In Search of India's Missing Calories: Energy Requirements and Calorie Consumption

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Abstract

Despite significant real expenditure growth and positive cross-sectional calorie-expenditure elasticities, measured caloric intake in India declined over the 1983-2005 period. Similarly, rural households are poorer than urban households but consume more calories on average. We test the energy requirements hypothesis of Deaton and Dreze (2009) as an explanation for these "missing" calories by using time-use data to impute household energy requirements. We analyze an Engel curve with variable energy requirements to emphasize that calorie quality may provide a better indication of energy requirements than food share. Empirically, caloric intake and requirements are highly correlated across household characteristics like size, age, education and occupation. Labor-saving durables play an important role in caloric intake. Quantitatively, energy requirements can explain most of the missing calories between urban and rural areas. Over time they can explain about half of the changes in food quality but only a modest share of the total missing calories, implying that other factors are important. We also consider implications of variable energy requirements for measurement poverty and welfare.

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1. Introduction

Deaton and Dreze (2009) use India's National Sample Survey to document a large (10%) decline in mean calorie consumption per capita over the 1983 to 2005 period. This is especially puzzling because the same data indicate significant growth of real expenditure per capita during the period (30%) and imply a positive cross-sectional calorie-expenditure elasticity (0.3), so we would have expected a significant increase in per capita calorie consumption (9%). The same pattern of higher real expenditures and equal or lower calorie consumption is observed between urban and rural households. Understanding the source of these "missing" calories is critical for our understanding of poverty and well-being in India. Poverty measures based on caloric norms would indicate a dramatic increase in poverty rates and greater poverty in urban than rural areas, contrary to conventional wisdom.

Deaton and Dreze (2009) propose the hypothesis that declining household energy requirements may explain the decline in caloric intake. Energy requirements may fall due to substitution of machine or animal power at work, structural change towards less energy-intensive occupations, infrastructure improvements, labor-saving appliances, and improvements in the health environment that increase nutritional absorption. This hypothesis is consistent with evidence of slow but steady progress from anthropometric measures (child heights and weights) and what we call an increase in food quality - the substitution away from staples that are cheap sources of calories, like grains, towards foods that are more expensive per calorie, such as dairy products or processed foods. Rather than impoverishment, caloric intake differences driven by lower energy requirements would imply greater welfare and lower poverty.

This paper makes three contributions to this debate. First, we use a simple framework to analyze how caloric requirements affect the calorie-expenditure Engel curve. We use this framework to motivate a decomposition of the calorie-expenditure relationship into a food quality and a food/non-food component and emphasize how the former is a better indicator of the effects of calorie requirements when food is separable in the household utility function. Second, we use time-use data to impute caloric requirements, allowing us to explore the covariation of intake and requirements with respect to household characteristics like age, size, education, and occupation. We then quantitatively assess whether these characteristics can explain the urban-rural or over time missing calories. Third, we provide some tentative evidence on the impact that variable caloric requirements have on poverty and welfare in India.

Our decomposition of the calorie-expenditure Engel curve into food quality and food/non-food implies that the urban-rural missing calories are largely explained by differences in food quality, with urban households consuming more foods that are expensive per calorie. The missing calories between 1983-1993 can also be explained by a transition to more expensive calories holding real food expenditures constant. By contrast, the 1994-2005 period is characterized by relatively stable food quality but a large decline in food expenditures relative to total expenditures (e.g. a downward shift in food Engel curves).

Our main innovation is to use time-use data for six Indian states to impute caloric requirements at the individual and household level. While there are limitations to our imputation procedure, our measure of caloric requirements has significant advantages to those provided by the India Council of Medical Research (ICMR), allowing us to examine the impact of variables like household size, age, hours worked, and home production that are not captured by the standard caloric requirement classification. We are also able to use identically defined household characteristics to compare caloric intake and requirements across time-use and consumption surveys. Our results indicate that demographic composition, age, education, occupation all have significant impacts on caloric intake and requirements, with education and occupation being especially important for explaining differences over time and between rural and urban areas. Ownership of labor-saving durables also has a large impact on caloric intake.

Quantitatively, when we control for these household characteristics we explain as much as 61% of the missing urban calories, rising to 100% when we look only at the food quality component. The missing calories over time are less affected by these household characteristics, declining by only 21% in rural areas and 15% in urban areas, rising to 42% and 60% respectively for the food quality component. These results confirm the model intuition that the food quality component is particularly responsive to changing caloric requirements and that changes in relative prices, the availability of new and better quality non-food goods, or other factors may be required to explain calorie declines that arise due to lower food relative to non-food expenditures (particularly over the 1994-2005 period).

We conclude with a preliminary assessment of the implications of variable caloric requirements for measurement of poverty and welfare. Poverty rates based on caloric inadequacy tend to be much higher than official rates, and variable caloric requirements leads to significant differences in poverty rates across states and across occupations within states. Using the simple Engel equivalence scale implied by our model we find that urban areas are up to 5% better off (expenditure-equivalent) due to lower caloric requirements, an effect largely driven by occupation as sedentary workers have up to 5% greater welfare than primary sector workers. This effect is large relative to the measured urban-rural average real expenditure gap of about 30%. The gains over time that we attribute to caloric requirements are smaller at around 2-3% (relative to growth of real expenditures around 30%).

Though our primary contribution is to explore the source and implications of India's missing calories, we make two additional contributions that extend beyond the Indian context. We provide evidence that household economies of scale in energy requirements may explain the Barten puzzle explored in Deaton and Paxson (1998).[1] We also find evidence that caloric requirements may play an important role in life-cycle consumption patterns for poor countries. Unlike the findings of Aguair and Hurst (2005) for the United States and Hicks (2010) for Mexico, we observe large declines in both caloric requirements and intake for older Indian households, with a limited role for consumption smoothing through greater home-production and shopping intensity.

Our paper is also related to the macroeconomics and history literature that uses food consumption patterns to measure welfare and price index bias. Costa (2001), Hamilton (2001), and Almas (2008) use shifts in food Engel curves to measure price index bias. Under the assumption that the budget share of food is a sufficient statistic for welfare, shifts in food Engel curves can be used to compute the true cost-of-living index and the bias in official price indexes. If caloric requirements shift food Engel curves, they should be considered another source of "bias" detected by these methods, one that will be particularly important when comparing countries or periods with very different levels of economic development. Li (2010) uses a different approach to measure welfare gains from greater food variety that can be interpreted

[1]The Barten puzzle is can be briefly stated as follows. When there are household economies of scale, larger households are better off holding per capita expenditures constant. Provided private and public goods are not too substitutable, the income effects imply that the share of household expenditures on private goods like food should rise. Data from poor and rich countries shows the opposite, with larger households spending a smaller share of budgets on food, and the effect is larger in developing countries (where substitution effects are likely to be lower). Our findings indicate that, at least for food, the results may be driven by economies of scale in caloric requirements, which are declining in household size at constant per capita expenditures.

as gains from food quality. Those gains are distinct from the ones discussed in this paper as they occur due to within-group substitution and are only partly related to caloric intake.[2] The welfare gains we estimate here operate only through the effect of our proxies for caloric requirements on the food share, and much of the change in food quality that we observe occurs due to across-group substitutions.

In section 2 we present the model that guides our empirical analysis. Section 3 examines the robustness of the decline in calories and its sources. Section 4 links energy intake and requirements to household characteristics in the cross-section. Section 5 quantitatively assesses the energy requirements hypothesis as an explanation for the missing calories. Section 6 considers implications for poverty and welfare, and section 7 concludes.

2. Theory

Suppose the consumer food subutility problem is given by:

$$\max_{Q,C} \left(C - \bar{C}\right)^{\alpha} (Q)^{1-\alpha} \ \ s.t. \ p_c(C + \bar{C}) + Q \leq X_f \tag{1}$$

where Q is food quality, $\bar{C}$ is the minimum calorie requirement [3], C is calories in excess of this minimum, p_c is price of calorie quantity relative to quality (the price of food quality is normalized to one) and X_f is food expenditure.

[2]Li (2010) suggests that the size of variety welfare gains that could plausibly be related to caloric requirements are about 1% to 2% in food expenditure equivalent for both the urban-rural gap and the change over time, while the total gains range from over 2% for urban versus rural households to 10% over time.

[3]We model $\bar{C}$ as exogenous, but a simple extension of the model allows caloric requirements to be an input into the expenditure-generating function. This has several implications, most notably, occupations that are more dependent on caloric inputs to generate expenditures will have steeper sloping (and higher) calorie-total expenditure Engel curves. They will also have lower welfare inequality relative to expenditure inequality due to the positive expenditure - caloric requirement correlation. We leave exploration of this aspect of the model for future work, but note that it implies that the measure of welfare advocated by Logan (2009) may be flawed. Logan (2009) suggests that the slope of calorie Engel curves is an intuitive measure of hunger or welfare and potentially superior to using budget share or total calorie consumption, as it takes into account the marginal propensity to consume on a basic necessity that should be falling in the standard of living. However, if the generation of expenditures is more calorie intensive in some areas and periods, this can result in steeper calorie Engel curve slopes regardless of the actual level of welfare of the population, though it will still be the case that *conditional on expenditures* a locally steeper calorie Engel curve slope implies lower welfare.

Solving this problem yields a **calorie-food expenditure Engel curve (CF)**:

$$\textbf{CF: } C + \bar{C} = \alpha \frac{X_f}{p_c} + 2[1-\alpha]\bar{C} \tag{2}$$

that is increasing in food expenditures and minimum energy requirements and decreasing in the price of calories relative to food quality. While Q may be unobserved, we have a proxy through the expression for food expenditures per calorie:

$$\frac{X_f}{C + \bar{C}} = \frac{1}{\frac{\alpha}{p_c} + 2[1-\alpha]\frac{\bar{C}}{X_f}} \tag{3}$$

which is increasing in food expenditures but *decreasing* in energy requirements. Total utility from food is given by

$$U_f = \frac{\alpha^\alpha (1-\alpha)^{1-\alpha}}{p_c^\alpha} \left[X_f - 2\frac{1-\alpha}{\alpha}\bar{C}p_c \right] \tag{4}$$

which is increasing in food expenditures and decreasing in minimum energy requirements. A higher price for calories lowers food utility by making it more expensive to meet minimum requirements and consume additional calories.

We model demand between food and non-food with a CES function of their sub-utilities:

$$U = \left(U_f^{\frac{\sigma-1}{\sigma}} + U_{nf}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{5}$$

with budget constraint $X_f + Q_{nf}(U_{nf})p_{nf} \leq Y$. The price of non-food relative to food is p_{nf} and total expenditure is Y. Let $U_{nf} = \gamma_{nf} Q_{nf}$ where γ_{nf} represents some combination of exogenous shifters that affect preference for non-food, including preferences, quality, and variety. Substituting this and equation 4 we have the consumer problem:

$$\max_{X_f, Q_{nf}} \left(\left[\frac{\alpha^\alpha (1-\alpha)^{1-\alpha}}{p_c^\alpha} \left[X_f - 2\frac{1-\alpha}{\alpha}\bar{C}p_c \right] \right]^{\frac{\sigma-1}{\sigma}} + [\gamma_{nf} Q_{nf}]^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{6}$$

subject to $X_f + Q_{nf}p_{nf} \leq Y$.

Denoting $\gamma_f = \frac{\alpha^\alpha(1-\alpha)^{1-\alpha}}{p_c^\alpha}$ and $\bar{C}^* = 2p_c(\frac{1-\alpha}{\alpha})\bar{C}$, the **food expenditure - total ex-**

penditure Engel curve (FE) is:

$$\textbf{FE: } X_f = \frac{Y + (\frac{p_{nf}\gamma_f}{\gamma_{nf}})^{1-\sigma}\bar{C}^*}{1 + (\frac{p_{nf}\gamma_f}{\gamma_{nf}})^{1-\sigma}} \tag{7}$$

with non-food demand given by $Q_{nf} = \frac{Y - X_f}{p_{nf}}$. If food and non-food are substitutes ($\sigma > 1$) then food expenditure increase in the price of non-food p_{nf} and decrease in the taste shifter for non-food γ_{nf}. Note that the calorie-total expenditure Engel curve (CE) can be derived by substituting equation 7 into equation 2.

Figure 1 provides a graphical interpretation of the effect of a fall in the relatively price of non-food (or alternatively an increase in taste, quality, or variety for non-food relative to food). The CE and FE curves both shift down, but there is no effect on the CE or food quality curves. However, the decline in food expenditures implies that there is movement along the CE and quality curves towards the origin, with both calories and quality (food expenditures per calorie) declining. Supposing the price of cell phones falls, the value of cell-phones rises because of network economies, or the returns to education rise, household will spend less of their budgets on food at any level of expenditure, and this downward adjustment in food leads to a decrease on both a (calorie) quantity and quality margin.

Figure 2 depicts a fall in energy requirements. While the CE and FE both shift down, in this case there is also a shift down in the CF curve and a shift up in the food quality curve. The decline in food expenditures reinforces the downward shift in the CE curve, causing movement along the new CF curve (CF_2) towards the origin and making calorie consumption fall further. However, the decline in food expenditures is more than offset by the shift up in the food quality curve, resulting in an increase in food quality at any level of food expenditure. Thus the characteristic that distinguishes energy requirements from other shifts is that they affect the CF curve and predict increases in food quality, because the downward adjustment in calories is larger that the downward adjustment in food expenditures.

The other interesting comparative static in the system is a change in the relative price of calories relative to quality (p_c). The effect of an increase in p_c is given by:

$$\frac{\partial X_f}{\partial p_c} = -[Y - \bar{C}^*]\frac{1}{(1+Z)^2}\frac{\partial Z}{\partial p_c} + \frac{Z}{1+Z}\frac{\partial \bar{C}^*}{p_c} \tag{8}$$

where $Z = (\frac{p_{nf}\gamma_f}{\gamma_{nf}})^{1-\sigma}$. Because $\frac{\partial \bar{C}^*}{\partial p_c} > 0$ and $\frac{\partial Z}{\partial p_c} > 0$ the sign of the expression above depends on the levels of Y and $\bar{C}$. For households with high expenditures relative to energy requirements the first effect dominates and food expenditures fall when the relative price of calories rises.

The model implies that an evaluation of welfare requires measurement of both total expenditures and minimum energy requirements, as indirect utility is given by

$$V = \Omega[Y - \bar{C}^*] \tag{9}$$

with $\Omega = \frac{1}{1+Z}\left[\gamma_f^{\frac{\sigma-1}{\sigma}} + \left(\frac{\gamma_{nf}Z}{p_{nf}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$. Rather than measuring $\bar{C}^*$ directly, we can rearrange equation 7 to get $\bar{C}^* = \frac{X_f(1+Z)-Y}{Z}$ and substitute this in to get indirect utility

$$V = \frac{1+Z}{Z}Y[S_{nf}] \tag{10}$$

where S_{nf} is the budget share of non-food. We can then use the budget share of non-food to compute Engel equivalence scales in this model. Holding other model parameters constant, households with a lower food share (higher non-food share) due to lower energy requirements have higher utility.

We summarize the implications of our model:

1. The calorie-expenditure Engel curve (CE) can be decomposed into two pieces, the calorie-food expenditure Engel curve (CF) and the food expenditure - total expenditure Engel curve (FE).

2. Lower caloric requirements manifest themselves through a downward shift in both the CF and the FE, raising food quality.

3. Lower relative prices or greater taste/variety/quality of non-food causes a downward shift in the FE with no effect on the CF, lowering food quality..

4. Welfare comparisons that do not adequately account for minimum energy requirements are incomplete, but a simple Engel equivalence scale using differences non-food budget shares orthogonal to real expenditures can be used to analyze the effect of calorie requirements on welfare.

3. Decomposing the decline in calories

3.1. Calories per capita

The National Sample Survey (NSS) provides the most comprehensive measure of food quantities and expenditures by Indian households. Consumption is measured at the household level using a 30-day recall period.[4] While there are other nutritional surveys in India that cover individual villages or smaller regions, the only other dataset with a wide scope comes from the National Nutritional Monitoring Bureau (NNMB) which covers several states and records calorie data using direct weighing of food over a 24-hour period.

Deaton and Dreze (2009) document the decline in caloric intake in India between 1983 and 2005 in the NSS data. Table 1 presents their estimates of per capita calorie consumption over this period. We also present independent estimates calculated by other authors with the same data - surprisingly the different studies disagree on both the direction and magnitude of calorie changes.[5] While Deaton and Dreze (2009) find a large decline in rural areas and modest decline in urban areas, Chatterjee et al. (2007) find a decrease in rural areas and an increase in urban areas, while Kumar and Dey (2007) find an increase in both areas. Both Kumar and Dey (2007) and Chatterjee et al. (2007) find that in recent years urban India has higher per capita consumption of calories than rural India. Below we also report calorie intake from the NNMB as calculated by Deaton and Dreze (2009). These data, presented at the bottom of table 1 show a dramatic decline in calories that is over the double the size of the decline for comparable states in the NSS based on the calculations of Deaton and Drèze.

In the data appendix we discuss our construction of calorie estimates their sensitivity to various imputation assumptions. The three main issues are (1) treatment of food with missing or imprecise quantity data (whose caloric conversions per quantity may be certain), (2) composite or processed food items with unknown calorie conversion factors (even though quantity may be precise), and (3) meals to/from others that bias the numerator or denominator of a household calories per capita. Our preferred

[4]The notable exception is the 55th (1999-2000) survey round which used a 30-day and a 7-day recall period. Critics observed that using a shorter additional recall period biases upward consumption measures over the 30-day period, leading to overestimation of the decline in poverty. See Deaton and Dreze (2002) or Deaton and Kozel (2005) for discussion. When pooling multiple rounds our results are not sensitive to excluding the 55th round entirely.

[5]As none of the studies make explicit the details of data-cleaning and calorie imputation we cannot pinpoint the reason for the divergent estimates.

calorie estimates, presented at the bottom of table 1, use direct calorie conversion whenever possible and make adjustments for meals to/from others. The "group" estimates impute calories for items missing quantities or conversion factors with an aggregate expenditure weighted average of calories per rupee at the group level. The "all food" estimate uses household average calories per rupee divided by two. The measures agree quite closely though the imputation method is quite different. Our estimates are close to those of Deaton and Drèze, showing a much larger decline in rural than urban areas and consequent convergence of rural and urban calories per capita.

Figure 3 presents kernel density estimates of log per capita calorie consumption using our preferred "group" estimates. In 1983 the urban calorie distribution is shifted left of the rural one, but over time the have compressed and grown similar. The large decline in mean calories per capita in rural areas is thus driven by a right-tail that shrinks much more than the left tail, while for urban households there is a smaller decline as the compression is symmetric.

3.2. Calorie Engel curves

Figure 4 non-parametrically plots log calories against log real expenditures for different periods and sectors.[6] We restrict the sample to households with an adult (over age 15) male and female with three children. The calorie Engel curves (CE) are upward sloping throughout with a slight decline at the top (the linear estimated slope is around 0.3). Given the rise of real expenditures over 1983-2005, the only way calories could have decreased is with the large shift down over time shown in figure 4. For any given year the urban CE lies below the rural CE, explaining how the on average richer urban households consume less calories on average. The downward shift in the curves over time has been greater at the upper end of the expenditure distribution, consistent with the inward shift of the per capita calorie distribution upper tail in figure 3.

The model from section 2. suggests a decomposition of the CE into a food-total expenditure (FE) and a calorie-food expenditure (CF) Engel curve. Figure 5(a) presents

[6] Our total expenditure measure excludes taxes, water charges, and rent to be comparable across all rounds. We use survey-based Tornqvist price indexes (base rural 50th round) to deflate expenditures, with median unit values as prices. This covers 58-83% of aggregate expenditures depending on the sector and survey year. We also trim the 1% tails of the calorie and expenditure distribution.

the FE curve. While the urban curves are slightly below the rural curves for 1983 and 1993, there is virtually no shift for rural or urban households over the period. There is a large downward shift in the 1994-2005 period, especially at the top of the expenditure distribution. As the CE falls throughout, a downward shift in the CF curve explains virtually all of the decline in calories between 1983-1993. Figure 5(b) documents the downward shift over the 1983-1993 period and stability over the 1994-2005 period. The difference between rural and urban areas remains large throughout the entire 1983-2005 period, so rural households consume more calories per rupee of food expenditure. Because the food expenditures are adjusted for rural/urban prices this is not the result of higher average urban prices and must be due to a compositional effect. Our decomposition highlights the potential for multiple explanations of the decline in calories as the source of the shift differs over the 1983-1993 and 1994-2005 periods.

Before examining food composition we briefly consider the composition of total expenditures and reasons for the downward shift of FE curves over 1994-2005. Figure 6 presents plots of budget share - log real expenditure Engel curves for different categories - food, clothing, fuel and light, intoxicants, medical care, education, entertainment services, transport services, other services, other nondurables and durables. Many of the Engel curves are highly non-linear and differ greatly across sectors, but as the shares sum to one at any level of real expenditure some must shift upward if food shifts downward. For rich households (with three children), education spending has the largest increase accounting for up to half the decline in food share. Durables are also important for these households. Other services, transport services, and fuel and light increase for all households. Poor households have larger increases in other nondurables and clothing.

The surveys provide unit values for clothing, fuel and light, and intoxicants so we can examine relative prices for these goods with the caveat that quality effects on unit values are large for clothing and intoxicants. Over the 1983-2005 period food prices rose 396% (423%) in rural (urban) areas, compared to 459% (381%) for the combined clothing, fuel and light and intoxicants price index. Note that although the relative prices of the food and non-food composites moved in opposite directions in rural and urban areas, the food Engel curves shift down for both. Looking at the individual components, clothing rose by 518% (382%), intoxicants by 559% (731%) and fuel and light by 342% (276%). The rising share of fuel and light may be related to lower relative prices.[7]

Downward drift in food Engel curves over time has been observed in the United States (Costa (2001),Hamilton (2001)) and in the United Kingdom and Spain[8]. Some studies interpret this drift as CPI bias which upwardly biases the price indexes used to deflate nominal expenditures. Disaggregating by group suggests that it is difficult to rule out other factors like prices, variety, quality and tastes, to which we add caloric requirements. Group Engel curves do not shift in parallel or follow a systematic pattern based on expenditure elasticities, implying that substitution effects are important and Engel curve shifts may be problematic for estimating bias in income.

3.3. Changes in food composition

Mean real food expenditure changed little over the 1983-2005 period. Table 3 documents real food expenditure growth of 6.7% (5.7%) in rural areas and 9.1% (7.3%) in urban areas depending on whether we use a base-period weighted or Tornqvist price index. The table also presents the differences in calories per real food expenditure over time and across sectors (normalized by 1983 rural sector) that are consistent with figure 5(b). Urban households consume significantly less calories per real food expenditure and there is a decline over time in both sectors concentrated in the earlier 1983-1993 period. The size of the decline is similar to figure 5(b) but here we pool all households regardless of size and make calculations based on the average household.

Figure 7(a) presents a pie chart for ten different food groupings that emphasize the importance of grains in food expenditures, especially for rural households, and their declining importance over time. Figure 7(b) shows that grains are even more important as a share of total calories. Linking these two figures together are the differences in calories per rupee of the different food groups, presented in table 2. We normalize the price per calorie using rice and wheat, the two most important foods in India, which together make up between 22-40% of food expenditures and 46%-56% of total calories across the years and sectors in our sample.

[7]While relative prices (including relative returns to education) may explain many of these shifts, the introduction and diffusion of consumer goods may also play a (Li (2010)). While the number of distinct food and clothing items per household rises, the increase for durable and nondurable goods (personal care and effects, toilet articles, and sundry) is twice as large. Consumption growth in these categories may be due to in part to an increase in the range of goods available due to advances in advertising, infrastructure and retailing.

[8]Our calculations

Three different factors could affect total calories per real rupee of food expenditure - (1)changes in the food budget share of different food groups, (2)changes in inter-group relative prices, and (3)changes in composition within food groups (including the effects of intra-group relative prices). This suggests a simple (non-additive) decomposition. We can write mean calories as:

$$cal = \frac{X_f}{P_f} \sum_g s_g P_g (\frac{cal}{rupee})_g \tag{11}$$

where P_f and X_f are the food price index and nominal food expenditures, g indexes the different food groups, P_g is the group price index, s_g is the group budget share, and $(\frac{cal}{rupee})_g$ are the calories per rupee of nominal expenditure on a group. Our three scenarios then correspond to changing s_g, $P_f/\{P_g\}$ and $(cal/rupee)_g$ holding the other variables constant.

Changing group shares turn out to be the most important factor. We use the nominal food expenditures and group calorie/rupee conversion factors at the rural 1983 average and vary only the group budget shares. Table 3 shows that the changes in group shares explain most of the differences in calorie per rupee of real expenditure over time but only part of the rural-urban difference. Households in the later periods spend a larger share of their food budget on food groups with lower calories per rupee.

We next vary relative group prices while holding shares and within-group composition (calories/rupee) constant at the rural 1983 level. This involves multiplying the rural 1983 nominal group expenditures by a conversion factor P_g/P_f constructed with base-weighted price indexes (normalized to one in base period). Table 3 shows that this exercise actually tends to increase calorie consumption because the prices of groups with lower calories/rupee (meat, vegetables, processed food and beverages) had more relative inflation than groups with higher calories/rupee (grains, oils, and fruits).

Finally, we examine the effect of intra-group prices and composition by holding group shares and nominal expenditures fixed at rural 1983 levels and deflating the calories/rupee in each sector and period by a base-weighted group price index. Differences in the calorie/rupee conversion factors are then due to intra-group relative price and composition effects. Table 3 indicates that intra-group composition plays a large role in explaining the rural-urban gap but is less important over time.

The evidence on compositional shifts argues against an interpretation of declining calories due to a rising relative price for calories versus food quality. The base-weighted relative price of the cheapest staple group grains declined while higher quality groups became relatively expensive. The pattern of inflation and substitutions is more consistent with story in which changes in food demand towards higher quality (lower calorie/rupee) goods due to lower energy requirements or increased the relative prices of those goods. Though some of the compositional changes are caused by rising real food expenditure, the growth in real food expenditure is quite modest over the 1983-1993 period and most of the change in composition reflects a downward shift in the CF curve.

4. Caloric intake and requirements in the cross-section

4.1. Imputation of energy requirements

We use the India Time Use Survey (TUS) to imputed energy requirements. The NSS Organization interviewed 18,620 households in six Indian states (Haryana, Madhya Pradesh, Gujarat, Tamil Nadu, Orissa, and Meghalaya) between July 1998-June 1999. Every household member over age five was asked their time-use over the previous 24 hours as well as for abnormal and variant days (e.g. weekends, trips into town). Time-use is recorded in 20 minute increments and is classified into 154 different types of activities. A major advantage of this survey is that it records many household variables in the same format as the NSS consumption surveys, including monthly household expenditures, age, gender, education, and occupation.

To convert activities in the TUS into caloric requirements we use age/gender minimum caloric requirements (corresponding to the Basal Metabolic Rate or BMR) multiplied by one of four scaling factors based on our own classification of the intensity of the 154 different survey activities. The data appendix contains the details of our imputation procedure. Children under 6 do not have time-use recorded in our data so we use caloric requirements from the India Council for Medical Research (ICMR). For most of our comparisons we aggregate to the household level as we do not have individual caloric intake.

Other than the subjectivity involved in classifying the intensity of activities, there are two major limitations of using time-use data to impute caloric requirements. First, we do not observe the heights and weights of individuals that affect baseline caloric requirements. Second, we are unable to capture differences in energy intensity *within* specific activities, particularly those that feature an important margin of substitution for animal and mechanical power. This issue arises primarily for transport but also for some agricultural activities and may bias up the energy requirements of richer households that use more capital than labor. Despite these limitations, we believe our measure of caloric requirements is superior that of the ICMR, which only feature three classes of energy intensity for adults - heavy, moderate, and sedentary. The ICMR also does not allow for different activity levels of children or allow age to affect the energy requirements of adults. Our measure allows significantly more variation along the extensive (length of the work day) and intensive (type of activity) margin, captures differences in home production, and allows us to link households to consumption data using variables with common definitions.

Table 4 presents summary statistics for the 1999-2000 NSS consumption data and the 1998-1999 Time Use data by sector. By restricting both samples to households without missing linking variables in the six common states, we are left with 29,415 NSS households and 18,571 TUS households. The first two rows show that average calorie intake (using our preferred group imputation) appears to above calorie requirements in urban areas but below in rural areas. The next two use alternate measures of intake ("all food imputation") and requirements based on ICMR data. The ICMR calorie requirement measure is higher than our due to greater calorie requirements for children aged 6-13 and for adults doing heavy activity. For example, the daily recommended intake of 3800 calories for adults doing heavy labor is much higher than our measures for rural (3275) and urban (2865) adult workers with similar occupations (see appendix for details).

The other variables in the two datasets are quite similar, though there is some discrepancy in household size and monthly per capita expenditure (MPCE), both a bit higher in the NSS. The difference in household size is driven by children but remains a bit of a mystery. The difference in expenditures may be partly due to inflation and real expenditure growth between 1998-1999 and 1999-2000, but another factor is recall bias. Measured expenditures are typically higher when households are asked for either (a)a specific list of items or (b)shorter recall periods, both features of the 55th NSS round but not the TUS. The bias caused by (b) may also affect imputation of calorie consumption (biasing it down relative to requirements recorded over a 24 hour period). These effects will probably bias the *level* of calories and expenditures across the two surveys making calculation of absolute calorie adequacy suspect. In most of the analysis that follows we focus on *percentage* differences in caloric intake and requirements across sectors and household characteristics so our results would be unaffected by scaling expenditures or energy requirements by a uniform factor. We revisit measurement of levels in section 6..

4.2. Household composition and life-cycle effects

Household composition affects consumption through multiple channels including total expenditures, economies of scale, and intra-household bargaining. Another channel is caloric requirements, which we investigate by regressing household calorie intake and requirements on the number of household members in different age/gender cells - seniors (aged 60 plus), adults (19-59), youth in the 16-18 and 13-15 range, children in the 10-12, 7-9,4-6, and 1-3 ranges and infants under 1 year of age. We use village/block dummies so we only use variation in household composition within areas to identify the effects. We also include a cubic in per capita expenditure to identify effects of household composition on calorie intake at constant total expenditure.

Table 5 present the results normalized by the coefficient on adult males. Calorie demand ratios by gender/age class are related to calorie requirement ratios with a correlation coefficient is 0.83. The third column presents average caloric requirements calculated directly for individuals, but the effects are similar to aggregating to the household level and using a linear regression. Columns four and five present results controlling for a cubic in monthly per capita expenditures (MPCE) and the patterns are similar. Seniors and children contribute less to caloric intake and requirements than adults. Compared to adult males, females and senior males contribute relatively more to intake than requirements. Female infants appear to contribute less to caloric intake than male infants, but gender discrimination against children not evident for other age groups. We do not observe individual caloric intake so any assessment of distributional issues is necessarily speculative.

The results in table 5 assume linear effects of household size for each gender/age class, but larger households may experience economies of scale. Holding expenditure per capita constant, larger households may have more leisure time if there are economies of scale in home production activities. For example, if two household members take turns shopping, cooking, cleaning, or taking care of children it may decrease their combined average energy requirements. This superior home production technology may also affect food expenditure patterns by leading household to purchase less prepared meals on the margin.

Table 6 confirms both of these hypotheses using OLS regressions of log household caloric intake or requirements on household composition variables in ratios (the ratios of each cell/class from 5), village/block dummies, a cubic in log MPCE and the log of household size. Column one shows that doubling household size holding composition and per capita expenditures constant lowers caloric intake by about 2.6%. This is directly related to the Barten paradox discussed by Deaton and Paxson (1998). Deaton and Paxson (1998) note that according to Barten's model, if calories (or food expenditures generally) are an exludable, private good we would expect an elasticity greater than one with respect to household size holding per capita expenditure constant. Households should economize on certain shareable goods like housing and durables and spend a greater share on food (and potentially calories).

The second column suggests that economies of scale in caloric requirements may explain why the Barten model does not hold for food in many developing countries. The elasticity of household calorie requirements to household size is negative and virtually identical to the elasticity of calorie intake. Larger households appear to benefit from economies of scale in caloric requirements for market work (with more productive household members supplying more labor) and/or home production. Most of the effect is driven by food expenditures, with a small negative elasticity of calories conditional on food expenditure to household size doubles. This could occur if the reduction in energy requirements (predicting a fall in the CF) is accompanied by a superior home production technology for converting unprocessed food into tasty calories, with the two effects cancel out.[9]

We also examine life-cycle effects for adults. There is a growing literature on life-cycle consumption in developed (Aguair and Hurst (2005)) and developing (Hicks (2010)) countries that uses time-use data to study substitution of time for expenditures. In the United States and Mexico households appear to smooth calorie consumption over the life-cycle (in spite of the usual hump-shaped profile of food and total expenditures) through home production and shopping intensity.

We use the average age of household members over age 18 as our life-cycle mea-

[9] We could interpret the latter effect in the model as higher p_c. We have not explored this finding in greater detail as it takes us far from the main subject of the paper, but we plan to explore it in future work.

sure but obtain similar results for households with one male and female adult. We control for household size and the ratio of men, women and children (in each gender/age cell) and regress log household calories on these controls and dummy variables for average adult age beginning with 23-27 and ending with 73-77. The omitted category is 19-22 year olds.[10]

Figure 8(a) plots of the coefficients on the dummies with no expenditure controls. The solid (dotted) line represents percent deviation in caloric intake (requirements) relative to households with mean age 19-22. Calorie intake and requirements are highly correlated over the life-cycle. From peak to trough calorie consumption falls about 20% while requirements fall about 30%. As the decline in calorie requirements begins earlier and is steeper, older households are relatively better off in terms of net intake than younger and middle-aged households. Figure 8(b) presents the results when a cubic in log expenditure is included, netting out life-cycle variation in expenditures. This is especially important if expenditure-selective mortality changes the composition of households in the later years (e.g. the poorest households with low intake are negatively selected). The decline in caloric intake is smaller at older ages, implying that the main mechanism behind the decline is the fall in total expenditures of about 20% over these ages.

There is relatively little adjustment over the life-cycle in food expenditure per total expenditure (figure 9(a)) or in calories per food expenditure (figure 9(b)). The margin for substitution towards home production over the life-cycle thus appears to be small in India. This may be due to already high home production in poor counties like India - very little processed food or meals out are consumed, so there is little scope for older households with less market work to substitute time for expenditures on food and calories. The decline in caloric intake in late-life should not necessarily be interpreted as impoverishment or an inability to smooth consumption, as a significant portion coincides with a decline in caloric requirements. The causality is not obvious and there may be an old-age calorie-poverty trap, though Deaton and Subramanian (1996) argue that calorie traps are unlikely to exist given the price of cheap staples. Whether these patterns are common to the poorest countries or unique to India is an interesting question for further research.

[10]The TUS only includes a single cross-section so we do not control for cohort effects. Pooling our cross-sections and controlling for cohort effects yields similar life-cycle patterns for calorie intake.

4.3. Occupation and education

Household occupation and education affect household total expenditures but may also affect the caloric requirements and intake conditional on expenditure. When the income-generating process is more dependent on energy inputs, we expect higher caloric requirements and intake conditional on expenditures. Comparing households with different occupations in the same area/period, or similar occupations in different areas/periods, allows us to isolate the importance of these structural factors calorie intake and requirements. Given that there have been significant increases in education and shifts from more to less labor intensive tasks this would be an obvious candidate for explaining the missing calories.

The data provide two occupational classifications based on the economic activity that brings the most income or in kind value to the household. The first is household type, divided into five rural types - self-employed non-agriculture, agricultural laborer, other laborer, self-employed in agriculture, and other - and four urban types - self-employed, wage/salary worker, casual laborer, and other. This measure does not capture the length of the work day or the occupation of spouses and extended family, but provides a simple way to link the NSS and TUS data using a common classification and examine whether caloric intake and requirements are correlated across types.

The top panel of table 7 presents the results of regressions that control for household composition ratios, household size, a cubic in expenditure and village/block dummies. We report the coefficients on household type dummies that represent the percent difference in caloric intake or requirements from the omitted categories (other rural and other urban). Conditional on total expenditures the household types with the highest caloric requirements - self-employed agriculture, agricultural laborer, other rural labor and casual labor - also have the highest caloric intake. Wage/salary earner, self-employed in urban areas, and the omitted categories have both the lowest intake and requirements. The correlation of household type dummy coefficients across intake and requirements is 0.87. The patterns are even stronger when conditioning on food expenditures instead of total expenditures (the CF curve). Consistent with our model the household types with higher caloric requirements tend to consume lower quality calories. Some of the adjustment also occurs on the FE margin, especially for self-employed in agriculture households.[11]

[11]One possibility is that they face a lower shadow-price for food since they can consume their own

The middle panel of table 7 uses occupational classifications from the National Classification of Occupations (NCO). The classification ignores industries so there are service workers in agriculture and clerical workers in manufacturing. We use the broad classifications - professional, administrative, clerical, sales, service, primary, secondary and other. The correlation of caloric intake and requirements across occupations is 0.88, with primary, secondary, and service workers consuming and requiring more calories than sedentary professional, administrative and clerical workers.

Education variables provide an alternative to household types or occupations, as education is correlated with occupational classes and we expect more educated households to perform more sedentary tasks. While educated households have higher expenditures and calories in an absolute sense, conditional on expenditures we would expect them to require less calories. We first analyze dummies for the education level of the head of the household, divided into 7 discrete categories - illiterate (the omitted category), literate but not attending primary, some primary, primary completed, middle completed, secondary completed, and college completed.

The bottom panel of table 7 confirms our expectation that conditional on expenditures households with more educated heads have lower caloric requirements. They may work less hours for a given total expenditure due to higher hourly wages, or the caloric requirements per hour of work may be lower. Differences in caloric requirements are reflected in caloric intake almost one for one. Households with a college educated head consume 10% less calories and require 12% less calories than illiterate households, conditional on expenditure. Similar to household type and occupation, most of the adjustment in caloric intake occurs along the CF "quality" margin rather than the FE margin.

We can also generate a continuous variable by assigning years of schooling to each education class and taking an average over all adult household members. In addition to our usual controls we use dummies for each one year interval of average adult education. Figure 10(a) presents the results for total calories, which echo the findings in the bottom panel of table 7. Figure 10(b) confirms that similar patterns hold for the CF and FE curves.

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production without middle-man and retail markups.

4.4. Other factors

There are several other variables in the NSS data that we believe are related to energy requirements but cannot be linked to the TUS. Some NSS rounds ask questions about the main source of energy for lighting and for cooking, presence of a home garden, income from non-labor sources (pensions, remittances, rent and interest payments), and ownership of labor-saving durables like bicycles, cars, washing machines, fridges, fans, etc. Most of these variables have an obvious expected effect on calorie demand - access to electricity and labor saving devices like washing machines, fans or air conditioning (caloric requirements are higher at extreme temperatures), fridges (which may decrease the frequency of energy-intensive shopping expeditions), and motorized transport would be expected to reduce caloric requirements. Conversely using wood for cooking should increase caloric requirements since acquiring and preparing wood is more energy intensive than other cooking fuels. Television ownership could potentially lead to more sedentary leisure activities or influence food consumption patterns through advertising. The effect of bicycles is ambiguous as cycling saves energy relative to walking but if it substitutes for animal or motorized transport or is correlated with traveling longer distances, it could potentially increase energy requirements.

To explore these other factors we add a series of dummies to our regression of log total calorie intake on expenditures, household size, and household composition ratios. Table 8 presents the results which confirm our predictions except for bicycle ownership, which has little to no effect on caloric intake. The biggest reductions in caloric intake come from owning motorized transport (5.1%), using electricity (3.6%) and owning a washing machine (3%). Using wood for cooking increases caloric intake by 6.7%. Once again most of the effect operates through the CF "quality" curve. Because items like motor vehicle ownership increase non-food expenditures we would expect them to lead to lower food expenditures given total expenditures. The substitution of non-human energy sources for human sources, whether through fuel to operate motor vehicles, electricity for household appliances, or denser cooking fuels with a lower complementary human energy input, has a large effect on caloric intake. From the TUS we know that free collection of goods (including wood for cooking) and household maintenance take 53 and 459 minutes per day for the average household, so the potential household energy savings from replacing human power with non-human power sources is large.[12]

5. Quantitative assessment of energy requirements hypothesis

In this section we answer the central question of the paper - can the energy requirements hypothesis explain the 'missing" calories over time and between sectors? We use a calorie Engel curve regression and a dummy for the missing calories (in later periods or urban areas) and see how the missing calorie dummy changes when we control for variables that are closely related to energy requirements. Reducing the missing calories requires variables that (1)have a large effect on caloric intake and requirements and (2)vary significantly across rural/urban areas or over time. While all of our controls satisfy the first criteria, the demographic variables do not appear to vary much over time or across sectors (see table 4).

5.1. Rural-Urban Gap

We begin by analyzing the unexplained rural-urban calorie gap for the six states in the TUS. The first row of table 9 presents baseline estimates by regressing log household calorie intake on log household size, a cubic in log per capita real expenditure and an urban dummy that represents the "missing" urban calories (equivalent to the area between calorie Engel curves in figure 4). The gap is 17.6% without controlling for higher urban prices, but conditioining on log per capita real expenditure reduces the gap to 12.5%. When we repeat this regression using calorie requirements instead of consumption, we find a 9.8% gap.

We add the controls cumulatively. The second row of table 9 adds controls for demographic composition (ratios of male and female adults and several age/gender classes for children) and dummies for adult average age. The third row adds dummies for average adult years of schooling and head of household education class. The fourth row adds dummies for household type and NCO occupation.[13] The fifth

[12]According to the National Planning Commission more than 85 million households in India spend 30 billion hours a year gathering firewood. See http://www.thaindian.com/newsportal/uncategorized/86-percent-rural-indians-use-dung-cakes-firewood_10087695.html

[13]The omitted categories imply that the rural-urban dummy is comparing self-employed or wage

row adds the household variables absent from the TUS like electricity, firewood for cooking, and ownership of labor-saving durables.

Controlling for demographics has little effect on the urban dummy for caloric intake or requirements, but adding the education variables decrease the gap for intake (requirements) by 20%(25%) compared to baseline and adding occupation reduces the gap by 56%(90%). Controlling for our other variables only reduces the intake gap a bit more (61%). The last two columns decinoise the calorie gap into calories conditional on food expenditure (CF) and food expenditure conditional on total expenditure (FE). As we add controls the reduction in 'missing' urban calories occurs mainly on the CF margin, with the urban coefficient falling by over 100% and becoming slightly positive. The coefficient on the unexplained gap in the FE curve falls by only 42%. This is consistent with our model and earlier findings, as a large number of factors may influence the division of expenditures between food and non-food but with separability only energy requirements or within-food relative prices affect the CF curve.

Table 10 uses the time-use data to shed more light on the source of rural/urban energy requirement differences. Rural households spend over 200 minutes less on leisure activities and 200 minutes more on market activities per day. Broken down by gender, we see that urban and rural males spend similar time on market, non-market, and leisure activities but the composition of market activities is different. Urban males work mostly in the tertiary/service sector, while rural males work mostly in the calorie-intensive primary sector. The story is different for females, as rural females spend an extra 2 hours per day on market activities (mostly primary activities and free collection) of which about 90 minutes comes out of leisure and 30 minutes out of non-market/home production. The extra leisure time is mostly spent on socializing and watching television. While males and females in rural areas have higher energy requirements, for males this is due to a labor intensive margin and for females this is due to a labor extensive margin. These differences are consistent with table 9 as controlling for occupation and factors that affect free collection and home production reduces most of the gap in caloric requirements and intake.

earning professionals.

5.2. Over time gap

Table 11 presents the missing calories over time. Each column presents the coefficient on the dummy for a different year/sector relative to the rural sector in 1983. We include dummies for all sector/years but only report them for 1983, 1993-1994 and 2004-2005. Each row cumulatively adds another set of variables - these are identical to the ones used in the rural-urban comparison, except that we are forced to exclude some variables that are not present in all survey rounds.[14] Unlike the rural-urban comparison we use data from the 17 biggest states in India and Delhi. The baseline estimates are the similar and use log household size and a cubic in log real expenditure.[15]

Row one of the top panel shows that the unexplained decline for rural areas between 1983 and 2005 was about 18% and the decline for urban areas was about 14%. When we add in all of our controls these fall to 14.5% and 12.2%, implying that our variables can only explain 20% and 15% of the decline in calories over time. The rural-urban fall by well over 50% for all years. The biggest effects come from education, occupation and other variables with little role for demographics.

The middle panel shows that our controls account for only 7.6% (urban) and 16% (rural) of the gap in FE curves over time. There appear to be other forces depressing food expenditures, especially in the 1993-2005 period, some of which were discussed earlier. The bottom panel shows that our variables do a much better job of capturing changes in the CF "quality" curve - 42% in rural areas and 60% in urban areas. This suggests that the energy requirements hypothesis still has a significant bite for changes over time, albeit not nearly enough to explain the dramatic fall in food budget shares conditional on total expenditures.

We consider three other specifications. First, we drop the 38th round allowing us to use a larger set of controls. When we do this, we find that the share of the missing calories that we can explain rises to 23% (41%) in rural areas and 35% (100%) in urban areas conditional on total (food) expenditure. Second, we estimate our equations separately by sector, allowing the control variables to have different effects for rural and urban households. This has little effect on the results. Third, we estimate the decline

[14] The 1983 NSS does not contain casual labor or wage/salary as household types. It also does not contain ownership data for durables, though we are able to construct a motor vehicle dummy based on petrol expenditure. Non-labor income is also not available for all survey rounds and are excluded.

[15] The base year/period is the rural sector of 1983 and we use a Tornqvist index though the results are largely unaffected by using different base years or indexes.

in calories separately by different household types and professions, conditioning on all of our other controls. The decline is 4-7% greater for primary sector households relative to administrative, sales, clerical, service or secondary sector workers. We see a similar pattern for self-employed agricultural households relative to self-employed non-agricultural households and other rural labor households. This suggests to us that significant changes in energy requirements *within* agricultural occupations are important to changes over time.[16]

6. Measuring poverty and welfare with caloric requirements

Although our primary purpose has been to explain demand patterns we briefly consider the implications of our analysis for poverty and welfare. We begin in table 12 by presenting poverty headcounts and rural/urban poverty line ratios for the five major Indian states in the 1999-2000 NSS and 1998-1999 TUS. According to official measures, poverty is highest in Orissa and Madhya Pradesh, is quite comparable between rural and urban sectors of each state, and the rural poverty lines are far below the urban ones for all states except Haryana. The second column presents modified estimates from Deaton and Dreze (2002) that use the NSS unit values to construct price indexes. Rural poverty remains similar but urban poverty falls dramatically as urban poverty lines are revised down. The third column presents a 'nutritional adequacy' poverty measure computed by Karan and Mahal (2005), who take daily recommended intakes of various nutrients from the ICMR and use linear programming methods to determine the least-cost bundle of food that meets requirements (subject to some palatability constraints).[17] The Karan and Mahal (2005) headcounts are higher in rural areas but lower in urban areas. The fourth column presents the share of undernourished children below age 5 in each state from the 2007 National Family and Health Survey, which is significantly higher than official headcounts[18].

[16] As the NSS data do not allow us to compare the length of work days, the composition of crops or the use of inputs into agricultural production we are unable to explore this possibility further but this would be a promising area for further research.

[17] In their calculations all rural adults are manual workers and all urban adults are non-manual workers.

[18] Undernourishment is defined as weight-for-age two standard deviations below the WHO reference growth charts (see Menon et al. (2009))

The official poverty lines were calculated in 1973 using the cost of consuming 2400 calories in rural areas and 2100 in urban areas in basic grains. The poverty lines were then updated over time based on broad-inflation measures. Defining poverty as calorie intake below these cutoffs leads to much higher head counts in all states and sectors except urban Orissa. We can improve on the 2400/2100 cutoffs by using calorie-cutoffs that vary by state/sector/occupation. Using state/sector averages of our imputed calorie requirements, we tend to find higher poverty in urban areas but similar poverty in rural areas. There is some variation across states, with a 6 point rise in poverty in urban Gujarat and an 8 point decline in rural Haryana. Using a 20% below requirement cutoff brings headcounts closer to official estimates, but we still find significantly greater poverty in most state/sectors with the exceptions of Orissa and urban Madhya Pradesh. While the poverty rates in the first three columns all point to Orissa as the state with greatest poverty, child undernourishment in Orissa is similar to Haryana and below Gujarat. Thus while our measure of poverty (like any calorie-based measure) may fail to capture balanced diets and non-food consumption, it is more highly correlated with some measures of extreme deprivation like child wasting.

We can also examine the impact of occupation-specific caloric requirements on poverty rates. Table 13 presents results for the state of Madhya Pradesh, comparing sedentary occupations (professional, administrative, clerical, and other occupations) to primary, secondary, and service/sales. We then compute poverty headcounts under (a)average sectoral energy requirements and (b)average occupation-specific requirements. With common energy requirements primary and secondary occupations have higher rates of poverty due to the distribution of per capita calories (and expenditures). When we use occupation specific energy requirements poverty rates for the primary sector rise and secondary and sedentary occupations fall. Accounting for different energy-intensities across occupations changes the distribution of poverty across occupations significantly when food and calories are used to measure poverty.

The model from section 2. provides a simple Engel equivalence scale for measuring welfare gains from lower caloric requirements. Holding relative prices and tastes constant utility is proportional to $Y[S_{nf}]$, with S_{nf} depending only on expenditures and caloric requirements. We regress the log of non-food budget share on log per capita expenditures (deflated by the appropriate price deflator), household size and dummies for different periods, sectors, and occupations. The coefficients on the dummies represent expenditure equivalent welfare gains under the assumption that relative prices and tastes are constant. Table 14 presents the results. While there appears to be a 5.6% (expedenditure-equivalent) welfare gain for urban areas, we cannot interpret this effect as a welfare gain because relative prices, variety and tastes may also differ. Because the coefficient on urban areas falls to about 0.5% when we add energy requirement controls, if these are orthogonal to the unobserved price, taste, and variety differences the implied welfare gain of lower calorie requirements is 5.1% for urban areas.

Over the 1983-2005 period there is a large percentage rise in non-food budget share at any level of expenditures, but our energy requirement proxies only have limited success explaining the increase so the welfare gain we attribute to energy requirements is only 3% in rural areas and 2.3% in urban areas. These welfare gains are of course tenative, depending on both the assumed functional form for demand and the exogeneity of our proxies for energy requirements. Perhaps more reliably we can calculate welfare effects across occupations, as prices, tastes and variety are similar across occupations within an area. Relative to sedentary professions we find that primary, secondary and service sector workers are significantly worse off, by 3-6% of total expenditure equivalent.

7. Conclusion

We find that energy requirements explain most of the missing calories for urban versus rural areas but are insufficient to explain the missing calories over time. This is largely because our energy requirement proxies are better at explaining gaps in quality (calories per food expenditure) than food expenditure per total expenditure, and this margin explains most of the urban-rural gap but a much smaller share of the gap over time. Other factors like relative prices, variety and quality that favor non-food and rising returns to education are likely important for explaining the downward drift in food expenditure Engel curves. We cannot definitively rule out a greater role for energy requirements as we have ignored the role of health improvements and our measure of energy requirements is limited and does not allow us to analyze changes in the energy inputs required *within* the 154 time-use categories.

Whether the pattern we observe in India - i.e. a downward shift in calorie Engel curves large enough to offset real expenditure growth - applies to other countries and time periods is an open question. Downward drift in food Engel curves is certainly widespread, but we do not know whether these (combined with changes in calories per food expenditure) are generally enough to outweigh income growth and generate a decline in calories per capita.

An extension of our approach could consider other nutrients. The link between household activity levels and food requirements is less clear cut outside of calories, but nutritional adequacy and hunger obviously encompass more than calories. A diet rich in cheap staples solves some health problems but causes others. The lowest expenditure per capita state in the TUS, Orissa, has relatively low calorie deficits by our measures (and relatively low child undernutrition), but Karan and Mahal (2005) find the highest rates of nutritional inadequacy.

Another direction we plan to explore is the relationship between household expenditures and caloric requirements through the household production function. This could add another dimension to general equilibrium models of structural change that use Stone-Geary preferences (e.g. Lagakos and Waugh (2009)). Our findings provide a reason why the degree of non-homotheticity caused by energy requirements may be a cause and consequence of economic growth.

Our potential resolution of the Barten puzzle through economies of scale in calorie requirements, this preliminary finding warrants further examination. More generally, the role of market/non-market substitution is critical for analyzing differences between life-cycle and business-cycle consumption in rich and poor countries. Our evidence for calories is quite different from what others have found for the United States and Mexico. Is there a general pattern and economic theory that would explain why poorer countries (and perhaps individuals) experience larger drops in calorie intake (and/or requirements) in old age and limited opportunities for substitution towards cheaper calories? A framework that allows market/home substitution to vary endogenously with household expenditures and/or economic growth and systematic cross-country evidence could be informative.

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Table 1: Estimates of mean per capita calorie consumption in India

Authors	Sector	1983	1987-88	1993-94	1999-00	2004-05	∆ 1983-2005
Deaton and Drèze	Rural	2240	2233	2153	2148	2047	-193
(2009)	Urban	2070	2095	2073	2155	2021	-49
Chatterjee, Rae	Rural		2135	2100	2097		
and Ray (2007)	Urban		2073	2091	2169		
Kumar and Dey	Rural	2205			2332		
(2007)	Urban	1972			2440		
Meenakshi and	Mean	2219			2132		
Vishwanathan (2003)	Median	2076			2024		
NSS for NNMB states		2131	2139	2076	2020	1960	-171
(Deaton and Drèze)	Year	1975-79	1988-90	1996-97	2000-01	2004-05	
NNMB		2340	2283	2108	1954	1907	-405
Our estimates							
Group imputation	Rural	2313	2285	2234		2140	-172
	Urban	2230	2234	2214		2136	-94
All food imp.	Rural	2320	2293	2244		2154	-166
	Urban	2178	2180	2192		2121	-58

Meenakshi and Vishwanathan (2003) report data by state for both sectors combined.
NNMB are the independent estimates from the National Nutritional Monitoring Bureau reported in Deaton and Dreze (2009), which cover a subset of states. Above are NSS estimates from Deaton and Dreze (2009) for the same set of states in nearby years.

Table 2: Ratio of calories per rupee of expenditure, relative to rice and wheat

	1983		1993-94		2004-05	
	Rural	Urban	Rural	Urban	Rural	Urban
Grains	1.20	1.08	1.13	1.03	1.09	1.03
Pulses	0.62	0.58	0.41	0.41	0.35	0.40
Milk	0.47	0.37	0.33	0.28	0.28	0.27
Oil	0.48	0.53	0.45	0.49	0.44	0.55
Meat	0.16	0.13	0.12	0.11	0.11	0.11
Veg	0.29	0.24	0.23	0.20	0.19	0.19
Fruit	0.96	0.86	0.71	0.63	0.61	0.60
Sugar	0.50	0.52	0.35	0.41	0.32	0.39
Bev.	0.06	0.06	0.04	0.04	0.04	0.04
Proc.	0.25	0.23	0.19	0.19	0.19	0.19
All	0.82	0.61	0.64	0.51	0.56	0.49

Table 3: Ratios of mean real expenditures and calories per real expenditure relative to 1983 rural sector

	Sector	1983	1993-94	2004-05	%Δ 1983-1993	%Δ 1983-2005
Real food exp.	Rural	1.00	1.08	1.07	0.08	0.07
(fixed base)	Urban	1.31	1.40	1.42	0.07	0.09
Real food exp.	Rural	1.00	1.08	1.06	0.08	0.06
(Tornqvist)	Urban	1.34	1.41	1.44	0.05	0.07
Calories at	Rural	1.00	0.87	0.84	-0.13	-0.16
const. real exp.	Urban	0.73	0.68	0.66	-0.08	-0.11
Scenario 1	Rural	1.00	0.89	0.83	-0.11	-0.17
(Change s_g)	Urban	0.81	0.75	0.72	-0.08	-0.10
Scenario 2	Rural	1.00	1.07	1.09	0.07	0.09
(Change P_g,P)	Urban	0.99	1.05	1.06	0.06	0.07
Scenario 3	Rural	1.00	0.94	0.98	-0.06	-0.02
(Change $(cal/exp)_g$)	Urban	0.91	0.90	0.90	-0.01	-0.01

Table 4: Comparison of Time Use Survey and NSS

		TUS		NSS Consumption	
	Sector	Mean	Median	Mean	Median
		Requirements		Intake	
Per capita calories	Rural	2363	2323	2236	2088
	Urban	2091	2122	2327	2180
Per capita calories alt.	Rural	2491	2473	2232	2095
	Urban	2200	2274	2277	2163
MPCE	Rural	459	400	505	429
	Urban	804	694	947	734
Hhsize	Rural	4.07	4	4.82	5
	Urban	4.10	4	4.40	4
Age of head	Rural	43.20	40	44.40	42
	Urban	42.32	40	43.43	42
Male head	Rural	0.90		0.90	
	Urban	0.91		0.90	
Adult males	Rural	1.10		1.10	
	Urban	1.19		1.10	
Adult females	Rural	1.10		1.19	
	Urban	1.10		1.16	
Years schooling	Rural	3.58	3	3.20	2
	Urban	8.33	8.8	7.65	7.5

Table 5: Contributions to household caloric intake and requirements relative to male adult

				Controlling for HH MPCE	
	HH Intake	HH Req.	Ind. Req.	HH Intake	HH Req.
Male 60+	0.96	0.81	0.75	0.97	0.79
Male 19-59	1.00	1.00	1.00	1.00	1.00
Male 16-18	0.86	0.96	0.91	0.93	0.94
Male 13-15	0.80	0.82	0.76	0.89	0.80
Male 10-12	0.69	0.70	0.62	0.79	0.67
Male 7-9	0.68	0.55	0.50	0.77	0.52
Male 4-6	0.55	0.63	0.55	0.67	0.60
Male 1-3	0.38	0.53	0.41	0.53	0.49
Male < 1	0.38	0.52	0.41	0.52	0.49
Female 60+	0.87	0.59	0.60	0.94	0.57
Female 19-59	0.92	0.81	0.83	0.97	0.80
Female 16-18	0.80	0.84	0.80	0.90	0.82
Female 13-15	0.74	0.77	0.73	0.83	0.74
Female 10-12	0.76	0.68	0.64	0.85	0.66
Female 7-9	0.64	0.59	0.55	0.74	0.57
Female 4-6	0.56	0.62	0.56	0.68	0.59
Female 1-3	0.41	0.52	0.41	0.53	0.48
Female < 1	0.30	0.50	0.41	0.46	0.46

Table 6: OLS - effects of household size on caloric intake and requirements

Dep. var.	log cal intake	log cal req.	log food exp.	log cal intake
Exp. Var.	tot. exp.	tot. exp.	tot. exp.	food. exp.
log hhsize	0.974***	0.977***	0.960***	0.997
s.e.	(0.003)	(0.002)	(0.002)	(0.002)

*** denotes significantly below 1 at the 1% level.

All regressions include household composition ratios, cubics in log real expenditures, and village/block dummies.

Table 7: Coefficients on household type, occupation and education dummies

Dep. var	Calorie intake	Calorie requirement	Food exp.	Calorie intake
Exp. control	Tot. exp.	Tot. exp.	Tot. exp.	Food exp.
		Rural types		
Self-employed non-agriculture	0.052 ***	0.055 ***	0.024 ***	0.036 ***
	(0.007)	(0.005)	(0.006)	(0.006)
Agricultural laborer	0.104 ***	0.160 ***	0.023 ***	0.091 ***
	(0.006)	(0.003)	(0.005)	(0.005)
Other laborer	0.079 ***	0.092 ***	0.014 *	0.071 ***
	(0.009)	(0.004)	(0.008)	(0.007)
Self-employed agriculture	0.094 ***	0.122 ***	0.050 ***	0.062 ***
	(0.006)	(0.003)	(0.005)	(0.005)
		Urban types		
Self-employed	0.059 ***	0.031 ***	0.008	0.056 ***
	(0.008)	(0.005)	(0.007)	(0.007)
Wage/salary worker	0.042 ***	-0.033 ***	-0.006	0.048 ***
	(0.008)	(0.003)	(0.007)	(0.007)
Casual laborer	0.090 ***	0.050 ***	-0.005	0.098 ***
	(0.009)	(0.004)	(0.008)	(0.008)
		National Classification of Occupations (NCO)		
Administrative	0.005	0.053 ***	0.007	0.001
	(0.008)	(0.007)	(0.007)	(0.007)
Clerical	0.007	0.001	0.002	0.004
	(0.008)	(0.005)	(0.007)	(0.006)
Sales	0.007	0.074 ***	0.010	-0.001
	(0.007)	(0.004)	(0.006)	(0.006)
Service	0.039 ***	0.041 ***	0.021 ***	0.027 ***
	(0.008)	(0.006)	(0.007)	(0.007)
Primary	0.075 ***	0.167 ***	0.029 ***	0.059 ***
	(0.006)	(0.003)	(0.006)	(0.005)
Secondary	0.042 ***	0.074 ***	0.008	0.038 ***
	(0.006)	(0.004)	(0.006)	(0.005)
Other occ.	-0.039 ***	-0.054 ***	0.001	-0.038 ***
	(0.008)	(0.008)	(0.007)	(0.007)
		Education levels		
Literate but no primary	-0.005	-0.012 **	0.000	-0.005
	(0.011)	(0.006)	(0.010)	(0.010)
Some primary	-0.015 ***	-0.024 ***	0.000	-0.015 ***
	(0.004)	(0.003)	(0.004)	(0.003)
Primary complete	-0.026 ***	-0.028 ***	-0.006	-0.025 ***
	(0.004)	(0.003)	(0.004)	(0.004)
Middle complete	-0.041 ***	-0.055 ***	-0.015 ***	-0.035 ***
	(0.004)	(0.003)	(0.004)	(0.004)
Secondary complete	-0.068 ***	-0.092 ***	-0.016 ***	-0.062 ***
	(0.004)	(0.003)	(0.004)	(0.004)
College complete	-0.099 ***	-0.116 ***	-0.026 ***	-0.084 ***
	(0.006)	(0.005)	(0.005)	(0.005)

OLS regression, standard errors in parentheses, *** and ** denote significance at 1% and 5% levels.
Household composition and size included with log expenditure controls and village/block dummies.
Omitted category is other for types.
Omitted category is professionals for NCO.
Omitted category is illiterate for education levels.

Table 8: Coefficients on other NSS household variables

Dep. var	Calorie intake	Food exp.	Calorie intake
Control for	Total exp.	Total exp.	Food exp.
Bicycle	-0.002	-0.005 *	-0.001
	(0.003)	(0.003)	(0.003)
Motorcycle/car	-0.051 ***	-0.048 ***	-0.020 ***
	(0.004)	(0.004)	(0.004)
AC/Fan	-0.008	0.008 **	-0.011 ***
	(0.004)	(0.004)	(0.003)
TV	-0.011 ***	-0.010 ***	-0.005
	(0.004)	(0.003)	(0.003)
Washing machine	-0.030 ***	0.002	-0.028 ***
	(0.007)	(0.007)	(0.006)
Refrigerator	-0.011 **	0.008	-0.014 ***
	(0.005)	(0.005)	(0.005)
Electricity	-0.036 ***	-0.013 ***	-0.030 ***
	(0.004)	(0.004)	(0.004)
Wood for cooking	0.067 ***	0.006	0.061 ***
	(0.004)	(0.004)	(0.004)
Non-labor income	-0.013 ***	-0.001	-0.011 ***
	(0.004)	(0.004)	(0.003)

OLS regression, standard errors in parentheses, ***, ** and * denote significance at 1%,5%, and 10% levels.

Household composition and size included with log expenditure controls and village/block dummies.

Table 9: Coefficients on urban dummy for caloric intake and requirements, 1998-1999 TUS and 1999-2000 NSS

Dep. var. (logs)	Cal. intake	Cal. req.	Food exp.	Cal. intake
Control for	Tot. exp.		Tot. exp.	Food exp.
Variables incl.				
Baseline	-0.125***	-0.098***	-0.077***	-0.093***
	(0.003)	(0.003)	(0.003)	(0.003)
Demographics	-0.123***	-0.105***	-0.076***	-0.093***
	(0.003)	(0.003)	(0.003)	(0.003)
Education	-0.100***	-0.074***	-0.068***	-0.066***
	(0.003)	(0.003)	(0.003)	(0.003)
Occupation	-0.054***	-0.010***	-0.054***	-0.025***
	(0.007)	(0.004)	(0.006)	(0.006)
Durables/other	-0.049***		-0.045***	0.013**
	(0.005)		(0.006)	(0.006)

OLS regressions, standard errors in parentheses.

***,**, and * denote significance at 1%,5% and 10% levels.

Baseline controls are cubic in log real expenditure and household size.

Controls are added cumulatively for each row.

Table 10: Minutes per day on various activities, by sector and gender

Activity	Household		Male adult		Female adult	
Sector	Rural	Urban	Rural	Urban	Rural	Urban
Primary	649.75	73.94	314.13	38.14	153.28	18.13
Free collection	73.33	17.13	12.22	2.39	38.10	10.25
Secondary	98.22	192.74	52.46	107.57	15.27	20.10
Tertiary	113.87	485.63	69.81	305.96	12.62	41.83
Total Market	935.16	769.44	448.62	454.06	219.27	90.32
Cook	229.04	233.30	5.40	5.99	161.51	171.63
Other hh maint.	230.15	241.47	23.06	19.56	137.30	157.02
Care for others	65.84	71.04	10.07	10.62	47.27	55.23
Total Nonmarket	525.02	545.81	38.54	36.18	346.09	383.88
Learning	248.41	317.16	7.83	18.46	2.31	12.12
Social	262.69	515.60	56.81	118.41	34.55	113.95
Sleep	1841.55	1817.84	528.54	503.76	515.28	511.11
Television	104.39	313.43	27.27	74.14	23.51	91.94
Other	1024.33	747.90	332.41	235.48	298.99	236.69
Total Leisure	3481.37	3711.93	952.86	950.24	874.64	965.80

Note: children under 6 are excluded from the household measure.

Table 11: Coefficients on sector/year dummies for caloric intake

Year	1983	1993-1994		2004-2005	
Sector	Urban	Rural	Urban	Rural	Urban
Total calories conditional on total real expenditure					
Baseline	-0.148	-0.078	-0.205	-0.183	-0.290
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Demographics	-0.146	-0.080	-0.205	-0.187	-0.295
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Education	-0.120	-0.075	-0.172	-0.175	-0.262
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Occupation	-0.087	-0.073	-0.140	-0.162	-0.228
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Durables/other	-0.063	-0.063	-0.100	-0.145	-0.185
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Total real food exp. conditional on total real expenditure					
Baseline	-0.035	-0.019	-0.048	-0.177	-0.239
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Demographics	-0.036	-0.019	-0.049	-0.177	-0.239
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Education	-0.033	-0.019	-0.044	-0.176	-0.235
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Occupation	-0.031	-0.018	-0.043	-0.173	-0.232
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Durables/other	-0.026	-0.013	-0.029	-0.163	-0.214
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Total calories conditional on total real food expenditure					
Baseline	-0.130	-0.068	-0.181	-0.092	-0.170
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Demographics	-0.128	-0.070	-0.182	-0.099	-0.179
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Education	-0.101	-0.064	-0.147	-0.079	-0.135
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Occupation	-0.070	-0.063	-0.115	-0.067	-0.102
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Durables/other	-0.049	-0.055	-0.082	-0.053	-0.065
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)

OLS regression, standard errors in parentheses. All coefficients significant at 1% level.
All regressions include household size, cubic in log real expenditure, and full set of dummies for sector/period (only selected coefficients reported).
Coefficients are % differences relative to Rural 1983 (ommitted dummy category).
Controls are added cumulatively for each row.

Table 12: Poverty headcounts

State	Sec.	Official	Deaton/Drèze	Karan/Mahal	% children undernour.	2400/2100 below	Avg. cal req. below	Avg. cal req. 20% below
Gujarat	Ru.	12.4	20	29.8	44.7	69.2	71.5	43.8
	Ur.	14.8	6.4	16.9		53.3	59.2	25.7
Haryana	Ru.	7.4	5.7	13.7	39.7	58.3	50.3	24.0
	Ur.	10	6.4	14.7		54.0	55.0	28.2
Madhya Pr.	Ru.	37.2	31.3	46.2	59.8	79.3	79.3	50.8
	Ur.	38.5	13.9	25.6		60.8	64.3	32.5
Orissa	Ru.	47.8	43.5	54.4	40.9	70.0	69.9	33.2
	Ur.	43.5	15.6	30.3		34.6	40.7	12.4
Tamil Nadu	Ru.	20	24.3	45	30	73.2	71.8	44.5
	Ur.	22.5	11.3	24.5		47.3	56.6	27.1

Table 13: Calorie-based poverty headcounts (by occupation) for Madhya Pradesh

		State/sector average calorie requirements		Occupation specific calorie requirements	
Occupation	Sector	below	20% below	below	20% below
		Poverty Headcounts			
Sedentary	Rural	68.9	24.2	58.9	17.6
	Urban	44.5	13.2	39.3	10.3
Primary	Rural	89.0	52.3	89.9	55.4
	Urban	82.0	49.1	81.0	49.2
Secondary	Rural	89.4	46.8	87.7	38.4
	Urban	81.5	36.6	79.0	34.8
Service/sales	Rural	80.6	32.7	87.7	29.5
	Urban	68.0	21.9	75.3	27.6

Table 14: Welfare gains/losses from caloric requirements

	$\%\Delta S_{nf}$	s.e.	Due to cal. req.
Urban vs. Rural 1999-2000	0.056	(0.004)	0.051
Rural 1983-2005	0.327	(0.002)	0.030
Urban 1983-2005	0.282	(0.002)	0.023
Occupations in 1999/2000			
Admin	-0.014	(0.010)	
Clerical	-0.012	(0.010)	
Sales	-0.018	(0.009)	
Service	-0.060	(0.011)	
Primary	-0.051	(0.008)	
Secondary	-0.028	(0.008)	
Other	-0.015	(0.010)	

Welfare gain is the effect of the dummy on log non-food share.
Controls for household size, composition, cubic real exp.
The last column measures the extent to which dummy is reduced by our variables that proxy for caloric requirements.
Omitted category for occupations is professional.
Occupation regressions include controls for urban/rural.

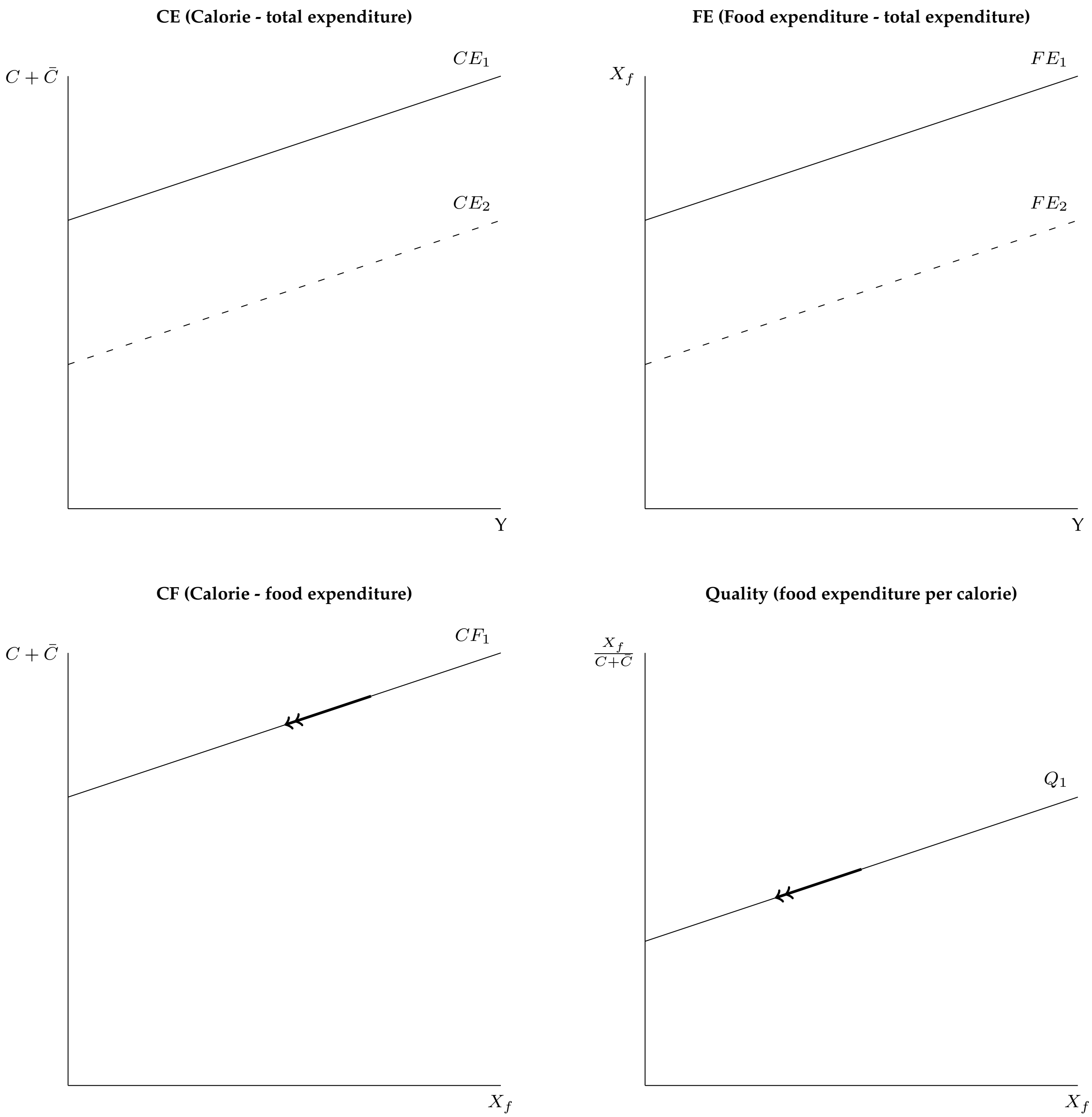


Figure 1: Fall in price of non-food p_{nf} (or rise in non-food taste/quality/variety p_f)

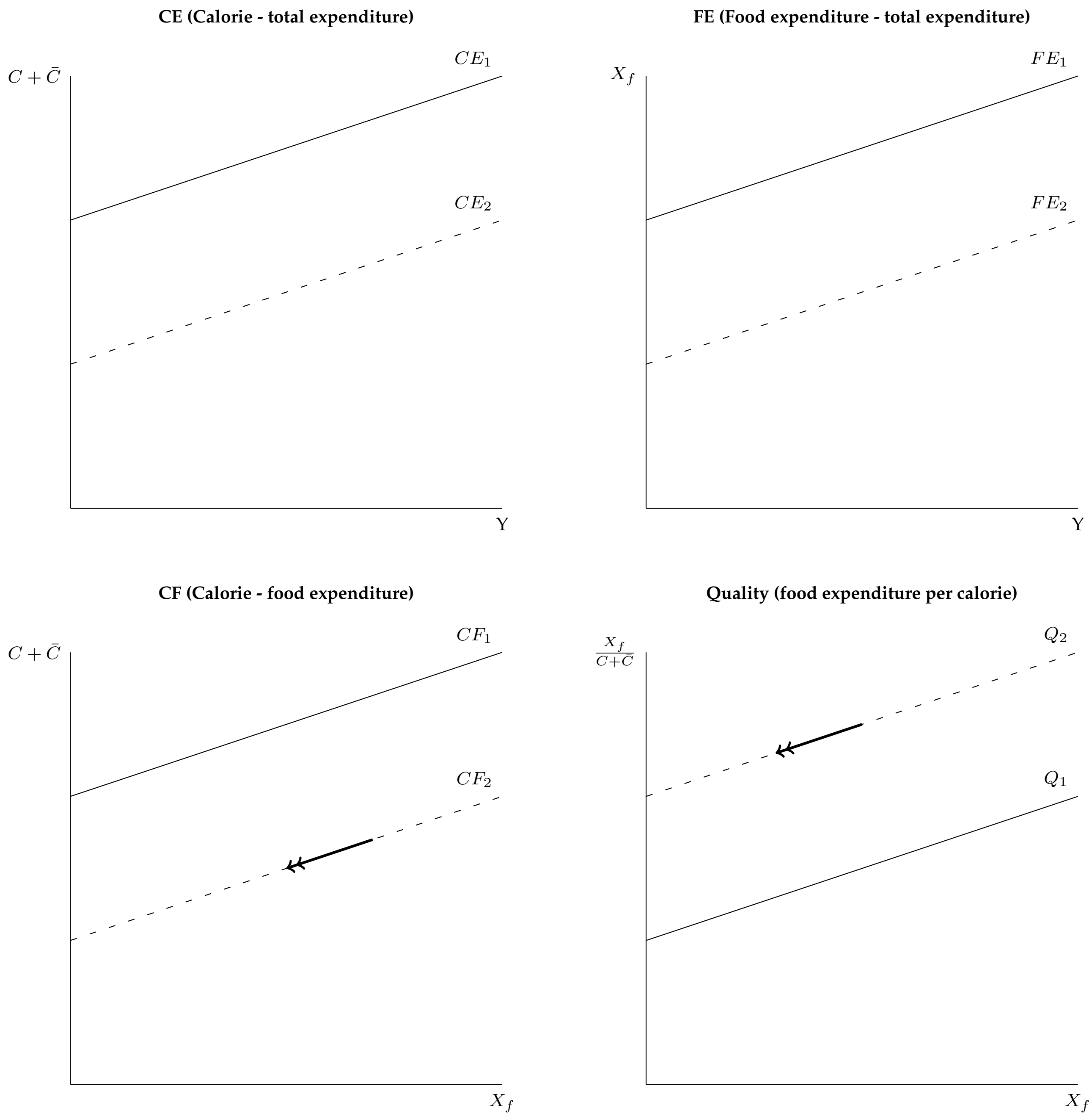


Figure 2: Fall in energy requirements $\bar{C}$

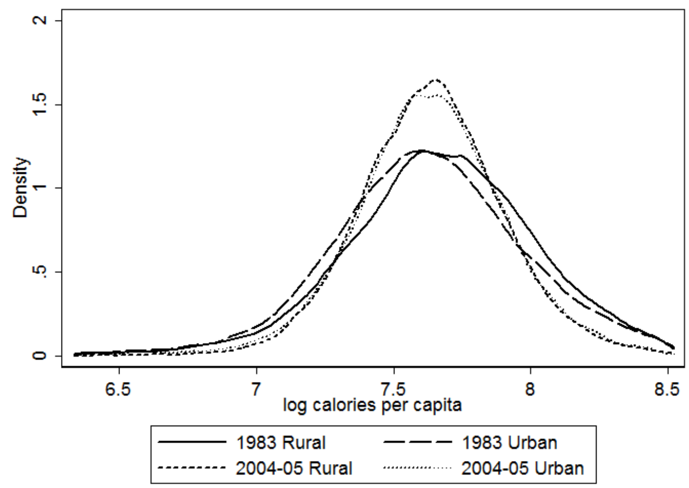


Figure 3: Kernel density estimation of log calories per capita

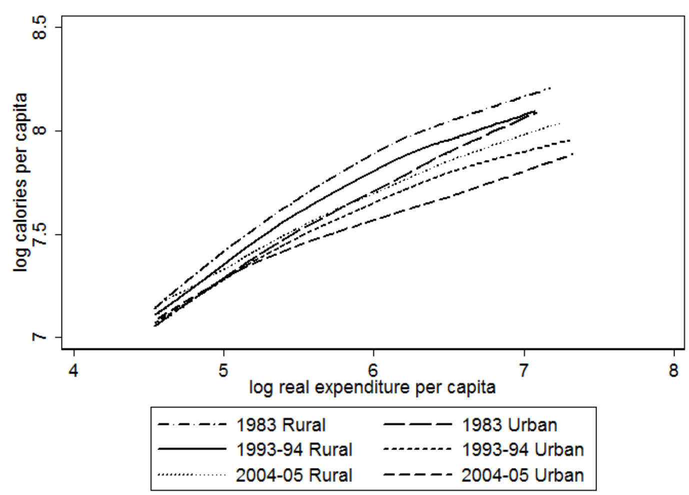
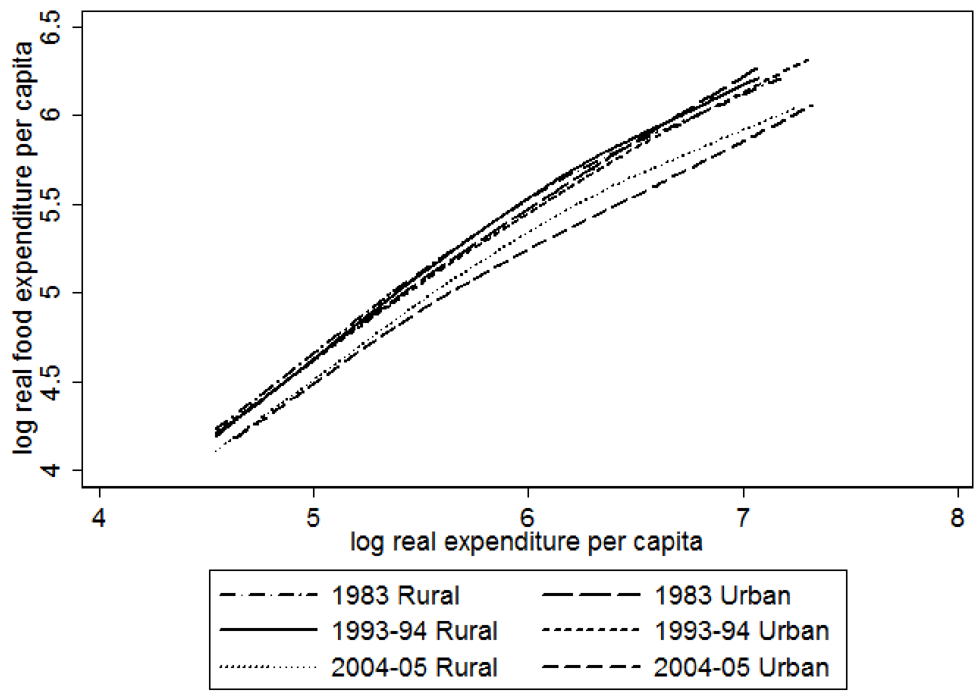
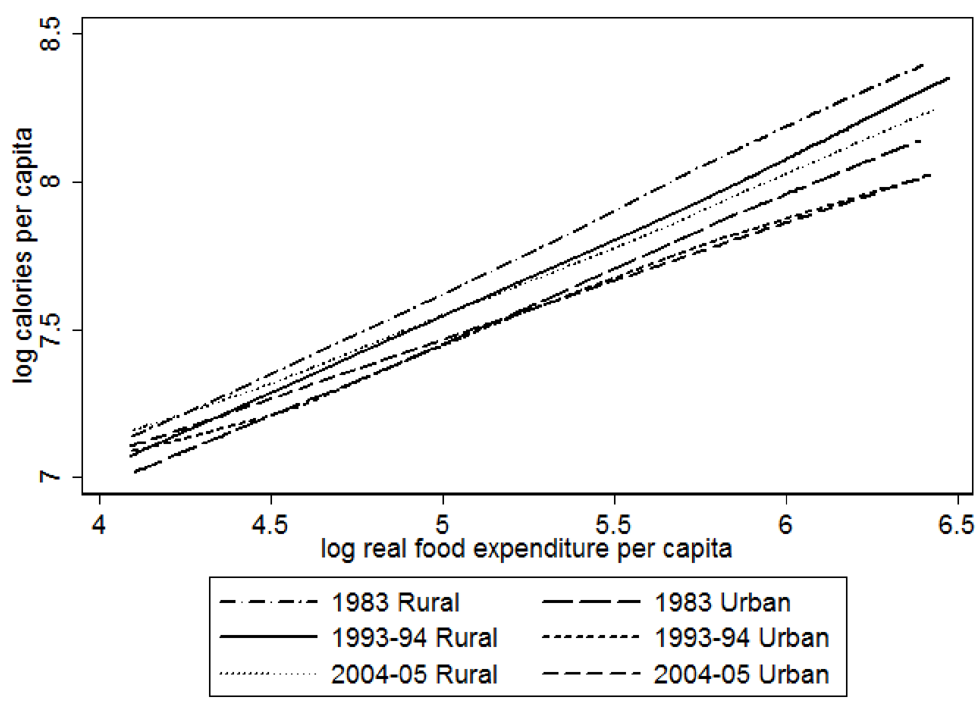


Figure 4: Locally weighted regression of log per capita calories on log per capita real expenditure (two adult, 3 child household)



(a) Food Expenditure - Total Expenditure



(b) Calories - Food expenditure

Figure 5: Locally weighted regressions for two adult, three child households (logs)

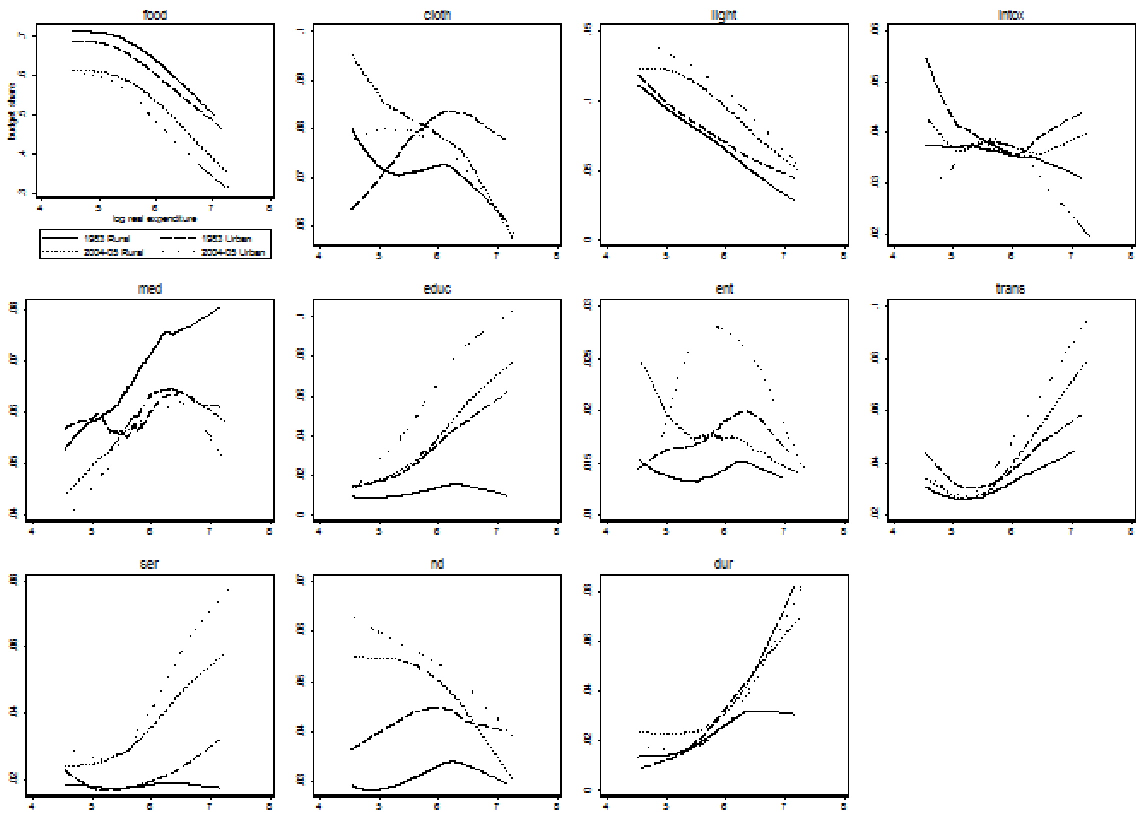
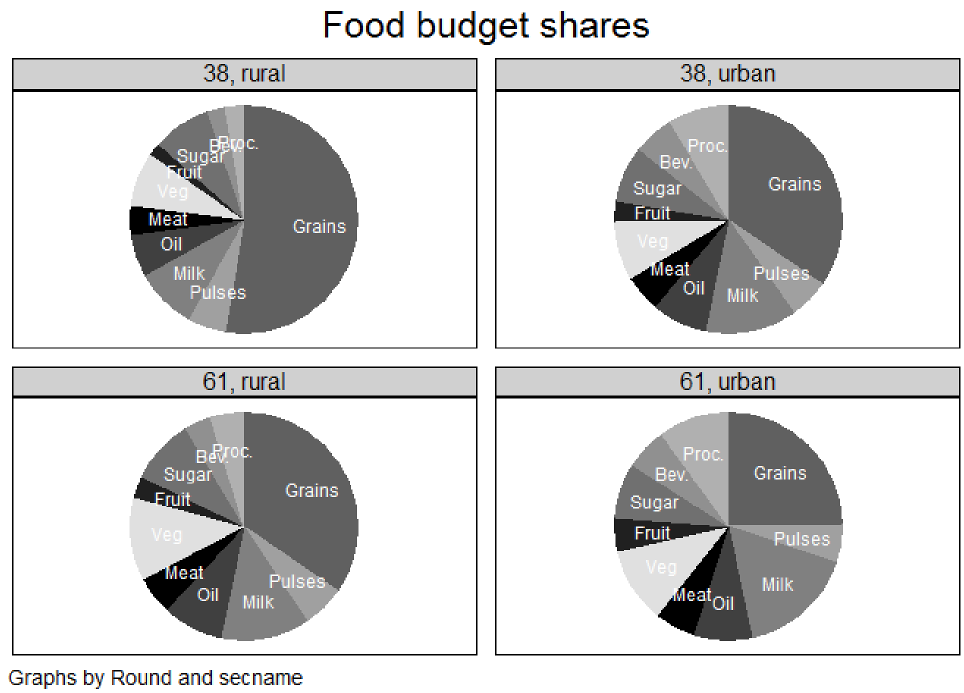
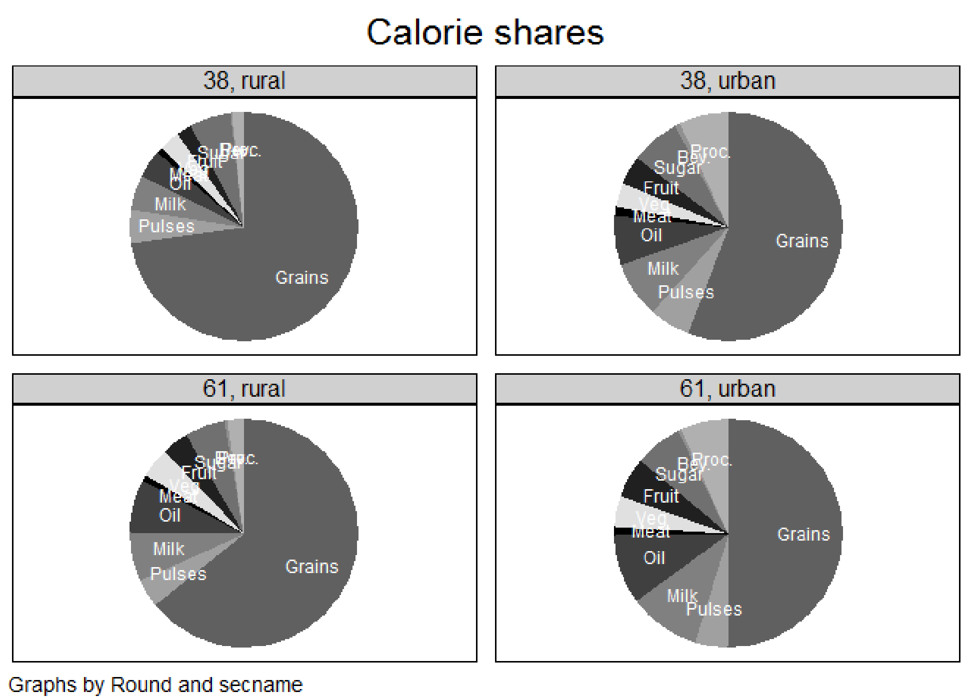


Figure 6: Locally weighted regression of budget share on log per capita real expenditure (two adult, 3 child household)

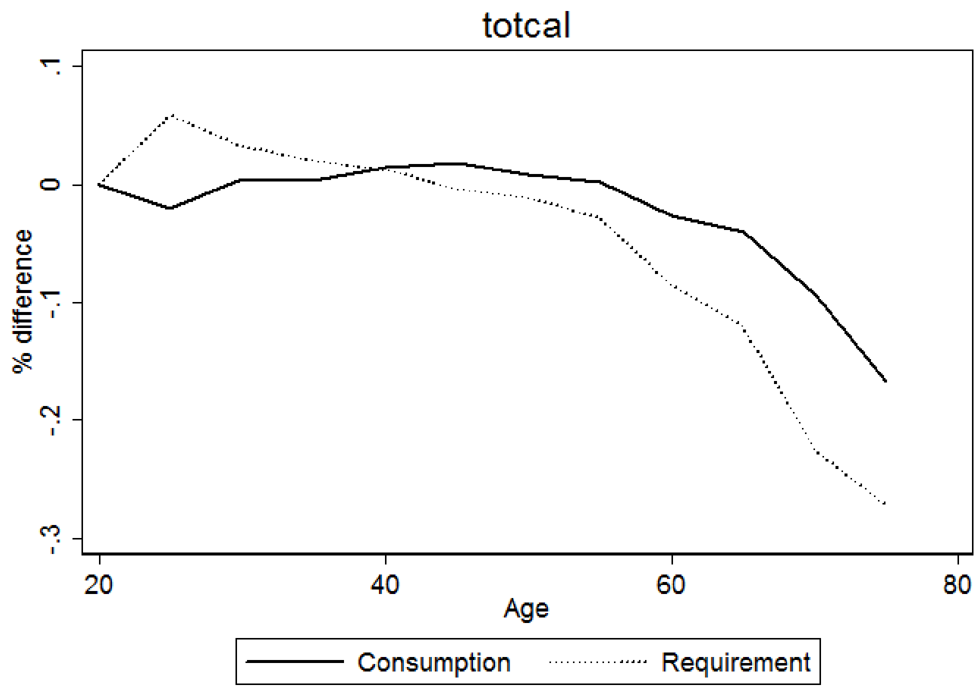


(a) Food expenditures

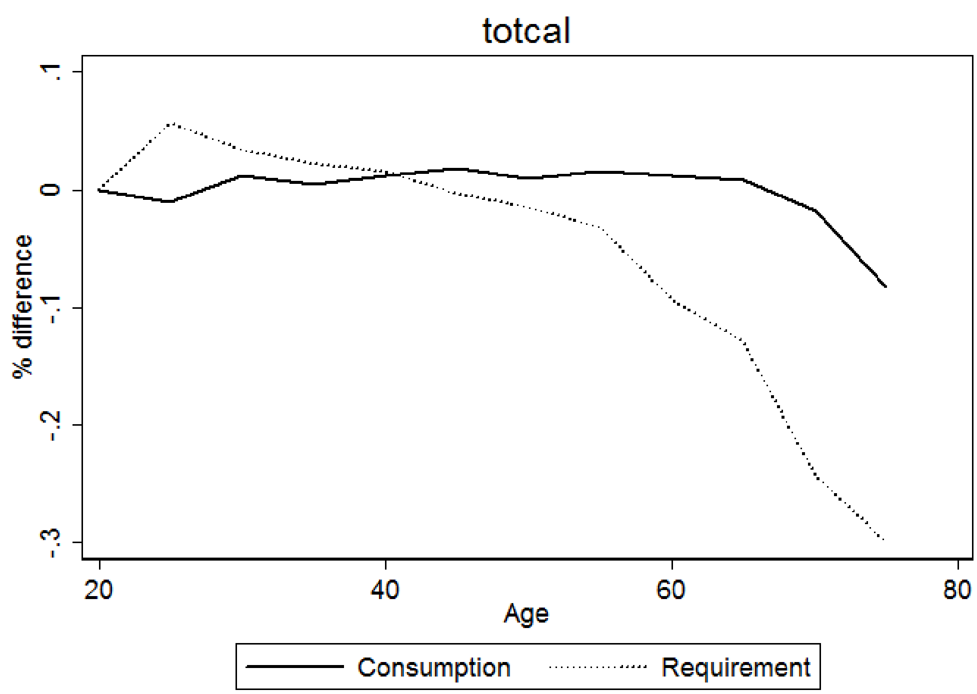


(b) Calories

Figure 7: Food group shares by year/sector

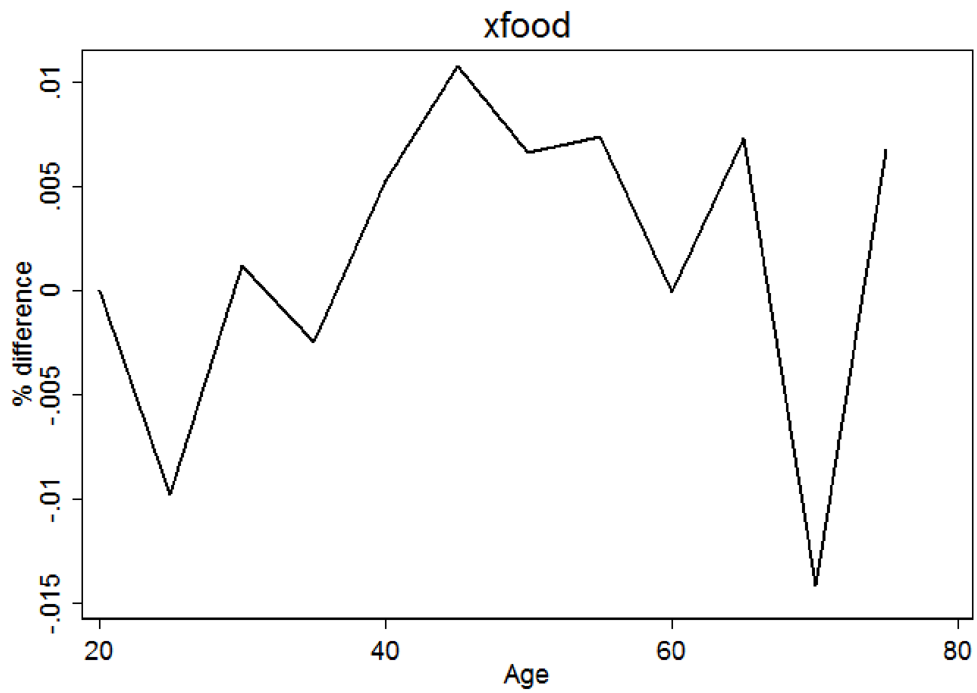


(a) Unconditional

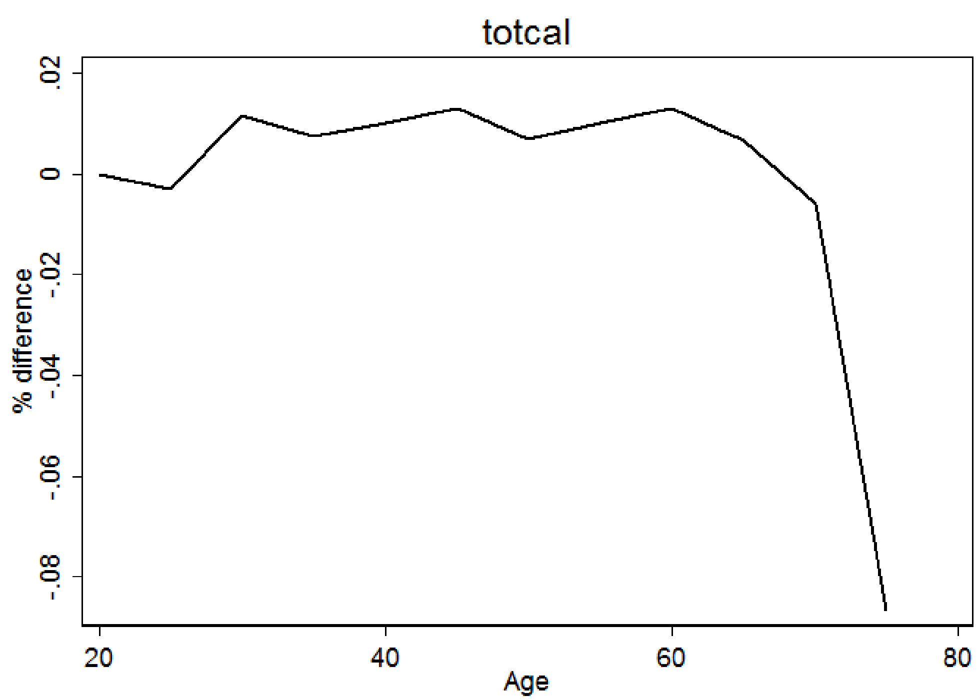


(b) Conditional on total expenditures

Figure 8: Life-cycle calorie consumption and requirements, relative to 19-22 year old adults

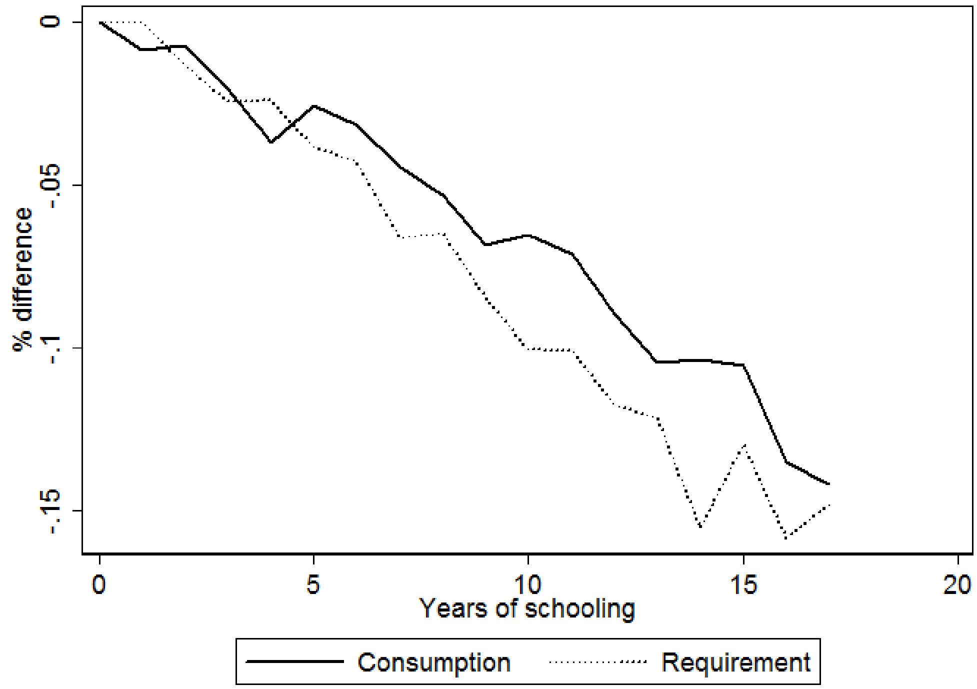


(a) Food exp. cond. on tot. exp.

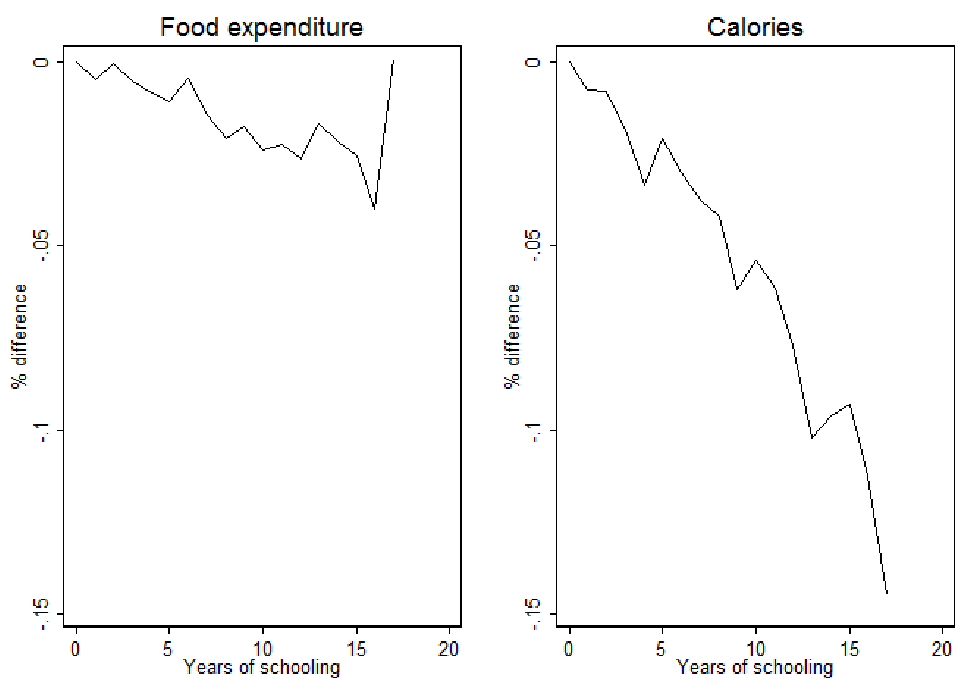


(b) Cal. cond. on food exp.

Figure 9: Life-cycle coefficients, relative to 19-22 year olds



(a) Cal. conditional on tot. exp.



(b) Cal. cond. on food exp. and food exp. cond. on tot. exp.

Figure 10: Effect of average adult years of schooling on calorie and food consumption/requirements

A Data Appendix: Imputing caloric intake

A1. Calorie Intake

As there is some disagreement about the direction and magnitude of the trend in calorie consumption and as quantitative evaluation is important to us we delve deeper into the construction of calorie intake measures. We cannot address the issue of systematic under-reporting or over-reporting using the NSS data alone, and the 30 day recall period and reliance on a single informant may bias measured food consumption in several ways. Beyond measurement error in the data itself, there are also several important assumptions and imputations that affect the calorie estimates. These can be broadly divided into 3 categories - (1)food items with no quantity data or imprecise quantity units (even though caloric conversion factors may be accurate), (2)composite food items with unknown calorie conversions (even though the quantity measures may be precise), and (3)meals received and given by the household that are not accounted for in total calories or household size (and hence bias estimates of calories per capita). Several items - most notably processed foods, beverages, and cooked meals - suffer from both the first and second problems, and there are some items with inconsistent measurement of quantity and different units across the five survey years we examine. The third problem takes two forms - meals received for free by household members (which are not recorded in the household consumption data but are sometimes recorded on the household roster) and meals given by the household to non-members. A fourth but less important issue is treatment of alcoholic beverages, which are typically not factored into food expenditures or calorie consumption but are potentially an important source of both for some households.

A2. Data issues

To get a sense of the magnitude of these issues, table 15 reports some summary statistics for consumption of the different sets of "problem" goods.[19] The first row reports the share of food expenditures on goods with no quantity data, which has been increasing over time and is higher in urban areas. Many of these goods fall into the processed food and "other" categories. The second row reports the share of expenditures on composite commodities - defined as those commodities with "other" in the description (with three exceptions - "palak/other leafy vegetables" and "other edible oils" are excluded, as their caloric content is likely to be very similar to other products in that category, and cereal substitutes are included since they include varied goods like tapioca, jackfruit suits, and sago). This narrow definition of composite commodities excludes some processed foods that could be considered composite commodities, like biscuits or salted refreshments but includes categories like "other vegetables" and "other animals" and "other dairy products" that contain quantity information. The expenditure share of the composite commodity categories has risen over time and is higher in urban areas. The third row reports spending on all items

[19]Unless otherwise noted, all summary statistics reported are weighted using the multiplier factors provided by the surveys. We use the combined central and state samples and use data from the 17 biggest states, urban Delhi, and Meghalaya.

in the processed foods and beverages categories, which contain several notable composite items, items lacking quantity data, and uncertain caloric conversions - the food expenditure share of this category is much larger for urban households and it has increased by about 3 percentage points for rural and urban households over the sample period, almost doubling for rural households. The fourth row presents expenditures on cooked meals, a subset of the expenditures on processed foods, which is higher in urban areas but has actually decreased over time. Cooked meals include both restaurant meals and transfers in kind from employers so this decline need not imply a decline in restaurant meals - it could also imply increased formalization of employee-employer relations and a shift in wage versus in-kind payment. Note that the expenditure share on cooked meals remains very low compared to what is observed in wealthy countries and middle-income developing countries (CITE). The fifth row shows expenditures on alcohol as a share of food expenditures, and while there has been a 25% increase the level remains low but slightly higher in rural areas.

The sixth and seventh rows of table 15 show the share of expenditures that can be directly converted to calories using either a conservative or a liberal imputation criteria. The conservative criteria only converts calories directly for goods that both include (a)quantity units in weights or volumes (as opposed to units or missing quantities, as is the case for most beverages, processed food, cooked meals and some fruits and other goods) and (b)obvious calorie conversions (which rules out most composite commodities even if they are measured in KG). The liberal criteria attempts to convert virtually all goods directly and only excludes goods with no quantity measures. Goods with discrete units are converted to masses, and the published caloric conversion tables (from Gopalan et al. (2004) or Karan and Mahal (2005)) are supplemented with data from the IndiaMD website and other sources. The conservative criteria only covers 80% of food expenditures in urban areas and about 90% in rural areas, and the share covered declined by 2-4% over the sample period. The liberal criteria covers over 95% and 90% of urban and rural food expenditures respectively, with a 1.4%-2.3% decrease in expenditure share. There is thus an intrinsic trade-off between measurement error induced by attempting to broaden the coverage for direct calorie conversion and the error induced by imputing the caloric content of the unconverted part of food expenditures.

We next turn to measurement of unrecorded meals to the household and meals provided to others. The expenditure data records all expenditures by the household on food and this includes food that is given to guests, as part of ceremonies, or to employees - provided they do not live with the household and therefore do not qualify as household members. An accurate measure of per capita calorie consumption by the household requires a downward adjustment to calorie consumption due to these meals to others. Conversely, each household receives free meals as guests of other households, through school or other public programs, or from employers. The NSS instructions require that these free meals not be recorded under household consumption (with their value imputed at market rates), unless their is some payment. Thus subsidized meal purchases would be recorded but free meals from school or employers would not. There is some ambiguity as meals from employers would constitute transfers in kind and should technically be recorded in the consumption data but due to uncertain valuation this is often not the case. Since some meals are received from institutional employers or schools it is not necessary that these free meals given to others and those received balance out on average.

Table 16 provides summary statistics on the share of households giving or receiving free meals, the mean number of meals given and received in the last month, and the median number of meals given or received conditional on giving or receiving meals. There is a clear pattern with rural households providing more meals to others than urban households and a reverse pattern for free meals received (until the last survey round). The pattern over time is less clear and a bit inconsistent, with some implausibly large jumps. As expected on average meals given exceed meals received, since all of the meals given would typically be recorded for both the giving and receiving household, while meals given by non-household employers, schools, government programs would not be recorded. While the distribution of meals given and received is quite skewed - with a few households hosting large ceremonies and a few households heavily dependent on free food received - the average effect is not quite large and is unlikely to significantly bias estimates of calorie consumption per capita. Table 16 also includes the quantity of purchased cooked meals consumed, with the main lesson being that cooked meals are much more important to urban than rural households and their consumption has declined, particularly in urban areas. Thus the decline in expenditure share from table 15 is not simply due to the availability of cheaper cooked meals.

A3. Calorie estimates

In light of these issues we construct several different measures of calorie consumption using different imputation schemes, which helps to clarify which basic facts are quite robust and which depend on contestable assumptions. Table 17 presents calories per capita per day using several different imputation schemes. There are three steps to the imputation procedure. We begin with either the conservative or liberal direct conversion of calories. For goods that normally have quantities reported but are sometimes missing quantities we use the median unit value (expenditure/quantity) to impute quantity, and we also censor quantities so that no household purchases a good for a unit value more than 20 times more or less than median unit value. These two steps ensure that the calorie measurements for categories with relative few quantity observations - especially processed foods - are not biased by the presence of outliers. Next we impute the non-converted part of food expenditures using either (a)calorie/rupee for directly converted goods by household, (b)the average calorie/rupee for directly converted goods across all households, or (c)the group average calorie/rupee averaged across all households. Imputation (a) allows the calorie per rupee of expenditure to vary across households, with richer households typically having lower calories per rupee of directly converted expenditure and hence less imputed calories per rupee of non-converted expenditure. Imputations (b) and (c) remove this idiosyncrasy by averaging across all households, by sector and survey round to control for differences in prices. Measure (c) allows differences in average calorie/rupee conversion rates across different food groups, which is important given the large range in calories/rupee documented later. When performing this imputation we can also consider an adjustment factor - for example, to take account of the fact that most of the unmeasured calories come from goods with generally high cost per calorie (e.g. processed foods, beverages, other meats, ice cream) we might apply a factor of 0.5 to the calories/rupee measure.[20] Finally, having imputed the calories of the missing food, we also need to consider outliers in the data, so we calculate both the uncensored mean, the median, or the trimmed mean which drops households in the top and bottom 1% of food expenditures and direct calories imputed.

The first row of table 17 presents the uncensored mean calories per capita per day using the liberal direct conversion and imputing the rest of the calories by multiplying the rest of expenditures by half of the calorie per rupee of expenditures directly converted for each household. This captures the fact that most of the imputed calories come from foods with a generally higher cost per calorie than the average directly converted basket, and allows the cost per calorie to rise with household budgets. The next five row each change one parameter at a time. The second row does uses the conservative direct conversion, meaning that a greater share of expenditures are imputed. The third row uses a one to one adjustment factor instead of a a one half factor, thereby assuming that the non-converted foods have a similar price per calorie as the directly converted expenditure. The fourth row imputes the non-converted expenditure using the sectoral annual average rather than the household-specific calorie/rupee factor. The fifth and sixth rows report the median and censored mean, which trims the 1% tails of the food expenditure and converted calorie distributions.

The seventh row of table 17 imputes the unmeasured calories using group-specific conversion factors equal to the average calorie per rupee for each group, averaged across all households. Direct imputation is done using the liberal conversion criteria (which ensures that there are at least 4 goods in each group with direct calorie conversion). Since imputation is now done by each group there is less concern about imputing the low cost per calorie of grains or pulses to goods like 'cooked meals,' 'other processed food' and 'other beverages' so we do not multiply by one half. For comparison the eighth row assumes that the imputed goods have a calorie/rupee rate half as high as the rest of the goods in the group - this might be more reasonable for some categories, such as ice-cream (which could have twice the cost per calorie as milk), other fruit (given that coconut, singara, and dried fruits and nuts are directly converted and have high calories per rupee), and cooked meals (compared to pickles, sauces, jam/jelly, and cakes). The ninth row presents the group results of row seven but trimming the 1% tails of expenditure and calories.

Altogether, the estimates presented in table 17 strongly suggest that there has been a large decline in calories per capita for rural households and that rural households in 1983 consumed significantly more calories than urban households on average. However, there is some uncertainty about whether urban calories per capita have risen or declined and whether calories per capita in urban areas exceed those in rural areas in 2004-05. These results are sensitive to the imputation method. Using medians we sometimes find a modest increase in calories per capita in urban areas, though the range in table 17 is quite small at -74 to 18. Using group-specific, average or higher calorie/rupee adjustment factors also tends to shift the rural-urban gap in 2004-05 in favor of urban households.

The bottom two rows of table 17 present our two preferred specifications, corre-

[20]Deaton and Dreze (2009) do this explicitly for cooked meals, implying that a cooked meal is equivalent to the aggregate food consumption basket with a markup of 100%.

sponding to row (6) and row (9), but adding in calories from alcohol and the effect of a 'household adjustment factor.' This factor accounts for free meals and meals to others by assuming that they have the same calories per capita of other meals consumed by the household. The precise formula used is

$$hh.\ adj.\ factor = \frac{pay\ meals\ at\ home\ + pay\ meals\ outside\ + free\ meals}{pay\ meals\ at\ home\ + pay\ meals\ outside\ + meals\ to\ others} \quad (12)$$

Note that the 55th survey round (1999-2000) did not record meals to others so it is excluded from this calculation, even though one can include a positive inflation factor accounting for free meals consumed. Comparing rows (10) and (11) to (6) and (9) we see that these last two adjustments have a minimal effect. The adjustments tend to increase calories per capita in urban areas but by a greater amount in the early period. In rural areas the pattern is reversed, with a slightly negative adjustment in the early period and positive in the later period. The net effect is thus to decrease the fall in calories in rural areas and increase in the fall in calories in urban areas, and a modest reduction in the rural-urban gap. The magnitude of the effect overall is at most 20%. Throughout the rest of the paper we use the estimate of row 10 as our baseline measure of caloric intake and check it against the other measures, noting the differences only if they are economically significant.

A final issue that we cannot address with our data is that the nutritional content of particular foods may vary over time and space. Many foods lose some of their nutritional content with transportation over longer distances and storage, the composition of the 'other' goods may vary systematically over different areas and periods, and the caloric content of processed foods may also vary. To the extent that transportation lowers caloric content for goods that we measure this would tend to decrease urban relative to rural calories and might also lower caloric intake further over time. For goods with unknown caloric content, our imputation procedure may capture some of these effects, as areas and periods with higher calories per rupee for directly converted goods might also have higher calories per rupee for imputed goods, but we cannot be certain.

B Data Appendix: Imputing caloric requirements

To record time-use information, the surveyors attempted to interview each member of the household over age 5 about their time-use over the preceding 24 hour period. Busy, reluctant or incapable members had their time-use recalled by another household member. Time-use was captured for up to three separate types of days - normal, abnormal, and variant - to capture variations in the weekly schedule including market days, weekend activities, etc. The measure we use is based on a weighted average of these three days based on how many days the household reported of each type in the preceding week. The interview team included both a male and female interviewer as the goal of the survey was to measure and validate the contribution of women to economic life in India.

The survey also records a number of other variables that are recorded in the same format as in the NSS consumption surveys - monthly expenditures, land ownership, religion, and scheduled caste/tribe at the household level and age, gender, education, and occupation for each household member. Unfortunately, the Time Use Survey was not carried out simultaneously with the NSS consumption survey, which means that comparable consumption data is only available for the July 1997-June 1998 period or the July 1999-June 2000 period. The closest geographical match is at the district level as individual villages and cities are not recorded or geocoded.

To go from time-use to caloric requirements, we begin by classifying the 154 different types of activities into four different levels energy requirement. This requires numerous judgment calls. The intensity level of each activity is relative to a complete state of rest (activity level 0), and we get the intensity factors from the calories per hour website at http://www.caloriesperhour.com/. The intensity ratios (relative to complete rest) are 1.7 for level 1 (playing cards), 3 for level 2 (cooking/housework/walking 2mph), and 5 for level 3 (chopping wood/push-mowing). To give some concrete examples from our data, activity level 3 includes ploughing, preparing land, cleaning of land, wood cutting, chopping and stocking of firewood, and building and construction of dwellings. Activity level 2 includes cooking, sweeping, and assembling machines, equipment and other products. Activity level 1 corresponds to sedentary labor such as service in government, professional work, reading, and watching tv. Activity level 0 corresponds to sleeping or 'doing nothing, rest and relaxation.' Our classification of activities into different levels of intensity are available upon request. Assuming that households sleep 8 hours a day, spend 8 hours awake at intensity level 1 and then another 8 hours working at intensity levels 1/2/3 for heavy, moderate, or sedentary market work a 26 year old man weighing 70 kilograms would require 3952/2928/2272 calories. This lines up roughly with the ICMR recommendations of 3800/2875/2424 calories.

We take as the baseline caloric requirements those corresponding to a 70 KG 26 year old man. We then convert this energy requirement by a multiplicative factor corresponding to the relative Basal Metabolic Rate (BMR) for a person of a given age and gender. The BMR captures the energy consumed by the body at a complete state of rest for a given age and gender, and it multiplicatively scales the energy requirement of different activities that consume more energy than resting. BMR rises and falls in age, starting out higher for women but peaking earlier. Our baseline female is 62 KG. For children under age 6 we use the daily energy requirements from the India Council for Medical Research (ICMR). For infants aged 0-6 months and 7-12 months, for which the ICMR gives energy requirements by weight, we use energy requirements for 1-3 year olds. These should be a reasonable approximation of calorie requirements based on an average child growth chart plus an extra energy requirement for lactating mothers. The NSS data do not report pregnancy status so we are likely to underestimate the calorie requirements for pregnant women by about 300 calories per day according to the ICMR.

The ICMR provides daily energy requirements for adult men and women as well children of different ages, but adult caloric requirements are only divided into three activity cells - heavy, moderate, sedentary. They also do not take account of activity levels by children, an important omission given that they have separate age/gender cells for boys/girls aged 13-15 and 16-18, age ranges where child labor inside and outside the household is likely to be quite important in some areas. The ICMR theoretically provides us with an alternative set of energy requirements for analysis but we prefer our measure for several reasons - it allows us to account for household age and life-cycle effects for adults and labor by children and adolescents, we can match energy requirements to a variety of household characteristics rather than industry or occupation (which would be the only way of imputing household calorie requirements in the NSS using the ICMR recommendations), and we have a much more fine-grained measure of energy requirements that has both an extensive margin - number of hours working on different activities - and an intensive margin - requirements for activities of different intensity.

The most important limitation of the TUS data is that we do not have a measure of the intensity of individual activities. While many agricultural tasks are likely to be highly labor intensive some may have assistance from mechanical and animal energy sources. This issue also occurs for all transportation related activities - since the TUS does not record mode of transport, we assume an activity level of 2 which would tend to overstate energy requirements for motorized vehicular transport but understate energy requirements for walking and cycling. Other limitations include the lack of data on height and weight for individuals or systematic biases in activity recall.

Table 15: Problem foods for calorie imputation

		1983	1987-88	1993-94	1999-00	2004-05
Share of food expenditure by problem category						
		38	43	50	55	61
No quantity	Rural	0.011	0.016	0.021	0.022	0.036
	Urban	0.028	0.035	0.042	0.041	0.057
"Other"	Rural	0.028	0.028	0.028	0.028	0.035
	Urban	0.025	0.026	0.031	0.033	0.045
Proc. food and bev.	Rural	0.052	0.064	0.066	0.073	0.085
	Urban	0.144	0.150	0.157	0.146	0.159
Cooked meals	Rural	0.016	0.019	0.012	0.014	0.013
	Urban	0.059	0.060	0.056	0.046	0.046
Alcohol	Rural	0.012	0.013	0.013	0.014	0.015
	Urban	0.009	0.011	0.011	0.012	0.013
Share of food exp. with calorie conversions						
Conservative	Rural	0.906	0.891	0.889	0.880	0.865
	Urban	0.808	0.797	0.788	0.799	0.787
Liberal	Rural	0.972	0.965	0.967	0.963	0.949
	Urban	0.909	0.904	0.900	0.912	0.895

Table 16: Cooked meals, meals to other households and free meals (per 30 days)

		1983	1987-88	1993-94	1999-00	2004-05
Cooked meals						
Mean number	Rural	1.985	2.512	1.561	1.606	1.537
	Urban	6.574	6.557	5.577	4.580	4.468
Share consuming	Rural	0.074	0.092	0.063	0.049	0.058
	Urban	0.154	0.171	0.144	0.122	0.127
Cond. Median	Rural	12	12	12	16	12
	Urban	30	28	30	27	20
Meals to guests, employees, ceremonies						
Mean number	Rural	14.650	10.311	10.429	.	7.862
	Urban	10.483	12.178	6.208	.	6.039
Share consuming	Rural	0.407	0.377	0.141	.	0.447
	Urban	0.354	0.350	0.104	.	0.382
Cond. Median	Rural	10	10	12		8
	Urban	10	10	12		7
Free meals						
Mean number	Rural	7.717	6.572	6.005	6.220	11.473
	Urban	8.152	6.993	7.040	6.342	7.836
Share consuming	Rural	0.261	0.228	0.193	0.179	0.329
	Urban	0.235	0.218	0.196	0.177	0.233
Cond. Median	Rural	14	12	16	20	24
	Urban	18	16	20	20	22

Table 17: Daily calories per person: different imputations

Direct conv.	Cal./rupee + adj. fact.	Stat.	Sect.	1983	1987-88	1993-94	1999-00	2004-05	Δ 1983 to 2005
Lib.	Ind x0.5	Mean	Rural	2350	2302	2226	2217	2121	-229
			Urban	2156	2165	2128	2201	2085	-70
Cons.	Ind x0.5	Mean	Rural	2305	2295	2213	2201	2105	-200
			Urban	2124	2150	2107	2170	2057	-67
Lib.	Ind x1	Mean	Rural	2377	2337	2261	2255	2171	-206
			Urban	2227	2254	2223	2287	2189	-39
Lib.	Avg. x0.5	Mean	Rural	2358	2312	2233	2223	2130	-229
			Urban	2214	2235	2189	2254	2159	-55
Lib.	Ind x0.5	Median	Rural	2158	2150	2107	2099	2027	-131
			Urban	2007	2046	2045	2114	2025	18
Lib.	Ind x0.5	Mean	Rural	2328	2297	2229	2217	2124	-205
		1% trim	Urban	2141	2154	2147	2203	2092	-49
Lib.	Gr.avg. x1	Mean	Rural	2341	2293	2215	2209	2104	-237
			Urban	2159	2208	2141	2243	2095	-64
Lib.	Gr. avg. x0.5	Mean	Rural	2327	2274	2200	2188	2081	-246
			Urban	2106	2135	2078	2169	2032	-74
Lib.	Gr. Avg. x1	Mean	Rural	2321	2289	2219	2212	2110	-211
		1% trim	Urban	2168	2202	2169	2250	2106	-62
		Including calories from alcohol and hh. adj. factor							
Lib.	Ind x0.5	Mean	Rural	2320	2293	2244		2154	-166
		1% trim	Urban	2178	2180	2192		2121	-58
Lib.	Gr.avg. x1	Mean	Rural	2313	2285	2234		2140	-172
		1% trim	Urban	2230	2234	2214		2136	-94