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

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Abstract

Although cross-sectional calorie-expenditure elasticities are positive in India and there has been significant real expenditure growth, measured caloric intake declined over the 1983-2005 period. This pattern is also reflected in rural-urban caloric disparities. We explore the energy requirements hypothesis of Deaton and Dreze (2009) as an explanation for India's "missing" calories. We analyze a stylized model that relates energy requirements to calorie and food Engel curves. Combining time-use and consumption data we show that caloric intake and requirements track each other closely over a series of demographic, occupational and other household variables. Quantitatively our results provide strong support for the energy requirements hypothesis as an explanation for rural-urban calorie gaps, but weaker support for changes over time, suggesting that other factors are important. We also provide some alternative measures of poverty and hunger and analyze the welfare gains from lower energy requirements.

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1. Introduction

Deaton and Dreze (2009) and other researchers have used India's National Sample Survey and other sources to document a large (10%) decline in mean calorie consumption per capita over the 1983 to 2005 period. This is particularly puzzling given that the same data indicates that real expenditures grew about 30% during this period and that the cross-sectional calorie-expenditure elasticity is about 30%. A similar puzzle is observed between rural and urban households - on average urban households are richer but consume less calories. Understanding the reasons behind 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 despite significant economic growth over the last twenty years and greater poverty in urban than rural areas.

While some would argue that the decline in calories indicates growing impoverishment in India due to market-based reforms, the general consensus among scholars is that poverty has decreased over the 1983-2005 period. Anthropometric evidence on child heights and weights shows slow but steady progress, and both national accounts and survey data clearly indicate that household incomes have been rising and lack of income is not what is constraining calorie demand. Further evidence comes from a tendency to substitute towards more expensive sources of calories over time and in urban areas.

Deaton and Dreze (2009) propose the energy requirements hypothesis as a possible explanation for the missing calories. The hypothesis holds that improvements in the health environment and some combination of mechanization of production, animal power, structural change, infrastructure improvements, and labor-saving appliances have decreased household energy requirements. This frees up valuable household resources to spend on higher quality (more expensive per calorie) food or non-food items rather than greater food quantities. While many authors have recognized that energy requirements may be an important input into food demand patterns, the quantitative role of energy requirements in consumption behavior has received little attention in the development and consumer economics literatures.

To explore the energy requirements hypothesis, we first develop a stylized model that incorporates energy requirements into a calorie Engel curve framework. The central insight of our model is that falling caloric requirements show up in two ways - a decline in calories per food expenditure (or rise in quality) and a decline in food expenditure given total expenditures. Other factors, such as lower relative non-food prices or the emergence of new non-food goods could shift down food expenditures given total expenditures, but since households adjust to the lower food expenditures on both a quality and quantity margin we would expect an increase in calories per food expenditure (or fall in quality). A decline in caloric requirements in our model is distinct from these other forces as it shifts down the food Engel curve, decreasing food quantity at any given level of total expenditures, while simultaneously *increasing* food quality. By endogenizing caloric requirements in our model we also show that households that expend more energy to earn income will have steeper calorie Engel curve slopes and lower welfare inequality relative to expenditure inequality.

We proceed to investigate the robustness of the decline in calories and its sources in greater detail. The unexplained decline is robust to a variety of assumptions about the construction of household calorie consumption, especially when factoring in a positive calorie-expenditure elasticity. We decompose the decline in calories into calories given food expenditure, and food expenditure given total expenditure, and find that while the former drives most of the decline in calories over the 1983-1993, the latter effect dominates in the later period. The decline in calories per food expenditure is largely due to shifts away from food groups that have higher calories per rupee of expenditure. Relative price changes have actually favored cheaper, high calorie staples, which argues against an important role for relative food prices in explaining declining calorie consumption.

We next turn to measurement of energy requirements using time-use for six Indian states and imputing caloric requirements at the individual and household level. Our key result is that caloric requirements imputed from the time-use survey closely track caloric consumption across several sets of variables that proxy for energy requirements, including household composition, the life-cycle, education, and occupation. We also show that ownership of labor-saving durables and energy sources (e.g. substituting gas for firewood) can have large impacts on calorie consumption given expenditures. These results show that the energy requirement hypothesis has real empirical bite and that any reduction in the 'missing' caloric intake explained by these variables is likely to operate largely through their effects on caloric requirements.

Quantitatively, the energy requirements hypothesis is very successful at explaining the rural-urban gap. Our proxies for energy requirements reduce the missing calories by 61%, and reduce the missing calories conditional on food expenditures by 100%. This suggests that relative prices, variety, and taste differences across rural and urban areas are not necessary to account for lower urban calories conditional on expenditure. Comparing similar households across sectors yields similar caloric demand and requirements. The energy requirement hypothesis is less successful at explaining the decline in calories over time. The magnitude of missing calories is reduced by only 21% in rural areas and 15% in urban areas, though when we condition on food expenditures the share rises to 42% and 60% respectively. While we cannot completely rule out the energy requirements hypothesis, our evidence indicates that other factors may be more important over the 1994-2005 period.

Finally, we provide some new measures of poverty rates, poverty gaps, and calorie gaps using our data on energy requirements. Defining poverty as a caloric deficit (negative consumption minus requirements) we find poverty rates well above official counts, even when we define poverty as a 20% caloric deficit. Like other poverty measures computed by Deaton and Dreze (2002) and Karan and Mahal (2005) the ratio of rural to urban poverty is much higher than official measures, and our measure is more highly correlated with low weight-for-age among children under age five. We also show that poverty rates are significantly higher for primary sector workers and lower for sedentary and secondary sector workers when occupation-specific calorie requirements are taken into account. The welfare implication of lower caloric requirements in our model is captured by changes in the non-food budget share conditional on expenditures and prices, and we use this approach to estimate expenditure-equivalent welfare effects. We find that urban areas are up to 5% better off due to lower caloric requirements, while the gains over time have been 2-3%. Sedentary workers have up to 5% greater welfare than primary and service sector workers.

Our paper contributes to the large literature on measuring poverty and nutritional status in India. Our paper is the first to use time-use data to impute caloric requirements and to analyze these requirements in tandem with caloric intake across a range of household variables, and we are the first to quantitatively assess whether the energy requirements hypothesis can explain India's missing calories. Our decompositions of the caloric decline is also novel to this literature. We also contribute to the literature on life-cycle expenditures and home production by analyzing time-use data alongside consumption data. Aguair and Hurst (2005) do this for the United States and Hicks (2010) does it for Mexico but to our knowledge there has been little work done on poor countries like India. Our findings contrast greatly with those in richer countries, as the decline in expenditures later in life coincides with a decline in caloric intake. We show that energy requirements are quite variable over the life-cycle, which combined with a smaller margin for substituting home production or shopping intensity for expenditures generates very different patterns.

Our work is also related to the literature that uses food Engel curves to measure CPI bias, most notably Costa (2001), Hamilton (2001), and Almas (2008). The model and findings of the paper suggest that energy requirements are likely to be an important factor in upward and downward shifts in food Engel curves. Attempts to use food Engel curve drift to measure CPI bias over time or across countries need to control for energy requirements explicitly unless the welfare effects of lower caloric requirements are meant to be included in the concept of CPI bias. Because our framework provides alternate measures of nutritional adequacy and well-being it is also related to papers that seek to broaden our set of measures for comparing living standards over time and space, such as Logan (2009).

The paper is organized as follows. Section 2 provides a model that guides our empirical analysis. In section 3 we examine the robustness of the decline in calories and its sources. Section 4 links energy intake and requirements across several household variables. Section 5 quantitatively assesses the energy requirements hypothesis for rural-urban differences and calorie consumption over time. Section 6 provides some new measures of poverty and hunger for Indian states and occupations as well as the welfare effects of lower caloric requirements, and section 7 concludes.

2. Theory

Suppose consumer's face a food subutility problem 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, C are calories in excess of minimum energy requirements, $\bar{C}$ are minimum energy requirements, p_c is the relative price of calories to quality (the price of food quality is normalized to one) and X_f are total food expenditures.

Solving this problem yields calorie demand:

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

which is increasing in food expenditures and minimum energy requirements, and decreasing in the price of calories relative to quality. We can also derive an expression for food expenditures per calorie consumed:

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

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 to consume additional calories.

Next consider the consumer's choice between food and non-food. We model this with a CES demand function in food and non-food subutility:

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

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 preferences for non-food and technology/variety. We can substitute this and 4 to get:

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

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 solutions are:

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

and $Q_{nf} = \frac{Y - X_f}{p_{nf}}$. Food expenditures rise in total expenditures but the food share is decreasing. Food expenditures rise in the minium energy requirement $\bar{C}$. If food and non-food expenditures are substitutes with elasticity $\sigma > 1$, food expenditures also increase in the price of non-food p_{nf} and decrease in the taste shifter for non-food γ_{nf}. The effect of a change in the price of calories relative to food quality (p_c) is ambiguous:

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

where $Z = (\frac{\alpha^\alpha (1-\alpha)^{1-\alpha}}{p_c^\alpha})^{1-\sigma} (\frac{p_{nf}}{\gamma_{nf}})^{1-\sigma}$. 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 very high expenditures relative to energy requirements the first effect dominates and food expenditures fall when the price of calories rises.

In terms of calorie demand, increases in the price of non-food and the taste for non-food only affect calorie demand through their effect on X_f so they increase and decrease calorie demand respectively. Note that they have no effect on the relationship between X_f and $C + \bar{C}$, which we call the calorie - food expenditure Engel curve. Changes in the price of calories (relative to food quality) and minimum energy requirements will now affect calorie demand directly through the parameters in equation 2 and indirectly through their effect on X_f. The effect of rising minimum energy requirements is unambiguous - the indirect effect reinforces the direct effect and calorie consumption increases. Both the food Engel curve (X_f given Y) and the calorie per food expenditure Engel curve ($C+\bar{C}$ given X_f) both shift up in $\bar{C}$. An increase in the price of calories decreases calories per food expenditure as household substitute towards quality, and it can be shown that this direct effect always outweighs the indirect effect on food expenditures so that the calorie total expenditure Engel curve shifts down.

So far we have taken expenditures U and the minimum energy requirement $\bar{C}$ as exogenous. We now consider a setting where they are linked. We can write the indirect utility function for the two-stage problem as:

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

where $\Omega = \frac{1}{1+Z}\left[\gamma_f^{\frac{\sigma-1}{\sigma}} + \left(\frac{\gamma_{nf}Z}{p_{nf}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$. Suppose now that total expenditures and total income are equal and are generated by $Y = wh^{\beta}$ where w is the individual wage (equal to their marginal product) and h is labor supply. The parameter β measures the return to labor supply and we assume $0 < \beta < 1$. The cost of additional energy intensive labor inputs takes the form of higher energy requirements, which are given by $\bar{C}^* = \eta h + H$ where η captures the cost in calories for extra labor inputs and H is exogenous energy requirements (possibly related to household tasks, transport, illness, etc.)

The household then maximizes the indirect utility function by choosing hours worked:

$$\max_h \Omega[wh^{\beta} - \eta h - H] \tag{10}$$

with the resulting solution $h = [\frac{w\beta}{\eta}]^{\frac{1}{1-\beta}}$. The labor supply h increases in marginal product and decreases in the cost η. If differences across households are driven entirely by differences in marginal products (w) then we would expect to see a positive correlation between total expenditures and minimum energy requirements, with the slope depending on the parameter β. If $\beta = 0$ so differences in income were only driven by differences in marginal product, and not energy inputs, then there would be no correlation between total expenditure and minimum energy requirements. Higher β would lead to a steeper relationship between total expenditures and caloric requirements - households with higher marginal product supply more labor which raises caloric requirements. While both caloric requirements and total expenditures increase in β, the effect is to increase caloric requirements for a given level of total expenditures as in equilibrium $\bar{C}^* = \beta Y$. The food expenditure - total expenditure Engel curve shifts upwards because caloric requirements are now higher for any given total expenditure. The calorie - food expenditure Engel curve also shifts up as holding food expenditure constant requires income to fall by less than β rises, leading to an increase in $\bar{C} = \beta Y \frac{1}{2p_c \frac{1-\alpha}{\alpha}}$ for a given X_f. These two effect reinforce each other and the calorie - total expenditure shifts up.

With variation in η across households we expect household with lower η to have higher expenditures, labor supply and minimum calorie requirements for any given distribution of marginal products. If households with higher marginal products also have a higher cost of labor supply then energy requirements may be relatively flat in total expenditures. However, variation in w or η does not affect the food expenditure - total expenditure or the calorie - food expenditure Engel curves. Unlike the β parameter or exogenous energy requirements (or income) they only produce movement along the curve.

Note that the effect of higher β is to compress the distribution of welfare for a given expenditure distribution. Because higher expenditure households also have higher energy requirements (all else equal), and utility is given by $V = \Omega[Y - \bar{C}^*] = \Omega Y[1-\beta]$, the 'slope' of welfare in total expenditure is lower relative to a world where energy requirements are exogenous.

The model suggests that evaluating welfare based on on total expenditures and failing to account for the minimum energy requirements would lead to misleading estimates. 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 $V\Omega\frac{1+Z}{Z}Y[S_{nf}]$ where S_{nf} is the budget share of non-food. This allows us to use the budget share of non-food to compute Engel equivalence scales. Provided that all of the other parameters are held constant the model predicts that households with a lower food share have higher utility because of their lower energy requirements.

We do not estimate this model structurally though we use the budget share of non-food to analyze welfare impacts of different caloric requirements. However, the intuition from the model guides our analysis for the rest of the paper. In particular, we take 7 lessons from the model:

1. The calorie - total 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.

3. Lower relative prices for non-food or rising taste/variety of non-food causes a downward shift in the FE but have no effect on the CF.

4. A higher relative price for calories relative to food quality leads to a downward shift in the CF and an ambiguous effect on the FE, though the former effect outweights the latter so the CE shifts down.

5. If the income generating process is more reliant on energy inputs, the calorie requirement - total expenditure curve will be steeper (and/or will shift up) and both the CF and FE shift up as well.

6. If expenditure and energy requirements are positively correlated then welfare inequality for a given distribution of expenditures is lower than in a context with negative or zero correlation.

7. Welfare comparisons that do not adequately account for minimum energy requirements are likely to be misleading and incomplete, and a simple Engel equivalence scale using non-food budget shares can be used to analyze the effect of calorie requirements on welfare.

3. Anatomy of the decline in calories

3.1. Calories per capita

The National Sample Survey (NSS) provides a recall-based measure of food quantities and expenditures consumed by Indian households since 1983. Consumption is measured at the level of the household using a 30-day recall period. An exception is the controversial 55th (1999-2000) survey round which used a 30-day and a 7-day recall period, leading critics to charge that using multiple recall periods biased upwards consumption measures over the 30-day period and led to overestimation of the extent of poverty reduction. While there are other nutritional surveys in India that cover individual villages or smaller regions, the only other dataset with comparable scope comes from the National Nutritional Monitoring Bureau which covers several states. Deaton and Dreze (2009) provide an overview of this evidence and 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 from the NSS data. We also present independent estimates calculated by other authors using the same data. Surprisingly the different studies disagree on both the direction and magnitude of calorie changes. While Deaton and Dreze (2009) find a large decline in rural areas and modest decline in urban areas, Chatterjee and Ray (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 and Ray (2007) find that in recent years urban India has higher per capita consumption of calories than rural India.

Deaton and Dreze also report calorie intake from an independent source, the National Nutritional Monitoring Bureau (NNMB), which records calorie data from mostly southern states through direct weighing of food or 24-hour recall. 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 Dreze.

As none of the studies make explicit the different steps of data-cleaning and calorie imputation it is difficult to pinpoint the reason for this divergence. In the data appendix we go through all of the steps for calculating calorie consumption in detail, documenting the numerous potential sources of bias in the survey and the sensitivity of calorie estimates to different assumptions. Broadly speaking 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 received and given by the household that bias either the numerator or denominator of household calories per capita. Our preferred calorie estimates are presented at the bottom of table 1. We use direct caloric conversion whenever possible and make adjustments for meals to and from the household that are not recorded in the consumption data. The group estimates impute calories for missing quantity/conversion factor items using an expenditure weighted average of calories per rupee of the entire food group, while the all food imputation imputes calories to all missing quantity/conversion factor items using a rate of calories per rupee equal to the household average divided by two. The measures agree quite closely though the imputation method is quite different. See the appendix for more details. Our estimates are fairly close to those of Deaton and Dreze, showing a much larger decline in rural than urban areas leading to a convergence of rural and urban calorie consumption.

Figure 1 presents kernel density estimates of the log per capita calorie consumption using the estimates corresponding to row 10. In 1983 the urban calorie distribution is shifted left of the rural one, but over time both have become more compressed and have become similar. The large downward shift in rural calories occurs because of a large decrease among households in the upper part of the distribution and a much smaller increase among households consuming below the average, while for urban households the shift has been more symmetric, resulting in a much smaller decline in mean calories per capita.

3.2. Calorie Engel curves

The decline in per capita calorie consumption in rural areas and the rural-urban difference are even more stark when presented through calorie Engel curves, which map log per capita expenditures on to log per capita calorie consumption. The expenditure measure used includes food expenditures along with several other categories - intoxicants, fuel and light, clothing and footwear, other nondurables, health, education, entertainment services, transport services, other services, and durables (which are calculated over the a whole year and divided by twelve). It excludes a few goods that are sometimes recorded by the NSS - taxes, water charges, and rent. Taxes are excluded because they are typically not considered consumption, and water charges are excluded because in some rounds they are not calculated independently of other taxes and cesses. The NSS records actual rent paid by households that pay rent, including rent on residential land and housing, but only records an imputed housing rent for urban households. Since we are unable to compare the value of the services provided by owner occupied housing and rental housing we simply omit all housing from our expenditure measure. To compare expenditures across periods we construct sector/period price indexes using the rural 50th round as the base. These indexes use median unit values as prices and combine food expenditures with intoxicants, fuel and light and clothing goods with recorded unit values.[1] The goods with unit values make up 58-83% of total expenditures depending on the sector and survey year (with the share being lower in later years and urban areas) and over 94% of expenditures on food, clothing and footwear, fuel and light, and intoxicants.

Figure 2 non-parametrically plots log calories against log real expenditures for different periods and sectors. We trim the 1% tails of the calorie and expenditure distribution and make a simple control for household demographics by restricting the sample to households with one adult male, one adult female, and three children.[2] In India calorie Engel curves appear to upward sloping over virtually of all of the real expenditure distribution. This upward slope makes the decline in calories between 1983 and 2005 even more surprising, as there has been 20-30% growth of mean real expenditures over this period for rural and urban areas. The only way to reconcile the rise in mean real expenditures and the decline in mean calories is if the calorie Engel curves shift downward, and figure 2 reveals that this has been the case. The urban calorie Engel curve is always below the rural one for the corresponding year, explaining why urban households that are richer on average consume less (or roughly equal in the later years) calories. The urban curves have a lower slope in the upper part of the expenditure distribution. The curves have also shifted downwards with a greater shift at the upper end of the expenditure distribution, which helps explain the inward shift of the right tail of

[1]We omit a few durable goods that have recorded quantities as the quality is likely to vary considerably and there is a lot of second-hand purchase, but these make up a very small share of expenditures.

[2]In the NSS adults are defined as age 15 or older. We defer a discussion of the role of household demographics in explaining caloric requirements and intake until later.

the calorie density distribution in figure 1.

We can gain more insight into the sources of the downward shift in calorie Engel curves by following the model presented in section 2. and decomposing the calorie Engel curve into a food expenditure - total expenditure Engel curve and a calorie - food expenditure Engel curve. The calorie - food expenditure Engel curve will reflect changes in relative prices, availability, and tastes for different foods as well as potentially changing caloric requirements, but will not itself be affected by factors that affect the food expenditure - total expenditure Engel curve, such overall food vs. non-food prices or changes in the availability or taste for non-food goods. Because food serves at least two purposes - direct utility and satisfying caloric requirements - movement in the calorie - food expenditure Engel curve is more informative about the tradeoff between these two purposes than the overall calorie - expenditure Engel curve, which also accounts for utility from all other consumption goods outside of food.

Figure 3 presents the food expenditure - total expenditure Engel curve. The most notable feature is that while the urban curves are slightly below the rural curves for 1983 and 1993, there is virtually no shift in the Engel curves for rural or urban households during this earlier period. However, there is a large downward shift for both sets of households in the later period from 1994-2005, with a more pronounced shift at the upper ends of the expenditure distribution. This implies that while factors like the relative food versus non-food price or the growing availability and social importance of education, clothing, consumer nondurables and durables might have squeezed calorie intake over 1994-2005 period and shifted the calorie Engel curve downward, they cannot explain the drop in calories over the earlier 1983-1993 period.

In this earlier period, changes in the mapping from a given level of food expenditure to calorie intake must explain virtually all of the decline in calories. We can see this clearly from figure 4 which presents the calorie - food expenditure Engel curve. There was a large downward shift in these curves over the 1983-1993 period but little to no change over the 1994-2005 period. The difference between rural and urban areas remains large throughout the entire 1983-2005 period, implying that rural households have always consumed more calories for a given food expenditure and continue to do so. Because the food expenditures are adjusted for prices this is not simply the result of higher urban prices and is instead due to a compositional effect. The stark difference in the source of the downward shift in calorie Engel curves over different periods argues strongly against a monocausal explanation.

Before analyzing changes in the composition of food expenditure in greater detail, we first explore the source of the downward shift of the food expenditure - total expenditure Engel curve. If real food expenditures and hence the budget share of food is lower for a given level of real expenditures, then there must be a corresponding increase in the share of some non-food expenditures. Figure 2 presents plots of budget share - real expenditure Engel curves for many 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 appear quite different across rural and urban households, but by simple accounting some of them must shift upward[3]. The upward shift is not uniform across the expenditure distribution and some categories with large shifts, like entertainment services, make up a very small share of expenditures. For households with higher real expenditures, education spending is the most important quantitatively accounting for up to half of the decline in the food share, though we emphasize that our sample is restricted to households with two adults and three children. Other services and transport services are also fairly important and durables are important for richer rural households. Fuel and light have increased for households across the real expenditure distribution. Poorer households have seen the largest increase in other nondurables and clothing.

While changes in relative prices across categories may explain the shifting Engel curves, another possibility is an increase in the variety of these goods available for purchase - this may mean the introduction of new goods or the diffusion of existing goods to remote households through advertising and advances in transportation infrastructure and retailing. Table 2 shows that the rise in budget share for other nondurables and durables corresponds with a large increase in the variety (measured as the number of distinct product categories) consumed

[3]The shares must sum to one at any particular level of real expenditure and the food share is shifted down at all levels of real expenditure

by households. There is a substantial increase in food variety over this period (see Li (2010)) but the growth of variety for other nondurables and durables is much larger. Clothing and other services have roughly similar percentage increases, while there is little growth or even negative growth for intoxicants, fuel and light, and entertainment services. Expenditure growth for fuel and light may thus be driven mainly by substitution - e.g. kerosene or gas for wood, dung cakes and coal, electricity for candles and matches - as the different products in the group perform similar functions. The proliferation of other nondurable goods - personal care and effects, toilet articles, and sundry - and consumer durables may also offer some simple trade-ups (e.g. motorcycles or autos for bicycles) but offers much more scope for new goods and consumption along an extensive margin.

It is difficult to test the role of relative price changes given our lack of data on prices for most categories, but we can at least compare the relative price of the aggregate food bundle compared to clothing, fuel and light, and intoxicants. The important caveat is that we are comparing unit values rather than real prices, and there is significant scope for quality upgrading in the clothing and to a lesser extent intoxicants category, while goods in the fuel and light category are fairly standardized. 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. The relative price of food fell in rural areas but rose in urban areas, but there was a similar pattern of downward shifting food Engel curves. 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 for both rural and urban households may be due in part to falling relative prices of these goods. However it is difficult to explore the role of relative prices between and non-food further due to the lack of data in the survey and the absence of highly disaggregated price indexes for India over our period.

The downward drift in food Engel curves has been observed in other studies, most notably in the US CEX by Costa (2001) and Hamilton (2001) but it is also present in the UK and Spain[4]. While one reason for this drift may be bias in the measurement of the price index used to deflate nominal expenditures, it is

[4]Author's calculations

difficult to rule out other factors like changing relative prices, new goods, and changing tastes, to which we must now add caloric requirements as well. The fact that Engel curves do not appear to shift in parallel and do not follow a systematic pattern suggests that substitution effects (that may vary with income) are likely to be very important, making it harder to use Engel curve shifts to estimate real expenditure effects. If our price index was biased downwards then other inferior goods like fuel and light or rural clothing, and goods with low income elasticity like entertainment and other non-durables, would not experience large upwards drifts, and we would not expect a downward drift in medical care which is highly expenditure elastic. These facts highlight the pitfalls of using food Engel curve shifts as a measure of CPI bias.

3.3. Changes in the food composition

The average real food expenditure has remained roughly constant over the 1983-2005 period. Using a fixed-weight index (with rural 1983 as the weights), the first row of table 4 documents that there was 6.7% real food expenditure growth in rural areas and 9.1% in urban areas. The second row uses the Tornqvist index and generates similar growth of 5.7% in rural areas and 7.3% in urban areas. However, as we have seen from the calorie - real food expenditure Engel curve in figure 4 there was a large decline in calories for any level of real food expenditure over the 1983-1993 period in both rural and urban areas, and the urban curves always lie below the rural curves. This is shown in the third row of table 4, where we document the relative calories per unit of real food expenditure over time and across sectors. As in figure 4 there is a much larger decline in calories per real expenditure for rural households than urban households, the decline mostly takes place in the earlier 1983-1993 period, and calories per real food expenditure are always lower in rural areas than urban ones. The size of the decline roughly mirrors that in figure 4 except here we pool all households regardless of size and we make calculations based on the average household.

To understand these facts we begin with simple pie charts showing the share of food expenditures across ten different food categories across rural and urban sectors in 1983 and in 2004-05. Figure 5 shows the importance of grains in food expenditures, especially for rural households, and the decline in grain consumption over time. Figure 6 shows the share of total calories coming from the different categories, and here we see that grains are even more important. Linking these two figures together are significant differences in the calories per rupee of expenditure of the different food categories, presented in table 3. Note that these figures are essentially the ones used to impute calories earlier, except in this table we only present results for the rural sector in 1983. 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. We see that relative to rice and wheat the price of calories varies across categories, across sectors and over time. Broadly we can think of three different factors that would affect calories per real rupee of expenditure - (1)changes in the shares of different food categories, (2)changes in inter-category relative prices, and (3)changes in the food composition within a food category (which also includes the effects of intra-category relative prices). This suggests a simple (non-additive) decomposition where we investigate each of these three factors in turn, where mean calories are given by:

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

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

We first explore the role of changing sectoral shares. We hold nominal food expenditures constant at the rural 1983 average and keep the calories/rupee conversion factors from the same sector/period, using this same conversion factor to impute the calories from expenditures that were not directly converted. We vary only the budget shares of the different categories. Row four of table 4 presents the results, where we normalize calories in rural 1983 to one. We see that the changes in sectoral shares can explain most of if not all of the differences in calorie per rupee of real expenditure across sectors and periods. Urban households and rural households in later periods simply spend a larger share of a given food budget on food groups with lower calories per rupee.

We next explore the role of changes in inter-category relative prices while holding shares and composition (calories per rupee) constant at the rural 1983 level. We do this by essentially multiplying nominal expenditures for each group in rural 1983 by a conversion factor equal to P_g/P_f, and using the 1983 rural calories per nominal rupee. We use fixed-weight indexes with 1983 rural sector as the base, but the results are similar using other base years or a superlative index. The fifth row of table 4 shows that this exercise actually tends to increase calorie consumption. This is because the prices of groups that have lower calories/rupee - such as meat, vegetables, processed food and beverages had among the highest rates of inflation while groups with higher calories/rupee, such as grains, oils, and fruits had the lowest rates of inflation.

Finally, we turn to intra-group prices and composition. We take shares and nominal expenditures fixed at rural 1983 levels and then deflate calories/rupee for each sector/period by the group-specific price index. Any differences in the calorie/rupee conversion factors are then due to the effects of intra-group prices and composition. The results are presented in the sixth row of table 4, which reveals that the intra-group differences play a relatively big role in explaining the rural-urban gap but are not very important for explaining changes over time. Urban households may face relatively higher prices for high calorie/rupee goods within each group and/or they may consume a more expensive (per calorie) basket for a variety of reasons.

The changes in group shares appears to be the single most important factor generating differences in calorie per rupee of real expenditure, while intra-group composition and prices play some role in the rural-urban gap and inter-group relative prices partly offset the decline in calories over time from the other two factors. These channels are by no means independent. Panel A of figure 7 shows that categories with prices that rose faster had rising shares on average, though the effect is mainly driven by grains and oil - the relationship is relatively flat otherwise. Panel B shows that there is not much of a relationship between changes in shares and changes in the real price per calorie across categories. However, from Panel C we see that categories that experience more rapid inflation of the fixed quantity basket also tended to have more rapid growth in calories per real rupee - this suggests that composition effects and intra-group relative prices in each category partly offset changes in the inter-group price index. Groups like fruit that have low group inflation see intra-group shifts towards goods with lower calories/rupee, while groups like sugar and processed food experience the opposite. Panel D shows that groups with the highest calories per rupee- grains and fruit - have seen stagnant or declining shares while those with low calories per rupee like vegetables and dairy products have seen the largest increases in shares.

Overall, the evidence on compositional shifts argues against an interpretation of declining calories based on rising relative prices for food calories versus quality. If anything, the relative price of calories compared to food quality has fallen over this period as basic grains experiences the lowest inflation rate. The pattern of inflation and substitutions is thus more consistent with a demand-side story whereby lower caloric requirements increase demand for higher quality goods (those with lower calories per rupee) which in turn increases relative prices for these goods.

4. Relating caloric intake to activity levels in the cross-section

4.1. Imputation of energy requirements

We impute energy requirements for each household using the India Time Use Survey (TUS), which is carried out by the National Sample Survey Organization independently of the NSS consumption surveys but follows a similar format. 18,620 households were interviewed between July 1998-June 1999 in six Indian states - Haryana, Madhya Pradesh, Gujarat, Tamil Nadu, Orissa, and Meghalaya. The surveyors attempted to interview each member of the household over age 5 their time-use over the preceding 24 hour period, with busy, reluctant or incapable members having 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 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. Time-use is recorded in 20 minute increments and is classified into 154 different types of activities.

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. Roughly speaking, activity level 3 corresponds to heavy manual labor (e.g. ploughing, preparing land, cleaning of land, wood cutting, chopping and stocking of firewood, building and construction of dwelling), activity level 2 corresponds to moderate labor involving manual tasks and movement that is not overly strenuous (e.g. cooking, sweeping, assembling machines, equipment and other products), activity level 1 corresponds to sedentary labor (service in government, professional work, reading, watching tv) and activity level 0 corresponds to rest (e.g. sleeping, 'doing nothing, rest and relaxation'). We take as the baseline caloric requirements those corresponding to a 70 KG 26 year old man with activity level 3 requiring 320 calories per hour, activity level 2 requiring 192 calories per hour, activity level 1 requiring 110 calories per hour, and activity level 0 requiring 64 calories per hour.

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. Figure 8 shows that BMR varies significantly with age, starting out higher for women but rising more rapidly for men initially and peaking much later. 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 are likely to be a reasonable approximations given the figures based on an average child growth chart combined with the extra energy requirement for lactating mothers. Unfortunately we do not have data on whether women in the household are pregnant, which means that we are likely to underestimate the calorie requirements for pregnant women by about 300 calories per day according to the ICMR.[5]

The ICMR also 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 lifecycle 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 major 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 which would make a large difference to the energy expended. This issue 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

[5]While there is a category for baby food in the NSS our understanding is that breastmilk is not included in consumption estimates.

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 5 presents some summary statistics to compare the 1999-2000 NSS consumption data and the 1998-1999 Time Use data for the urban and rural sectors of the six states in the Time Use data. Restricting to these 6 states gives us 29,415 households in the NSS data and 18,571 in the TUS data. The first row presents the per capita caloric requirements we impute from the TUS and the calorie consumption we impute from the NSS using group calories/rupee for items not converted directly. According to these measures urban households are generally in energy surplus and rural households are in energy deficit. Note that the NSS data for these six states shows higher per capita calorie consumption in urban areas than rural areas, though given much higher urban expenditures per capita the urban calorie Engel curve will still lie well below the rural one. The second row presents an alternate measure of per capita caloric requirements based on daily recommended intakes from the Indian Council for Medical Research (ICMR). We classify adults into heavy, moderate, and sedentary work based on their industry and a work status variable.

The ICMR generally finds higher per capita caloric requirements due to two factors - it assumes children under age 13 require more calories than implied by our direct imputations, and it assumes that adults performing heavy activity require more calories than implied by our direct imputations. In particular, the daily recommended intake of 3800 calories for adults doing heavy labor is much higher than what we find by direct imputation for the same rural (3275) and urban (2865) adult workers that we classify as heavy labor. The second row also presents our alternative measure of calorie consumption for the six states in the TUS that imputes missing calories using total average calories per capita instead of group averages. The other variables in the two datasets appear quite similar, though there is some discrepancy in household size and monthly per capita expenditure (MPCE), which are both a bit higher in the NSS. The difference in household size is a bit of a mystery though it does not appear to be driven by adults aged 19-59 (rows seven and eight).

The difference in expenditures may be due to well known recall biases whereby recalled expenditures are higher when households are asked for expenditures on a long list of specific items rather than for a single measure. Households were also asked to recall expenditures over a seven day period in the 55th NSS round which many have argued biases expenditure estimates up as well. As a result of these differences in the way expenditures are measured, which may carry over to imputation of calorie consumption, it is dangerous to interpret the expenditure and calories requirements/consumption across the two surveys in level terms. In the next section we simply examine percentage deviations in our caloric intake and requirement measures due to different households variables so these level differences are unlikely to matter, but we return to them later when analyzing poverty.

4.2. Demographics and lifecycle effects

Household demographics always play an important role in household purchase decisions, but they potentially operate through multiple channels - contributions to total expenditures, effects of sharing rules and intra-household bargaining and allocation, and also through their different contributions to household-level caloric requirements. As figure 8 shows there is significant variation in caloric requirements by gender and age even without differences in activity levels. To assess the impact of household demographics we take our total household caloric intake and caloric requirements from the NSS and TUS and regress them on the number of household members by gender and by different age categories - seniors (aged 60 plus), adults (19-59), youth in the 16-18 and 13-15, children in the 10-12, 7-9,4-6, and 1-3 ranges and infants under 1 year of age.[6] We use village/block dummies so we only compare households within a specific area. We also consider a cubic in per capita expenditure to distinguish effects on caloric demands that may be due to income effects from those due to demographics holding total expenditure constant. We take the ratio of each gender/age class coefficient relative to adult males aged 19-59.

The results of the household decomposition are presented in the first two columns of table 6. We see that the calorie demand ratios by gender/age class

[6]Except for seniors these correspond to the categories in the ICMR daily recommended intakes.

are highly correlated with calorie requirement ratios - the correlation coefficient is 0.83 for these two series. The third column presents average caloric intake for individuals in each class. Because the TUS has data on individual activities we can use this directly instead of aggregating to the household level and then using a linear regression for the decomposition but the results are broadly similar. Columns four and five present results controlling for a cubic in household monthly per capita expenditures (MPCE). The patterns are very similar whether or not we control for expenditures.

Table 6 broadly reflects the pattern in 8 with seniors and children contributing less to caloric requirements than adults, and this pattern also holds for their contribution to household caloric intake in the decomposition. Compared to adult males, senior males and females contribute relatively more to calorie intake than they do to calorie requirements. When not controlling for household expenditure children under 16 contribute relatively more to requirements than intake, but this effect is less evident when controlling for income. Female infants appear to contribute noticeably less to caloric intakes than their male equivalents, but this is the only age group where there appears to be significant discrimination against female children. Because we do not observe caloric intake directly, any assessment of distributional issues within the household is necessarily speculative. However, our results clearly indicate that demographic structures are likely to cause large differences in caloric intake across households that correspond to differences in caloric requirements.

The results of table 6 assume linear effects of the number of household members of different types on energy requirements and consumption. This may be limiting if larger households experience economies of scale. For example, holding expenditure per capita constant larger households may have more leisure time if home production activities experience economies of scale - if two household members take turns cooking and cleaning it may result in lower average energy requirements for both. This superior home production technology may in turn influence food expenditure patterns, leading household to purchase less prepared meals on the margin.

Table 7 confirms both of these hypotheses by presenting results of OLS regressions of log household calories consumed and required on household composition variables (the ratios of the number of individuals in each class from 6 to household size), a cubic in log MPCE and the log of household size. The first column uses caloric intake from the NSS and indicates that doubling household size holding composition and per capita expenditures constant lowers calories by about 2.6%. This is the well known 'Barten paradox' discussed by Deaton and Paxson (1998) - given that calories are an exludable, private good we would expect an elasticity greater than one with respect to household size holding per capita expenditure constant. Households would economize on certain shareable goods like housing and durables and would therefore spend a greater share on food (and hence calories).

The results in the second column that use caloric requirements provide one possible explanation for this paradox. The elasticity of household calorie requirements to household size is virtually identical to the elasticity of household calorie intake. Larger households benefit from economies of scale on the energy expenditure side. These effects could operate both through market work (with higher paid household members supplying more labor) and home production activities like cooking, cleaning, laundry, shopping, childcare, etc. Column three indicates that most of the effect is driven by food expenditures, as there is only a slight decrease in calories conditional on food expenditure when household size doubles (column four). This zero effect on calories conditional on food expenditure might be expected if the reduction in energy requirements (which predicts a fall in calories per food expenditure) is accompanied by a superior home production technology for converting unprocessed food in tasty calories (which predicts a rise in calories per food expenditure) and the two effects cancel out.[7]

In addition to the effects of household composition there are additional lifecycle effects for adults. There is a growing literature addressing lifecycle consumption in developed and developing countries (see Aguair and Hurst (2005) for the United States and Hicks (2010) for Mexico). This literature generally finds that households are able to smooth out calorie consumption over the lifecycle, relative to the hump-shaped profile of food and total expenditures, by substituting towards greater home production and cheaper calories upon retirement. How-

[7]We have not explored this finding in greater detail as it takes as far from the main subject of this paper, but we plan to explore it in future work.

ever, we find that for India there is a steep decline in calorie intake after middle-age, but that this can be largely explained by a decline in caloric requirements of a similar magnitude.

To analyze life-cycle effects we use the average age of all household members over age 18. We obtain similar results if we restrict to one male, one female adult households and use their average age. We then control for household demographics - the number of men, women, boys and girls in different age categories. We then regress log household calories on these controls and on a series of dummy variables for mean adult age beginning with 23-27 and continuing with five year intervals up to 73-77. The omitted category is 19-22 year olds, so that these dummies have the interpretation of percentage deviations from the caloric intake or requirements of otherwise identical households with head/average age 19-22.

Figure 9(a) presents our first plot of these dummies without any controls for expenditure. The solid line represents percent deviation in caloric intake relative to households with mean age 19-22 and the dotted line represents energy requirements. [8] Energy consumption and requirements track each other fairly closely over the lifecycle. 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 intake versus requirements than younger and middle-aged households. The large decline in caloric intake in old age contrasts with findings from the United States and Mexico, but at least in India it is reasonable to conclude that the decline is related to a decline in caloric requirements and not just impoverishment at older ages.

Figure 9(b) presents the same results including a cubic in log expenditure in the regression, so we are netting out lifecycle effects on expenditures. This is especially important if expenditure-selective mortality changes the composition of household in the later years (which might lead us to underestimate the decline in caloric intake or requirements, as the poorest households with low intake and/or requirements are negatively selected). The decline in caloric intake is smaller at

[8] Note that since both energy consumption and energy requirements are relative the 19-22 year old levels we cannot interpret the distance between the two lines as a measure of net energy consumption.

older ages, suggesting that the main mechanism driving the decline in caloric intake is the decline in total expenditures of about 20%, shown in in figure 10.[9] In fact, it turns out that there is relatively little adjustment over the lifecycle in food expenditure per total expenditure (figure 11(a)) or in calories per food expenditure (figure 11(b)). There appears to be relatively little margin for substitution to home production over the lifecycle, which may simply reflect the fact that home production in poor counties like India is already relatively high - very little processed food or meals out are consumed, so there is not much scope for older households with less market work to substitute time for expenditures on food and calories.

Note that none of this analysis incorporates cohort effects, in order to compare the NSS and TUS directly. However, using multiple cross-section and controlling for cohort effects yields similar patterns.

4.3. Occupation and education

Household occupation and education are related to expenditures, caloric requirements and caloric consumption. Simply comparing households in different areas or periods confound location-based factors that affect caloric intake and requirements with occupation-based factors. If we can compare households with a similar occupation - e.g. self-employed not working in agriculture, or professionals - we can isolate the differences in calorie intake and requirements that are due to work-related and non-work related factors.

The NSS and TUS data offer two ways of classifying households by occupation. Household type is a classification of households based on the most important economic activity (the one that brings in the most income or in kind value). Households are broken up 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. While this measure does not capture length of intensity of the work day or the occupations of spouses and extended family, it enables us to the NSS and TUS data by a common variable and thereby analyze correlations between caloric in-

[9]The decline is slightly larger in the TUS data but there are not a lot of observations at the highest age groups.

take and requirements across these household types. We can also condition on expenditure, thereby isolating the shifts in the calorie Engel curves that are of interest from movements along calorie Engel curves due to higher remuneration from some occupations.

The top panel of table 8 presents the results of our household type regressions. We control for household composition, household size, a cubic in expenditure and use village/block fixed dummies. The variables of interest are the coefficients for the four rural and three urban household type dummies, which give the percent difference in calories intake and requirement relative to the omitted categories - other rural and other urban[10]. The correlation across household types between caloric intake and caloric requirements is 0.87. 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 rural and urban other have both the lowest caloric intake and requirements. [11] These patterns are even stronger with respect to calories conditional on food expenditure - household types with higher caloric requirements tend to consume lower quality calories, consistent with the model presented earlier. There is also some adjustment along the food expenditure per total expenditure margin, especially for self-employed in agriculture households that may face a lower shadow-price for food since they own their production.

The middle panel of table 8 uses occupational classifications from the National Classification of Occupations (NCO). These are based on the main occupation of the household rather than industry, 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 calorie intake and requirements across occupations is 0.88, with primary, secondary, and service workers clearly consuming and requiring more calories than more sedentary professional, administrative and cler-

[10]Note that these categories include professionals as well as wage/salary workers in rural areas

[11]Note that these results do not take into account rural/urban differences in prices, home production, secondary occupations and occupations of other household members, etc. so even relatively similar household types, like rural self-employed non-agriculture and urban self-employed, or rural other labor and urban casual labor are not exactly comparable.

ical workers.

As an alternative to household types we can also use education variables. Education is likely to be highly correlated with different occupational classes with more educated households performing more sedentary tasks and requiring less energy. While more educated households are likely to have much higher expenditures and hence higher food expenditures and calories, conditional on total 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 8 confirms our expectation that conditional on total expenditure and household composition households with more educated heads have lower calorie requirements. This may occur both because higher hourly wages enable the household to work less total hours to achieve a given level of total expenditure, or because the calorie requirements per hour of work are lower. These differences in caloric requirements are reflected in the caloric intake of these households almost one for one. Households with a college educated head consume 10% calories and require 12% less calories than illiterate households conditional on expenditure. Unconditionally they have higher expenditures which increases their calorie consumption. In graphical terms the calorie Engel curves for more educated households are shifted down, but higher expenditures produce movement along the curve that usually overhwelms the downward shift. Once again we see that most of the adjustment in caloric intake occurs along the ‘quality’ margin of calories per food expenditure and no the ‘quantity’ margin of food expenditure per totale expenditure.

We also consider a more continuous variable by assigning years of schooling to each of the education classes above and taking an average over all adult household members. In addition to our usual controls we use dummies for each 1 year average adult education interval. Figure 12(a) presents the results for total calories, which echo the findings in the bottom panel of table 8, and figure 12(b) confirms that similar patterns hold for food expenditures and calories per food expenditure.

4.4. Other factors

There are several other variables in the NSS data that may be related to energy requirements but cannot be linked with the TUS data. While coverage varies between survey years, many 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 potentially 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 transports all would be expected to reduce caloric requirements. Conversely using wood for cooking would tend to increase caloric requirements since gathering and/or transporting wood is more energy intensive than other cooking fuels. Television ownership could potentially lead to more sedentary leisure activities or influence food consumption patterns in other ways. The effect of bicycles is a bit more ambiguous as cycling saves energy relative to walking but if it substitutes for animal or motorized transport, especially over 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. Table 9 presents our results, which follow a fairly predictable pattern except for the finding that owning a bicycle has little to no effect on household calorie intake. The biggest reductions in calorie intake come from owning motorized transport (5.1%), using electricity (3.6%) and owning a washing machine (3%). Using wood for cooking increases calorie intake considerably by 6.7%. Most of the effect operates through calorie quality, with the notable exception of motorized vehicles (though this would be expected if costs of fuel and maintenance of these vehicles depressed food expenditure for a given total expenditure). The substitution of non-human for human power sources - whether through fuel to operate motor vehicles, electricity for household appliances, or denser cooking fuels with a lower complementary human power input -clearly has a large effect on caloric intake. From the TUS we see that free collection of goods (including wood for cooking) and household maintenance take 53 and 459 minutes per day for the average household respectively, so the potential household energy savings from replacing human power with non-human power sources is quite large.[12]

5. Quantitative assessment of energy requirements hypothesis

We demonstrated in the previous section that there appear to be close correlations between caloric requirements and caloric intake across a range of household variables, including household demographics, occupation/education, and some other household variables that relate to human versus non-human power sources. We now turn to the central question of the paper - can these differences explain the large gaps in calorie Engel curves between rural and urban areas and over time, thereby providing support for the hypothesis that differences in energy requirements have driven the decline in caloric intake in India?

In attempting to reduce the unexplained shifts in calorie Engel curves by adding controls, it is important to emphasize that we are looking for variables that both (a)have a large effect on caloric intake and requirements and (b)vary significantly across rural and urban areas over time. While all of our controls have been shown to satisfy (a), many of them do not satisfy (b). Table 10 provides summary statistics across the years and rural/urban sectors in the NSS data. Most notably the differences in demographic variables do not appear to be very large over time or across sectors, but there are substantial differences for education, occupation, and our other control variables. These are thus the variables that are most likely to explain the 'unexplained' gaps in caloric intake that we observe.

[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

5.1. Rural-Urban Gap

We begin by analyzing the unexplained rural-urban calorie gap that exists for the six states common to the 55th NSS round and the TUS. The first row of table 11 presents baseline estimates, equivalent to the average gap between rural and urban households in figure 2. We estimate the gap parametrically by regressing log household calorie consumption on log household size, a cubic in log per capita real expenditure and an urban dummy and report the dummy and its standard error in the table. While the urban dummy is as high as 17.6% when we use nominal expenditure per capita, when we adjust urban expenditures downwards by 15% to account for higher urban prices the gap falls to 12.5%.[13] When we repeat this regression using calorie requirements instead of consumption, we find a 9.8% gap.

We proceed to augment the baseline regression by adding other variables in sequence. The second row of table 11 adds our controls for demographic composition (ratios of males and females in adult and various child age classes) and dummies for average age class of adults. The third row adds dummies for average adult years of schooling and head of household education level. The fourth row adds dummies for household type and NCO occupation, which allows the rural-urban dummy to capture location-specific effects rather than occupation effects.[14] The fifth row adds the other household variables from table10 such as electricity, use of 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%), but keep in mind that some of these variables are likely to have direct food expenditure displacing effects (e.g. expenditures on electricity or fuel for motor vehicles). The last two columns of table 11 break down the calorie gap into calories conditional on food expenditure and food ex-

[13] As before we use all unit values in the NSS to calculate our rural-urban price index, and apply it to both NSS and TUS expenditure estimates. Our urban expenditures exclude imputed house and garage rent to be fully comparable since only urban households are asked this question.

[14] The omitted categories imply that the rural-urban dummy is comparing self-employed or wage earning professionals.

penditure conditional on total expenditure. Most of the reduction in the unexplained rural-urban calorie gap as we add our controls occurs along the calories per food expenditure margin, which veers into positive territory when we use the full set of controls. The unexplained part of the rural-urban food expenditure gap given real expenditures only falls by 42% when we add our controls. Thus the factors we think are related to energy requirements operate mostly on the calories per food expenditure margin and have a much smaller impact on the food expenditure per total expenditure margin. This is consistent with our theory, as a large number of factors may influence the division of expenditures between food and non-food but a fall in calories per food expenditure (or rise in food quality) is only driven by falling caloric requirements.

To gain more insight into the source of calorie requirement differences across sectors we can compare time-use in specific categories for rural and urban households. Table 12 presents the results, broken down by sector and by household, adult male, and adult female. We see that 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 roughly the same amount of time on market, non-market, and leisure activities but the composition of market activities vary greatly. Urban males work mostly in the tertiary or service sector, while rural males work mostly in the more calorie intensive primary sector. For females the story is different. 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. Altogether these results suggest that rural males require more energy on the intensive margin (calories per hour of market work) while rural females require more energy on the extensive margin (they have less leisure and instead do labor intensive market work). It is thus not surprising that when we use our occupation dummies and compare urban and rural households engaged in services (which more or less overlaps with our non-agriculture, non-laborer excluded category) the rural-urban gap is reduced substantially. When we control for some factors that might affect free collection or home production, we further reduce the gap, though mostly on the calories per food expenditure margin.

5.2. Change over time

To quantitatively assess the impact of changing energy requirements on calorie consumption over time we rely only on the NSS data. We do not have time-use data for multiple periods so we are unable to directly verify that caloric requirements fell over time. However, we feel confident in interpreting our variables as stand-ins for changing energy requirements since we have already shown that they affect calorie intake and requirements in the cross-section. We thus follow a similar procedure to the cross-section case, beginning with a simple specification that captures the unexplained or puzzling gap between calorie Engel curves, and then adding our controls in sequence to see how much of the gap can be explained by the energy requirements hypothesis.

We present our results in the top panel from table 13 where the rows show the dummies for different year/sectors relative to the rural sector in 1938. Each column 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.[15] Unlike the rural-urban comparison above, we use all data from the 17 biggest states in India and Delhi (which explains in part why the rural urban differences are different for the 1999-2000 NSS round). Once again our baseline uses log household size and a cubic in log real expenditure (the base year/period is the rural sector of 1983 and we use a Tornqvist index).

Column one 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. This is much smaller than the reduction in the rural-urban gaps, which fall by well over 50% for all years. Once again the biggest effects come from education, occupation

[15]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 whether the household has expenditures on petrol. Non-labor income and kitchen garden are also not available for all survey rounds and are excluded.

and other variables with little role for demographics.

The middle panel reveals that the our control variables account for very little of the changes in food expenditure conditional on total expenditure - between 7.6% (urban) and 16% (rural) of the decline over time. It thus appears there is another force depressing food expenditures, especially in the 1993-2005 period when most of this decline occurs, that is not captured by our set of variables. The bottom panel shows that our variables do a much better job of capturing changes in calories conditional on food expenditures - 42% in rural areas and 60% in urban areas. This is reassuring for the energy requirements hypothesis since declines in calories given food expenditure are the surest indicator of declining energy requirements in our model. Declines in food expenditure given total expenditures could occur due to many other factors, including changes in relative food/non-fiid prices, the introduction of new goods, or bias in our price index.

To explore this result further we consider three other specifications. First, we drop the 38th round which enables us to use a larger set of household type and durable ownership controls. When we do this, we find that the share of the decline in calories conditional on total expenditures that we can explain with our variables rises to 23% in rural areas and 35% in urban areas. This rises to 41% (rural) and 100% (urban) when we use calories conditional on food expenditure. This increase in explanatory power appears to be mainly driven by improved fit of our variables and the inclusion of additional ones. Second, we estimate our equations separately by sector, which allows the control variables to have different effects for rural and urban households. The results are little changed.

Third, we estimate the decline 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. The decline is similarly about 7% greater for self-employed agricultural households relative to self-employed non-agricultural households or other rural labor households (but only 2% greater for agricultural laborers). As the differential decline occurs *within* occupation classes it is not picked up by the inclusion of occupational dummies, which only capture the effects of movement across occupations/household types and their average caloric intake differences (over all periods). A similar pattern also occurs looking at the decline in calories conditional on food expenditure by occupation. This would suggest that significant changes in energy requirements within agriculture - perhaps due to shorter work days, substitution towards animal and mechanized inputs, or changes in crop mixes - are playing an important role in the unexplained decline in calorie consumption. As the NSS data does 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 our finding of differential declines across occupations is certainly suggestive.

6. Measuring poverty, hunger and welfare with caloric requirements

We now consider the implications of variable caloric requirements for measurement of poverty, hunger and welfare. The previous analysis only used percent differences in calorie requirements and consumption so mismeasurement of levels was not an issue. In the case of calorie deprivation, however, use of our measured calorie requirements (or of the original 2400 rural and 2100 urban requirements proposed by the National Planning Commission) and calorie consumption to compute poverty leads to much larger measured poverty. We therefore also consider a definition of poverty or calorie deprivation based on calorie intake 20% below requirements.

We begin in table 14 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 - Gujarat, Haryana, Madhya Pradesh, Orissa, and Tamil Nadu. The first column presents the 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, which results from a significant increase in the ratio of rural to urban poverty lines (driven mainly by a fall in urban poverty lines). The third column presents a 'nutritional adequacy' poverty measure computed by Karan and Mahal (2005). Karan and Mahal (2005) take daily recommended intakes of a variety of nutrients from the Indian Council for Medical Research and then use linear programming methods to determine the least-cost bundle of food that satisfies these requirements (subject to some 'palatability constraints'). They assume all rural adults are manual workers and all urban adults are non-manual workers. Their resulting poverty headcounts are significantly higher in rural areas than the official measures but they find urban poverty is much lower. The fourth column presents the share of children under age 5 in each state that are undernourished from the NFHS (2007), where undernourishment is defined as weight-for-age two standard deviations below the WHO reference growth charts Menon and Bhaskar (n.d.). Undernourishment of children under five is significantly higher than any of the poverty headcounts and above the nutritional adequacy measure in 3 of the 5 states.

Our first calorie-based measure of poverty uses our preferred estimates of calorie intakes and calculates the share of the population that consumes less than 2400 in rural areas and 2100 in urban areas. This leads to much higher poverty rates than official measures in all of our states and sectors except for urban Orissa. Because our own imputed energy requirements differ from the 2400/2100 cutoffs and also vary across our states and sectors we perform a similar calculation using per capita average rural and urban caloric requirements for each sector. The ratio of rural to urban poverty lines is much higher than the official ratios, reflecting the fact that rural energy requirements are lower but not that much lower than urban energy requirements, which leads to significantly higher poverty in rural areas. There is some variation across states, as evidence by a 6 point rise in poverty in urban Gujarat and an 8 point decline in rural Haryana compared to the 2400/2100 cutoffs. Because our imputed levels of caloric requirement and intake may be biased, and because a small deficit in caloric intake relative to requirements does not accord with our concept of poverty or hunger, we also compute a poverty rate based on the share of the population consuming 20% below our state/sector average caloric requirements. This lowers poverty rates considerably and makes them more in line with official estimates, though we still find significantly greater poverty in most state/sectors, with the exceptions being urban Madhya Pradesh and rural and urban Orissa. The last two columns of table 14 estimate non-parametric calorie requirement and calorie intake Engel curves and use the level of expenditure per capita where they intersect as the poverty cutoff. Households with expenditure below this cutoff are considered poor. This measure generally accords with the use of state/sector averages, though there are some important differences - in particular poverty rates based on a 20% or greater energy deficit are much lower under this measure.

Note that our measure of poverty accords much better with the share of children under five that are undernourished. While the measures of the first three columns all point to Orissa being the state with greatest poverty, the child undernourishment measure puts Orissa right alongside Haryana which has much less measured poverty and significantly below Gujarat. Thus while our measure may not accord well with some concepts of poverty - especially those based on a consumption of a balanced diet or consumption of non-food goods - a calorie intake/requirement based measure of poverty appears to correspond more closely to a hunger-based conceptualization of poverty. Table 15 presents poverty gaps and calorie gaps for our measures. Our poverty gaps are computed in standard fashion using the cutoff per capita expenditure levels from the intersection of calorie requirement and intake Engel curves. The calorie gap is computed like a poverty gap as the average calorie deficit for all households with a calorie deficit (with calorie surplus households counting as zeros), as a fraction of energy requirements. We use the 2400/2100 cutoffs and our state/sector averages. The last two columns offer a slight modification of the calorie gap - using our calorie requirement and intake Engel curves, we estimate the predicted calorie deficit as a function of expenditures. We then integrate over the expenditure distribution to get the calorie gap. The main difference from standard measures is that we allow calorie requirements to vary with expenditure as well, so that lower expenditure households may have higher/lower energy requirements. We generally find that calorie gaps are much lower than poverty gaps, but that both our poverty and calorie gap measures based on a 20% calorie energy deficit cutoff are much larger than the official or Deaton and Dreze (2002) measures with the notable exception of Orissa.

We next turn to poverty by occupation in table 16 for the state of Madhya

Pradesh. We group professional, administrative, clerical, and other occupations as sedentary, and compare them to the primary, secondary, and service/sales sectors. We then compute poverty headcounts, poverty gaps and calorie gaps based on the intersection of calorie consumption and requirement Engel curves, or the 20% energy deficit threshold using both average sector energy requirements or occupation specific requirements. We see that with common energy requirements primary and secondary sector households tend to have higher (and quite similar) rates of poverty and calorie deficits, whether we use the intersection of the two Engel curves or the point where the deficit reaches 20%. This is solely due to the distribution of per capita expenditures for each occupation group. When we use occupation specific energy requirement Engel curves, poverty and calorie deficiency fall significantly for sedentary and secondary occupations in both sectors. Poverty and calorie deficiency remains constant or even rises among primary sector households, and there is also an increase in poverty and calorie deficiency for households in the urban service/sales sector (and for the less extreme poverty/calorie measure in the rural sector as well). Incorporating calorie requirements into the analysis of hunger and poverty thus significantly changes the distribution of poverty across occupation classes towards energy-intensive primary sector workers and away from sedentary workers.

Finally, we provide one possible estimate of the welfare gains from lower caloric requirements motivated by the simple model of section 2.. Recall that holding relative prices and tastes constant we showed that utility is proportional to $Y[1 - S_f]$ or $Y[S_{nf}]$. S_f and S_{nf} depend only on expenditures and caloric requirements in this case. This motivates a simple equivalence scale for the welfare gain from lower caloric requirements, where we regress the log of the non-food budget share $log(S_{nf})$ on log per capita expenditures (deflated by the appropriate price deflator) and household size and dummies for different periods, sectors, and occupations. The coefficients on the dummy then represent approximate welfare gains in expenditure equivalents. Table 17 presents the results. The first row estimates that the non-food budget share is 5.6% higher in urban areas conditional on expenditures and household size. We cannot interpret this effect as a pure welfare gain because relative prices, variety and tastes may also differ across sectors. However, we can show directly that the coefficient on urban areas falls to about 0.5% when we add our controls that proxy for energy requirements. This suggests that the total average welfare gain to urban areas relative to rural areas from reduced caloric requirements is on the order of 5.1%.

Rows two and three perform a similar analysis for shifts in the non-food budget share over time. While there is a very large percentage rise in non-food budget share at any level of expenditures, our energy requirement proxies only have limited success explaining this rise and consequently we estimate the average welfare gain to be 3% in rural areas and 2.3% in urban areas. Of course the gains could be larger and we cannot conclude that our proxies for energy requirement are exhaustive, and changes in relative prices, tastes, or new goods could bias these welfare estimates. We are thus cautious in interpreting these welfare gains, and recognize that shifts in food and non-food Engel curves could be due to any number of unmodelled factors and are likely to be an unreliable source for estimating changes in welfare (or CPI bias) over time.

Perhaps more reliably we compare the effects of different occupations on the log non-food budget share. This avoids large potential changes in tastes and relative prices that could confound the estimated welfare effect of lower calorie requirements and is closer in spirit to Engel equivalence scales. Here table 17 compares professionals to other occupations, and we find that primary, secondary and service sector workers are significantly worse off than the sedentary professions at the same level of expenditure - their welfare is 3-6% lower due to their need to consume significantly more calories. Our model and results so far indicate that these welfare losses are likely to take the form of lower food quality and lower expenditures on non-food goods.

7. Conclusion

The findings of our paper indicate that the energy requirements hypothesis has significant explanatory power for patterns of calorie intake in India. In particular, along the dimension that we identify as most directly related to energy requirements - calorie intake conditional on food expenditure, or calorie quality - our set of demographic, education, occupation, and durables variables explain all of the rural-urban gap and a majority of the changes over time. However, there are large shifts in food Engel curves, particularly between 1994 and 2005, that are not well explained by our control variables. While there may be some substantial changes in energy requirements that are not captured by our variables, we suspect that other factors like the rising accessibility of new goods and rising returns to education play an important role as well. Because of the difficulty of measuring these factors with the available consumption data, any discussion of the source of the remaining missing calories is bound to be speculative. However, in light of our simple model and the tendency for the energy requirements hypothesis to show up primarily through changes in calorie quality, the data seem to indicate that declining calorie requirements are driving some of the downward trend in calorie consumption in India with important welfare gains to households.

An obvious extension of our research would be to examine consumption of other nutrients. While other studies have gone into greater depth in analyzing nutritional adequacy, the link between household activity levels and requirements for different nutrients is more complicated as the proble becomes multidimensional nutritional requirements do not all scale up with calorie requirements. Nevertheless, a notion of hunger or food inadequacy based only on calories is likely to be misleading - we find relatively low calorie deficits in Orissa, the poorest state in the Time-Use sample, but other studies have found high rates of nutritional inadequacy. While our measure may accord better with measured child undernutrition, a diet high in cheap staples that supply plentiful calories has its own drawbacks.

Another aspect of the problem that we would like to pursue in greater detail is the linkage between household expenditures and caloric requirements through the production function. Our simple model suggests that different production technologies have important implications for the shape of food and calorie Engel curves by linking household income, expenditures and caloric requirements, as well as implications about the distribution of welfare. As these production functions relating caloric inputs to monetary outputs may vary both across occupations, education levels, and over time (due to mechanization, animal power, and other new technologies) we could potentially analyze a much richer set of facts, including general equilibrium growth models and sectoral shifts, in light of the energy requirements hypothesis.

Equally important is to expand our study to other countries and time periods. While various authors have discussed the role of labor-saving devices and energy requirements we are not aware of other studies in the economics literature that seek to combine caloric intake and caloric requirement measures to study nutritional adequacy, the causes and consequences of changes in food vs. non-food demand, and measurement of CPI bias using Engel curves. We have no idea whether other countries have experienced downward shifting calorie Engel curves and whether the downward shifts have been sufficient to induce falling per capita calories despite growing incomes, but there are plenty of other time use and household consumption datasets that might be linked in a similar manner.

Our paper has also uncovered several facts along the way that deserve a more detailed exploration but are not related to India's missing calories per se. We provide a potential explanation of the Barten puzzle - that holding expenditure per capita constant bigger households consume less of a private, excludable good like food - by showing that household economies of scale in terms of energy requirements are quite large. The way these economies of scale in energy requirements operate deserves greater analysis, as is the role of economies of scale in food preparation specifically.

Finally, our results for calorie intake and substitution towards cheaper calories over the life-cycle stand in contrast to findings for the United States and Mexico. Is India a unique case or is there a general pattern and economic theory that would explain why poorer countries (and individuals) experience larger drops in calorie intake in old age and limited opportunities for substitution towards cheaper/costlier calories? The growing literature on market vs. non-market substitution and the opportunity cost of time would benefit from such a cross-country empirical exercise and theoretical framework.

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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	Δ 1983-2005
Deaton and Dreze	Rural	2240	2233	2153	2148	2047	-193
(2009)	Urban	2070	2095	2073	2155	2021	-49
Chatterjee, Rae and Ray	Rural		2135	2100	2097		
(2007)	Urban		2073	2091	2169		
Kumar and Dey	Rural	2205			2332		
(2007)	Urban	1972			2440		
Meenakshi and	Both	2219			2132		
Vishwanathan (2003)	Median (both)	2076			2024		
NSS for NNMB states		2131	2139	2076	2020	1960	-171
(Deaton and Dreze)	Year	1975-79	1988-90	1996-97	2000-01	2004-05	
NNMR		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.
We weight by state population to get comparable All India figures.
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 the estimates from Deaton and Dreze for the same set of states in nearby years.

Table 2: Mean number of distinct products consumed, by group

	1983		1993-94		2004-05		Change 1983-2005	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Food	21.43	26.47	26.39	31.51	31.44	37.32	46.70%	41.03%
Entertainment	0.24	0.61	0.23	0.43	0.27	0.67	15.13%	11.06%
Intoxicants	2.01	1.54	1.80	1.24	1.61	0.97	-19.98%	-36.94%
Fuel and light	3.51	3.46	3.80	3.53	4.10	3.73	16.66%	7.54%
Clothing	5.96	6.27	6.77	6.92	8.72	9.13	46.18%	45.74%
Other services	1.39	2.07	1.74	2.23	2.25	2.87	62.00%	38.81%
Other nondurables	3.14	4.41	5.27	6.55	6.80	7.93	116.50%	79.79%
Durables	0.63	0.69	1.33	1.34	2.12	2.26	234.32%	224.69%

Table 3: 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 4: 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 5: 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 6: 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 7: 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)

All coefficients significantly below 1 at the 1% level.
except column (4).
All regressions include household composition ratios,
cubics in log expenditure variable, and village/block dummies.

Table 8: 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
Agricultural laborer	0.104	0.160	0.023	0.091
Other laborer	0.079	0.092	0.014	0.071
Self-employed agriculture	0.094	0.122	0.050	0.062
	Urban types			
Self-employed	0.059	0.031	0.008	0.056
Wage/salary worker	0.042	-0.033	-0.006	0.048
Casual laborer	0.090	0.050	-0.005	0.098
	National Classification of Occupations (NCO)			
Administrative	0.005	0.053	0.007	0.001
Clerical	0.007	0.001	0.002	0.004
Sales	0.007	0.074	0.010	-0.001
Service	0.039	0.041	0.021	0.027
Primary	0.075	0.167	0.029	0.059
Secondary	0.042	0.074	0.008	0.038
Other occ.	-0.039	-0.054	0.001	-0.038
	Education levels			
Literate but no primary	-0.005	-0.012	0.000	-0.005
Some primary	-0.015	-0.024	0.000	-0.015
Primary complete	-0.026	-0.028	-0.006	-0.025
Middle complete	-0.041	-0.055	-0.015	-0.035
Secondary complete	-0.068	-0.092	-0.016	-0.062
College complete	-0.099	-0.116	-0.026	-0.084

OLS regression; omitted category is other for types.

Omitted category is professionals for NCO.

Omitted category is illiterate for education levels.

Household composition and size included with log

expenditure controls and village/block dummies.

Table 9: 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
Motorcycle/car	-0.051	-0.048	-0.020
AC/Fan	-0.008	0.008	-0.011
TV	-0.011	-0.010	-0.005
Washing machine	-0.030	0.002	-0.028
Refrigerator	-0.011	0.008	-0.014
Electricity	-0.036	-0.013	-0.030
Wood for cooking	0.067	0.006	0.061
Kitchen garden	-0.002	0.003	-0.004
Non-labor income	-0.013	-0.001	-0.011

OLS regressions inclllude household composition and size
as well as expenditure controls and village/block dummies.

Table 10: Means of different variables across sectors and over time.

Year	1983		1987-88		1993-94		1999-00		2004-05	
Sector	R	U	R	U	R	U	R	U	R	U
Adult age	38.8	36.1	38.4	36.2	38.7	36.2	38.8	37.1	39.1	37.6
Age	26.4	26.2	26.5	26.5	27.4	27.2	27.6	28.2	28.4	29.4
Size	5.18	4.81	5.08	4.70	4.90	4.46	5.03	4.52	4.89	4.37
Male adult	1.31	1.37	1.32	1.36	1.33	1.34	1.38	1.41	1.36	1.41
Male child	1.33	1.15	1.29	1.10	1.19	1.00	1.21	0.98	1.14	0.87
Female adult	1.34	1.24	1.33	1.25	1.33	1.23	1.37	1.29	1.38	1.32
Female child	1.21	1.05	1.14	1.00	1.05	0.89	1.07	0.85	1.01	0.76
Adult years sch.	1.97	5.79	2.23	6.19	2.77	6.95	3.28	7.74	3.98	8.39
Frac. Lit. adult	0.32	0.63	0.36	0.65	0.42	0.70	0.48	0.74	0.54	0.77
Self non-agg.	0.12	0.00	0.12	0.00	0.12	0.00	0.13	0.00	0.16	0.00
Agr. Labor	0.31	0.00	0.31	0.00	0.31	0.00	0.34	0.00	0.27	0.00
Oth. Labor	0.06	0.00	0.09	0.00	0.08	0.00	0.08	0.00	0.11	0.00
Self agg.	0.41	0.00	0.38	0.00	0.37	0.00	0.34	0.00	0.36	0.00
Self. Urban	0.00	0.33	0.00	0.34	0.00	0.33	0.00	0.34	0.00	0.38
Wage Urban	.	.	0.00	0.44	0.00	0.43	0.00	0.41	0.00	0.41
Labor Urban	.	.	0.00	0.13	0.00	0.13	0.00	0.14	0.00	0.12
Professional	0.02	0.08	0.02	0.08	0.06	0.17	0.02	0.09	0.03	0.08
Admin.	0.00	0.04	0.01	0.05	0.01	0.06	0.01	0.08	0.02	0.09
Clerical	0.02	0.11	0.02	0.11	0.02	0.11	0.02	0.10	0.02	0.09
Sales	0.04	0.14	0.04	0.15	0.05	0.15	0.04	0.15	0.05	0.16
Service	0.02	0.09	0.02	0.09	0.02	0.08	0.02	0.08	0.02	0.08
Primary	0.74	0.09	0.71	0.08	0.71	0.08	0.69	0.07	0.63	0.06
Secondary	0.11	0.37	0.13	0.36	0.13	0.35	0.13	0.34	0.17	0.35
Electric light	0.15	0.64	0.24	0.72	0.37	0.83	0.48	0.89	0.55	0.92
Cook with wood	0.77	0.46	0.79	0.37	0.78	0.30	0.76	0.22	0.75	0.22
Nonlabor inc.	.	.	0.11	0.15	0.12	0.19	0.14	0.21	.	.
Kitchen Garden	.	.	.	.	.	.	0.12	0.05	.	.
Bicycle	.	.	0.19	0.23	0.29	0.30	0.41	0.39	0.47	0.42
Motor vehicle	.	.	0.02	0.09	0.03	0.14	0.05	0.21	0.09	0.28
AC or fan	.	.	0.01	0.05	0.13	0.42	0.26	0.69	0.38	0.83
Television	.	.	0.00	0.04	0.06	0.30	0.18	0.60	0.25	0.66
Washing machine	.	.	0.00	0.00	0.00	0.03	0.01	0.09	.	.
Refrigerator	.	.	0.00	0.01	0.01	0.10	0.02	0.23	0.04	0.32

Table 11: 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.

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

Controls are added cumulatively for each row.

Table 12: 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

Table 13: Coefficients on sector/year dummies for caloric intake

Controls		Baseline	Demog.	Educ.	Occ.	Dur./other
Year	Sector					
Total calories conditional on total real expenditure						
1983	Urban	-0.148	-0.146	-0.120	-0.087	-0.063
1987-88	Rural	-0.026	-0.027	-0.026	-0.025	-0.022
1987-88	Urban	-0.183	-0.180	-0.155	-0.122	-0.091
1993-94	Rural	-0.078	-0.080	-0.075	-0.073	-0.063
1993-94	Urban	-0.205	-0.205	-0.172	-0.140	-0.100
1999-00	Rural	-0.135	-0.136	-0.132	-0.126	-0.114
1999-00	Urban	-0.240	-0.242	-0.211	-0.177	-0.134
2004-05	Rural	-0.183	-0.187	-0.175	-0.162	-0.145
2004-05	Urban	-0.290	-0.295	-0.262	-0.228	-0.185
Total real food exp. conditional on total real expenditure						
1983	Urban	-0.035	-0.036	-0.033	-0.031	-0.026
1987-88	Rural	-0.024	-0.024	-0.024	-0.024	-0.022
1987-88	Urban	-0.048	-0.050	-0.046	-0.044	-0.037
1993-94	Rural	-0.019	-0.019	-0.019	-0.018	-0.013
1993-94	Urban	-0.048	-0.049	-0.044	-0.043	-0.029
1999-00	Rural	-0.080	-0.080	-0.080	-0.077	-0.071
1999-00	Urban	-0.126	-0.127	-0.122	-0.120	-0.105
2004-05	Rural	-0.177	-0.177	-0.176	-0.173	-0.163
2004-05	Urban	-0.239	-0.239	-0.235	-0.232	-0.214
Total calories conditional on total real food expenditure						
1983	Urban	-0.130	-0.128	-0.101	-0.070	-0.049
1987-88	Rural	-0.013	-0.014	-0.012	-0.011	-0.008
1987-88	Urban	-0.159	-0.157	-0.128	-0.097	-0.069
1993-94	Rural	-0.068	-0.070	-0.064	-0.063	-0.055
1993-94	Urban	-0.181	-0.182	-0.147	-0.115	-0.082
1999-00	Rural	-0.093	-0.096	-0.087	-0.083	-0.072
1999-00	Urban	-0.178	-0.182	-0.144	-0.111	-0.075
2004-05	Rural	-0.092	-0.099	-0.079	-0.067	-0.053
2004-05	Urban	-0.170	-0.179	-0.135	-0.102	-0.065

All regressions include househould size and cubic in expenditure.

Controls are added cumulatively for each column.

Coefficients are % differences relative to Rural 1983.

Table 14: Poverty headcounts

					% children	2400/2100	Avg. cal req.		MPCE intersect	
State	Sector	Official	Deaton/Dreze	Karan/Mahal	undernourished	below	below	20% below	below	20% below
Gujarat	Rural	12.4	20	29.8	44.7	69.2	71.5	43.8	80.2	33.3
	Urban	14.8	6.4	16.9		53.3	59.2	25.7	61.3	17.2
Haryana	Rural	7.4	5.7	13.7	39.7	58.3	50.3	24.0	48.5	18.4
	Urban	10	6.4	14.7		54.0	55.0	28.2	57.0	21.1
Madhya Pradesh	Rural	37.2	31.3	46.2	59.8	79.3	79.3	50.8	88.0	50.1
	Urban	38.5	13.9	25.6		60.8	64.3	32.5	68.1	28.2
Orissa	Rural	47.8	43.5	54.4	40.9	70.0	69.9	33.2	75.6	29.1
	Urban	43.5	15.6	30.3		34.6	40.7	12.4	36.0	3.9
Tamil Nadu	Rural	20	24.3	45	30	73.2	71.8	44.5	78.0	39.6
	Urban	22.5	11.3	24.5		47.3	56.6	27.1	55.8	23.0
Ratio of Rural to Urban poverty line										
Gujarat		0.67	0.91	0.83		0.88	0.89	0.89	0.80	0.86
Haryana		0.86	0.87	0.85		0.88	0.93	0.93	0.71	0.82
Madhya Pradesh		0.65	0.90	0.84		0.88	0.90	0.90	0.80	0.84
Orissa		0.68	0.96	0.85		0.88	0.90	0.90	1.01	1.04
Tamil Nadu		0.65	0.92	0.83		0.88	0.95	0.95	0.81	0.80

Table 15: Poverty gaps and calorie gaps

		Poverty gap				Calorie gap			
		Official	Deaton/Dreze	mpce intersect below	mpce intersect 20% below	2400/2100 below	state avg. below	mpce intersect below	mpce intersect 20% below
Gujarat	Rural	2.2	3.8	28.2	7.3	17.1	18.1	15.4	4.7
	Urban	2.4	1	19.8	2.9	9.8	11.5	9.2	1.5
Haryana	Rural	1.3	0.7	12.6	3.2	12.4	10.1	8.2	1.9
	Urban	2	0.7	18.6	4.5	11.2	11.5	9.8	2.3
Madhya Pradesh	Rural	7.7	6.6	36.1	12.2	21.0	20.9	20.0	6.9
	Urban	9.5	2.6	24.8	6.1	12.9	14.2	12.3	3.1
Orissa	Rural	11.7	10.5	25.1	5.7	14.6	14.5	13.1	3.4
	Urban	11.1	3	8.5	0.6	5.1	6.1	3.7	0.3
Tamil Nadu	Rural	3.8	4.6	29.1	9.2	19.2	18.5	16.4	5.5
	Urban	4.8	2	18.2	5.0	9.2	12.1	10.5	3.3

Table 16: Poverty rates, poverty gaps and calorie gaps by occupation

		State/sector cal. req.		Occ. spec. cal. req.	
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
		Poverty Gaps			
Sedentary	Rural	21.8	5.5	18.1	3.9
	Urban	13.1	2.2	11.4	1.7
Primary	Rural	37.2	12.8	38.5	14.1
	Urban	35.7	11.8	34.8	12.2
Secondary	Rural	34.7	10.6	31.7	8.9
	Urban	31.5	8.4	29.8	8.0
Service/sales	Rural	27.6	7.9	34.9	6.0
	Urban	22.4	4.3	28.1	5.7
		Calorie Gaps			
Sedentary	Rural	11.7	3.1	8.9	1.3
	Urban	6.3	1.1	5.2	0.6
Primary	Rural	20.7	7.3	21.6	8.0
	Urban	18.3	6.0	19.6	7.8
Secondary	Rural	19.0	6.0	16.8	4.7
	Urban	15.8	4.3	15.3	4.2
Service/sales	Rural	15.0	4.4	14.6	4.0
	Urban	10.8	2.1	12.5	2.6

Table 17: 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.
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.

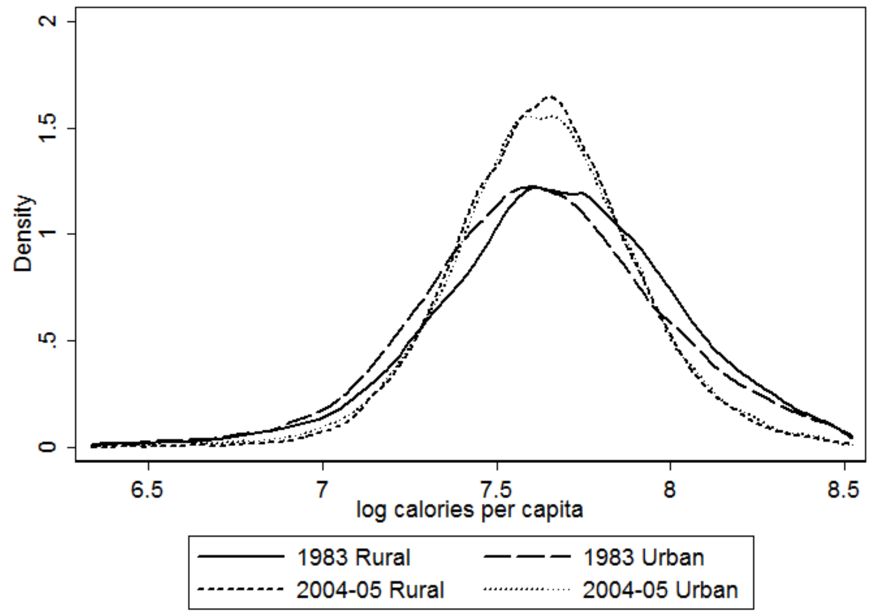


Figure 1: Kernel density estimation of log calories per capita

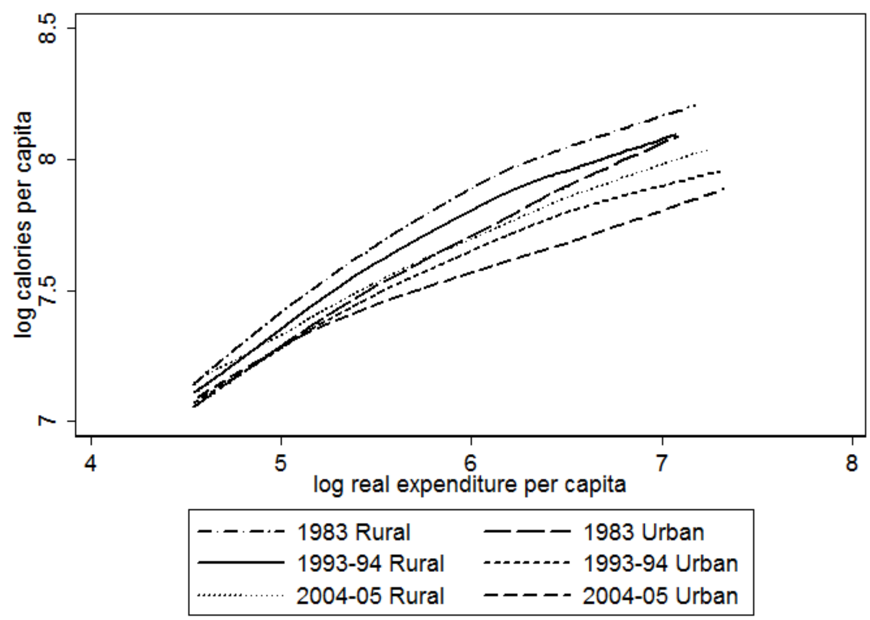


Figure 2: Locally weighted regression of log per capita calories on log per capita real expenditure (two adult, 3 child household)

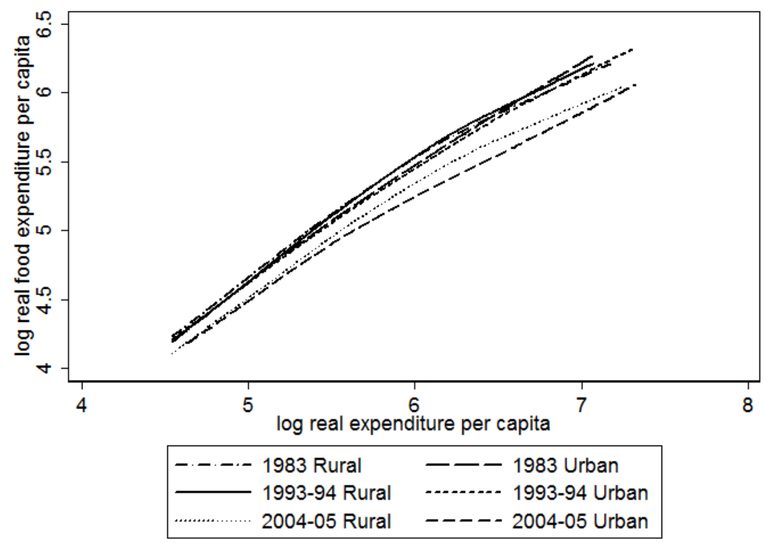


Figure 3: Locally weighted regression of log per capita real food expenditure on log per capita real expenditure (two adult, 3 child household)

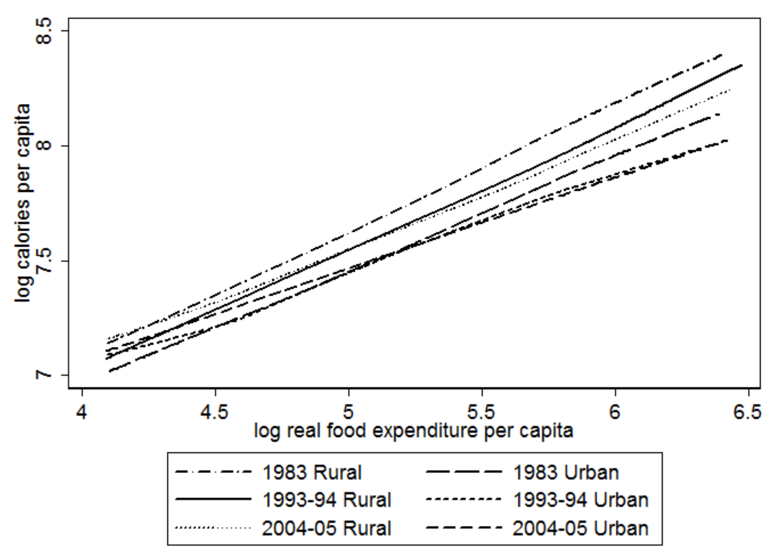


Figure 4: Locally weighted regression of log per capita calories on log per capita real food expenditure (two adult, 3 child household)

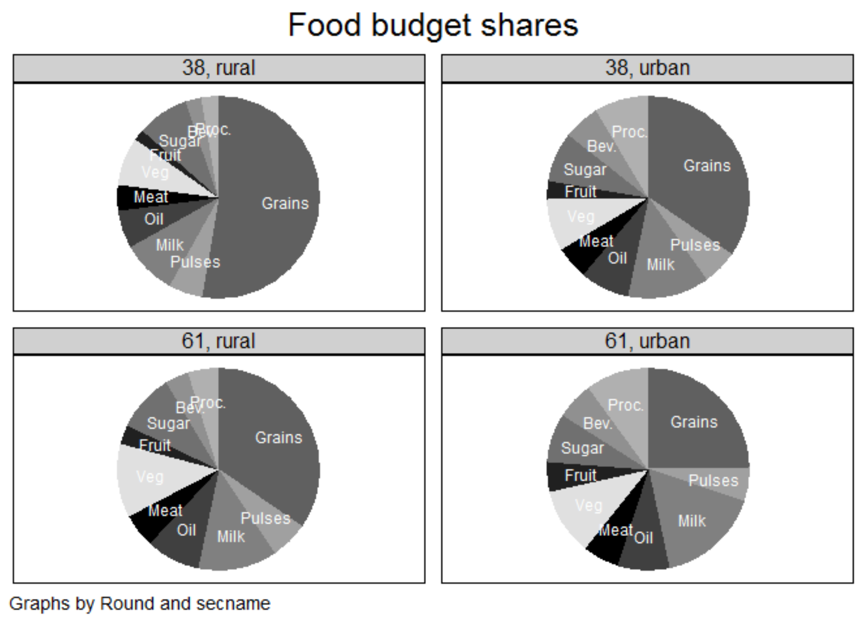


Figure 5: Share of food expenditures on different categories by year and sector

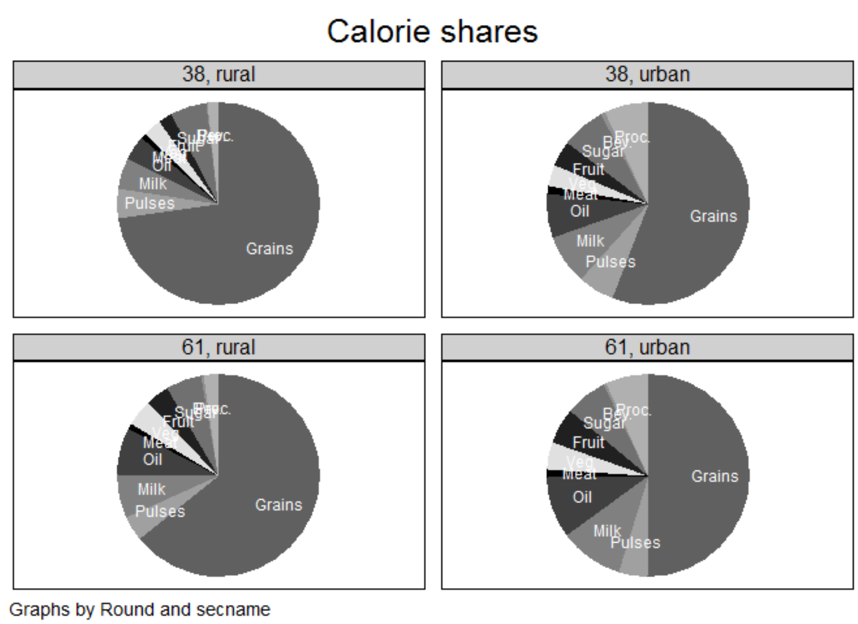


Figure 6: Share of calories from different sources by year and sector

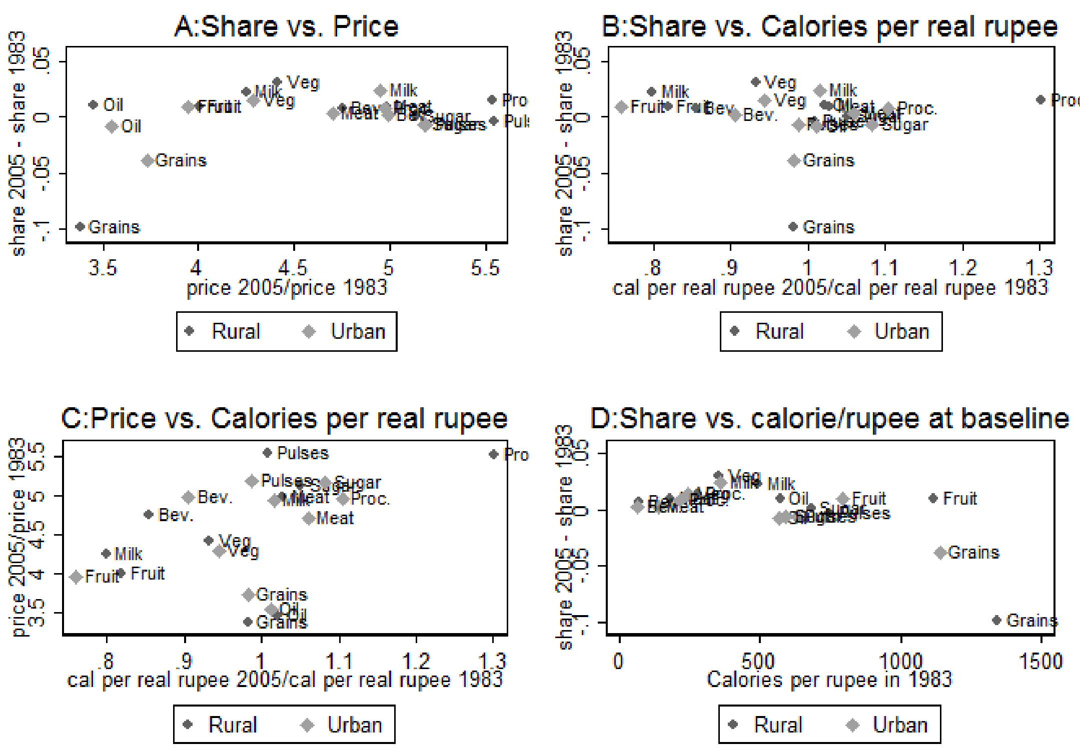


Figure 7: Correlations of calorie decomposition by food category, 1983-2005

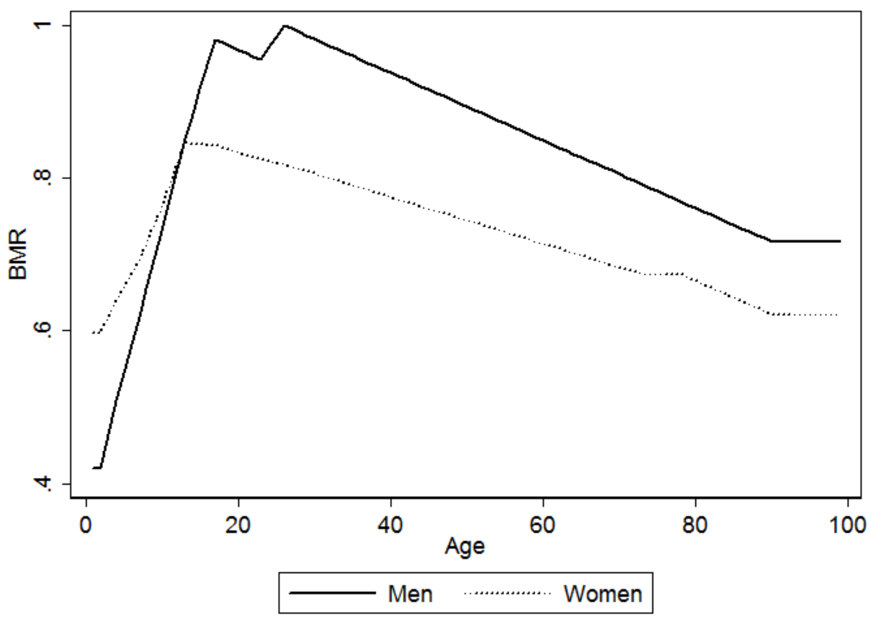
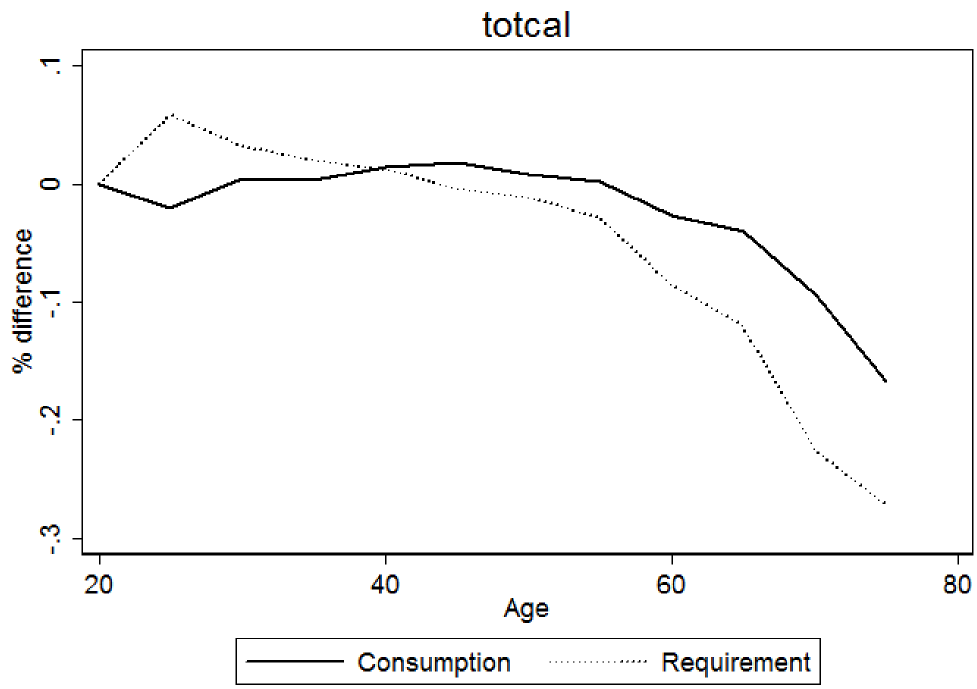
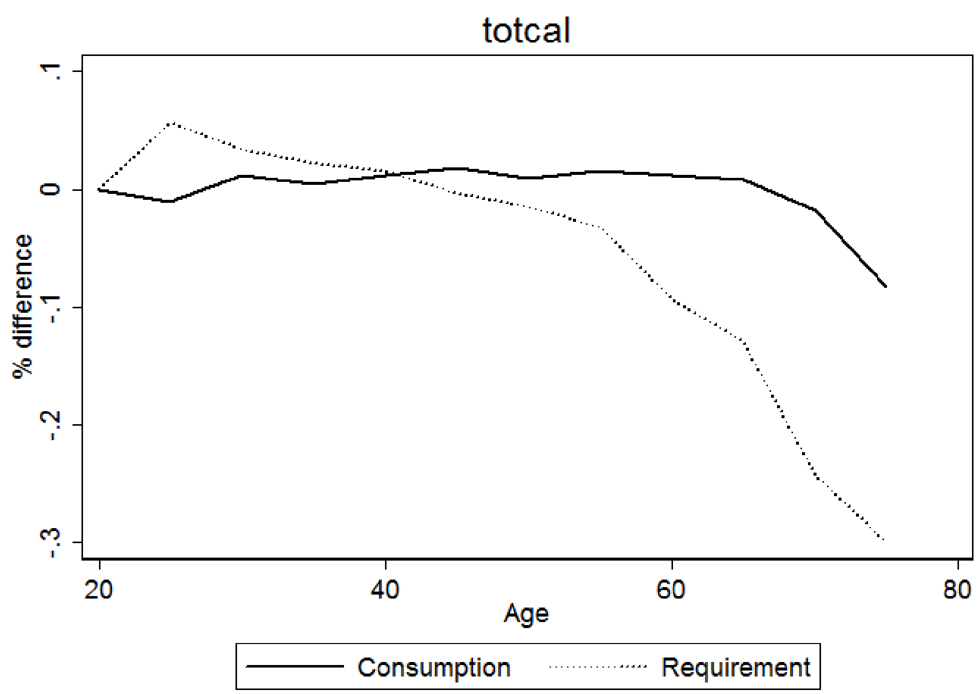


Figure 8: Basal metabolic rate by age and gender



(a) Unconditional



(b) Conditional on total expenditures

Figure 9: Lifecycle calorie consumption and requirements, relative to 19-22 year old adults

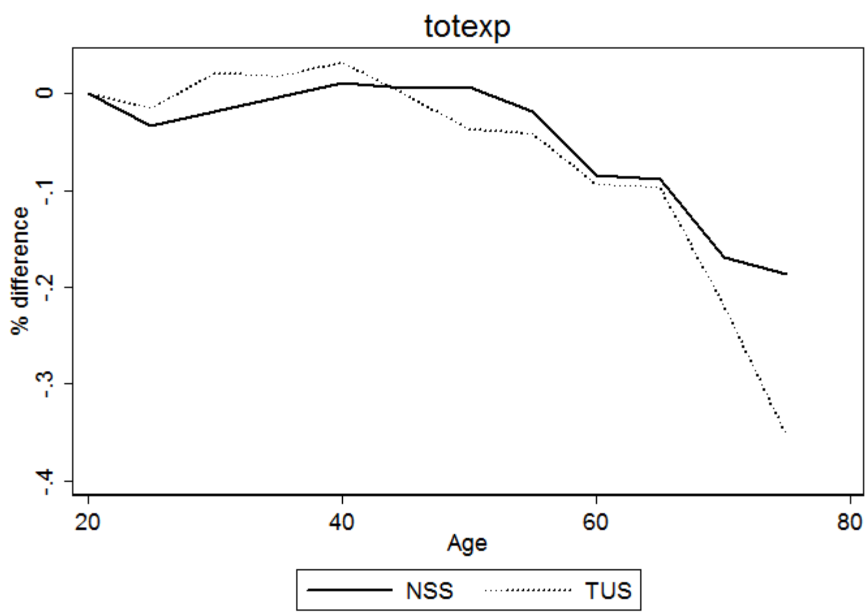
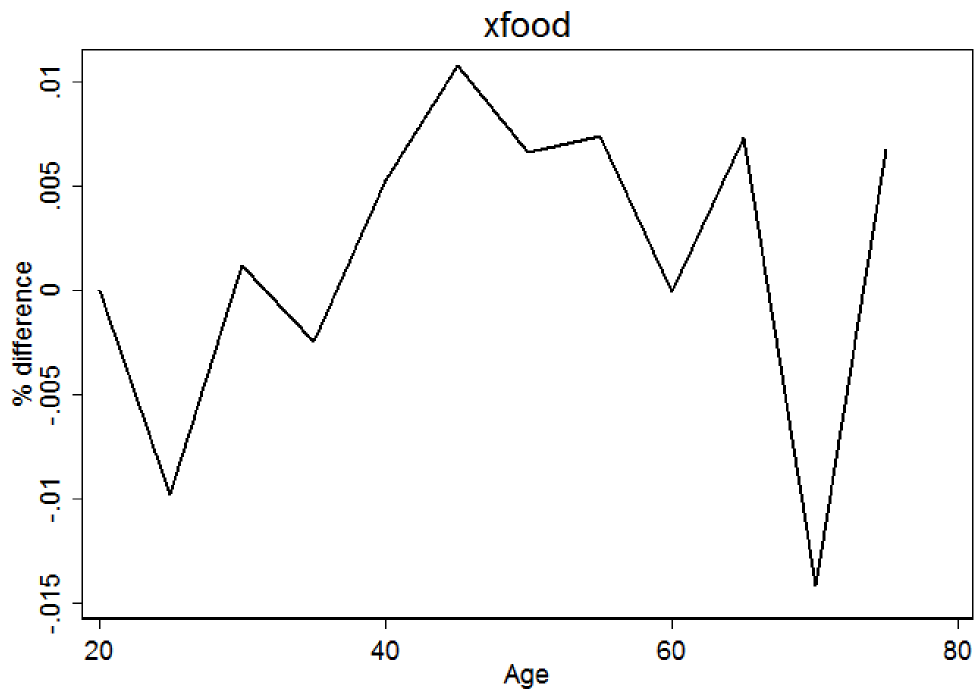
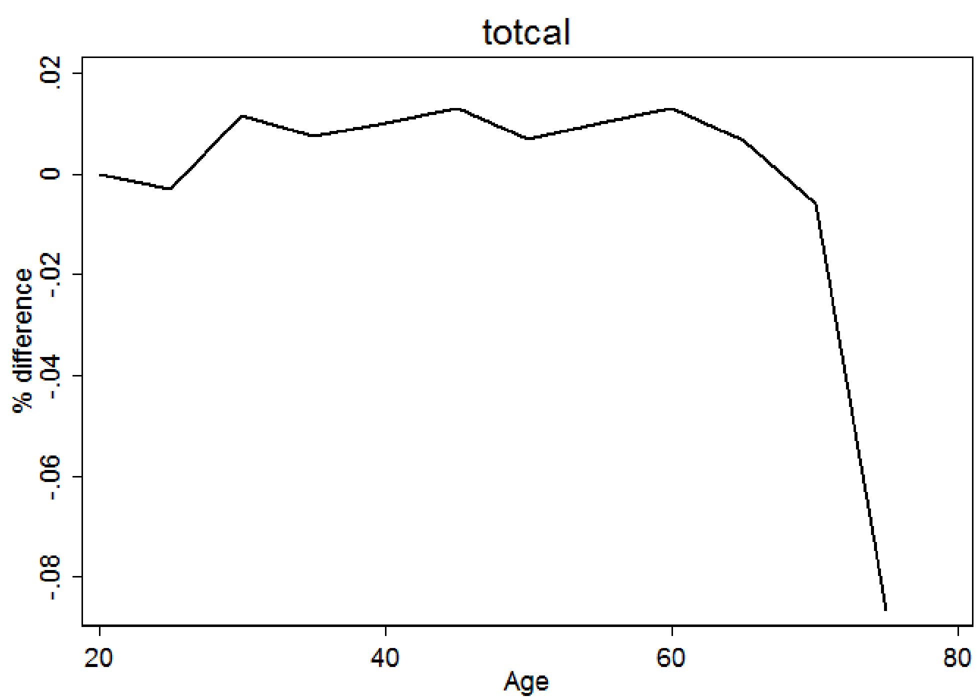


Figure 10: Lifecycle total expenditure, relative to 19-22 year old adults

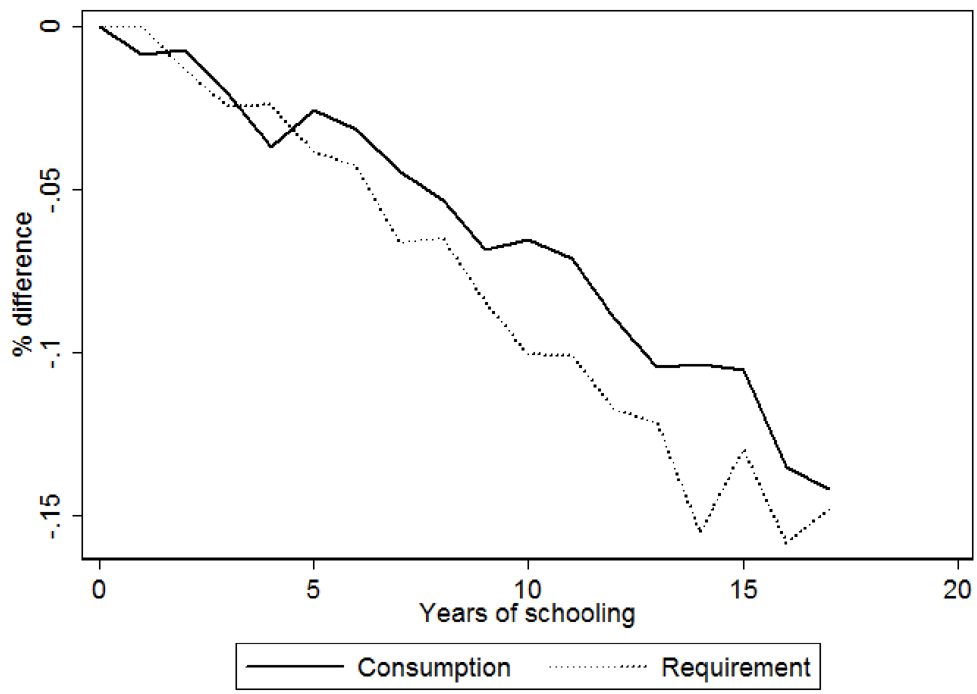


(a) Food exp. cond. on tot. exp.

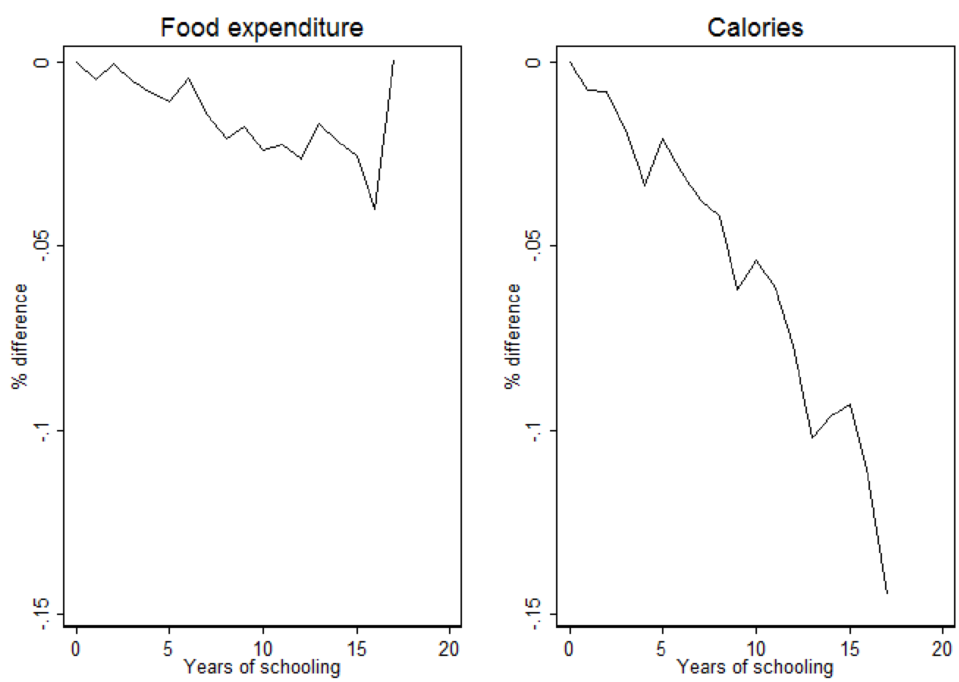


(b) Cal. cond. on food exp.

Figure 11: Life-cycle coefficients, relative to 19-22 year olds



(a) Calories conditional on total expenditures



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

Figure 12: Effect of average adult years of schooling on calorie and food consumption/requirements

A Appendix: Imputing calorie consumption

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.

A1. Data issues

To get a sense of the magnitude of these issues, table 18 reports some summary statistics for consumption of the different sets of "problem" goods.[16] 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

[16]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.

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 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 18 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 C Gopalan and Balasubramanian (2004) or Karan and Mahal (2005)) are supplemented with data from the IndiaMD website and the internet.[17] 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 19 provides summary statistics on the share of households giving or receiving free meals, the mean number of meals given and received in the last

[17] Website address. What we took from elsewhere, and from where...

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 19 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 18 is not simply due to the availability of cheaper cooked meals.

A2. 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 20 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.[18] 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 20 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.

[18] 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%.

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 20 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 20 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 20 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 20 present our two preferred specifications, corresponding 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

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

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.

Table 18: 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 19: 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 20: 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