THE TRANSFORMATION OF HUNGER: THE DEMAND FOR CALORIES PAST AND PRESENT

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ABSTRACT

According to conventional income measures American and British industrial workers in the nineteenth century were two to four times as wealthy as those in developing countries today. Estimated calorie income elasticities of American and British industrial workers based on the 1888 Cost of Living Survey are greater than calorie elasticity estimates for developing countries today—yesterday's wealthy workers were much hungrier than today's poor. The result is robust to numerous criticisms. Using the Engel curve implied by the calorie elasticities, I derive new income estimates for developing countries that are six to ten times greater than those using traditional methods.

Hunger continues to plague many developing nations and the poorest segments of developed nations. In 2002 the World Health Organization listed hunger as the number one health risk in the world, accounting for an estimated 3.4 million deaths in 2000, nearly all of which occurred in poor countries. If the past is prologue, developing nations may be well served by studies that explore the dimensions of hunger and malnutrition in the past, allowing us to think about the evolution of wellbeing over time. Given the long struggle with subsistence and chronic malnutrition throughout human history (Fogel 2004), the quantification of hunger seems a likely candidate to tell us about how living standards have changed over time. Building on this insight, this paper adopts a novel approach to measuring living standards over time— exploring how the demand for calories in the late nineteenth century compares to the situation in today's developing countries.

Using calorie elasticities to analyze living standards in the past is important in two ways. First, the methodology allows us to look at living standards today and in the past in the same manner and with the same interpretation. This gives us a common measure for living standards and eliminates the need to qualify our comparisons of the past and present. Secondly, this methodology allows us to ask and answer the question of how living standards have changed over time in a tractable way. While looking at the average number of calories per person or the share of the budget devoted to food over time may be suggestive, such analysis must be qualified by changes in human physiology, dietary tastes, food quality, and relative prices over time and space.[1] While food income elasticities will not be comparable if people purchase more and more

[1]Many of the problems that may be present in the level of calories will not be present in demand elasticities, which are more robust than calorie averages. For example, the lack of information about the home production of calories for historical households is shown to have very little effect on the historical elasticities presented here, but such an omission would lead to biased estimates of average calorie intake. Also, our estimates of calories per capita for historical populations are rarely based on microeconomic evidence—they are usually based on nutritional balance sheets, and as such are not directly comparable to calorie per head estimates from developing country household surveys.

expensive food as their incomes grow, calorie income elasticities are an intuitive and straightforward way to estimate hunger. Since hunger and malnutrition persist in poor countries today (FAO 2006), quantifying hunger would tell us a great deal about how living standards have changed.

In this paper I compare the late nineteenth century estimates of income and expenditure elasticities of calories for industrial workers in the United States and Great Britain to those from developing countries today. While calorie elasticity estimation is standard in development economics, we know little about how calorie demand has changed over time. Unfortunately, calorie elasticities can only be estimated with detailed microeconomic data, and not all historical household survey data is appropriate for this purpose. The historical data used in this paper, the 1888 Cost of Living Survey, is one of the few historical household surveys that allow us to derive precise estimates of historical nutrition, which are necessary to estimate calorie elasticities.

I find that estimates of calorie elasticities for both British and American households in the late nineteenth century are significantly greater than contemporary calorie elasticity estimates in the developing world today. When one considers that American and British industrial workers in the late nineteenth century, using conventional income measures, are at least twice as wealthy as a household in rural India in the 1980s, this result is surprising.[2] More concretely, the hypothesis that the historical expenditure elasticity of calories estimates are equal to or less than Subramanian and Deaton's (1996) estimates for rural India in 1983 or estimates derived from a large 1992 household survey in Bangladesh is rejected in every specification. This finding implies an extraordinary improvement in nutritional well-being among the poor in the last century. Furthermore, the finding here is robust to estimation bias, the failure to capture home produced calories in the 1888 Cost of Living Survey (such as gardens and poultry), measurement error, and accounting for substitution in the diet as income increases.

We can use these elasticity estimates to gauge the extent of mismeasurement of the true cost of living over time. To the extent that the Engel curve with respect to real income has been stable over time, departures from the Engel curve will be due to mismeasured relative price changes between food and non-food and/or mismeasured real income. This Engel curve implicitly takes into account features of the standard of living that aggregate measures do not capture. Using the Engel curve implied by the calorie elasticities for both American and British households in the late nineteenth century, I construct an expenditure elasticity of calories-real income relationship and derive new income estimates for developing countries based on the Engel curve. While traditional income-based poverty estimates imply that those in developing countries today are many times poorer than American and British workers in the late nineteenth century, the Engel-based income estimates are six to ten times greater than traditional real income estimates. The fact that Engel income estimates are many times greater than the traditional estimates shows a dimension where our traditional income measures may be flawed either through failure to account for changes in the relative price of food or mismeasurement of real income.

Together these facts lead to two related conclusions. First, the press of hunger has transformed dramatically over time and in a way not captured by our income estimates. Second, these new income estimates imply that economic growth has been understated. Either those in the past were much poorer than previously thought or those from developing countries today are wealthier than our income estimates suggest. In both cases the conclusion is the same—living

[2] For more on historical income measures see Maddison (1995).

standards have increased dramatically over time, and our current estimates of economic growth are too low.

I. Data and Summary Dietary Measures

A. Data

The historical calorie elasticities come from a unique and rich household survey from the late nineteenth century. The "Cost of Living of Industrial Workers in the United States and Europe 1888-1890" (henceforth 1888CEX), was conducted by the United States Department of Labor to assess the living standards of American and European industrial workers in the late nineteenth century. The 1888CEX contains a sample of 8,544 families working in industrial sectors in both Western Europe and the United States. The majority of the households in the survey, 6,809, are from the United States. The European sub-sample comes from Germany, Switzerland, Belgium, Great Britain, and France, although the majority of the European households, 1,024, come from Great Britain. Since the survey was designed to investigate the living standards of industrial households, the geographic distribution of households in the United States is not even, but both the American and British samples appear to be broadly representative of industrial households at the time.[3] Comparison with the *Historical Statistics of the United States*, for example, reveals that these households are close to the 40th percentile in the expenditure distribution at the time. The survey contains detailed annual expenditure information for both food and non-food items and annual income information for all members of the household (father, mother, and children). In addition, demographic information on the

[3] See Haines (1979) compares the 1888CEX to Census returns and finds the sample representative of industrial families, Lees (1979), and Modell (1978) make similar comparisons for the British and American samples, respectively and independently confirm its representativeness. Williamson (1967) describes the 1888CEX in greater detail.

household's age and sex composition, as well as a detailed recording of the household head's occupation, is included in the survey. Calorie conversions were created in conjunction with the Aldrich Report on retail prices in a methodology described by Logan (2006a).[4]

B. Summary Dietary Measures

Before turning to calorie elasticity estimates, it is useful to present other measures of nutrition that can be derived from the survey and compared to estimates from developing countries such as average calories per head, the percent of the budget devoted to food, and the average price of calories as a percent of a day's wage are all useful ways of measuring nutritional well-being. While these measures do not have the straightforward economic interpretation of calorie elasticities, and may not be strongly related to hunger per se, these measures serve as a motivating force for the use of calorie elasticities as the quantification of hunger. To foreshadow the case study presented in the next section, I compare the historical summary measures with those for India in 1983 as given by Subramanian and Deaton (1996).

An obvious summary measure of nutrition is the average number of calories per person. Table 1 shows the average calories per head for the American and British samples of the 1888CEX as well as those for India in 1983. As the table shows, those in the late nineteenth century had far fewer calories per head than those in modern India. The Indian households in 1983 had 40% more calories than British industrial households, and 20% more calories than American industrial households, and the qualitative implications are the same if we look at calories per adult male equivalent. By this measure, it would appear that those in the past were nutritionally worse off, and this directly contradicts the conclusions one would draw from the

[4] Since the Aldrich report contains retail prices for the United States and Great Britain, only those subsamples are used to derive estimates of calories. For further details see Logan (2006a).

income comparisons. At a minimum, the calorie levels suggest that we look deeper at the nutritional well-being of these households.

But can we make inferences about hunger based on calories per head? Yes and no. While it is easy to conjecture that more calories are better, it is harder to say who is hungrier. In order to make the case that one group was hungrier than another we would need answers to the following questions: What are the calorie requirements of the two groups? Are there differences in calorie wastage between the two groups? Would technology differences effect the preparation of food? How is food, in general, distributed in this culture, and what manipulations to the data must be performed in order to capture those features of food distribution? Since so much additional information is needed demand for nutrition cannot be known from average calories. While the implication of the calorie levels reported here suggest that those in developing countries are doing better nutritionally than nineteenth century industrial workers, we need more information to make such a conjecture a conclusion.

The share of the budget devoted to food has been a measure of well being since Engel first noted that wealthier families devoted a smaller share of their budget to food than poorer families. Table 1 lists the fraction of the budget devoted to food for the American and British samples of the 1888CEX as well as those for India in 1983. As the table shows, American and British families in the late nineteenth century devoted at best 50% of expenditure to food, while those in India devoted more than 60% of expenditure to food. The budget shares suggest that those in India are slightly worse off than industrial families in the United States and Great Britain in the late nineteenth century. Even if one adds housing expenditure to the historical estimates, which includes fuel and heating, the situation is unchanged. From this measure of nutritional well-being we would reach the opposite conclusion from that obtained with calorie levels.

The open question is whether the share of the budget devoted to food is the appropriate quantification of hunger. There are several problems with budget shares as the measure of hunger. Budget shares take no account of the trade-offs between home production and direct purchases of food, differences in calorie prices over time, or differences in the relative price of calories. Each of these will have a direct effect on food's share of total expenditure. Banerjee and Duflo (2007) further note that among poor households in poor countries today the variation in the foodshare is large, so drawing inferences from the foodshare itself are difficult. Budget shares also tell us nothing about diet quality, and it could be true that equal fractions of the same budget could yield very different bundles of food with highly dissimilar quality and subsequently large differences in nutritional well-being. As such, it is unclear how we could form inferences about hunger from differences in the budget share devoted to food.

Another measure of nutrition would be the price of calories. Mirrlees (1975) and Stiglitz (1976) have described the situation in which people are so wasted that they cannot work, and this leads to very low wages and continued malnourishment. In this way, a person is trapped in a malnourishment and poverty feedback loop—poor nutrition produces low income, and this low income produces further poor nutrition. Fogel (1994) has asserted that such traps did exist well into the eighteenth century, but notes that these sorts of poverty traps, where nutrition feeds back to wages, were non-existent in western populations after the middle of the nineteenth century.

If these sorts of poverty traps did exist they would yield biased estimates of calorie demand, so it is useful to analyze the price of calories before estimating the elasticity. Endogeneity would only be a problem, however, if one could produce evidence that a day's worth of calories (both calories needed for sustenance and for a day's worth of labor) were far out of reach of the general population. As Table 1 shows, a day's worth of calories (using 2,300 calories as a lower bound) cost around ten percent of a typical day's wage among industrial workers in the United States, and around thirteen percent of an industrial worker's daily wage in Great Britain.[5] Subramanian and Deaton (1996) find that a day's worth of calories, namely 2,600 calories a day—more than needed for sustenance and a day of hard labor, cost less than five percent of a typical day's wage in Maharastra, India in 1983. By this measure those in India are better off than the industrial workers in the late nineteenth century. Even when looking by industry, which helps control for calorie price and income differentials, the variation in the percentage is slight. It is surprising that calories cost less than a 20th of a day's wage in rural India in 1983 and more than a 10th of a day's wage in both the United States and Great Britain. The fraction of the nineteenth century industrial workers wage, in today's income, is many times larger than the value of the low wages earned in India, which could be used as a rough way of measuring the decline in calorie prices over time.

C. The Case for Calorie Elasticities

While the three summary dietary measures are informative, they do not point in the same direction. Average calories and calorie prices tell us that those in the past were significantly worse off, but the budget share tells us the opposite. While these results by themselves conflict with inferences based on income estimates, it is not clear if any of these measures capture living standards and quality of life, at least on their own. Additionally, these measures do not survive time and space transformations well. A more theoretically-grounded approach, where we quantify the demand for nutrition, would allow us to measure hunger in such a way that we could compare demand over time and space.

[5] For the methodology used to construct household-specific calorie price estimates from the 1888CEX, see Logan (2006a).

Imagine an experiment where two individuals, *A* and *B*, were each given an additional dollar to spend on whatever they chose. If *A* used her additional dollar to consume 500 additional calories, but *B* used his additional dollar to consume 100 additional calories we would infer, from their behavior, that *A* was hungrier than *B*. This follows from our intuition that if one is hungry they will devote a large share of their marginal income to securing more calories.[6] Instead of looking at the fraction of the marginal dollar spent on calories, we can estimate elasticities of calorie demand—the percentage of additional expenditure that is devoted to calories.[7] Since elasticities are unit-free measures of demand responsiveness, they can be compared over time and space without the qualifiers, caveats, and conjectures needed when using the other measures mentioned above. Additionally, calorie elasticities reflect demand for nutrition, not a predescribed measure of nutritional adequacy. Unlike food expenditures, people can only consume so many calories in a given period of time. Calorie elasticities should be decreasing function of income, where wealthier households have lower calorie elasticities.[8] So while food elasticities will be weakly related to hunger, calorie elasticities will be a better marker of hunger. As such, calorie elasticities allow us to compare demand for nutrition and infer which group is hungrier—those that are hungrier will have larger calorie elasticities. To be sure, there are limits to this approach. For example, differences in dietary taste or the demand and price of diet variety could lead to differences in calorie elasticities that would not be related to hunger per se. As will be shown later, there are ways of gauging the extent of the effect of these factors on

[6] In some respects, such an argument has the flavor of Samuelson's (1947) weak axiom of revealed preference.
[7] Throughout the paper, per capita household expenditure and calories are used. As such, the elasticities estimated here are the percent increase in per capita calories given an increase in per capita expenditure or income.
[8] This is confirmed in the 1888CEX in Logan (2006a), and for the NSS in Subramanian and Deaton (1996). Although calorie elasticity estimates are rare for developed countries, the food elasticities reported for the 1888CEX in Logan (2006a) (> .80) are much greater than food elasticities estimated for the US and Great Britain in the middle of the twentieth century (< .50) or today (< .20) by the USDA.

the demand for calories generally, and the main result of this paper is robust to such considerations.

II. Comparing Calorie Elasticities – A Case Study

A. Calorie Elasticity Estimates

I first compare the historical estimates to the range advanced by Subramanian and Deaton (1996), who find that the expenditure elasticity of calories is between .3 and .5 for families in rural Indian villages in 1983. I compare my results to their estimates as a case study for three reasons. First, my methodology is similar to theirs, and it is important to have similar methodologies if the results are to be comparable. Secondly, Subramanian and Deaton's work is concerned with a rural population in the developing world, and as such it serves as an example of the sorts of space and time comparisons one may do when using calorie elasticity estimates. Third, their work is concerned with the plausible range of calorie elasticities for developing countries. While there is no general agreement on the size of the calorie elasticity in developing countries an upper bound has been established in the literature.[9] I then compare the historical elasticity estimates with a broad sample of calorie elasticity estimates from the developing world, and also explore how the conclusions drawn from the calorie elasticity comparisons are similar to and different from the conclusions drawn from comparing other measures of well-being.

Following convention, I estimate the elasticity with the log linear regression of per capita calories (PCC) on per capita income (PCI) and a vector of controls (Z)

[9] Subramanian and Deaton were responding, in part, to the work of Behrman and Deolalikar (1987, 1989), who argued that calorie expenditure elasticities in India were close to zero and that households seemed to prefer increasing the variety of the diet as opposed to its quantity. Subramanian and Deaton correctly note that Behrman and Deolalikar's point estimate for the expenditure elasticity of calories falls within the range Subramanian and Deaton advocate (.3 to .5), but that the Behrman and Deolalikar point estimate is imprecisely estimated. Banerjee and Duflo (2007) concur that the "Deaton and Subramanian estimate is one of the higher estimates." (p. 147)

$$\ln\left(PCC_i\right) = \alpha + \beta \ln\left(PCI_i\right) + \Gamma Z_i + \varepsilon_i \qquad (1)$$

where β is the calorie income elasticity.[10] The log linear functions presented here were estimated using ordinary least squares (OLS).[11] The OLS regression estimates presented here are taken as summary measures of each respective population's demand for calories.

Table 2 shows the OLS regressions of the calorie elasticities for American and British households in the late nineteenth century. As the table shows, the American calorie elasticities are ten to forty percent lower than the corresponding British calorie elasticities. These differences suggest a large gap in the nutritional well-being between British and American industrial classes in the late nineteenth century in favor of American households, which agrees with Ward and Devereux's (2003) estimates of American and British income in the late nineteenth century. When one considers Lees' (1979) description of the British households in the 1888CEX these results may well understate that differential. Narrative evidence confirms British industrial families were more malnourished than American industrial households in the late nineteenth century, so we would expect the British calorie elasticities to be greater than the American calorie elasticities.[12] Given their congruence with the historical record, a comparison of these historical elasticities with those from contemporary countries seems appropriate.

Subramainian and Deaton (1996) estimate the expenditure elasticity of calories in rural India. Their data come from the thirty-eighth round of the National Sample Survey (NSS) in 1983. They have a total sample of 5,630 households, 10 from each of 563 villages. Using both parametric (OLS) and non-parametric techniques, they conclude that "the range of estimates that

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[10] The controls include the log of household size, the fraction of the household in five-year age-sex categories (e.g. the fraction of the household that is female aged 5-9), the industry of the household head, and geographic controls.
[11] Since taking the logs of both income and calories produces an approximate joint normality, OLS is indeed appropriate for estimating the elasticity. For the linearity of the calorie-income relationship see Logan (2006a). For more on the normality of the calorie distribution in the 1888CEX see Logan (2006c).

we have established for the expenditure elasticity of calories, from .3 to .5, is the right one for this part of rural India," (p. 161).

In Table 2, I reject the hypothesis that the historical expenditure elasticity of calories estimates fall within the range noted by Subramanian and Deaton in every specification. In Subramanian and Deaton's first specification, a regression of the log of per capita calories on the log of per capita expenditure, they obtain a point estimate near .5.[13] In the historical regression of the log of per capita calories on the log of per capita expenditure the American point estimate is .61, and the British point estimate is .68, and I reject the hypothesis that either of the historical expenditure elasticities is less than or equal to .5. Even controlling for family size and the share of the household in five year age categories in the regression, where the American elasticity estimate is .55 and the British estimate is .62, I reject the same hypothesis.

While constructing the NSS data to be similar to the 1888CEX and then estimating the calorie elasticities would be an attractive research strategy, it would not be as informative as the results presented below.[14] Constructing the NSS as if it were the 1888CEX would create biased calorie availability measures in the Indian data. It is well known that in Indian villages poor families consume many meals outside of the home and wealthy families serve many meals in their homes that are not consumed by household members.[15] With this being true, simply taking household measures of calories would systematically understate the calories available to poor households (since they consume a sizable fraction of their calories outside the home) and overstate the calories available to wealthy households (since they provide a large number of

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[12] See Shergold (1982) for more on comparative living standards in the late nineteenth century, and Logan (2006a) for more on the calories elasticity differential between the US and Great Britain.
[13] They in fact use a non-parametric technique and their global slope is close to .45.
[14] As will be shown, the historical calorie estimates are greater than all of the estimates for developing countries, so doing such a comparison of one country would not explain why the finding holds for other countries.
[15] See Subramanian and Deaton (1996) for a full discussion of this issue and the remedies available in the NSS.

calories to others) in the NSS. For this reason, Subramanian and Deaton construct their measure of calorie availability based on information about where the meal was consumed in order to capture calories consumed by household members outside of the household. Indeed, one of the reasons that the NSS collects information about where calories are consumed is to overcome this potential problem. For the 1888CEX, however, such information is unnecessary. It is well known that members of industrial families in the late nineteenth century consumed nearly all their meals in their own households, where guests were infrequent and the diet monotonous.[16]

To tackle the issue of comparability fully I took data from "Credit Programs for the Poor" household survey conducted in rural Bangladesh in 1991 and 1992.[17] These data are comprised of household surveys conducted in 87 villages in 29 randomly selected thanas (subdistricts) out of a total of 391 thanas in Bangladesh. Although the goal of the survey was to determine the effects of micro-credit programs for the poor, the general structure of the survey is a multipurpose household survey. As such, the data has details information on household food purchases and production (which is valued at market prices as in the NSS), as well as household demographics and expenditures. There were 1,543 households from the survey whose responses are sufficient to estimate the calorie elasticity.[18] In using this data I took no account of the distribution of calories between households, and in this way the data mirrors the methodology used for the 1888CEX, where calories are accounted for at the household level and distribution between households is ignored.

[16] See Kertzer and Barbagli (2002), Byington (1910), and Chapin (1909).

[17] For a further description of the data see Pitt and Khandker (1998).

[18] A particular advantage of this survey is the fact that the survey design incorporated seasonal variation in the Bangla calendar. The households in the villages were surveyed during the post-harvest period of the three harvest seasons (*Aman*, *Boro*, and *Aus*), so that each season corresponds to one-third of the year. Pitt and Khandker (1998) note that the three seasons go from the most plentiful (after the *Aman* harvest) to the leanest (the *Aus* harvest).

In Subramanian and Deaton's fullest parametric specification of the model, they regress the log of per capita calories on the log of per capita expenditure, the log of family size, shares of the family by sex and age, and other covariates such as religion, caste, and geographic location. When I replicate their regression in Table 3, I continue to reject the hypothesis that the historical expenditure elasticities of calories are less than or equal to .5. When Subramanian and Deaton estimate the same regression their point estimate of the elasticity is .37, and for Bangladesh in 1992 the elasticity is .35 in the simplest specification and .24 in the fullest specification. For the United States in 1888 the elasticity is .54 and for Great Britain it is .67. Not only are the historical estimates greater than Subramanian and Deaton's estimates, but they are, in the fullest model, greater than the largest either of Subramanian and Deaton's or the Bangladeshi elasticity estimates.[19] Table 3 supports the conclusion that those in America and Britain in the late nineteenth century were hungrier than those in developing countries today.

An important caveat in this case study is measurement error. If there were only traditional measurement error in the 1888CEX it would imply that the historical elasticities are biased downward, and the strength of my conclusions would be enhanced since attenuation bias would imply that the historical estimates are too low. If, however, both calories and expenditure are measured with error, and if these errors are correlated, I will overstate the true expenditure elasticity of calories if the correlation between the errors dominates the attenuation bias. Depending on the correlation in the error, estimates of calorie elasticities can be substantially overstated. Even more Bouis and Haddad (1992) have shown that when both types of measurement errors are present in a linear model of calorie demand the correlated measurement

[19] Table 3 shows that the coefficients on the demographic controls are not always in the same direction in the historical and Indian regressions. In nearly every instance in which the signs of the coefficients disagree with one another, however, I am unable to reject the hypothesis that the Indian and historical estimates are the same sign (the

error dominates the attenuation bias, so the net effect leads to upward biased estimates of calorie elasticities. Subramanian and Deaton show, however, that if the log of non-food expenditure is used as an instrument for the log of per capita expenditure the resulting elasticity estimate is guaranteed to be biased downward even if there is correlated measurement error.

While OLS may be biased upwards depending on which type of measurement error dominates, and therefore constitutes an upper bound on the elasticity, the instrumented estimates will certainly understate the expenditure elasticity of calories. Table 4 shows the upper and lower bound estimates of the expenditure elasticity of calories. The lower bound estimates for the historical elasticities, which fall to .45, are greater than Subramanian and Deaton's or the Bangladeshi upper bound estimates for their respective calorie elasticities, which at their highest are .38. This result confirms that these historical estimates of the expenditure elasticity of calories are much larger than Subramanian and Deaton's estimates for India in 1983 or the Bangladeshi estimates for 1992. Even when using historical estimates that are too low by construction, the historical estimates are still greater than the contemporary estimates.

B. Calorie Price Elasticities

Another measure related to calorie elasticities is the expenditure elasticity of calorie price. Earlier, I noted that the food elasticity is not a good quantifier of hunger since even well-fed people may have high food elasticities if they have high demand for expensive foods. Taking this idea further, we can decompose increased food expenditure as income increases into two components—the increased number of calories they consume and the increased average price they pay for the calories they consume. People who are very hungry should have relatively

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only exception being females aged 10-14). Additionally, the demographic controls are not precisely estimated in the British data, most likely due to the smaller sample size.

low expenditure elasticities of calorie price since they would desire increased quantity over quality. Since each household faces a unique price of calories based upon the quantity and types of foods that they consume, household-specific calorie prices can be constructed from the survey data. Further, when one considers that the expenditure elasticity of food can be decomposed into the expenditure elasticity of calories (a diet quantity measure) and the expenditure elasticity of calorie price (a diet quality measure), the share of the food elasticity that is devoted to quantity will be larger for those who are hungry.[20] While it may be true that nearly all people will increase the price they pay for calories somewhat as their income increases, the share of the food elasticity devoted to increased quantity is a standardized way of looking at hunger that is very closely related to calorie elasticities and retains the calorie elasticity's intuitive appeal.

The price elasticities of calories further confirm the finding that workers in the late nineteenth century were worse off nutritionally than households in rural India in 1983. Table 5 shows the expenditure elasticity of calorie price for the American, British and Indian data.[21] While the Indian price elasticity is .32, the American price elasticity is .13, and the British price elasticity is .15. Also, note that the hypothesis of price elasticity equality between the American and British households cannot be rejected. Subramanian and Deaton find that the food elasticity is equally divided between the price elasticity and the calorie elasticity (so that roughly 50% of

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[20] First, consider the expenditure elasticity of food, which is $E[\ln(foodbudget_i)] = \alpha_F + \beta_F \ln(PCE_i)$ where β_F is the expenditure elasticity of food. Total food expenditure is also total calorie expenditure, and it is the product of the price of the calories and the quantity of the calories. This gives the identity $foodbudget_i \equiv P_i Q_i$ where P is the price of calories and Q is the quantity of calories. Since calorie price has an expenditure elasticity $(E[\ln(P_i)] = \alpha_P + \beta_P \ln(PCE_i))$ and calorie quantity has an expenditure elasticity $(E[\ln(Q_i)] = \alpha_Q + \beta_Q \ln(PCE_i))$, taking the log of food identity and substituting the calorie price and calorie quantity elasticities into the food elasticity equation gives $E[\ln(foodbudget_i)] = \alpha_F + (\beta_P + \beta_Q)\ln(PCE_i)$ where the slope of the food expenditure elasticity is simply the expenditure elasticity of calorie price added to the expenditure elasticity of calorie quantity and where $\alpha_F = \alpha_P + \alpha_Q$. In looking at the share of the food elasticity devoted to calorie quantity, $\beta_Q / (\beta_P + \beta_Q)$, we control for the overall size of the food elasticity.

the food elasticity is due to increased quality), and this pattern holds for many developing countries. Indeed, Banerjee and Duflo (2007) assert that "even for the extremely poor, for every 1 percent increase in the food expenditure, about half goes into purchasing more calories, and half goes into purchasing more expensive calories" (p. 147). Historically, however, these industrial workers devoted less than 25% of the food elasticity to more expensive calories. Put another way, more than 75% of the food elasticity for American and British households was devoted to increasing the size of the diet, and less than a quarter to increasing the diet quality.

This comparison of calorie elasticities has established that those in contemporary South Asia are better fed than American and British industrial workers in the late nineteenth century, and runs counter to the conclusions drawn about historical living standards from conventional income estimates. That a person in rural India in 1983 was better-fed than an American industrial worker a century before is surprising when one considers that American industrial workers were among the highest paid in the world at the time. If it is true that an American industrial worker in 1889 had nearly twice the purchasing power parity of a rural Indian in 1983 then this result is truly surprising.[22] In less than a century some of the poorest people in the world are better fed than some of the wealthiest workers in the world were a century ago. From this case study I conclude that the press of hunger has undergone a significant transformation in the last century. Next, we expand beyond the case study to consider the general pattern of calorie elasticities and other measures of wellbeing such life expectancy and infant mortality.

III. Evidence from the General Pattern of Calorie Elasticities

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[21] It was not possible to construct household measures of calorie prices with the Bangladeshi data.

[22] This estimate of PPP comes from the estimates of Officer (2001, 2002, and 2003) and McCusker (2003).

The main results of the case study hold when considering a host of calorie elasticity estimates. The general pattern reveals that the historical estimates are indeed at the highest end of what is seen today for developing countries. Table 6 list the calorie elasticity estimates compiled by Strauss and Thomas (1995) that use a methodology similar to my own. Namely, each of the estimates in the table come from an OLS or two-stage least squares (2SLS) estimate of the calorie elasticity where the calorie unit is the number of calories available to the household and income and expenditure are the measures of household resources. Both the income and expenditure elasticity estimates for both Great Britain and the United States are among the highest estimates when compared to those compiled by Strauss and Thomas.

In looking at the general pattern it is important to note the role that urban and rural locations play in calorie elasticities.[23] The households in the 1888CEX are generally urban households, while contemporary calorie elasticities are usually estimated for rural populations. In contemporary developing nations those in urban locations generally have lower calorie elasticities (Strauss and Thomas 1995). Economic historians have established that rural households were better off than industrial, urban households in the past. Steckel (2005) and Haines, Craig, and Weiss (2003) note that increasing urbanization has been blamed for the decline in living standards in the middle of the nineteenth century. In a broader survey, Steckel (2000) analyzed eight developed countries and finds that health was negatively correlated with urbanization throughout the industrialization process. Cuff (2005) has shown that those in remote locals in the antebellum period enjoyed a significant health advantage over their urban contemporaries. Not only were cities more disease-filled, but the lack of diet variety in urban locations could have left city dwellers more susceptible to disease. With these considerations in

[23] Of course, what exactly is meant by "urban" and "rural" has changed over time, and even today their meaning can only be derived from context.

mind, we can say that, a priori, urban households in late nineteenth century industrial countries and rural households in developing countries will have the largest calorie elasticities for their times.

Demographic measures such as infant mortality and life expectancy support the notion that those in the late nineteenth century were worse off than those in developing countries today. Returning to the case study, we can note that while 90% of children born in 1983 Maharastra, India lived to see their fifth birthday, 80% did so in the United States, and only 75% did so in Great Britain. Similarly, life expectancy was also much shorter in the past. While males aged ten in the United States and Great Britain in the late nineteenth century could expect to live another 50 years, males aged ten in India in 1983 could expect to live another 55 years.[24] In general, both infant mortality and life expectancy are much better today in developing countries than they were in the late nineteenth century.

When considering other estimates of well-being, such as height, the comparison between the past and present is more nuanced. Historically, the country with the taller population had greater per capita GDP and lower calorie elasticities. In the contemporary developing world, however, the relationship is not as straightforward. Development economists generally agree that, as a region, Sub-Saharan Africa has the lowest per capita GDP and highest calorie elasticities, and yet stature in many Sub-Saharan African nations is greater than many nations with much higher per capita GDP.[25] There are several nations in Sub-Saharan Africa with statures that would make them taller than American and British industrial workers in the late

[24] While a five year life expectancy differential may appear small, changes in life expectancy at age ten require large reductions in later-life mortality that are much more difficult to achieve than reductions in infant mortality.
[25] It must be noted that ethnic and cultural differences in diet (namely, the propensity to eat significant amounts of animal protein) may explain the lack of a GDP-height relationship in developing countries today. For more on the significance of animal protein in historical diets see Logan (2006b).

nineteenth century, and others with shorter statures.[26] South Asians are shorter than late nineteenth century industrial workers.

Due to the inherent problems of comparing point estimates of height, a look at the growth rate of average stature in centimeters per year would be more appropriate.[27] Moradi (2006) analyzes height trends in Sub-Saharan Africa and South Asia from 1950 to 1980. He finds that South Asians were making steady but slow height gains, but Sub-Saharan Africa had two nations where the height trend was increasing, nine with decreasing stature, one with a U shaped trend, and nine with inverted U shaped trends. These types of dissimilarities are not found in historical height trends. Steckel (2005) has shown that height and per capita GDP behave uniformly for nearly every nation of Western Europe and the United States. Since stature varies greatly from country to country toady without a clear short-run trend it is difficult to extend the comparison to stature.

IV. Is the Comparison Valid?

The lessons and conclusions that we draw from the comparison of calorie elasticities are only as valid as the comparison itself. Below I consider objections to the comparisons of calorie elasticities across time and space. I consider the consequences if the estimates of calorie elasticities in the past are contaminated with indirect estimation bias, the failure to report home production of calories, measurement error, and accounting for differences in substitution between food groups as income increases. I conclude that these objections, while potentially damaging, do not apply to the calorie elasticity comparisons made here.

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[26] This comparison is made through the evidence presented by Moradi (2006) on heights, and assumes that industrial women in the late nineteenth century were 158 centimeters tall.

A. The Indirect Estimates Objection

The first objection to the comparison would be that the historical elasticity estimates are more indirect than the other estimates presented in Table 6. Indirect estimates of calorie elasticities are calculated by computing the income and/or expenditure elasticity of food for each respective food group and then converting that measure to calories. The problem with indirect estimates is that they miss the substitution that households make between foods within particular food groupings. Elasticity estimates derived using indirect methods are usually greater than those that use the direct (calorie) method.

I do not believe that the historical estimates are contaminated with “indirect bias” for four reasons. First, Strauss and Thomas (1995) note that there is, a priori, nothing inherent in the indirect methodology that necessarily creates larger estimates-- in some studies a bias appears while in others it does not. While empirically calorie elasticities estimated with indirect estimates tend to be greater than direct estimates, this does not hold for every study. Secondly, food groups in the 1888CEX are fairly well detailed for the time of the survey, and I therefore capture a large amount of substitution between calorie groups. It is well established in the historical record that the diet of the working classes in the late nineteenth century was monotonous (Kertzer and Barbagli 2002). Third, for food groupings that were fairly broad (fruit, for example), the calorie price of the foods in that group did not vary significantly, which means that substitution between goods within a food group were largely not substitutions towards more or less expensive calories, as far as we can calculate for the time. Fourth, looking at changes in food groups across the income distribution strongly suggest a great deal of substitution away

[27] Comparing height at a point in time is analogous to comparing GDP at a point in time—it would be unreasonable to expect people who have only had fifty years of a stature transition to achieve the same heights as those whose

from and towards different food groups. If the vast majority of the substitution was within a food group then the expenditure shares devoted to particular food groups would remain nearly constant from the top to bottom deciles of the income distribution, and this was clearly not the case. In fact, I find substantial substitution between food groups for industrial workers in the late nineteenth century; this would not be true if the historical estimates were more indirect than their elasticity estimates.[28]

B. The Home Production of Calories Objection

The second objection to the validity of the comparisons made in Table 6 has to do with the home production of calories.[29] If the distribution of home-produced calories is skewed towards the poorest families in the historical survey the estimates of available calories are too low for poor households. This yields calorie elasticity estimates that are too high in that they have systematically underestimated the total calories available to poorer households. Comparing the 1888CEX calorie elasticity estimates to estimates that account for home production, as most studies in the developing world attempt to do, is therefore not appropriate.

It is true that the 1888CEX does not include home produced calories. It is also true that the distribution of home-produced calories is skewed towards poorer families, but only in the total population. The distribution within the 1888CEX, however, is not likely to be as skewed as the distribution in the general population. Furthermore, if the home production objection is valid, poor families would have food expeditures whose calorie content would be biased away from calories that are easily produced in the home (e.g. fruits and vegetables), and this is not

statures have been growing for more than a century.

[28] See Logan (2006b) for more on substitution within and between food groups in the late nineteenth century.

[29] This is attributed to Martha L. Olney, who reminded me that even in very urban locations it was not uncommon to have live animals, in particular chickens, in the backyard in the late nineteenth century.

supported by the data. Finally, this argument implicitly assumes that the error in calories are correlated with income or expenditure, and earlier I noted that the result was robust to this sort of measurement error.

Narrative historical evidence also cast doubt on the home production objection. In an insightful monograph, Byington (1910) conducted intensive interviews of nearly 100 families in a mill town near Pittsburgh, Pennsylvania near the turn of the century. She found that poor families lacked the income necessary to partake in significant home production, which runs counter to the assumption of the home production objection. In particular, Byington found that the poor families she studied bought their food in the market on a daily basis, while the wealthier families were able to buy in bulk and to buy whole animals (including chickens and pigs) since they had the income to provide for their storage.[30] In short, home production in the late nineteenth century required planning and savings which poor families could not afford. If anything, it was wealthier families who practiced significant home production of calories. The narrative evidence implies that any home production bias in the 1888CEX would lead to higher estimates of the calorie elasticities than those presented here.[31]

We can also turn to the data itself for more information on home production. Within the 1888CEX interviewers commented on the general condition of the home and noted items that the family owns, including gardens, poultry, cows, and fruit trees. The comments were not uniform,

[30] Byington also found that poor families lacked the money to buy ice by which they could store food. She also noted that these were the families who would be most helped by buying in bulk. Instead, these families were forced to live day to day and nearly all of the food they consumed was purchased in the market.

[31] Additional narrative evidence supports Byington's conclusions. Streightoff (1911) notes a study by Forman which found that very poor families in Washington "spend what little they have unwisely…these people never bought their own flour for breadmaking…and they seemed to ignore the value of such a cheap wholesome food as corn meal" (p. 99). He goes on to say that "some of the economies practiced among working families of the lowest rank are pitiful" (p. 100). He also found that perishables were rarely purchased far in advance since poor families could not afford ice. Chapin (1909) similarly found that "most families buy their supplies from day to day in very small quantities, partly from lack of facility for storing and keeping food, and partly from the lack of money enough at one time to enable them to buy any large amount" (p. 132).

however, and comments were not made for all households. Nevertheless, the comments can be used to identify the income distribution of home producing households, and to learn if the income distributions of home producing and non-home producing households are similar.[32] In a close analysis of the comments the results point in the opposite direction of the home production objection.[33] The means of the log of per capita income and the log of per capita expenditure for both home producing and non-home producing households are very close to one another, and households with home production are found at all points of the income and expenditure distributions. I find no evidence that home production of calories is concentrated in low income households.

The strongest argument against the home production objection involves only simple arithmetic. Suppose that the poorest households—for convenience let us say the poorest third—all participated in home production. I would therefore understate the total calories available to those households and overstate their expenditure elasticity of calories. Yet even if this were true the finding would hold. Estimates for the wealthier two thirds of households will be correct, and certainly for the top half they will be. Non-parametric expenditure elasticity estimates, which are based on small local neighborhoods of the log of per capita expenditure, will not be influenced by the failure to capture home production in the bottom third of households.[34] Those results show that the average of the expenditure elasticity for the wealthier two-thirds of households still yields an estimate above .5 for the United States, and above .6 for the British. Therefore, even if I were to exclude the poorest third of households from the 1888CEX the historical elasticity estimates would still be greater than what is seen in the developing world today. Given such

[32] It is important to note that the comments mentioned several types of household items, and occasionally made observations about the family and its organization and well-being. Given their detail, it is unlikely that comments systematically under-counted home production.
[33] These results are not decisive, however, since the comments were not uniform (see the appendix).

strong narrative evidence and the lack of evidence from the comments of the interviewers, I do not see the home production objection as applying to the historical calorie elasticity estimates.

C. The Measurement Error Objection

If there is more measurement error in the developing country expenditure data than in the past the results in the previous section could be due to attenuation bias. Deaton (1997) has noted that surveyors in developing countries have taken great pains to ensure that their measures are accurate. For example, the NSS does not ask for household income, as that question appeared to seriously hamper the response rate, and is difficult to measure for poor rural households. For the Bangladeshi data household expenditure is used because income varies by season. Indeed, one reason that expenditure, rather than income, is taken as the measure of household resources is that expenditure has less errors than income.

Turning to the particulars of this objection, measurement error could explain a small part of the results presented here, but to assert that they explain any significant portion of the differences in the elasticities one would have to take two contradictory positions. It could be true that expenditure is measured with more error in developing countries, but that would also mean that the greater errors in expenditure in developing countries would be (potentially) correlated with the errors in calories, resulting in even higher calorie elasticity estimates. As noted earlier, Bouis and Haddad (1992) have shown that in a linear model the correlated measurement error will usually be greater than the attenuation bias, leading to upwardly biased estimates of calorie elasticities when both types of errors are present.[35] Asserting that there is greater measurement error in contemporary developing countries is equivalent to stating that the calorie elasticity

[34] For the non-parametric results see Logan (2006a).

estimates for developing countries presented in Table 6 are too high. Section III showed that even the estimates for the United States and Great Britain that were too low by construction were greater than the estimates from India that may be plagued with correlated measurement error.

We can construct a reasonable bound for this measurement error with a simple calculation. First, consider the traditional errors-in-variables problem where the equation to be estimated is $y = \beta x + \varepsilon$ where y, x, β and ε are vectors and further assume that $x = \bar{x} + \upsilon$ where υ is orthogonal to the true $\bar{x}$. In reality, we would like to estimate $y = \beta\bar{x} + \varepsilon$ but the well-known result is that the probability limit becomes $b = \beta\left(\frac{\sigma_{\bar{x}}^2}{\sigma_{\bar{x}}^2 + \sigma_{\upsilon}^2}\right)$.

Using the case study for illustration, and noting that the relative variance is the important feature, we can further assume that the variance in properly measured expenditure can be normalized to one so that $\sigma_{\bar{x}(US,1888)}^2 = \sigma_{\bar{x}(GB,1888)}^2 = \sigma_{\bar{x}(India,1983)}^2 = 1$. Also, we can assume that the true elasticity, β, is either the American or British expenditure elasticity of calories. Using the results of Table 3 we can use the probability limit to bound the measurement error and estimate how much measurement error there would have to be in the Indian data to explain the differences in the calorie elasticity estimates. Formally, what this measures is the proportional variance of the measurement error, σ_{υ}^2, relative to the variance of expenditure properly measured, $\sigma_{\bar{x}}^2$, since we have normalized the variance of properly measured expenditure.

The arithmetic shows that the variance of the Indian measurement error must be almost half of properly measured expenditure variance ($\sigma_{\upsilon(India,1983)}^2 = .5\sigma_{\bar{x}(India,1983)}^2$) for the true calorie elasticity in India to be equal to the American elasticity estimate, and the variance of the error

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[35] An important caveat here is that linearity appears to be a very good approximation to the actual relationship between calories and expenditure.

must be nearly 85% of the properly measured expenditure variance ($\sigma^2_{\upsilon(India,1983)} = .85\sigma^2_{\bar{x}(India,1983)}$) for the British elasticity to be the true elasticity for India. Similarly, if we use the results of Table 4 and compare the lowest bound estimates of the historical expenditure elasticity of calories (which by construction are too low) to the upper bound of the Indian elasticities (which may be too high) we find that the variance of the Indian measurement error must be almost 20% of properly measured expenditure for the true elasticity in India to be equal to the American estimate, and the variance of the error must be nearly 35% of the properly measured expenditure variance for the British elasticity to be the true elasticity. Both of these calculations yield implausibly high amounts of measurement error.

D. Accounting for Dietary Substitution

As income increases, households may move out of and into different food groups. To the extent that foods of certain types have more or fewer calories than others, differences in dietary substitution could give rise to large differences in calorie elasticities that would not be due to hunger. In terms of the comparison made here, the limited variety of food available in the past could have forced industrial workers to consume more of the same types of foods because increasing the variety of the diet was not possible. Similarly, to the extent that there was dietary substitution in the past, it could have been markedly different from the types of substitution that we see in developing nations today due to differences in dietary tastes. To determine if the demand elasticities reported here are robust to such concerns two issues must be addressed: (1) to determine whether the extent of dietary substitution in the past was less than it is in developing countries today and (2) to determine if these differences in substitution could explain the calorie elasticity differentials.[36]

Both of these issues are addressed in Table 7. In that table, I take the differences from the highest to lowest decile of the per capita expenditure distribution for both food expenditure shares and calorie shares for the 1888CEX and the NSS data. Because the range of income in the surveys was similar, the movement from the first to tenth decile covers roughly the same range in all three samples. The first item to note is that the substitution trend in terms of food expenditure is more alike than different, not only in the direction of the substitution (moving out of cereals and oils, fats and sugars and into dairy and meat, for example), but also in the magnitude. The largest difference is in terms of fruits and vegetables, which we would expect given their home production in the past and due to innovations in refrigeration. The expenditure shares show that the both the historical and contemporary households exhibited pronounced substitution between food groups in the past, and the expenditure results would make it difficult to argue that there were marked differences in food-group substitution between the historical and contemporary surveys.

The calorie shares mirror the results of the expenditure shares for the most part. Where there are differences, however, the results are in directions that make it difficult to argue that the elasticity differences reflect differences in food substitution that would not be related to hunger. For example, suppose that poorest households in India consume mostly cereals and that the poorest historical households consume mostly meat and potatoes. If the Indian villagers increases the amount of meat in her diet (which is relatively low calorie per unit of expenditure) while the industrial worker increases the amount of sugar and fat in her diet (which is high calorie per unit of expenditure) then the result could not be due to hunger but to differences in

[36] This is related to part of the discussion on indirect estimates made earlier.

substitution. Table 7 shows exactly the opposite, wealthier households in the past moved out of oils, fats and sugars and into meats and dairy in greater proportion than the Indian households today—large enough to result in significant increases in calories coming from those sources.

Taken together, the expenditure and calorie results in Table 7 show that there was significant dietary substitution in the past between food groups and that the types of substitutions we see are consistent with historical households being hungrier than households in developing countries today. Households in the past were not filling their stomachs with "empty" calories as their incomes rose, but with meats and dairy and other "filling" foods. Although it is important to note that food quality has changed substantially over time, accounting for taste for variety and dietary substitution does not explain the differences in calorie elasticities.

V. Calorie Demand, Engel Curves and New Income Estimates

Moving beyond hunger, the findings in this paper tell us something about the standard of living that may lead us to reexamine the reliability of our traditional income estimates. In this section I use the Engel curve suggested by the historical elasticity estimates to derive new income estimates for developing countries today based upon their calorie elasticities. The 1888CEX is unique in this regard because the survey allows us to specify a relationship between calorie elasticities and real income at a single point in time for two nations whose calorie elasticities were estimated in the same way. [37]

[37] Using Engel curves to derive estimates of real income has been advanced by Hamilton (2001) and Costa (2001). There are some assumptions necessary to use Engel curves to estimate the true cost of living. Food must be separable from non-food in the utility function, the Engel curve with respect to real income must be stable over time, and subutilities of food and non-food need to be homothetic. Additive separability of food and non-food is needed so that bias or errors in non-foods do not effect the demand for food. If these conditions are met then differences between Engel estimates of income and other estimates of income will reflect changes in the relative price of food and the mismeasurement of real income. The application to calorie elasticities carries over directly. See Hamilton (2001) for the decomposition.

The calorie elasticity-GDP per capita relationship taken from the expenditure elasticity of calories estimates from Table 2 and the real 1889 GDP per capita estimates given by Ward and Devereux (2003). The income and elasticity values determine the line given by $\xi_D = 1.324 - .0035(GDP_{1889})$. It is noteworthy that this line is entirely plausible. Greater GDP per capita gives us lower calorie elasticities, and at very low levels of income the calorie elasticity will be very large, implying that food is a luxury at very low income levels. Since we know the expenditure elasticity of calories for developing countries in Table 6, we can place those calorie elasticities on the line given above to derive estimates of real GDP per capita. Table 8 reports both the traditional and the Engel derived estimates of GDP per capita for these nations whose expenditure elasticity of calories is reported in Table 6.[38]

The factor of convergence reported in Table 8 is the amount that the traditional income estimates must be multiplied by to equal the new Engel-based income estimates. Given the large factors of convergence in the table, it is safe to say that the Engel and GDP deflator estimates of real GDP per capita are not in line with one another. As the table shows, traditional income estimates understate the Engel income by a factor of more than six. The lowest factor of convergence in Table 8 is 6.93, for the Philippines, and the largest is 11.36, for Sri Lanka, with an average factor of convergence of more than 8.5.

What could account for such large differences between the two methods? As economic historians have noted in making the case for the use of height as a measure of the standard of living, aggregate measures have several microeconomic flaws (Steckel 1995). Indeed, since

[38] The traditional GDP estimates listed in Table 8 are made by taking the real 1983 GDP per capita of the developing nations expressed in 1997 dollars and then dividing this by the purchasing power of a 1997 US dollar relative to that of a 1889 US dollar. Another method would be to divide the real GDP expressed in 1997 dollars by the GDP deflator, and if those results were used the qualitative implications would be the same. The value of the deflator comes from Officer (2003). Also, the use of 1983 is to set the estimates of income at a point in time for specificity,

height reflects net nutritional status in the growing years, it is a natural extension to note how some of those deficiencies would play out in the comparisons made in Table 8 beyond general claims of mismeasured income. Take the case of climate, which could have several different effects on calorie requirements. In a colder environment, a person would need more calories for basal metabolism and maintenance. Additionally, the colder the environment, the more expenditure must be devoted to housing, clothing, and utilities such as heat, which would indirectly lower the expenditures on calories. Someone living in a much warmer climate, however, would require calories to keep their bodies from overheating, particularly when exerting effort when working. On net colder climates require more calories for maintenance.

A second factor would be the amount of work itself, work intensity. It has been well established that the workday was long for industrial workers in the nineteenth century (Atack and Bateman 1992, Costa 2000). Long working hours would have increased the demand for calories. A third factor that makes large claims on the diet is disease. The disease rates estimated for historical populations have been so high that some have argued that nearly every human being was chronically malnourished before the twentieth century (Fogel 1994). This high rate of disease would also lead to increased demand for calories in the past. Since the Engel method reflects demand for calories, it implicitly includes reduced form comparisons of climate, work intensity, disease environment, public health, and stature (to the extent that taller individuals will have greater calorie needs than shorter individuals), each of which is missing from conventional growth accounting measures.[39]

Finally, since the factors of convergence reflect both mismeasurement of real income and relative price changes we cannot say how much of each is involved in the overstated income

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and since it is a midpoint of the 1980-1985 GDP estimates. Similar income numbers are found when using the average of 1980-1985 real GDP and the average of 1975-1985 real GDP.

estimates. Given the calorie prices discussed earlier it is likely that a significant portion of this mismeasurement is due to changes in the relative price of calories over time. Putting a bound on the effect of relative prices and other factors, however, would still leave us with a significant amount of the differences in income estimates accruing to mismeasured income. Even if we were to assume that three-quarters of the factor of convergence in Table 8 are due to relative price changes our real income estimates would still be understated by several orders of magnitude on average.

VI. Conclusion

Using the income and expenditure elasticities of calorie demand, this paper has quantified a profound transformation of hunger in the past 100 years. The empirical results in this paper establish a number of facts. First, people in developing countries today are well fed in comparison to yesterday's industrial workers. Secondly, calorie elasticities have an intuitive appeal and their interpretation is robust to a number of objections that would seriously damage comparisons of other measures of nutritional well-being. Third, hunger-based estimates of aggregate income tell us a very different story about the well-being of people in developing countries today and industrial workers in the past. The income estimates here add further impetus to the recent suggestions that quality of life measures be incorporated into discussions of growth (Kenny 2005, Deaton 2005, Banerjee and Duflo 2007).

What are we to make of the finding that the poor of today are quite well fed when compared to the relatively wealthy only a century ago? A rapidly declining price of calories may be the answer to the empirical puzzle presented here. The Engel analysis suggests that our relative price estimates perform poorly over time. While one objection to the conclusion that

[39] See Weil (2007) and Acemoglu and Johnson (2007) for models of the effects of health on economic growth.

living standards have improved dramatically for poor households would be that there are different prices, different bundles, and different taste over time and space, PPP has been advanced as a method to deal with such differences. Given the Green Revolution, transportation innovations, and increasing technological sophistication of agriculture in developing countries in the second half of the last century, we should expect the price of calories to be relatively low in developing nations when compared to the price of calories faced by the historical households analyzed here.

Economists have known of these problems for some time, and recently Deaton (2006) has derived PPP estimates based on household surveys to overcome some of the shortcomings with traditional PPP estimates. Banerjee and Duflo (2007) note that these problems will have an impact on our PPP estimates to the extent that poor households in some countries face relatively cheap prices for consumption goods as opposed to others. We are left, then, with an incomplete and potentially biased picture of living standards in the past and present. These findings give us hope that the defeat of hunger is closer than many have previously thought, and they are in line with the calls to eliminate extreme poverty in twenty years (Sachs 2005). History provides some clues as to which track to take, but it is up to contemporary policy makers to use the comparative measures of living standards effectively.

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Table1

Summary Dietary Measures

Number of Calories Per Head

	US 1888	GB 1888	India* 1983
Calories Per Head	1,646	1,390	2,098

Percent of Total Household Expenditure Devoted to Food

	US 1888	GB 1888	India* 1983
Percent of Budget Devoted to Food	44.50%	50.10%	67.40%

Price of a Day's Worth of Calories as a Percentage of a Day's Wage

Industry	US 1888	GB 1888	India** 1983
Pig Iron	11.25%	16.96%	-
Bar Iron	8.26%	14.49%	-
Steel	9.98%	12.97%	-
Bitminous Coal	13.53%	16.88%	-
Coke	11.18%	19.70%	-
Iron Ore	17.88%	-	-
Cotton Textile	15.92%	16.66%	-
Wool Textile	12.18%	20.01%	-
Glass	7.45%	14.97%	-
Average	11.15%	16.04%	< 5%

The percentage is the proportion of a male head's daily wage, in each industry, that would purchase 2,300 calories at the average calorie price faced by households in each industry. The differences in calories per head is robust. Calories per adult male equivalent for the US are approximately 2,300, 1,800 for Great Britain, and 2,800 for India.

Clothing was 16.7% of expenditure, and housing 13.7% of expenditure in the US.
Clothing was 16.1% of expenditure, and housing 10.8% of expenditure in the Great Britain.

* Results come from Subramanian and Deaton (1996), pg. 140, Table 1

* Results come from Subramanian and Deaton (1996) p. 155, and are for 2,600 calories at average prices for Maharastra, India in 1983.

Table 2

Log-Log Transformation OLS Estimates of Caloric Elasticities, 1888 Cost of Living Survey
(Dependent Variable = Log of Per Capita Calories (lnPCC))

	I	II	III	IV	V	VI	VII	VIII
	GB	GB	GB	GB	US	US	US	US
Intercept	7.555	6.779	8.477	7.289	8.836	7.478	10.057	8.140
	(.203)	(.229)	(.328)	(.388)	(.067)	(.067)	(.094)	(.097)
lnPCI	0.595		0.502		0.465		0.358	
	(.022)		(.032)		(.007)		(.009)	
lnPCE		0.684		0.624		0.613		0.550
		(.025)		(.039)		(.007)		(.009)
lnFamSize			0.020	0.086			-0.078	0.016
			(.034)	(.036)			(.012)	(.011)
Share 0-4*			-0.330	-0.311			-0.358	-0.339
			(.076)	(.075)			(.025)	(.022)
Share 5-9*			-0.271	-0.272			-0.256	-0.243
			(.079)	(.078)			(.028)	(.025)
Share 10-14*			-0.095	-0.126			-0.197	-0.211
			(.085)	(.083)			(.032)	(.028)
Share 15-19*			-0.048	-0.026			0.052	0.003
			(.085)	(.087)			(.034)	(.030)
Share 20-24*			0.060	0.046			0.086	0.033
			(.050)	(.049)			(.023)	(.022)
R-Square	0.48	0.50	0.50	0.52	0.44	0.56	0.49	0.58

N = 6809 for all US Regressions, 1024 in all Great Britain Regressions
Mean of lnPCC = 13.2049 in US, 13.0739 in Great Britain
Each column is a separate OLS regression in which lnPCC was the dependent variable.
Robust standard errors are listed under coefficient estimates in parentheses.
* Share x-y is the share (proportion) of the household aged x to y.

Table 3

Log-Log Transformation OLS Estimates of Caloric Elasticities
1888 United States, 1888 Great Britain, 1983 India, and 1992 Bangladesh

	US 1888 I	GB 1888 II	Bangladesh 1992 III	Bangladesh 1992 IV	India* 1983 V	India* 1983 VI
Intercept	8.014	6.814	7.356	7.137	6.028	
	(.119)	(.378)	(.379)	(.378)	(.077)	
lnPCE	0.543	0.674	0.351	0.244	0.366	0.341
	(.011)	(.038)	(.069)	(.070)	(.013)	(.013)
lnFamSize	-0.033	0.090		-0.052	-0.157	-0.163
	(.011)	(.048)		(.009)	(.011)	(.008)
Male 0-4	-0.225	-0.212		-0.312	-0.097	-0.146
	(.038)	(.144)		(.491)	(.044)	(.036)
Male 5-9	-0.114	-0.183		-0.113	0.049	0.032
	(.039)	(.155)		(.492)	(.041)	(.032)
Male 10-14	-0.087	-0.102		0.078	0.089	0.061
	(.039)	(.156)		(.051)	(.047)	(.032)
Male 15-55	0.162	-0.057		0.206	0.164	0.163
	(.040)	(.140)		(.422)	(.032)	(.028)
Male 55+	0.120	0.084		0.329	0.141	0.121
	(.038)	(.152)		(.566)	(.047)	(.043)
Female 0-4	-0.219	-0.248		-0.236	-0.136	-0.187
	(.036)	(.142)		(.485)	(.044)	(.038)
Female 5-9	-0.131	-0.274		0.104	0.018	-0.004
	(.038)	(.147)		(.491)	(.044)	(.040)
Female 10-14	-0.121	-0.065		0.096	0.114	0.068
	(.042)	(.155)		(.052)	(.041)	(.034)
Female 15-55	0.054	0.023		0.108	0.042	0.051
	(.036)	(.131)		(.396)	(.026)	(.025)
R-Square	0.64	0.57	0.42	0.62	0.55	0.67
N	6,809	1,024	1,543	1,543	5,624	5,624
Industry Dummies?	Yes	Yes	No	No	Yes	Yes
State/Region Dummies?	Yes	NA**	No	Yes	No	Yes

* Results come from Subramanian and Deaton (1996) Table 2, p. 153.
**Note: Geographic detail is not available for the British sample
Male/Female x-y is the share (proportion) of the household that is in that age-sex category.
Each column is a separate OLS regression in which lnPCC was the dependent variable.
Robust standard errors are listed under coefficient estimates in parentheses.

Table 4

Upper and Lower Bound Expenditure Elasticity of Calories Estimates

	Dependent Variable	Independent Variable	Instrumental Variables	Upper Bound		Lower Bound	
Great Britain, 1888	lnPCC	lnPCE	lnNFE, lnTIF	0.722	(.031)	0.512	(.031)
United States, 1888	lnPCC	lnPCE	lnNFE, lnTIF	0.594	(.009)	0.450	(.009)
India, 1983*	lnPCC	lnPCE	lnNFE	0.439	(.006)	0.334	(.009)
India, 1983*	lnPCC	lnPCE	lnNFE, lnTIF	0.378	(.006)	0.281	(.008)
Bangladesh, 1992	lnPCC	lnPCE	lnNFE	0.351	(.068)	0.341	(.067)
Bangladesh, 1992	lnPCC	lnPCE	lnNFE, lnTIF	0.309	(.069)	0.238	(.067)

* Results come from Subramanian and Deaton (1996) Table 3, p. 160.
lnNFE is the log of total non-food expenditure, and lnTIF is the log of household size. lnTIF was used as an instrument for itself. Standard errors are in parentheses.

Upper bounds come from OLS estimates of lnPCC on lnPCE, lnTIF regressions. Lower bounds are IV regressions with the same variables as OLS, with lnNFE as the instrument for lnPCE.

Table 5

Log-Log OLS Estimates of Elasticity of Calorie Price for United States, Great Britain, and India
(Dependent Variable = Log of Calorie Price)

	US 1888 I	GB 1888 II	US 1888 III	GB 1888 IV	India* 1983 V	India* 1983 VI
Intercept	-3.828	-3.995	-3.401	-3.588	-1.593	
	(.056)	(.207)	(.087)	(.291)	(.089)	
lnPCE	0.156	0.187	0.126	0.147	0.380	0.322
	(.006)	(.022)	(.008)	(.028)	(.015)	(.014)
lnFamSize			-0.012	-0.077	0.084	0.066
			(.009)	(.036)	(.012)	(.008)
Male 0-4			0.010	0.091	0.102	0.101
			(.027)	(.112)	(.045)	(.031)
Male 5-9			-0.052	0.171	-0.047	-0.033
			(.029)	(.116)	(.039)	(.028)
Male 10-14			-0.024	0.136	-0.112	-0.084
			(.030)	(.125)	(.049)	(.029)
Male 15-55			-0.151	0.113	-0.170	-0.135
			(.030)	(.111)	(.039)	(.027)
Male 55+			-0.046	0.019	-0.157	-0.107
			(.029)	(.104)	(.044)	(.037)
Female 0-4			-0.013	0.120	0.046	0.074
			(.027)	(.113)	(.042)	(.034)
Female 5-9			0.055	0.197	-0.064	-0.048
			(.029)	(.113)	(.046)	(.034)
Female 10-14			-0.054	0.058	-0.111	-0.087
			(.031)	(.124)	(.041)	(.029)
Female 15-55			-0.110	0.107	0.009	-0.002
			(.025)	(.104)	(.028)	(.021)
R-Square	0.10	0.09	0.34	0.23	0.43	0.64
N	6,809	1,024	6,809	1,024	5,624	5,624
Industry Dummies?	No	No	Yes	Yes	Yes	Yes
State/Region Dummies?	No	No	Yes	NA**	No	Yes

* Results come from Subramanian and Deaton (1996) Table 2, p. 153.
**Note: Geographic detail is not available for the British sample
Male/Female x-y is the share (proportion) of the household that is in that age-sex category.
Robust standard errors are listed under coefficient estimates in parentheses.

Table 6

Comparison of 1888 Estimates of Caloric Elasticities With Estimates From
Household Surveys Conducted in the Developing World Today

Expenditure Elasticity of Calories

Nation	Method	Estimate
Indonesia-Urban	OLS	0.26
Philippines	2SLS	0.32
Philippines	OLS	0.34
Philippines	OLS	0.43
India	2SLS	0.44
Indonesia-Rural	OLS	0.51
United States - 1888	2SLS/IV	0.51
United States - 1888	OLS	0.55
Sri Lanka	OLS	0.56
Great Britain -1888	2SLS/IV	0.62
Great Britain - 1888	OLS	0.62

Income Elasticity of Calories

Nation	Method	Estimate
Mexico	OLS	0.01
Philippines	OLS	0.11
Brazil	OLS	0.24
Philippines	2SLS	0.28
Thailand	OLS	0.33
United States - 1888	OLS	0.36
Great Britain - 1888	OLS	0.50
Brazil	2SLS	0.53

Note: All non-1888 estimates are taken from Table 34.1 of Strauss and Thomas (1995, pp. 1894-1895) except those of Mexico, which come from Ruiz-Arranz, et. al. (2002)

For methodological consistency, only OLS and 2SLS estimates based upon caloric availability are reported in this table. For a discussion of the heterogeneity introduced by the estimation procedure and type of caloric unit see Strauss and Thomas (1995) and Deaton (1997).

Table 7

Food Expenditure and Calorie Share Changes From Highest to Lowest Per Capita Expenditure Decile

	Food Expenditure Shares (%)			Calorie Shares (%)		
	US	GB	India	US	GB	India
	1888	1888	1983*	1888	1888	1983*
Dairy	6.9%	4.4%	6.9%	10.2%	13.1%	3.6%
Fruits and Vegetables	-0.6%	-0.9%	3.5%	0.8%	0.3%	3.1%
Oils, Fats, and Sugars	-3.1%	-2.3%	-1.8%	-2.9%	-2.8%	3.8%
Meats	2.1%	1.0%	3.0%	3.5%	3.8%	0.6%
Cereals	-13.3%	-11.5%	-15.0%	-18.2%	-17.5%	-20.0%
Other Foods	8.0%	9.4%	3.4%	6.7%	3.1%	8.9%

Note: Each entry represents the change in food expenditure or calorie shares when moving from the highest to lowest deciles of the per capita expenditure (PCE) distribution. Negative values imply that households in the highest (top 10%) decile have lower expenditure or calorie shares for that food grouping than households in the lowest (bottom 10%) decile. The range of expenditure over the samples is roughly the same. On the log scale the range of per capita expenditure is approximately 3 for the US data, and 2.5 for both the Great Britain and Indian data. For the exact ranges of PCE see Logan (2006a) for the US and Great Britain range and Subramanian and Deaton (1996) for the Indian range.

*Results come from Subramanian and Deaton (1996) Table 1 and Deaton (1997) Table 4.1

Table 8
Traditional and Elasticity (Engel Curve) Predicted GDP for Selected Countries

	Expennditure Elasticity of Calories	GDP Deflator GDP per capita estimate	Engel Curve GDP per capita estimate	Factor of Convergence
Indonesia-Urban	0.26	30.71	304	9.89
Philippines	0.32	36.88	286.86	7.77
Philippines	0.34	36.88	281.14	7.62
Philippines	0.43	36.88	255.43	6.93
Indonesia-Rural	0.51	30.71	232.57	7.57
Sri Lanka	0.56	19.2	218.29	11.36
United States - 1888	0.54	221	221	-
Great Britain - 1888	0.67	183.4	183.4	-

All GDP estimates in the table are in 1889 US dollars.
All non-1888 estimates of calorie elasticities are taken from Table 34.1 of Strauss and Thomas (1995, pp. 1894-1895)

Traditional GDP estimates for developing countries are for 1983 and are computed using the GDP deflator. The facor of convergence is the factor that the traditional GDP estimates must be multiplied by in order to produce the income estimates derived by the Engel curve.

Appendix

The comments in the 1888CEX were analyzed systematically in order to investigate household production. Comments usually included a description of the dwelling (e.g. "home well kept" or "house filthy") and a mention of items owned by the household (sewing machines, poultry, organs, pianos, etc.). If a comment mentioned poultry, gardens, chickens, pigs, pork, cows, beef, fruit trees, or vegetables I noted that household as having home production. In looking at the comments, these were the only words and phrases that could be construed as implying home production of calories. As Table A1 shows, 27.15% of American households and 9.38% of British households in the survey had evidence of home production.

I then looked at the average log of per capita income and log of per capita expenditure for these groups. If the home production of calories objection is valid, then the income and expenditure distributions of home producing households should be markedly different from households with no evidence of home production. If the distributions are the same then home production is a level effect (in logs) and the elasticity estimate will not be influenced by the exclusion of home production. As Table A1 shows, the means of the log of per capita income and the log of per capita expenditure are very close for the two groups. In the British sample the means are approximately eight percentiles apart, and in the American sample they are approximately five percentiles apart. Even this difference, however, is an overstatement. In Table A2 I take account of households for which there are no comments and the differences between the two means falls to less than seven percentiles for the British sample, and less than four percentiles for the American sample.

The mean, however, is a relatively small part of the story. It is the distribution of home production that matters most. As the skewness results in Tables A1 and A2 confirm, American households with home production are just as skewed as households with no home production. In

Britain households with home production are less skewed, but they account for a relatively small fraction of the total sample, and since more than a third of all households have no comment it is unclear how such evidence should be interpreted. Also, the kurtosis of the home producing households was less than that of the non-home producing households, and this suggest that the distribution of home production was more uniform than that of households with no home production. This once again suggests a level effect on the estimates of the elasticity. On balance, these results imply that the distribution of home production was not concentrated in lower income households.

While these results do not support the home production of calories objection, they do not deal a fatal blow to it. It would be cavalier to say that this analysis establishes that home production was not concentrated in low income households for two reasons. First, we do not know with any degree of certainty that a comment which does not mention home production implies that the household did not have home production. The true distribution of home production cannot be identified by these comments. Secondly, there is nothing in the remarks themselves that give us any clues about the amount of home production. While establishing that households with home production of calories were concentrated at lower incomes is necessary for the home production of calories objection, it is not sufficient for the objection to hold. One must show that wealthier households had less home production than poorer ones. This cannot be known or inferred from the comments.

Table A1

Income, Expenditure and Remarks from 1888CEX

United States Sample

Household Has	Total	% of Total	Average Log of Per Capita Income	Skewness of Log of Per capita Income	Average Log of Per Capita Expenditure	Skewness of Log of Per Capita Expenditure
Poultry and/or Garden*	1,849	27.15%	9.4021 (.51649)	0.2573	9.3126 (.44097)	0.3208
No Poultry and/or Garden	4,960	72.85%	9.5125 (.51604)	0.2581	9.4424 (.43848)	0.3136
Total	6,809	100%	9.4821 (.51848)	0.2533	9.4066 (.44296)	0.3033

N = 6,809

Great Britain Sample

Household Has	Total	% of Total	Average Log of Per Capita Income	Skewness of Log of Per capita Income	Average Log of Per Capita Expenditure	Skewness of Log of Per Capita Expenditure
Poultry and/or Garden*	96	9.38%	9.1823 (.38533)	0.1050	9.1204 (.35741)	0.0413
No Poultry and/or Garden	928	90.62%	9.2807 (.42345)	0.2926	9.2109 (.37361)	0.2321
Total	1,024	100%	9.2714 (.42083)	0.28743	9.2025 (.37289)	0.2197

N = 1,024

Note: Only non-flower garden homes are included in the homes with gardens and/or polutry.
*Households with fruit trees, cows, and pigs are inclued in the Poulty and/or Garden Households.
Standard errors are listed in parentheses under the sample means
Positive values of skewness indicate the the distribution is skewed towards values greater than the mean.

Table A2

Income, Expenditure, Remarks, and Missing Values from 1888CEX Remarks

United States Sample

Household Has	Total	% of Total	Average Log of Per Capita Income	Skewness of Log of Per capita Income	Average Log of Per Capita Expenditure	Skewness of Log of Per Capita Expenditure
Poultry and/or Garden*	1,849	27.15%	9.4021 (.51649)	0.2573	9.3126 (.44097)	0.3208
No Poultry and/or Garden	4,594	67.47%	9.5065 (.51561)	0.2630	9.4410 (.44175)	0.3286
No Comments Made	366	5.38%	9.5869 (.51629)	0.2041	9.4603 (.39566)	0.0823
Total	6,809	100%	9.4821 (.51848)	0.2533	9.4066 (.44296)	0.3033

N = 6,809

Great Britain Sample

Household Has	Total	% of Total	Average Log of Per Capita Income	Skewness of Log of Per capita Income	Average Log of Per Capita Expenditure	Skewness of Log of Per Capita Expenditure
Poultry and/or Garden*	96	9.38%	9.1823 (.38533)	0.1050	9.1204 (.35741)	0.0413
No Poultry and/or Garden	579	56.54%	9.2546 (.40570)	0.3219	9.1886 (.36324)	0.2703
No Comments Made	349	34.08%	9.3239 (.44864)	0.2082	9.2480 (.38792)	0.1492
Total	1,024	100%	9.2714 (.42083)	0.28743	9.2025 (.37289)	0.21967

N = 1,024

Note: Only non-flower garden homes are included in the homes with gardens and/or polutry.
*Households with fruit trees, cows, and pigs are inclued in the Poulty and/or Garden Households.
Standard errors are listed in parentheses under the sample means.
Positive values of skewness indicate the the distribution is skewed towards values greater than the mean.