverse effects by and large. These declines in consumption come about due to the decline in purchasing power by the poor. Why do they lose from China's growth, while the representative household in Bangladesh gains? The answer lies in the composition of factor ownership. The only factors of production for which real income rises are capital and natural resources. Yet the poor control little of these endowments.

Table 9B translates these consumption changes into nutritional outcomes for households beginning the period at the poverty line. The decline in nutritional intake is quite strong and could have serious health consequences. Fortunately, this simulation considers solely the impact of China's growth on Bangladesh, abstracting from growth in the rest of the world, including Bangladesh. That growth – particularly the domestic growth – is likely to prove more beneficial to the poor.

Conclusions and future directions

This paper represents an initial attempt to incorporate nutritional considerations into a widely used applied general equilibrium model of the global economy. The key building block is the AIDADS demand system which permits us to predict consumption patterns at very low levels of income. Indeed, it incorporates the notion of a subsistence level of consumption, below which the household cannot survive. In the neighborhood of subsistence income, expenditures on staple foods are relatively unresponsive to price changes. However, as discretionary income increases, the scope for behavioral responses to price changes increases. At the international poverty level of income the subsistence and discretionary components of staple food expenditure are roughly of equal importance.

We imbed this demand system in the GTAP model of global trade in order to investigate the impacts of rapid growth in India and China on nutrition in Bangladesh. We find that the impacts are quite different, largely due to the differential impact on incomes of the poor. Rapid growth in India raises real returns to land and unskilled labor, and improves nutritional intake for all households at the poverty line, with the slight exception of the non-farm self-employed. On the other hand, China's growth boosts real returns to capital and natural resources, at the expense of labor, in Bangladesh. This has far less favorable consequences for the poor and nutritional attainment falls for all groups, with the exception of transfer-dependent households who benefit from rising tax revenues.[6]

Future research should focus on bringing household survey data to bear in the estimation of the consumer demand system. Cranfield et al. (2007) develop an approach

[6] Tax revenues and transfers are indexed to net national income, which rises due to the increased returns to capital and natural resources.

to merging micro- and macro-data in the estimation of an AIDADS demand system, and similar techniques could be used here – albeit with a greater emphasis on food consumption. Further disaggregation of food commodities in the AIDADS system might also be useful. Another critical area of work is to improve the estimates of the nutritional conversion factors in equation (6) of this paper. Currently our estimates are based on adjusted national averages. However, these conversion factors are likely to be quite different for the poor. Finally, it is important to model the entire distribution of expenditure and nutritional outcomes, not just those at the poverty line. Future work should endeavor to produce malnutrition headcount measures akin to those provided in the poverty literature.

References

Cranfield, J.A.L., J.S. Eales, T.W. Hertel, and P.V. Preckel. 2003a. "Model Selection when Estimating and Predicting Consumer Demand Using International, Cross-Section Data," *Empirical Economics* 28: 353-64.

Cranfield, J.A.L., P.V. Preckel, J.S. Eales and Thomas W. Hertel, 2000. "On the Estimation of an Implicitly Additive Demand System," Applied Economics, December, 32(15):1907-1915.

Cranfield, J. A. L., P. V. Preckel, J. S. Eales, and T. W. Hertel, 2003b. "Estimating Consumer Demand Across the Development Spectrum: Maximum Likelihood Estimates of an Implicit Direct Additivity Model," Journal of Development Economics, (68):289-307.

Cranfield, J. A. L., P. V. Preckel, J. S. Eales, and T. W. Hertel, 2003b. "Estimating Consumer Demand Across the Development Spectrum: Maximum Likelihood Estimates of an Implicit Direct Additivity Model," Journal of Development Economics, (68):289-307.

Cranfield, J.A.L., P.V. Preckel and T. W. Hertel. 2007. "Poverty Analysis using an International Cross-Country Demand System", GTAP Working Paper No. 34, also forthcoming as a World Bank Policy Research Working Paper.

Dimaranan, B.D. 2007. *Global Trade Analysis and Protection: The GTAP 6 Data Base*. Center for Global Trade Analysis, Purdue University.

Fang, C., J. Zhang and B. Bengelhassen. 2006. "The Impact of Multilateral Trade Liberalization on Food Security in Sub-Saharan Africa and South Asia." Paper presented at the Ninth Annual Conference on Global Economic Analysis, Addis Ababa, June 15-17, 2006.

Food and Agriculture Organization of the United Nations. 2003. *The State of Food Insecurity in the World*. Rome: FAO. www.fao.org/sof/sofi/index_en.htm

Golub, A., T.W. Hertel, H. Lee and N. Ramankutty. 2006. "Modeling Land Supply and Demand in the Long Run," paper presented at the Ninth Annual Conference on Global Economic Analysis, Addis Ababa, June 15-17, also available at: https://www.gtap.agecon.purdue.edu/resources/download/2628.pdf

Hertel, T.W., M. Ivanic, P.V. Preckel, and J.A.L. Cranfield. 2004. "The Earnings Effects of Multilateral Trade Liberalization: Implications for Poverty," *World Bank Economic Review* 18: 205-36.

Hertel, Thomas, W., Roman Keeney, Maros Ivanic and L. Alan Winters. 2007. "Distributional effects of WTO agricultural reforms in rich and poor countries," *Economic Policy* 50(1):1-49 (April).

Hertel, Thomas W. (editor), 1997. *Global Trade Analysis: Modeling and Applications*, New York; Cambridge University Press, 1997.

Organization for Economic Cooperation and Development (OECD).2001. *Market Effects of Crop Support Measures*, OECD Publications, Paris.

Reimer, J.J., and T.W. Hertel. 2004. "Estimation of International Demand Behavior for Use with Input-Output Based Data," *Economic Systems Research*, 16: 347-366.

Rimmer, M., and A. Powell. 1996. "An Implicitly Additive Demand System," *Applied Economics*, 28: 1613-1622.

Rosegrant, M.W., S. A. Cline, W. Li, T.B. Sulser, and R. Valmonte-Santos. 2005. *Looking Ahead: Long-Term Prospects for Africa's Agricultural Development and Food Security*. 2020 Discussion Paper No. 41. Washington, D.C.: International Food Policy Research Institute.

Table 1. Estimated Consumption Relationships: AIDADS Parameters

Commodity Group	International Estimates			Calibrated-Bangladesh		
	Subsist Shr	MBS-Poor	MBS-Rich	Subsist Shr	MBS-Poor	MBS-Rich
Crops	0.57	0.19	0.00	0.57	0.29	0.00
Meat, Dairy, Fish	0.00	0.16	0.05	0.00	0.13	0.05
Food and Beverages	0.10	0.20	0.07	0.10	0.09	0.03
Textiles and Apparel	0.00	0.07	0.05	0.00	0.10	0.08
Utilities	0.00	0.05	0.06	0.00	0.01	0.01
Trade	0.04	0.07	0.20	0.04	0.01	0.03
Manufactures	0.17	0.07	0.15	0.17	0.04	0.09
Transportation and Communication	0.06	0.10	0.11	0.06	0.17	0.20
Financial Services	0.01	0.02	0.10	0.01	0.01	0.07
Housing and Public Services	0.05	0.08	0.21	0.05	0.16	0.43

Source: Authors' estimates.

Table 2. Calories consumed at the poverty line, kcal/capita/day

	Baseline	Crop Pr Shock	Livestock Pr Shock	Other food Pr Shock
Crops	808	766	796	808
		-5	*-1*	*0*
Livestock	29	28	26	29
		-3	*-12*	*0*
Other Food	1063	1044	1043	1010
		-2	*-2*	*-5*
Total	1900	1838	1864	1848
		-3.3	*-1.9*	*-2.8*

Note: The numbers in italics are percentage change over the baseline figures.

Table 3. Stratum Contributions to the $1/day Poverty Population in each Country

Country	**Strata**							
	Agric.	Non-Agric.	Urban Labor	Rural Labor	Transfer	Urban Diverse	Rural Diverse	Total
Bangladesh	0.15	0.13	0.04	0.22	0.03	0.07	0.37	1.00

Notes: Values are shares of the impoverished population that are specialized in a particular stratum of earnings. Shares are derived from country-specific household surveys. Total column reflects that entire poverty population is allocated among the seven strata.

Table 4. Earnings Shares for Rural Diversified Stratum, $1/day

Stratum	Land	Ag. Unskilled Labor	Ag. Skilled Labor	Non-Ag. Unskilled Labor	Non-Ag Skilled Labor	Wage Labor Unskilled	Wage Labor Skilled	Agricultural Capital	Non-agricultural Capital	Transfers	Total
Agriculture	0.025	0.943	0	0	0	0	0	0.028	0	0.004	1.00
Nonagric	0.003	0	0	0.955	0	0	0	0.003	0.037	0.002	1.00
UrbLabor	0.002	0.002	0	0.002	0	0.99	0	0.003	0	0.001	1.00
RurLabor	0.002	0.003	0	0	0	0.919	0.072	0.002	0	0.001	1.00
Transfer	0	0.003	0	0	0	0.017	0	0	0	0.98	1.00
UrbDiverse	0.016	0.197	0	0.192	0	0.43	0.045	0.017	0.01	0.093	1.00
RurDiverse	0.009	0.18	0	0.204	0	0.426	0.041	0.01	0.031	0.098	1.00

Source: Authors' calculations, based on household survey data.

Table 5. Annualized Growth rates in TFP, Endowments and GDP, by Region
(average percentage growth over 1997- 2025 period)

Region	Annualized TFP Growth in Agric			Unskilled Labor	Skilled Labor	Population	G-Dyn Predictions	
	CR	RU	NR				Capital	GDP
China	1.41	3.42	6.47	0.83	3.65	0.17	6.93	9.15
SAsia	0.95	1.40	3.13	1.83	4.26	0.12	7.86	9.2

Table 6. World Price Changes Resulting from Economic Growth in Individual Regions: 1997-2025

Commodity	India	China
Rice	-1.72	-12.62
Wheat	-3.88	-8.53
Crsgrns	-1.74	-8.55
Oilseeds	-0.05	7.79
Sugar	2.26	-9.28
Cotton	9.62	-4.15
OthCrps	-0.04	-6.65
Milk	0.64	-9.49
Cattle	-2.06	-7.62
NRumin	-2.69	-40.04
Fish	-2.94	22.85
Forest	74.35	509.02
PrDairy	-4.32	-8.42
PrBeef	-5.57	-8.36
PrNRumn	-4.12	-65.87
PrSugar	-2.8	-4.92
PrRice	-5.34	-14.56
PrOilsd	-3.51	-7.43
OthFdBev	-4.48	-9.4
TextAppl	-5.44	-54.3
Autos	-5.71	-13.31
HvyMnfcs	-4.78	-9.86
Electron	-5.85	-32.63
OthMnfcs	-7.09	-34.38
WRtrade	-7.81	-16.47
TransCom	-3.5	-12.64

Table 7. Terms of trade decomposition for Bangladesh

Commodity	India Grows World Pr	Export Pr	Import Pr	Total	China Grows World Pr	Export Pr	Import Pr	Total
Rice	0	0	0	0	0	0	0	0
Wheat	-0.01	0	0.39	0.38	-0.21	0	-0.01	-0.22
Crsgrns	-0.01	0	0	-0.01	-0.04	0	0.09	0.05
Oilseeds	-0.04	0	0.01	-0.03	-0.23	0	0.12	-0.11
Sugar	0	0	0	0	0	0	0	0
Cotton	0.45	-0.36	0.04	0.13	0.08	-0.27	0.02	-0.17
OthCrps	-0.05	0.03	-0.18	-0.2	-0.05	-0.13	0.04	-0.14
Milk	0	0	0	0	0	0	0	0
Cattle	0	0	0	0	0	0	0	0
NRumin	0	0	0	0	0.03	0.01	-0.01	0.03
Fish	0	0.01	-0.01	0	0.05	-0.05	0.01	0.01
Forest	-0.06	-0.03	-0.04	-0.13	17.08	-3.43	0	13.65
PrDairy	0	0	-0.02	-0.02	-0.09	0	-0.03	-0.12
PrBeef	0	0	-0.01	-0.01	-0.01	0	-0.01	-0.02
PrNRumn	0	0	0	0	0.08	0.02	-0.03	0.07
PrSugar	-0.01	0	-0.01	-0.02	-0.08	0	0	-0.08
PrRice	0.01	0	0.01	0.02	-0.02	0	0.01	-0.01
PrOilsd	-0.04	0	-0.09	-0.13	-0.41	0	-0.43	-0.84
OthFdBev	0	0.03	0.07	0.1	0.51	-0.16	0	0.35
TextAppl	-0.53	1.98	0.31	1.76	-11.58	15.79	1.32	5.53
Autos	0.02	0	0.21	0.23	-0.09	0	0.47	0.38
HvyMnfcs	0.06	0.06	1.43	1.55	-0.81	-0.18	1.09	0.1
Electron	0.05	0	0.28	0.33	0.66	0.02	0.67	1.35
OthMnfcs	0.36	0.05	1.76	2.17	3.15	0.25	1.71	5.11
WRtrade	0.04	0.01	-0.04	0.01	-0.02	0.01	-0.09	-0.1
TransCom	-0.1	0.05	0.26	0.21	-0.52	-0.05	0.16	-0.41
FinSvce	-0.02	0.11	-0.02	0.07	0.06	0.02	0	0.08
HsEdHe	-0.12	0.33	0	0.21	0.2	0.62	-0.02	0.8
Utility	0.24	0.01	0.23	0.48	0.32	0.01	0.08	0.41
Petrol	-1.38	0	0	-1.38	-3.99	-0.02	0	-4.01
Constrct	0	0	0	0	0	0	0	0
Total	-1.14	2.28	4.58	5.72	4.07	12.46	5.16	21.69

Table 8A. Bangladesh Consumption Impacts of India's Growth (1997-2025): percentage change

Commodity	National Average	At poverty Line, by stratum Agric.	Non-Agric.	Urban Labor	Rural Labor	Transfer	Urban Diverse	Rural Diverse
Crops	-1	3.9	-1.8	-0.2	-0.3	-0.4	0.3	0.1
MeatDairy	-0.1	10.4	-3.1	0.6	0.4	0.2	1.9	1.4
OthFoodBev	3	8	0.2	2.4	2.2	2.1	3.1	2.8
TextAppar	4.8	16	1.3	5.4	5.1	4.9	6.8	6.3
Utilities	4.8	16.2	1	5.2	4.9	4.7	6.6	6.1
WRTrade	2.8	5.1	-0.2	1.3	1.2	1.1	1.7	1.6
Mnfcs	3.4	4.6	0.2	1.4	1.3	1.3	1.8	1.7
TransComm	2	10.5	-1.2	2	1.8	1.7	3.1	2.7
FinService	4.1	11.2	-0.2	2.8	2.6	2.5	3.9	3.5
HousOthServ	3.6	13.5	-0.4	3.4	3.2	3	4.7	4.3

Table 8B. Bangladesh Consumption Impacts of China's Growth (1997-2025): percentage change

Commodity	National Average	At poverty Line, by stratum Agric.	Non-Agric.	Urban Labor	Rural Labor	Transfer	Urban Diverse	Rural Diverse
Crops	3.4	-4.9	-5	-5.2	-5	3.1	-4.1	-4
MeatDairy	1.8	-14.3	-14.6	-15.1	-14.6	3.7	-12.6	-12.3
OthFoodBev	1.3	-7.9	-8.1	-8.4	-8.1	1.9	-7.1	-6.9
TextAppar	51.4	26.2	25.7	24.9	25.7	53.5	28.6	29.2
Utilities	2.5	-15.5	-15.8	-16.3	-15.8	3.5	-13.8	-13.4
WRTrade	6.8	-3.8	-3.9	-4.1	-3.9	3.1	-3.2	-3.1
Mnfcs	-16.1	-10.3	-10.4	-10.5	-10.4	-6.2	-9.9	-9.9
TransComm	3.8	-11.1	-11.3	-11.8	-11.3	4.1	-9.7	-9.4
FinService	7.8	-9	-9.2	-9.6	-9.2	5.6	-7.7	-7.5
HousOthServ	6.2	-11.8	-12.1	-12.6	-12.1	6.1	-10.3	-9.9

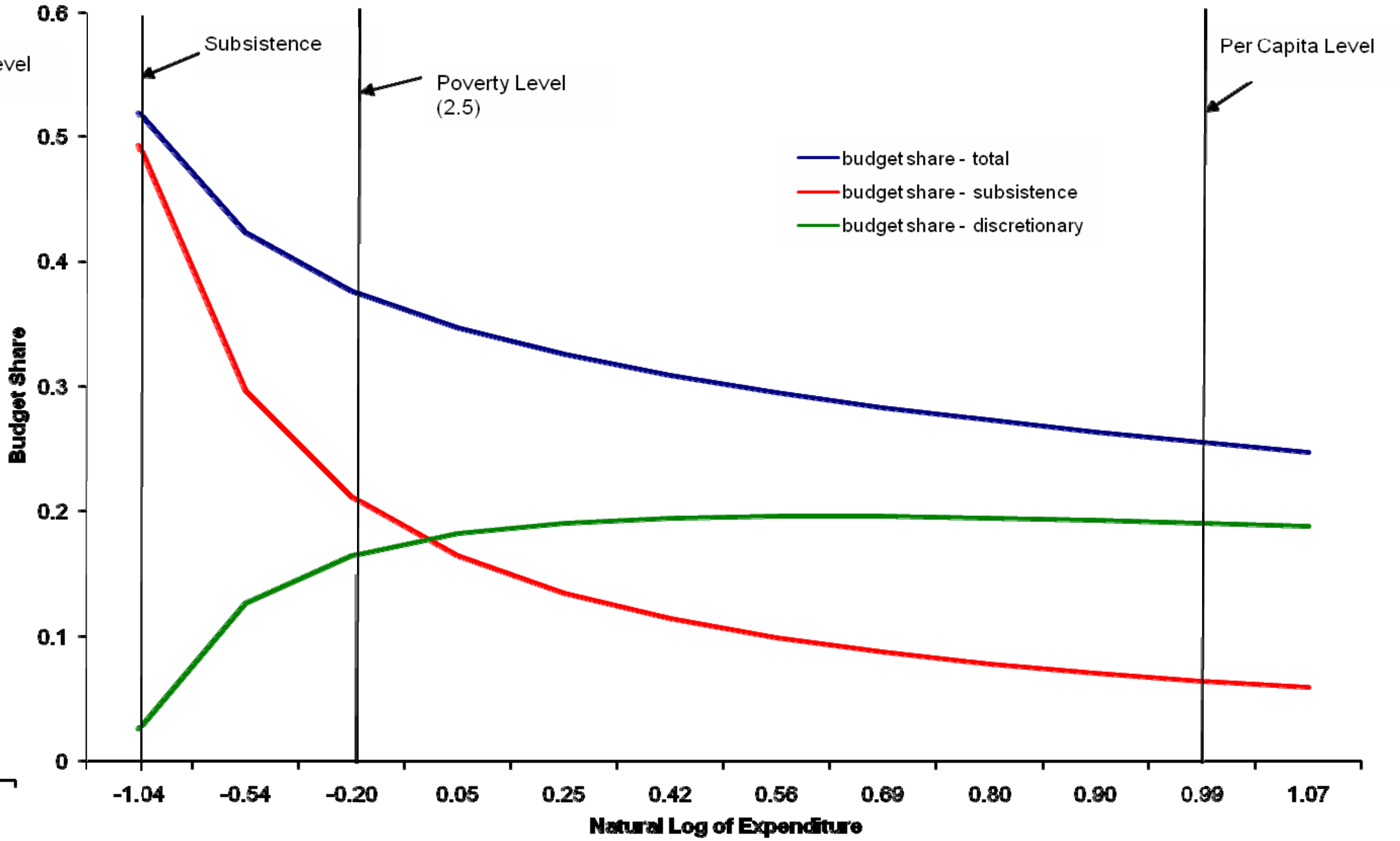
Table 9A. Nutritional Impacts by Stratum in Bangladesh, due to India's Growth (1997-2025) kcal/person/day

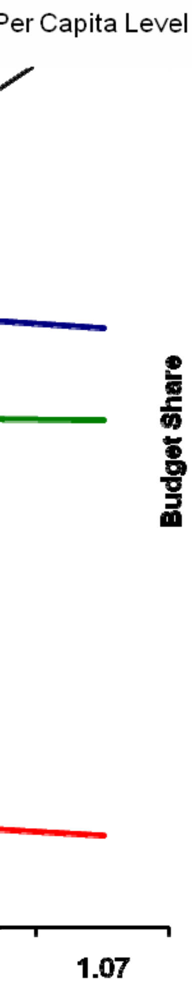
	Agric.	Non-Agric.	Urban Labor	Rural Labor	Transfer	Urban Diverse	Rural Diverse
Baseline	1900	1900	1900	1900	1900	1900	1900
Post-Shock	2019	1887	1924	1921	1919	1936	1932
Change	119	-13	24	21	19	36	32

Table 9B. Nutritional Impacts by Stratum in Bangladesh, due to China's Growth (1997-2025) kcal/person/day

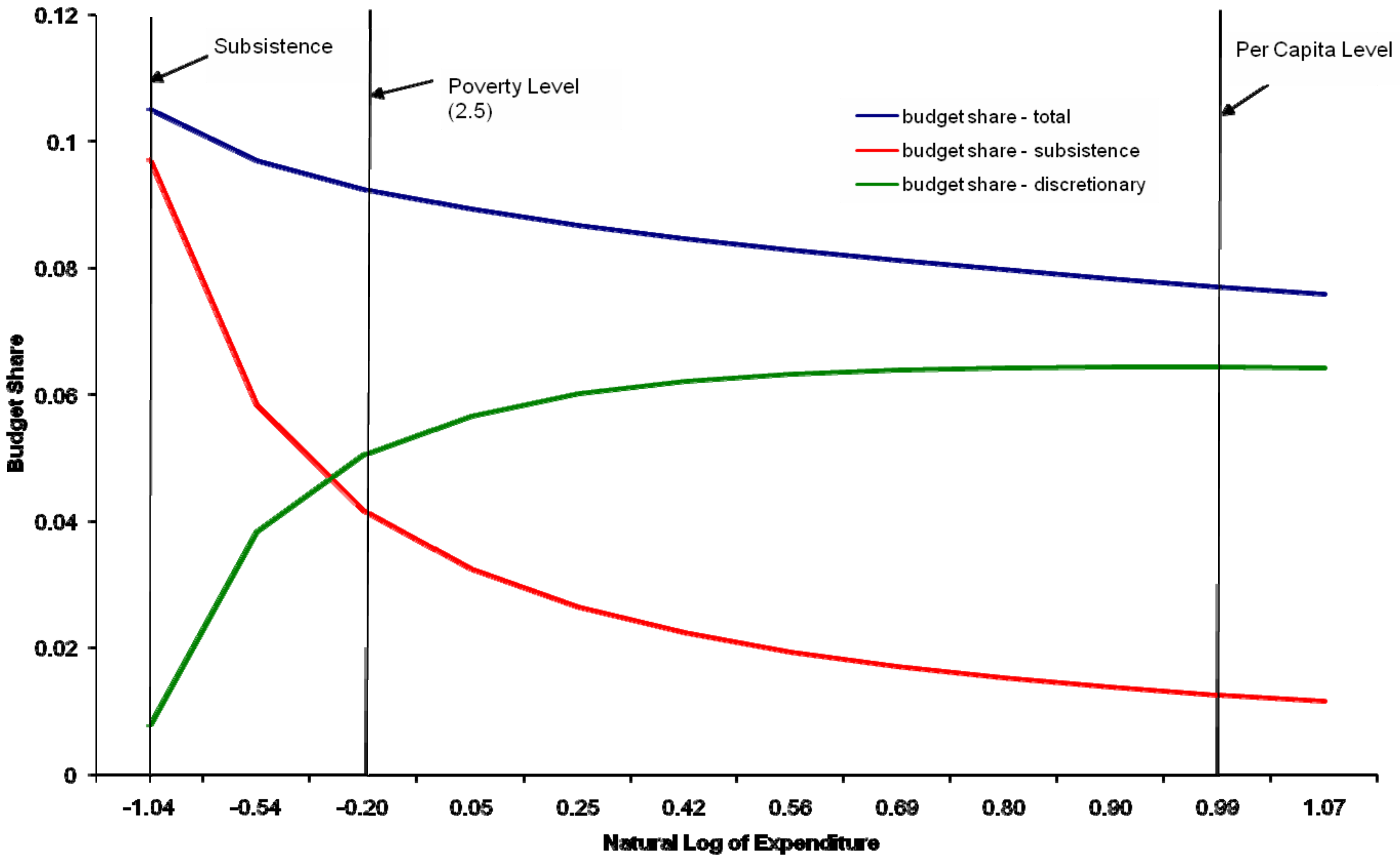
	Agric.	Non-Agric.	Urban Labor	Rural Labor	Transfer	Urban Diverse	Rural Diverse
Baseline	1900	1900	1900	1900	1900	1900	1900
Post-Shock	1772	1769	1764	1769	1946	1788	1791
Change	-128	-131	-136	-131	46	-112	-109

Budget Shares For Staple Food Across Income Spectrum at Initial Prices





Budget Shares For Other Food Across Income Spectrum at Initial Prices



Demand For Crops, Livestock and Other Food Across Income Spectrum - At Initial Prices and with 10% Rise in Crop Prices