Impact of Income on Calorie and Nutrient Intakes: A Cross-Country Analysis

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Abstract

The relationship between income and nutrient intake is explored. Nonparametric, panel, and quantile regressions are used. Engle curves for calories, fat, and protein are approximately linear in logs with carbohydrate intakes exhibiting diminishing elasticities as incomes increase. Elasticities range from 0.10 to 0.25, with fat having the highest elasticities. Countries in higher quantiles have lower elasticities than those in lower quantiles. Results predict significant cumulative increases in calorie consumption which are increasingly composed of fats. Though policies aimed at poverty alleviation and economic growth may assuage hunger and malnutrition, they may also exacerbate problems associated with obesity.

Keywords: calorie and nutrient consumption, food and nutrition policy, income elasticities, nonparametric, panel, quantile regression.

Introduction

"For the first time since 1970, more than 1 billion people, about 100 million more than last year and around one-sixth of all of humanity, are hungry and undernourished worldwide" FAO (2009).

"Obesity has reached epidemic proportions globally, with more than 1 billion adults overweight, at least 300 million of them clinically obese, and is a major contributor to the global burden of chronic disease and disability" WHO (2004).

The number of undernourished people in the world increased from 854 million in 2006 to an estimated 1.02 billion in 2009, representing the greatest amount of hungry people in nearly half a century (FAO 2009). The FAO (2009) contends that while the current economic crisis plays a role in the global escalation of hunger, surging domestic food prices and deteriorating household incomes are especially to blame. Paradoxically, the growing international prevalence of hunger and starvation resulting from energy and nutrient deficiencies continues amidst global concern regarding the rapidly increasing prevalence of chronic diseases resulting from overweight and obesity. As of 2005, an estimated 1.6 billion adults over age fifteen were overweight and 400 million were obese (WHO 2006). Although the spread of obesity was confined historically to the developed countries, emerging trends indicate the growth of overweight and obesity in the developing world (Hossain et. al 2007). In fact, in many developing countries both childhood malnutrition and adult obesity are concurrently observed within households resulting in a "dual burden of disease" (Doak et. al 2004; Caballero 2005).

A potential key determinant of nutritional status is income. Therefore, studies on the relationship between income and nutrient intake receive considerable attention.

Reutlinger and Selowsky's (1976) influential work sparked a prolific literature on estimating the income elasticity for calorie intake using an Engel curve approach. Knowledge of these elasticities is a critical component in the design of policies to combat malnutrition in poor countries and to improve diets in both rich and poor countries. For example, a large elasticity suggests a policy designed to increase the income of the poor and promote economic growth is an effective long-term strategy. Conversely, a small elasticity suggests limited scope for income-enhancing economic policies. Just as important, knowing how calorie and nutrient elasticities change with income becomes necessary in light of the obesity epidemic. The process of economic development spurs a "nutrition transition" in which diets high in carbohydrates are replaced with more varied diets high in fat (Popkin 1994). If calorie-income elasticities show no indication of decreasing at higher incomes there is a stronger need for public programs to influence diets in developed and developing countries.

The debate regarding the relationship between nutrient intake and income has high prominence in the development literature. Historically, the "conventional wisdom" of the World Bank and other development institutions was that deficient energy intake and hunger can be assuaged through income growth (World Bank 1980, 1981). However, a series of articles emerged in the 1980s casting doubt on the role of income (Wolfe and Behrman 1983; Behrman and Wolfe 1984; Behrman and Deolalikar 1987). The role of income in nutrition continues to spawn serious investigation, with contrasting results appearing throughout the literature. While the positive relationship between nutrient intake and income is reinforced in some studies, other studies find either small or insignificant income elasticities. Moreover, some studies argue that the relationship is linear (Bhargava 1991), while other studies uncover important nonlinearities in the income-calorie relationship (Gibson and Rozelle 2005; Skoufias 2003). Finding a nonlinear relationship implies the impact of income on calorie intake is affected by the actual level of calorie intake. For example, high calorie consumers may not be as greatly affected by a marginal increase in income as low calorie consumers and as such will have a smaller elasticity.

With the evidenced mixed, the debate persists regarding the actual relationship between nutrient intake and income and the appropriate economic policies for combating hunger and malnutrition. Also left unclear is the extent the nutrition transition is expected to occur in the developing economies, which involves not only a worsening in diet quality across the developing world but also a likely global epidemic from diet related chronic disease. The role of income in nutrition is clearly important for developing countries. However, as people in developed countries consume calories at increased levels, asking if further increases in income are likely to aggravate problems associated with obesity also becomes important. The primary objective of this paper is to assess the relationship between income and nutrient intake in an international sample of developing and developed countries. In particular, the analysis utilizes a cross-national sample of 171 developing and developed countries across two different time periods (1990-1992 and 2003-2005). Most studies tend to focus on a particular country in a single year using household data. Estimates from an aggregate Engel curve using international data on nutrient intake and income provides a global perspective and generalizes results at a macroeconomic level.

The paper proceeds as follows. The second section reviews the recent literature. The third outlines the data and the econometric methods. The fourth section presents the empirical results and discusses major implications. The final section concludes.

Empirical Literature

While estimates of the income elasticity are abundant, the true approximate magnitude is a controversial topic because of the wide range of estimates. Bouis and Haddad (1992) provide a good review and, though not up to date, find elasticity estimates in the range of 0.01 to 1.18, some statistically significant and others not. In one of the earliest studies using cross-country data to estimate an aggregate Engel curve, Reutlinger and Selowsky (1976) obtain a statistically significant but small income elasticity of around 0.17, suggesting that nutritional status cannot be improved through income-enhancing economic policies alone. A number of other papers claim that income is not the most salient factor in malnutrition, such as Sahn (1988), Ravallion (1990), Bouis and Haddad (1992), and Bouis (1994).

Even though a substantial literature warns against an income-focused policy, the role of income is still considered important by many development institutions. According to the latest FAO (2009, p.36) report on the growing concern of food insecurity, the recent "diminished economic access to food because of higher prices was compounded by lower incomes." While a number of early papers substantiate the conventional wisdom of the World Bank before the "revisionist" papers emerged in the 1980s (Pinstrup-Andersen and Caicedo 1978; Ward and Sanders 1980), more recent studies also counter the revisionist regime (Subramanian and Deaton 1996; Dawson and Tiffin 1998; Tiffin and Dawson 2002; Abdulai and Aubert 2004). Table 1 provides a summary of recent studies since the review in Bouis and Haddad (1992). The estimated elasticities are of moderate magnitude (between 0.2 and 0.5) and most authors conclude that improving income is crucial to combating malnutrition. Different approaches partly explain the variation in estimates.

One important difference is how the Engel curve and resulting income elasticity is estimated. Some studies assume a specific parametric relationship between income and calorie intake while some generalize the relationship using nonparametric estimators, which allows for potential nonlinearities. For example, a higher income elasticity of calorie intake ought to be expected for poor households since they may have insufficient income to pay for adequate nutrition. Nonparametric regression procedures allow for such a possibility and mitigate problems of statistical bias resulting from a misspecified parametric form. Some studies investigate the potential for nonlinearities and find they are not present (Subramanian and Deaton 1996; Abdulai and Aubert 2004). Other studies using nonparametric methods, however, suggest the income elasticity is better described by a curve rather than a line (Roy 2001; Gibson and Rozelle 2002; Skoufias 2003; Meng, Gong, and Wang 2009). These studies conclude that nonlinearity is an important characteristic in the relationship between income and calorie intake.

In addition to using a parametric panel estimator to test for time-effects in the income-nutrient relationship, this paper also uses a nonparametric estimator. Since the nonparametric approach lets the relationship be both non-linear and non-monotonic, calorie intakes between poor households and rich households can respond differently to income. This paper also employs quantile regression to explore the heterogeneity in intake response to income across countries over time. Since the effect of income may differ across the distribution of calorie intake, particular segments of the intake distribution are of great interest, especially from a public health and nutrition policy perspective. Concerns regarding obesity and hunger solicit special attention to the tails of the intake distribution, where dietary excess and deficiency occurs, rather than at the means. Since most previous studies rely on a form of ordinary least squares (either parametric or nonparametric), the marginal effects of income derived from these studies are assumed to be the same over the distribution of calorie intake. Since this is a very strong assumption, results from these studies are of limited value. Quantile regression relaxes this assumption and allows for heterogeneous responses of calorie intake to income. Despite the strong appeal of quantile regression in application to nutrition problems, very few studies employ them. The few that do use a quantile approach focus on the nutrient intake for one country only (Fousekis and Lazaridis 2005; Skoufias et. al 2009; Shankar 2010).

Even if a reasonably sized and statistically significant income-calorie elasticity is found, the role of income in nutritional status is still unclear since people may shift the composition of their nutrient consumption as income increases (Behrman and Deolalikar 1989). Evidence suggests that as incomes rise household expenditure on food increases because more expensive food is being purchased, but the nutrient content of these foods does not increase proportionately (Pitt 1983; Behrman, Deolalikar, and Wolfe 1988). In other words, improvements in income may result in increases in food expenditures or total calorie intake but this may not coincide with a diet more rich in nutrients (Brinkman et. al 2010; Behrman and Deolalikar 1987). Households tend to increase the variety of their diet based on features other than nutrient content, such as taste and quality, as they substitute away from cheaper sources of calories towards more expensive ones. Conversely, studies that uncover a small or zero elasticity do not necessarily imply that a change in income does not affect nutrition. For example, a drop in income may result in unchanged calorie intake, but the consumption of vital nutrients may fall as households substitute towards cheaper and less nutritious foods. Regardless of the size of the estimated income elasticity for calories, there is little room for conclusions regarding the consumption of important nutrients, such as proteins, fats, and carbohydrates (Skoufias 2009).

The existing evidence on income elasticities for nutrient intake from single-country studies reveals considerable differences (Pitt and Rosenzweig 1985; Berhman and Deolalikar 1989).The present paper decomposes calorie intake into proteins, fats, and carbohydrates. In so doing, this paper provides the first income elasticity estimates of key macronutrients for an international cross-country sample. Obtaining income elasticity estimates that break down total calorie intake into individual nutrients is important from a policy perspective. For example, economic growth may increase total calorie intake, reducing problems related to hunger and malnutrition, but may also result in a greater proportion of fat in the diet, causing higher rates of obesity and diet-related chronic diseases. The income-calorie elasticity alone is not enough to guide policy makers. Understanding the general composition of the diet and the consumption of particular nutrients becomes crucial in this context.

In addition to problems of deficient calorie and nutrient intake is the problem of excessive intake leading to overweight and obesity. The World Health Organization (2006) projects that by 2015 nearly 2.3 billion adults will be overweight and over 700 million will be obese. As developing countries experience economic growth, overweight and obesity are on the rise in low- and middle-income countries, particularly in urban areas (WHO 2006). Higher income countries tend to obtain most of their dietary energy supply from fat (Drewnowski 2003). The analysis in Drewnowski and Popkin (1997) reveals a global convergence towards a diet deriving a higher proportion of energy from fat across a sample of developed and developing countries. Specifically, they warn about the possibility that a diet containing close to 30% of energy from fat could become the global norm. Also worrying is the trend that the nutrition transition is occurring at lower levels of income than previously thought. As pointed out in Popkin and Ng (2007, p.200), "even poor nations had access to a relatively high-fat diet by 1990 when a diet deriving 20% of energy (kilocalories) from fat was associated with countries that have a GNP of only $750 per capita".

Data and Econometric Methods

Aggregate data on average per capita dietary energy supply are derived from national food balance sheets obtained from the FAO Statistics Division. A cross-sectional sample of 171 developing and developed countries across two different time periods (1990-1992 and 2003-2005) is constructed (refer to table A1 in the appendix for countries included). Dietary energy consumption per person is defined as the amount of food, in kilocalories per day, for each individual in the total population. The measure is based on food available for human consumption computed as the residual from the total food supply less waste and other uses, such as from industry or agriculture. Income data is sourced from the International Financial Statistics of the International Monetary Fund and is the Gross Domestic Product (GDP) for each country in billions of 2005 U.S. dollars. To convert these values to GDP per capita, population data is obtained from the Penn World Tables.

Three main estimation methods are employed in this paper. All three are Bayesian. First, there is the nonparametric approach outlined in Chapter 10 of Koop (2003). The second is a linear (in parameters) panel regression that can be estimated using the framework outlined in Chib and Greenberg (1995). Finally, the recently developed method for estimating quantile regressions (the Bayesian Exponentially Tilted Empirical Likelihood, BETEL method) outlined in Lancaster and Sung (2010). When using the panel approach, alternative models are evaluated using the Bayesian Deviance Information Criteria (DIC) outlined in Spiegelhalter et al. (2002). A full description of each of the methods can be found in the references above, therefore, the coverage here is succinct.

The Nonparametric Approach

The motivation for a nonparametric approach is because the relationships between calorie or nutrient consumption and incomes may be highly non-linear and plausibly non-monotonic. The flexibility of the nonparametric approach allows the examination of whether simple functional forms may be viable. Therefore, the nonparametric approach is employed first before investigating the relationships using a parametric approach. The nonparametric approach assumes:

(1) $$y_i = f(x_i) + e_i$$

where y_i is the average consumption in country i of calories or one of the nutrient groups, and x_i is per capita income in country i. Alternatively y_i and x_i may be logged values of these variables. The error term e_i is assumed to be independently and identically normally distributed. As outlined in Koop (2003), the nonparametric relationship can be modelled by estimating $f(x_i)$ at each point value of x_i. The estimation of the nonparametric relationship requires a smoothing parameter η to be estimated. This parameter is analogous to bandwidth selection using classical kernel estimation. Within the Bayesian approach to estimation, this parameter can be estimated by maximizing the marginal likelihood of the relationship or through crossvalidation, with the former method used (Koop 2003). When using the nonparametric approach, the models are estimated for the two periods separately. Thus, there are two sets of nonparametric regressions for each of the time periods.

The Panel Approach

For the panel approach, the models investigated are of the form

$$(2) \qquad y_{it} = \alpha_t + \beta_{1t} x_{it} + \beta_{2t} x_{it}^2 + \beta_{3t} x_{it}^3 + e_{it}$$

where $e_{it} \sim N(0, \sigma^2)$, $E(e_{it}, e_{jt}) = 0$ for all $i \neq j$ and $E(e_{it}, e_{jt*}) = \rho\sigma^2$ where $t \neq t^*$. Also, y_{it} denotes the dependent variable (calories or nutrients or logs of these variables) for country i at time t and x_{it} is per capita income (or logged values) for country i at time t. Since there are only two time periods, the values of t are one and two . By allowing the relationship to be cubic, the model deals with functions that have variable second derivatives whereby the function may be convex and concave over alternative regions of the variable space. The imposition of restrictions are investigated, such as $\beta_{it} = \beta_{it*}$ (no time effects) and/or $\beta_{2t} = 0$ and/or $\beta_{3t} = 0$, in which case the function may become quadratic or linear (or linear in logs). The Bayesian approach further allows imposition and investigation of whether inequality restrictions are consistent with the data. For example, in the cubic relationship the hypothesis might be that $\beta_{3t} < 0$ since one might expect that consumption of calories or nutrients would not increase at an accelerating rate as incomes rise. Finally, an alternative panel approach assumes that $\beta_{jt} = \beta_{jt*}$ for all j along with $e_{it*} = e_{it} + z_i$ where z_i is a normally distributed country effect. This "within country/between time" regression is also estimated.

The Quantile Approach

Unlike the previous two approaches, the BETEL does not have an explicit functional form for the likelihood. Instead, the empirical likelihood is constructed by optimizing an entropy measure for any given value of the parameters. The empirical likelihood is multiplied by some relatively diffuse priors to obtain the posterior distribution of the parameters, and then this can be mapped using a Metropolis-Hastings algorithm. The BETEL approach can be used more generally than for quantile regressions. The moment conditions are derived from the condition that (for two variables y_i and x_i)

$$\Pr\left(y_i < \alpha(\tau) + \beta(\tau) x_i \mid x_i\right) = \tau \qquad (3)$$

The parameters $\alpha(\tau)$ and $\beta(\tau)$ represent the intercept and slopes for the τ^{th} quantile. Like the nonparametric regressions, quantile regressions are run separately for each time period.

Results and Discussion

Discussion of the results proceeds sequentially examining the nonparametric results first, followed panel regression results, and then the quantile results. As stated, the nonparametric regressions were run separately over the two periods (1990-1992 and 2003-2005). Only the latter period is presented, since the nonparametric plots are almost the same between the two periods. First, figure 1 examines the raw nutrient shares modelled as a function of the raw per capita variable. The middle line is the fitted (mean) nonparametric relationship, with the two outside lines containing the 95% confidence intervals for the mean. As seen from the plots, the relationship between shares of nutrients and per capita income appears to be non-linear, with poorer countries having relatively high levels of carbohydrates as a proportion of their diet (top left hand corner of figure 1). As incomes increase, however, the shares of carbohydrates decrease with a small rise in proteins but a much larger rise in fats. In the poorest countries, about 80% to 85% of the diet is in the form of carbohydrates and only around 10% in fats. As incomes increase though, there is a rapid switch to fats, levelling off at around a 50% share in carbohydrates and a 38% share in fats, with the remainder being proteins. The warnings from Drewnowski and Popkin (1997) about the possibility of a diet containing close to 30% of energy from has in fact become the norm for many countries already.

The second set of nonparametric plots in figure 2 are for the logged calorie and nutrient consumptions regressed against logged per capita income (the relationships between the raw data were also examined, and these were highly nonlinear and are not presented). What is more interesting about the fitted curves using the logged data is that for each of the variable pairs, the nonparametric curves are quite linear. In other words, the data are consistent with being linear in logs, and therefore have constant elasticities. There is some evidence of a slightly lower slope at very low levels of per capital income for total calories, fats, and proteins. Surprisingly, however, the increases in consumption of these quantities towards the upper end of the income range does not appear to level off. This implies that as per capita incomes rise, a percentage increase in per capita incomes continues to give the same percentage increase in calories, along with increases in fats, proteins, and carbohydrates. Also evident is that the carbohydrate line is much flatter, meaning that increases in incomes are not leading to the same increases in carbohydrates as for fats and proteins. This is consistent with the nonparametric results using nutrient shares.

In view of the nonparametric results, the linear in log specifications represent plausible empirical characterizations of the relationships between calories/nutrients and per capita income. This hypothesis is explored further using parametric methods. As outlined in the methods section, a set of panel regressions are specified, where the variables have been logged prior to estimation. Before presenting parameter estimates, alternative specifications including only a quadratic term and excluding a cubic or quadratic term are investigated first. No other restrictions are imposed at this stage, with further restrictions investigated subsequently. The DIC for each of the models is computed, with the preferred model being the one with the lowest DIC. The results are presented in table 2. The models with the lowest DIC are highlighted in bold, and the linear (in variables) specification is preferred for total calories, protein, and fats. However, the quadratic model is preferred for carbohydrates. Results conclude therefore that the panel results are broadly in concordance with the nonparametric results. The evidence suggests that total calories, protein, and fats have approximately constant elasticities over per capita incomes. This is not the case, however, for carbohydrates. The restrictions on the parameters across the time periods are investigated in table 3 in order to test whether the relationships differ across the two periods (1990-2 and 2003-5). For these comparisons the linear models are used, even for carbohydrates. As can be seen from the results in table 3, while there is evidence that the constants in the models can be restricted across the two periods none of the models support constant elasticities across the two periods, suggesting that there have been changes in consumption patterns other than those driven by incomes.

Table 4 presents the elasticities estimated using the panel approach. Again, the linear model results are given in table 4. As mentioned above, the quadratic model is preferred for carbohydrates, therefore carbohydrates are discussed further below. The estimates in table 4 reveal that while the DIC does not support constant elasticities over the two periods, the differences in elasticities across the periods is very small. The calorie elasticity is around 0.09 for both periods and both periods have 95% elasticity confidence intervals that would be contained within the interval (0.072, 0.104). Both protein and fat elasticities are significantly larger than the calorie elasticities (at about 0.14-0.15 and 0.23-0.24, respectively), whereas the carbohydrate elasticity is much smaller (at around 0.02-0.025). This is consistent with the previous results regarding nutrient shares. Overall, results suggest that a 10% increase in per capita incomes will lead to around a 1% rise in calorie consumption, but with the larger components being an increase in fat consumption, followed by protein consumption, with a very small increase in carbohydrate consumption. As already noted, however, the carbohydrate elasticity does not appear to be constant. To further investigate carbohydrate consumption the income elasticity is estimated at each level of income. These are plotted in figure 3 for the two time periods, which again are very similar. The basic picture that emerges is that the carbohydrate elasticity is around 0.10 for very low levels of income, decreasing at a decreasing rate from there on, but remaining positive until around $US7500 per year. Beyond this point carbohydrate consumption has a negative elasticity.

The results for the quantile regressions are presented in table 5. Again, these are linear in log specifications for each of the variables. Table 5 reports the upper 75%, the median, and the lower 25% percentile elasticity estimates. In all cases, for all quantiles, the results are very similar to the estimated elasticities from the panel results. Of central interest is whether there seems to be a divergence between the different percentile values. As can be seen by table 5, these are very small. A large divergence between the lower and the upper percentiles would mean that countries with a higher consumption (for a given level of per capita income) are responding differently to those with a lower consumption (for a given level of per capita income). For example, if for calories the β 0.25 was much smaller than β 0.75 then countries with lower consumption of calories or nutrients would be less responsive to income changes than those with relatively high consumption of calories. This, arguably would be the most worrying scenario, since increased incomes would be having the least effect on those with the lowest consumption, and increased incomes would be having the highest effect on those with the highest income. From table 5, however, the opposite tends to be true. For both periods, the majority of the variables have non-decreasing or increasing elasticities moving down the percentile groups. Therefore, those consuming relatively small amounts of calories or nutrients (for a given level of income) tend to be the most responsive to changes in the levels of income. As already noted though, the divergence between the quantiles is small.

To summarize, calories, fats, and proteins are found to have positive significant income elasticities. The data on these variables are also consistent with having constant elasticities across the income range. Carbohydrate consumption is found to have high positive elasticities only at low income levels, becoming negative at high incomes. A quantile regression approach yields similar elasticity estimates to the nonparametric and panel approaches at both the upper and lower quantiles, but there is some evidence to suggest that the higher consuming countries (for both calories and nutrient components) had slightly lower elasticities than for those in the lower quantiles. These findings have both positive and negative implications. First, in line with the majority of previous studies, the small but positive income elasticities suggest that income growth will increase calorie consumption and increase all nutrient consumption for low income countries (below US$7500). However, the elasticity estimates fall below the majority of existing estimates.

In terms of overall calorie consumption, a 10% rise in incomes is required for 1% rise in calorie consumption. Thus, rather large increases in income are needed for an improvement in the nutrition status of people in poorer countries. The implications for higher income countries are perhaps no less important. Findings suggest that this overall rise in calorie consumption as incomes rise holds also for rich countries. Thus, for countries that are already consuming well beyond the recommended calorie levels, further increases in income will lead to even larger consumption of calories. Moreover, the consumption of fat has the largest elasticity at around 2.5 that of overall calorie consumption, meaning that the larger component of increased calorie consumption will be in terms of fats. While these elasticities may seem small, in the absence of any other change in behavior, extrapolating current income growth predicts significant cumulative increase in calorie consumption that would exacerbate existing problems associated with obesity. Indeed, such has been the case in parts of Asia, such as China, in which substantial economic growth has been met with marked increases in rates of obesity (Popkin and Ng 2007).

Overall, the results obtained in this paper have two important implications. First, economic growth does have the potential to assuage hunger and malnutrition in the developing world, however, the impacts are likely to be small and not as substantial as some studies have concluded (Subramanian and Deaton 1996; Meng, Gong, and Wang 2009). In fact, some studies suggest that good nutrition is a driver of economic growth and therefore development policies should be geared specifically towards reducing chronic malnutrition in order to spur economic growth rather than focusing on economic growth to spur good nutrition (Correa and Cummins 1970; Strauss 1986; Strauss and Thomas 1998; Fogel 2004). Second, economic growth may also change the structure of diets and the composition of nutrient intakes. In particular, result here suggest that as countries become richer not only are calorie intakes on an increasing trajectory, but that diets becomes increasingly composed of fats rather than proteins or carbohydrates. These results are in accord with the nutrition transition hypothesis of Popkin (2004). Economic growth, while contributing to the alleviation of malnutrition, also results in diets that become composed more of fats, worsening rates of obesity and obesity-related diseases.

Summary and Conclusion

Understanding the relationship between calorie intake and income is crucial to designing economic strategies towards combating chronic diseases associated with both nutrient deficiency and nutrient excess. Given the nature of the dual burden of hunger and obesity, careful analysis must pay special attention to the tails of the nutrient intake distribution. Given the historical difficulty in coordinating effective international action against hunger and undernutrition, in addition to the escalating global obesity epidemic, there is a continued need for research on effective policy instruments to combat these dual burdens.

This paper examined the relationship between calorie/nutrient consumption and per capita incomes using a two-period panel of 171 countries and extends the literature in two important ways. First, the relationship between income and average calorie intake is disaggregated into important nutrient components: carbohydrates, proteins, and fats. The disaggregation of calorie intake permits the relationship with income to differ between each nutrient. Most of the literature on nutrition and income, especially in the development literature, focuses entirely on total energy (calorie) intake. While the income elasticity of calories infers how the total level of energy is affected by income, it reveals nothing about how income affects diet composition. The few studies that do estimate nutrient-income elasticities (Pitt and Rosenzweig 1985; Behrman and Deolalikar 1987; Behrman and Wolfe 1987; Skoufias et. al 2009) confine their analysis to a single country.

Second, this study employs three different estimators (nonparametric, parametric, and quantile) for a robust interpretation of the income-nutrient relationship. A nonparametric estimator allows the relationship between income and calorie or nutrient consumption to be non-linear and non-monotonic. The parametric panel estimator permits estimation of both 'within-country' and 'between-time' effects and allows for testing of changes in the relationship over time. The quantile estimator lets the marginal effect of income on calorie/nutrient intake to be different over the entire intake distribution. In other words, the impact of income may be different between rich and poor countries, which consume calories at different levels, so improvements in income may not impart equal benefits. While some studies use both parametric and nonparametric estimators, few studies utilize quantile regression.

Results suggest that development strategies aimed at improving economic growth may prove to be insufficient at alleviating hunger and may at worst exacerbate problems of poor diet and obesity in both developing and developed countries. Even in the absence of targeted food policies, the global economic crisis will likely worsen the quality of diets internationally. In response to falling incomes, households will turn to fatty and calorie-dense, but nutrient poor, inexpensive processed foods. As the composition of diets change towards more fatty foods, countries across the globe will experience deteriorating nutritional status and health. Global efforts to improve diets require the coordinated design and implementation of policies that can address the dual public health problems of nutrient excess and deficiency.

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Table 1. Summary of Recent Studies

Author	Year	Data Level	Model	Timeframe	Country	Elasticity
Bhargava	1991	Individual	Panel	1976-1977	India	0.13
Grimard	1996	Household	Cross-sectional	1984-1985	Pakistan	0.40-0.50
Subramanian and Deaton	1996	Household	Cross-sectional	1983	India	0.40-0.55
Dawson	1997	Aggregate	Cross-sectional	1992	41 DCs	0.07
Dawson and Tiffin	1998	Aggregate	Time-series	1961-1992	India	0.34
Roy	2001	Individual	Panel	1976-1978	India	<0-0.15
Dawson	2002	Aggregate	Time-series	1961-1998	Pakistan	0.19
Gibson and Rozelle	2002	Household	Cross-sectional	1985-1987	Papua New Guinea	0.18-0.59
Tiffin and Dawson	2002	Aggregate	Time-series	1961-1992	Zimbabwe	0.31
Skoufias	2003	Household	Cross-sectional	1996, 1999	Indonesia	0.01-0.45
Abdulai and Aubert	2004	Household	Panel	1998-1999	Tanzania	0.49
Aromolaran	2004	Household	Cross-sectional	1999-2000	Nigeria	0.19
Skoufias et. al	2009	Household	Cross-sectional	2003-2004	Mexico	<0-0.07
Meng, Gong, and Wang	2009	Household	Panel	1986-2000	China	0.20-0.49
Babatunde et.al	2010	Household	Cross-sectional	2006	Nigeria	0.18

Table 2. DIC for Functional Forms

	Calories	Carbs	Protein	Fats
Cubic	-1180.25	-1109.16	-966.52	-738.66
Quadratic	-1178.46	**-1109.56**	-967.91	-738.32
Linear	**-1180.93**	-1102.93	**-969.28**	**-741.57**

Table 3. DIC for Restrictions Across Periods for Linear Models

	Calories	Carbs	Protein	Fats
Unrestricted	-1180.93	-1102.93	-969.28	**-741.57**
Constant Elasticities	-1178.20	-1103.60	-969.27	-733.40
Constant Intercept	**-1182.60**	**-1104.83**	**-971.27**	-739.89
Constant All Parameters	-1151.22	-1090.24	-947.37	-716.88

Table 4. Elasticity Estimates from Linear Panel Regression

	Calories		Carbohydrates		Proteins		Fats	
	Mean	Stdv	Mean	Stdv	Mean	Stdv	Mean	Stdv
2003-05	0.086	0.006	0.020	0.007	0.140	0.009	0.230	0.014
1990-02	0.092	0.006	0.025	0.007	0.148	0.009	0.241	0.014
Difference	0.074	0.030	0.026	0.036	0.162	0.041	0.209	0.060

Table 5. Quantile Elasticity Estimates

	Calories		Carbohydrates		Proteins		Fats	
2003-05	beta	stdv	beta	stdv	beta	stdv	beta	stdv
$\tau = 0.75$	0.083	0.009	0.016	0.007	0.130	0.012	0.197	0.020
$\tau = 0.50$	0.088	0.007	0.020	0.009	0.140	0.007	0.229	0.016
$\tau = 0.25$	0.089	0.010	0.026	0.010	0.152	0.011	0.257	0.024
1990-92	beta	stdv	beta	stdv	beta	stdv	beta	stdv
$\tau = 0.75$	0.093	0.008	0.019	0.007	0.137	0.012	0.217	0.018
$\tau = 0.50$	0.094	0.007	0.019	0.010	0.147	0.010	0.264	0.021
$\tau = 0.25$	0.094	0.008	0.028	0.007	0.156	0.014	0.274	0.027

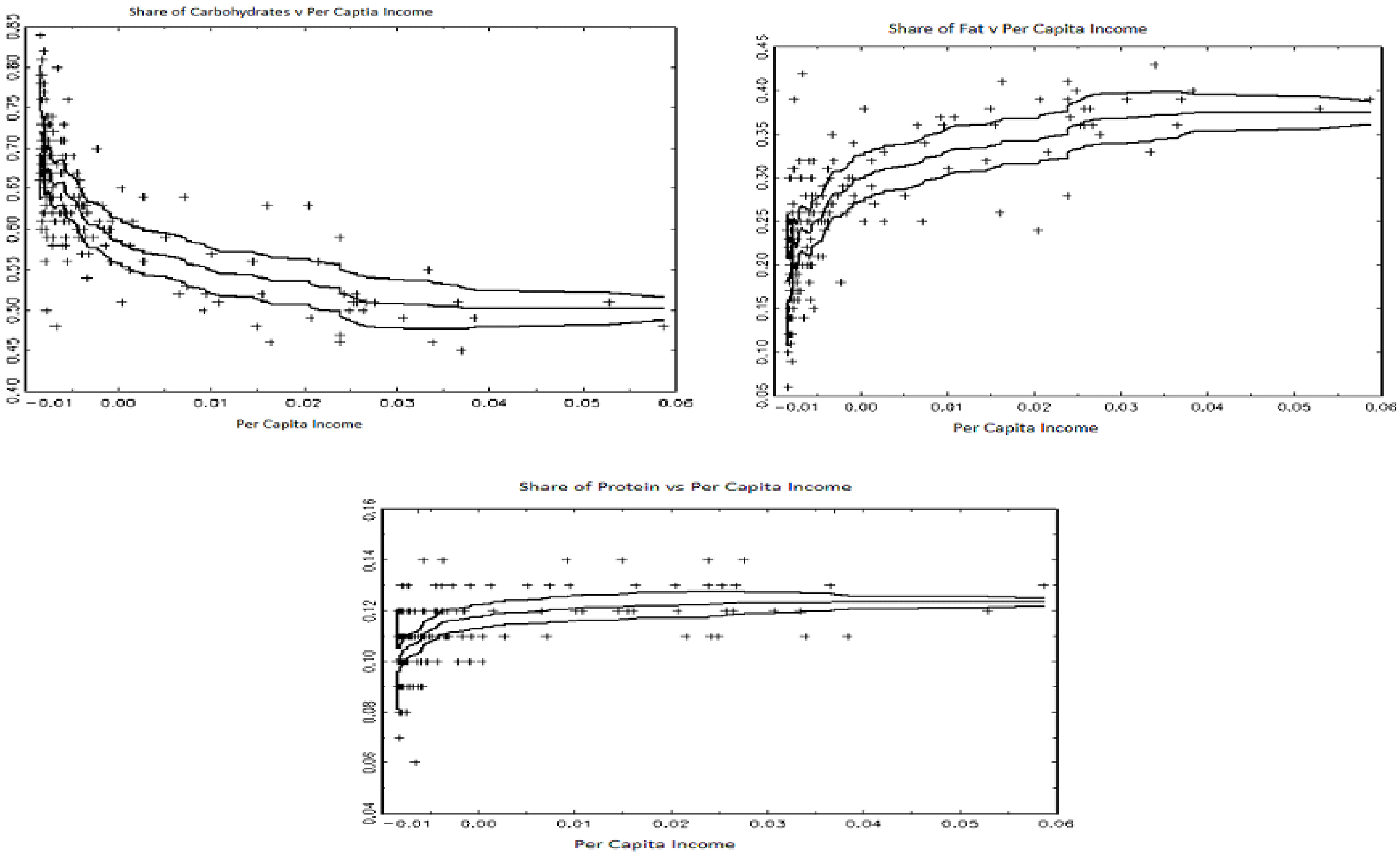

Figure 1. Nutrient shares versus per capita income

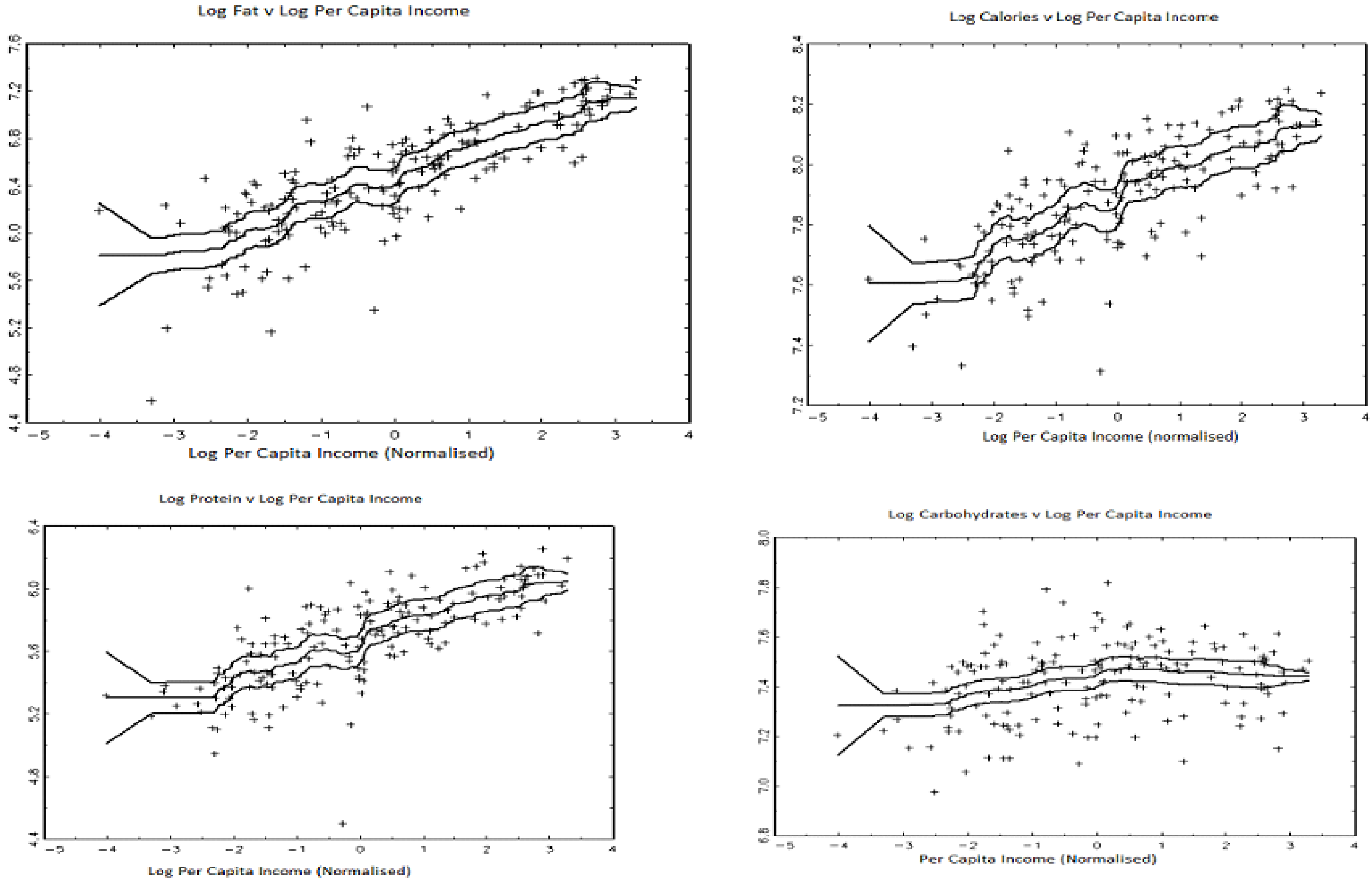

Figure 2. Log nutrient consumption versus per capita income

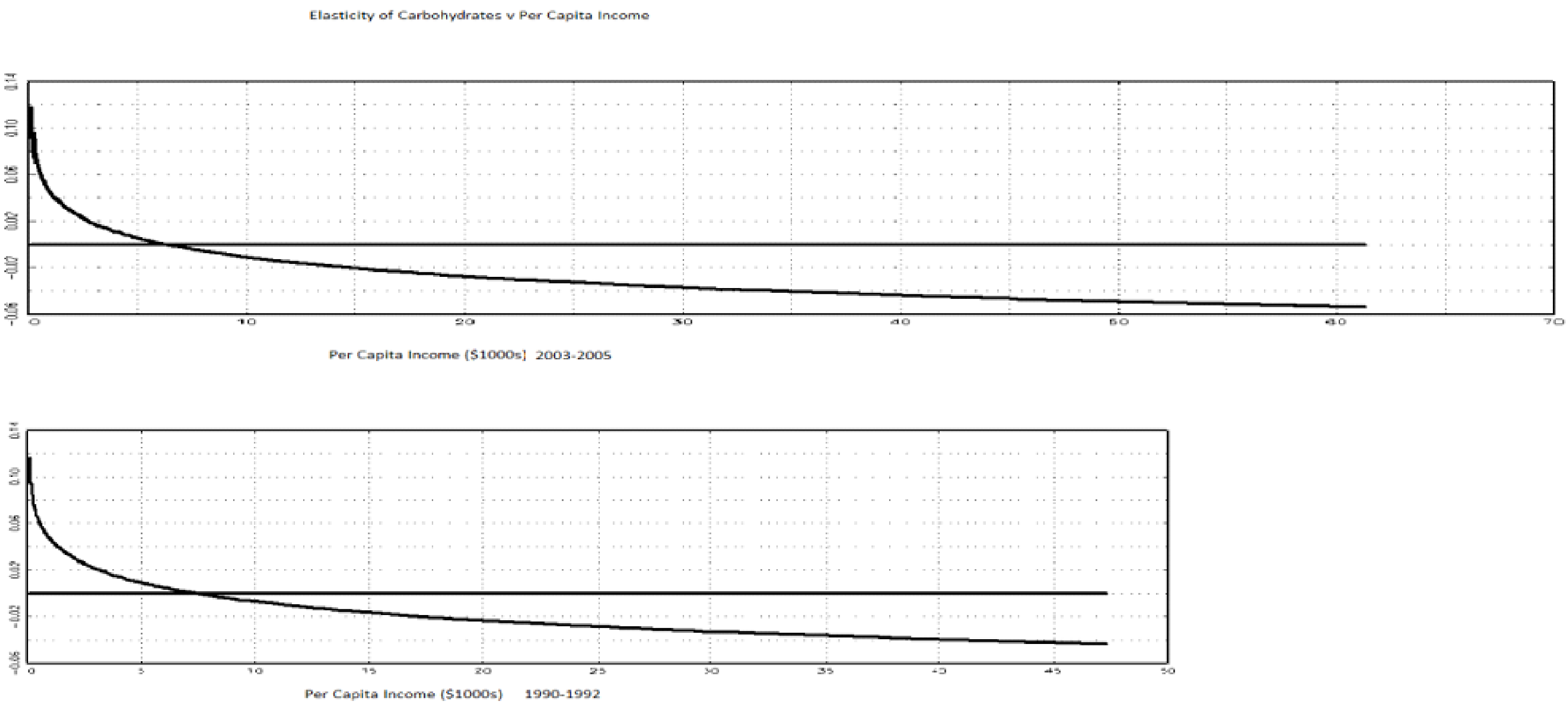

Figure 3. Carbohydrate income elasticity

Table A1. List of Countries

Albania	Denmark	Laos	St. Lucia
Algeria	Djibouti	Latvia	St. Vincent & Grenadines
Angola	Dominica	Lebanon	Samoa
Antigua and Barbuda	Dominican Republic	Lesotho	Sao Tome and Principe
Argentina	Ecuador	Liberia	Saudi Arabia
Armenia	Egypt	Libyan Arab Jamahiriya	Senegal
Australia	El Salvador	Lithuania	Serbia & Montenegro
Austria	Eritrea	Luxembourg	Seychelles
Azerbaijan	Estonia	Madagascar	Sierra Leone
Bahamas	Ethiopia	Malawi	Slovakia
Bangladesh	Fiji	Malaysia	Slovenia
Barbados	Finland	Maldives	Solomon Islands
Belarus	France	Mali	South Africa
Belgium	French Polynesia	Malta	Spain
Belize	Gabon	Mauritania	Sri Lanka
Benin	Gambia	Mauritius	Sudan
Bermuda	Georgia	Mexico	Suriname
Bolivia	Germany	Mongolia	Swaziland
Bosnia and Herzegovina	Ghana	Morocco	Sweden
Botswana	Greece	Mozambique	Switzerland
Brazil	Grenada	Myanmar (Burma)	Syrian Arab Republic
Brunei Darussalam	Guatemala	Namibia	Tajikistan
Bulgaria	Guinea	Nepal	Thailand
Burkina Faso	Guinea-Bissau	Netherlands	Togo
Burundi	Guyana	New Caledonia	Trinidad and Tobago
Cambodia	Haiti	New Zealand	Tunisia
Cameroon	Honduras	Nicaragua	Turkey
Canada	Hungary	Niger	Turkmenistan
Cape Verde	Iceland	Nigeria	Uganda
Central African Rep.	India	Norway	Ukraine
Chad	Indonesia	Pakistan	United Arab Emirates
Chile	Iran	Panama	United Kingdom
China	Ireland	Paraguay	Tanzania
Colombia	Israel	Peru	United States of America
Comoros	Italy	Philippines	Uruguay
Congo, Rep. of	Jamaica	Poland	Uzbekistan
Costa Rica	Japan	Portugal	Vanuatu
Côte d'Ivoire	Jordan	Rep. of Korea (S. Korea)	Venezuela
Croatia	Kazakhstan	Republic of Moldova	Viet Nam
Cuba	Kenya	Romania	Yemen
Cyprus	Kiribati	Russian Federation	Zambia
Czech Republic	Kuwait	Rwanda	Zimbabwe
Dem. Rep. of the Congo	Kyrgyzstan	St. Kitts and Nevis	