Economies of Scale in the Household:
Evidence and Implications from the American Past

Trevon D. Logan
The Ohio State University and NBER

October 31, 2006

Abstract

Household economies of scale arise when households with multiple members share public goods, making larger households better off at lower per capita expenditures. Research into household scale economies has not considered how household economies of scale have changed over time. I use American household expenditure surveys, covering 1888 to 1935, to produce the first comparable historical estimates of household scale economies in consumption. I find that scale economies changed significantly from 1888 to 1935 for all expenditure categories considered. Scale economies in clothing, entertainment, and housing declined from 1888 to 1935, consistent with market expansion and increasing substitutes for these expenditure categories over time. Households in the past had fewer scale economies in food than today, however, exactly the opposite of what theory would predict and deepening a puzzle noted by Deaton and Paxson (1998). I then consider the implications of changing scale economies for estimates of real income and CPI bias. Previous estimates of CPI bias based on Engel curves do not account for changing scale economies in the household, and failure to account for changing scale economies can lead to omitted variable bias. My estimates of the annual rate of CPI bias are reduced by at least 25% once changing scale economies are accounted for, which suggest that household economies of scale have a large, material effect on estimates of real income.

JEL Classifications: D1, E3, J1, N3

[0] Comments welcome and appreciated. Mailing Address: Department of Economics, The Ohio State University, 410 Arps Hall, 1945 North High Street, Columbus, OH 43210. E-Mail: logan.155@osu.edu. I thank Dora L. Costa, Matthew S. Lewis, Audrey L. Light, Muna S. Meky and seminar participants at The Ohio State University and Indiana University for helpful discussions. Yasin Akcelik and Yunhui Tan provided excellent research assistance. Please do not quote or cite without permission. The usual disclaimer applies.

1 Introduction

In one example of economies of scale, households with multiple members are able to achieve the same standard of living at lower per capita expenditures on public goods than smaller households. For example, if two adults unite to form one household, the couple will be better off as they can share public goods (such as an apartment or utilities), lowering the per capita expenditure on them. The couple can funnel these savings into increased consumption of public goods (a larger apartment than either could afford separately), making each member better off than they were when they lived by themselves. The basic idea has strong intuitive appeal– living standards for households of different sizes could be equated with lower per capita expenditures for larger households who are able to economize on public goods. Such economies of scale move beyond their textbook importance when they are applied to the measurement of poverty, inequality, real income, and the costs of children. To measure the distribution of income, the extent of poverty and the development of poverty thresholds one must take these household economies of scale in consumption into account. The measurement of economies of scale, therefore, is fundamental to the measurement of living standards.

One difficulty with household economies of scale in consumption is that it can be difficult to identify the size of the scale economy. While economies of scale are a function of the size of the household, the demand for goods and services generally derives from both household size (the number of people in the household) and composition (the types of people in the household). This difficulty is related to the more general issue of the proper modeling of demographic variables in demand analysis, although the primary goal of that literature was the creation of equivalence scales that were consistent with utility theory (Gorman 1976, Deaton and Muellbauer 1980, Pollack and Wales 1981, Lewbel 1985). When researchers turned their attention to economies of scale in the household, they overcame the problem of detection and measurement by concentrating on adult-only households, as in Nelson (1988). Doing so allows one to disregard the compositional aspects of demand since all household members are adults. Measuring economies of scale for households where all members have identical tastes and are treated equally, however, will not aid in the measurement of poverty and the distribution of income, where compositional heterogeneity matters.

Another difficulty lies in the income and substitution effects that scale economies have on private goods. While both the income and substitution effects would imply increased consumption of public goods, the savings realized on public goods could lead to increased or decreased consumption of private goods. A priori, the income and substitution effects work in opposite directions, and it is not possible to know which effect will dominate unless we know more about the private good. Deaton and Paxson (1998) suggest that food would be a good choice for a private good for whom the income effect will dominate because food has few substitutes, and they also argue that substitution will be even less likely for households close to subsistence. This would imply that food expenditures should increase with household size– the savings realized on public goods would be funneled to food, a necessity which has few substitutes. Rather than increasing with household size (with per capita expenditure held constant), Deaton and Paxson find that expenditure per capita on food falls with household size using a number of contemporary household expenditure surveys. After considering and dismissing a number of possible explanations, Deaton and Paxson conclude that their empirical results are a puzzle.

While a literature analyzing this "food puzzle" has developed (Perali 2001, Horowitz 2002, Gibson 2002, Gan and Vernon 2003, Deaton and Paxson 2003, Vernon 2005) the research on household scale economies in consumption has yet to look at how or if scale economies change over time. Just as knowledge about scale economies at a point in time tells us about poverty and inequality, knowledge about changes in scale economies is useful to analyze changes in living standards over time. Even more, knowledge about changes in scale economies is important since average household size has changed over time. Indeed, Pistaferri, et al. (2005) use the concept of substitution between public and private goods to explain declines in household size over time. The effect of household size on demand could change along with average household size, and we would need to know the extent of both. Lastly, time series information on economies of scale could allow us to resolve puzzles in the literature by eliminating potential explanations for the "food puzzle" and providing evidence of trends in economies of scale more generally.

With these ideas in mind, this paper has three related goals: (1) To estimate economies of scale in the American past to see how household economies of scale have changed over time. This paper provides the first comparable historical estimates of household economies of scale. (2) To use estimates of economies of scale in the past to analyze the empirical "puzzles" with household scale economies– seeing which expenditure categories are consistent with theoretical predictions and which are not. (3) To consider the implications of changing economies of scale on measures of living standards in the past, particularly the measurement of real income.

Using historical household surveys from the United States, covering the period 1888 to 1935, I estimate household scale economies for a number of different expenditure categories. I find that scale economies in clothing declined over the period considered, and are the same in 1990 as they were in 1935. Scale economies in entertainment also fell from 1888 to 1935. I find that housing expenditures decreased significantly for larger households in 1888, but by 1935 household size had a substantially smaller effect on housing expenditures, which suggests decreasing public good properties for housing over time. In general, I find that scale economies changed significantly over time for every expenditure category considered.

When I consider scale economies for food in the past, nearly as many puzzles as answers emerge. In the past, there were fewer substitutes for food expenditure than there are today, and households were much closer to nutritional subsistence. While these facts suggest that food consumption should be positively related to household size, the Deaton and Paxson puzzle holds for the past as well. I find that American households in the past had fewer scale economies in food than today, exactly the opposite of what theory would predict if food is a private good with few substitutes. Furthermore, there is no time trend with food economies of scale. These findings deepen the Deaton and Paxson "food puzzle" and cast serious doubt on whether food should be considered a private good for the measurement of economies of scale.

Since scale economies changed dramatically over time I conclude that changes in household scale economies, and the effect of household size on demand more generally, are important to understanding and estimating welfare, income, and the costs of children in the past. As an extension of this idea, this paper considers a key implication of changing scale economies in the household– the measurement of real income. Costa (2001) and Hamilton (2001) have used a method based on Engel curves to estimate Consumer Price Index (CPI) bias in the past. Their methodology, however, does not estimate CPI bias independent of changes in household scale economies over time. Since the methodology used to estimate economies of scale is also based on Engel curves, integrating the two methodologies is straightforward. I show that CPI bias estimates, which attribute differences in food shares over time not explained by household characteristics and relative price changes to CPI bias, implicitly assume that scale economies are unchanged over time. Given the large changes in household scale economies over time, estimates of CPI bias may suffer from omitted variable bias.

I modify the CPI bias estimation methodology, using an Engel curve that controls for both household composition and size but also allows the scale economy to vary over time independent of CPI bias. I then estimate CPI bias with and without controls for changing household economies of scale. When I estimate CPI bias in a way that controls for changing scale economies my CPI bias estimates, while still statistically significant, are reduced by at least 25%. These results suggest that changes in the effect of household size on demand play a material role in the measurement of real income.

The paper unfolds as follows. The next section summarizes the theoretical model and highlights empirical predictions about scale economies in household consumption in the past and over time. The third section outlines the empirical methodology. The fourth section discusses the estimates of scale economies in the household and discusses the results in light of the "food puzzle" described above. The fifth section analyzes CPI bias, and presents estimates of CPI bias that control for changing scale economies over time. The final section concludes.

2 Measuring Economies of Scale

There are two popular methods in the literature for measuring economies of scale in the household. The oldest and best known is the Engel method, while recent literature uses the Barten model to measure economies of scale. The Engel method has been preferred since it is easy to compute, but, as will be shown below, the Barten model is the superior approach for generating theoretical predictions about economies of scale in the household, although this claim has been debated in light of the "food puzzle" (Perali 2001, Gan and Vernon 2003). Below, I review both methods and show why the Barten model will be employed here.

2.1 Engel Measures of Economies of Scale

In Engel measures of economies of scale, the scale economy is simply the difference in per capita expenditures between two households (the per capita expenditure of the smaller household minus that of the larger household) who devote the same share of total expenditure to food. This method almost always gives positive values for scale economies. Following Engel's Second Law, two households with identical budget shares devoted to food are equally well off if the foodshare is an indicator the standard of living. There is, however, a flaw in the logic involved in the Engel procedure that prevents it from being the measure of scale economies here.

The problem with this approach is that it assumes that food expenditure per capita, presumably a private good, will decrease with household size. Taking w to be food's share of the budget, x as total expenditure, and n as household size, the Engel method uses $\left(\frac{x}{n}\right)_{\overline{w_k}} - \left(\frac{x}{n}\right)_{\overline{w_j}} > 0$, where $\overline{w_i} = w^*\left(\frac{x}{n_i}, n_i\right)$, $j > k$ and $\overline{w_k} = \overline{w_j}$. The per capita expenditure of the larger household, holding the foodshare constant, is smaller than for the smaller household. This, on the surface, appears to agree with scale economies in the household, where larger households are as well off as smaller households with larger households having smaller per capita expenditures. Figure 1 gives a graphical description of the Engel method.

The Engel method implies, however, that the larger household has lower per capita *food* expenditures than the smaller household as well. At a constant budget share of food, lower per capita expenditures by the larger household imply lower per capita food expenditures for the larger household as well, $\left(\frac{x}{n}\right)\overline{w_k} > \left(\frac{x}{n}\right)\overline{w_j}$. This assumption disagrees, directly, with the notion that there are economies of scale in the household since consumption of the private good (food) is lower for larger households. If food is a marker of private welfare, and if there are economies of scale in public goods, the consumption of food should be greater for larger households. While this does not have to hold in all cases, the Engel measure requires it to hold to derive estimates of economies of scale. The point here is that the Engel method does not give us theoretical justification for the procedure, or show us how this measure is related to scale economies in the household in a tractable way. As such, we cannot use the Engel method to estimate economies of scale in the household since it is not a theoretically grounded measure of scale economies.[1]

2.2 The Barten Model

The Barten model, developed first by Barten (1964) and extended to the analysis of scale economies in the household by Muellbauer (1977), Pollak and Wales (1980, 1981), Deaton and Muellbauer (1986) and Nelson (1988), generates theoretical predictions about scale economies. As such, it has served as the model used by Deaton and Paxson (1998) and the basis for those who have attempted to resolve the puzzle they discovered and others more generally concerned with public and private goods in the household (Perali 2001, Horowitz 2002, Gan and Vernon 2003, Deaton and Paxson 2003, Pistaferri, et

[1] Nicholson (1976) has shown that Engel's method cannot be used to calculate child equivalence scales, but Perali (2001) argues that the puzzle is a problem of functional form. He concedes, however, that more theoretical research on household economies of scale is needed because "the literature on household economies of scale is not fully developed in the sense that the concept of economies of scale in the household does not have a close analog to the traditional concept defined in production theory." (p. 19) This issue is discussed futher in section 4.6.

al. 2005, Vernon 2005). As this paper's goal is to broaden the perspective on household economies of scale with estimates covering a long time period, the Barten model is used here as well.

In the two good Barten model a household of size n allocates expenditure on two goods. For convenience, one good is completely private, f (food) and the other is completely public, h (housing). The household maximizes the utility function

$$\max_{q_f, q_h} nv\left(\frac{q_f}{\phi_f(n)}, \frac{q_h}{\phi_h(n)}\right)$$

where $v(.)$ is the utility function, q_f and q_h are the quantities of food and housing, and $\phi_f(n)$ and $\phi_h(n)$ are scaling functions for the economies of scale realized for food and housing respectively. The scaling function converts the size of the household (n) to its effective unit for both housing and food. The budget constraint reflects the fact that the price of the private good (p_f) does not change with respect to household size, but the cost of the public good (p_h) lowers per head as household size increases. In per capita terms this gives the budget constraint

$$p_f\left(\frac{q_f}{n}\right) + \left(\frac{p_h}{n}\right) q_h = \frac{x}{n}$$

Maximization of the utility function subject to the budget constraint gives a per capita demand function for food

$$\frac{q_f}{n} = \frac{\phi_f(n)}{n} g_f\left(\frac{x}{n}, \frac{p_f\phi_f(n)}{n}, \frac{p_h\phi_h(n)}{n}\right)$$

where $g_f(\cdot)$ is the per capita demand function for food. The per capita expenditure on food is therefore

$$\frac{p_f q_f}{n} = \frac{p_f\phi_f(n)}{n} g_f\left(\frac{x}{n}, \frac{p_f\phi_f(n)}{n}, \frac{p_h\phi_h(n)}{n}\right)$$

What we would like to know is how much per capita food expenditure changes for a given increase in household size. Taking logs of the equation above and taking the derivative with respect to household size gives

$$\frac{\partial \ln\left(p_f q_f/n\right)}{\partial \ln(n)} = \left[1 - \frac{\partial \ln \phi_h(n)}{\partial \ln(n)}\right](\epsilon_{fx} + \epsilon_{ff}) - \left[1 - \frac{\partial \ln \phi_f(n)}{\partial \ln(n)}\right](1 + \epsilon_{ff})$$

where ϵ_{ff} is the own price elasticity of food and ϵ_{fx} is the income elasticity of food.[2] In order for per capita food expenditure to increase with household size it must hold that

[2] Note that if a good is purely public that $\left[1 - \frac{\partial \ln \phi_i(n)}{\partial \ln(n)}\right] = 1$ because there would be no change in the scaling function for an increase in household size. If a good is purely private then $\left[1 - \frac{\partial \ln \phi_i(n)}{\partial \ln(n)}\right] = 0$ because the scaling parameter would change exactly as much as household size.

$$\left[1 - \frac{\partial \ln \phi_h(n)}{\partial \ln(n)}\right] (\epsilon_{fx} + \epsilon_{ff}) > \left[1 - \frac{\partial \ln \phi_f(n)}{\partial \ln(n)}\right] (1 + \epsilon_{ff})$$

When food has few substitutes, meaning that ϵ_{ff} is small in absolute value, and if food has fewer scale economies than housing, meaning that $\frac{\left[1-\frac{\partial \ln \phi_f(n)}{\partial \ln(n)}\right]}{\left[1-\frac{\partial \ln \phi_h(n)}{\partial \ln(n)}\right]}$ is small, then we would expect the derivative given above to be greater than zero. This is essentially asserting that the savings obtained by economizing on the public good are used to increase consumption of the private good, where the income effect dominates the substitution effect for the private good because there are few substitutes for it. In this way, the Barten model gives us theoretical grounds upon which we can hypothesize about when, where, and for what goods we would expect economies of scale to be present.

To summarize, if there are economies of scale in the household the Barten model predicts that:

- Holding per capita expenditure constant, the share of the budget devoted to the private good will increase with household size if it has few substitutes and a sizable income elasticity.
- If it is true that poorer households have fewer substitutes for expenditures on the private good, such that ε_{ff} is smaller for poorer households, the increase in private good expenditures will be greatest for the poor.
- Over time, as the market expands and more substitutes for expenditure on particular private goods are available, ϵ_{ff} will increase and economies of scale in private goods should decrease.

The Barten model also has implications for public goods and their scale economies over time:

- Holding per capita expenditure constant, the share of the budget devoted to the public good will decrease with household size. This would be the source of cost savings funneled towards private goods.

2.3 Economies of Scale in the Past

We can use our knowledge of the past to generate further predictions about economies of scale and how we believe they would change over time. While we know that the predictions of the Barten model have been rejected for food in contemporary populations, there are several reasons to believe that the model should hold for food and other private goods in the past. In the past, there were even fewer substitutes for food, and it was not possible to substitute food preparation for expenditure to the extent that it is in contemporary populations.[3] As such, it is reasonable to expect ε_{ff} to be particularly small in the past. Similarly, the demand for food in the past was greater than it is today, particularly if one is studying the same nation over time, although there is evidence that demand for nutrition in the past was greater than it is in developing nations today.[4] If the income elasticity of food, ε_{fx}, was very large in the past it would be even more likely food consumption would increase with household size.[5] All of this implies that we should expect for food to behave in a manner consistent with the Barten model in the past– holding per capita expenditure constant food expenditure should increase with household size.

Additionally, for certain explanations of the "food puzzle" to hold the scale economies in food should display a specific time trend. Estimates of economies of scale over time, then, can test the viability of these explanations. If direct economies of scale in food cause the per unit price of food to be lower in larger households this effect should intensify over time as technology allows larger households to purchase and store large quantities of food, which are sold at cheaper prices in bulk. Also, if income is distributed unequally within the household (where larger households have more unequal distributions than smaller households) food consumption could decline with household size and explain the "food puzzle."[6] If the Engel curve is relatively stable over time, however, the effect should attenuate and the scale economies in food should increase over time.

Furthermore, food is not the only private good that can be tested against the predictions of the Barten model, and Horowitz (2002) has argued that food may not be the appropriate private good on theoretical grounds. It is therefore useful to estimate economies of scale for other household expenditure categories. Clothing and entertainment expenditures have each been considered private goods in the literature, although the degree to which each is private is subject to debate. Similarly, the Barten model has implications for public goods. This can be tested by looking at housing expenditures to see if they are consistent with the predictions of the Barten model. In short, we can estimate economies of scale in the past for a number of different goods and to see if the time trends would be consistent with the predictions of the Barten model for both public and private goods.

In this paper I estimate economies of scale with American household survey data covering 1888 to

[3] See Aguiar and Hurst (2005) for more on the substitution between food expenditures and time preparation in contemporary populations.

[4] See Logan (2005) for more on the comparison of calorie demand elasticities over time.

[5] Logan (2006) finds expenditure elasticities for food between .6 and .9 in the late nineteenth century.

[6] This also requires that the Engel curve be concave.

1935. The survey data used here comes from three national consumer expenditure surveys taken in 1888-1890, 1917-1919, and 1935-1936.[7] Each survey is a large national survey of consumer expenditures and these surveys are comparable insofar as they each detail household expenditures, income, composition and demographics. Similarly, each survey used a similar methodology, interviewing subjects in their homes, verifying expenditures where possible, and using consistent categories for products and services.[8] In addition, each survey has comprehensive demographic information on all household members, including the age and sex of all household members, which allows us to measure the effect of household size on demand separate from the effects of household composition on demand. Because these surveys are broadly consistent over time, it is possible to derive time trends in household scale economies from them. For each survey, I estimate the scale economies of consumption for food, clothing, entertainment, and housing.

3 Empirical Strategy

Following Deaton and Paxson, I estimate economies of scale in four ways for robustness. Three of the methods allow for increasing flexibility of the underlying Engel curve, and the fourth method addresses the problems of the endogeneity of the budget share with per capita expenditure. In each survey, I take total annual expenditures on food, clothing, entertainment and housing and divide each separately by total annual household expenditure as the dependent variables (the budget shares) in the analysis that follows. I detail each estimation procedure below.

1. *Linear (Ordinary Least Squares)*- The first method estimates the economies of scale with a linear Rothbarth Engel curve using ordinary least squares (OLS). This specification attempts to separate the effect of household size from household composition on the budget share. The regression takes the form

$$w = \alpha + \beta \ln\left(\tfrac{x}{n}\right) + \gamma \ln n + \sum_{k=1}^{K-1} \delta_k \left(\tfrac{n_k}{n}\right) + \zeta z + \varepsilon$$

where w is the budget share, x is total expenditure, n is household size, k is a grouping of the household by age and sex (such that n_k/n is the fraction of the household belonging to demographic group k), and z is a vector of control variables including the fraction of the household

[7] The surveys are the Department of Labor's Cost of Living of Industrial Workers in the United States and Europe (1888-1890), the Bureau of Labor Statistics' Cost of Living in the United States (1917-1919), and the Department of Labor's and Department of Agriculture's Study of Consumer Purchases in the United States (1935-1936).

[8] See the appendix for more information on the data sources.

that is employed, geographic controls, and the industry that employs the head of the household. The composition of the household is broken into 5-year age categories up to the age of 25. The measure of economies of scale is γ, the effect of household size on the demand for food.[9]

2. *Fourier Engel Curve-* The second method uses a Fourier functional form for the Rothbarth Engel curve, giving it greater curvature and flexibility. This regression takes the form
$$w = \alpha + \beta \ln\left(\frac{x}{n}\right) + \phi \ln\left(\frac{x}{n}\right)^2 + \sum_{j=1}^{3}\left[\vartheta_j \sin\left[j \ln\left(\frac{x}{n}\right)\right] + \xi_j \cos\left[j \ln\left(\frac{x}{n}\right)\right]\right] + \gamma \ln n + \sum_{k=1}^{K-1} \delta_k \left(\frac{n_k}{n}\right) + \zeta z + \varepsilon$$
where once again the measure of economies of scale is γ.[10]

3. *First Differencing Method-* The third method allows the Engel curve to take the form of any continuous function, giving it the greatest flexibility. Following the method proposed by Estes and Honore (1995) and Yatchew (1997) we can difference out the Engel function if it is continuous and still obtain unbiased (but not efficient) estimates of economies of scale. The differencing is achieved by sorting the data by per capita expenditure and then taking the difference in the covariates from their nearest neighbor such that $\Delta = \left(x_{(i)} - x_{(i-1)}\right)$. This estimation takes the form
$$\Delta w = \alpha + \gamma \Delta \ln n + \sum_{k=1}^{K-1} \delta_k \Delta\left(\frac{n_k}{n}\right) + \zeta \Delta z + \nu$$
Note that if the Engel function is continuous and the sample sufficiently large, sorting by per capita expenditure implies that $\Delta f\left(\frac{x}{n}\right) \rightarrow 0$, such that it can be omitted from the regression. The measure of economies of scale is γ.

4. *Instrumental Variables-* The fourth method addresses the fact that w and $\ln\left(\frac{x}{n}\right)$ are constructed from the same information and are therefore correlated with one another. Indeed, the errors of both may be correlated as well, which would lead to biased estimates of β. Also, since x/n and n are also correlated, such errors would also lead to biased estimates of γ, the coefficient of interest. Even more, we do not know, a priori, which direction the bias would be in. Income, which is highly correlated with expenditures but measured independently of it, is a good candidate as

[9] Formally, estimates of the economy of scale would regress the log of the budgetshare on the log of per capita expenditure and household size, which would be consistent with the theory described earlier. Since the log of the budget share is simply a monotonic transofmation of the budget share itself, all of the estimates here are qualitatively similar.

[10] In this analysis the range of the variable in the Fourier analysis must be less than 2π, or it must be rescaled. All of the per capita expenditure ranges considered in this paper have a range of less than 2π, and therefore do not need to be rescaled.

an instrument for per capita expenditure. The instrumental (IV) estimates use the log of per capita income as an instrument for expenditure.

4 Household Scale Economies in the Past

In this section, I present estimates of household scale economies for food, clothing, entertainment and housing from 1888 to 1935. Testing another prediction of the Barten model, that poorer households should increase their consumption of private goods more than wealthier households, I estimate economies of scale by income quartile over time. I then consider possible explanations of the "food puzzle," and show that the results for food are inconsistent with theory. I conclude that the puzzle hinges on what it means to equate the welfare of households of different sizes and whether food expenditure is the measure of welfare that Engel intended.

4.1 Scale Economies in Food

Table 1 shows estimates of the scale economy of food estimated in 1888, 1917, and 1935. The coefficients in the table show the effect of household size on the budget share devoted to food. For example, linear (OLS) estimates show that if household size were doubled in 1888, the share of the food budget share would decrease by 2.3%. The first item of interest from the table is the fact that the four estimation methods yield remarkably similar estimates of the scale economy with respect to food. The second item of interest is that all of the estimates of the food scale economy are negative. Regardless of the year, the food share never increases with household size. This mirrors the result found in Deaton and Paxson, but the results in Table 1 deepen the puzzle to the extent that, in the past, there were fewer substitutes for food expenditures than there are today. Indeed, the conditions under which food expenditures should increase with household size were stronger in the past. The failure of household size to be positively correlated with food expenditures in the past is truly a puzzle.

Even more troubling, there is no clear time trend from the estimates of the scale economy with food, which is a further contradiction of the predictions of the Barten model. Although it is true that the estimates are statistically different from one another, there is no discernible time trend. The scale economy is least private in 1917, and closest to zero in 1888. The increase in the size and scope of the market should lead to greater substitutes for food, and the increasing number of substitutes should lead the scale economy to decrease over time, *ceteris paribus*. Although the scale economy does decrease from 1888 to 1917, it increases from 1917 to 1935. It is unclear what movements could be behind such a pattern.

As a further check of robustness, we can look at food consumption at and away from home. This information is not available in the 1888 survey, but it is detailed in the 1917 and 1935 surveys. Although meals out of the home were infrequent in the past, it is still possible that the negative coefficient on household size seen in Table 1 could reflect the fact that larger families consume fewer meals out of the home. If that was true, larger households would have lower food expenditures since meals out of the home are usually more expensive than those consumed in the home. Table 2 shows the coefficients on the log of family size for regressions on food at and away from home. Food expenditures away from home increase with family size, and over time the effect grows larger. Food expenditures at home decrease with household size, and the trend from 1917 to 1935 is the same as it is for food expenditures in general. Meals away from home cannot explain this result.

The ultimate conclusions drawn from the scale economy of food are that it does not have a clear time trend consistent with the Barten model and it does not behave generally in the way that a private good consistent with the Barten model would. While we will consider the implications of this later, we can also compare these historical estimates of the scale economy to contemporary estimates. Deaton and Paxson's estimate for 1990 from the Consumer Expenditure Survey, -.008, is significantly lower than any of the historical estimates for the economies of scale in food consumption in Table 1. This further deepens the puzzle insofar as the scale economy in the past should be most likely to be positive, yet empirically the historical estimates are all more negative than the contemporary estimates.

4.2 Scale Economies in Clothing

Clothing is another good that, a priori, is private, and we would expect clothing expenditures to increase with household size. Table 3 shows estimates of the scale economy with respect to clothing expenditures. As with the estimates of the food scale economy, the four estimation techniques yield similar estimates of the scale economy. Unlike the food scale economy, however, the clothing scale economy is always positive, consistent with a the prediction for private goods in the Barten model. Increases in household size lead to increases in clothing expenditure throughout the entire period under consideration.

The scale economy of clothing, like the scale economy of food, changes over time. Furthermore, the trend in clothing scale economies is consistent with the predictions of the Barten model. As the market develops and there are more substitutes in the market for expenditures on the private good, the size of the scale economy should diminish over time, and this is exactly what happens with the scale economy of clothing.[11] The scale economy is 1888 is approximately 70% greater than the scale economy measured in 1917, and the scale economy in 1917 is approximately 40% larger than the scale economy measured in 1935. These differences are statistically significant. The conclusion from the clothing scale economy is that clothing appears to be a private good that behaves in a way that is consistent with the Barten model.

The clothing scale economy is also consistent with the Barten model over the twentieth century. The scale economy in clothing in 1990 was .0194. The estimate for 1935 is close to that range, but slightly higher. If the scale economy declined consistently over time, the effect of household size would have decreased by .00084 per year from 1888 to 1935, while it would have declined .00018 per year from 1935 to 1990, a significant slowdown. This suggest that scale economies in clothing decreased at a decreasing rate from 1888 to 1990. Such a trend is entirely consistent with the notion that the most likely substitutes for clothing appeared on the market between 1888 and 1935, and the slowing pace of the decreasing scale economy would reflect the fact that fewer substitutes for clothing expenditure have been placed on the market since that time.

4.3 Scale Economies in Entertainment

Expenditures for entertainment may be private, if they are enjoyed by a certain segment of the household. The estimates of the scale economy in entertainment are consistent with entertainment behaving as if it were a private good. Table 4 shows the results. The economy of scale estimates for entertainment are positive for every year considered. As with food and clothing, the estimates for entertainment's scale economy change from year to year, and these differences are statistically significant. From the OLS results, the scale economy estimate in 1888 is 75% larger than the 1917 estimate, and the 1935 estimate is approximately 25% larger than the 1917 estimate.

As with food, the entertainment scale economy does not follow any particular time trend. The estimates in 1888 are the largest, and the 1935 estimates are larger than the 1917 estimates. So

[11] This could also be due to the real price of clothing declining over time, such that households devote expenditutre on other private goods, or goods being placed on the market that substitute for home production, although these are not the only possibilities.

although entertainment appears to be a private good in the Barten model sense, it does not behave with any clear time trend as predicted by the Barten model. Overall, however, the changes in the entertainment economies of scale, while statistically significant, are not very different qualitatively. This may be due to the fact that what comprises entertainment changes from survey to survey, and of all the expenditure categories considered it is the most difficult one to construct a time consistent estimate for.[12] Entertainment may incorporate some of the items that would be substitutes for entertainment in a previous or subsequent survey. Due to the difficulty of constructing a time-invariant measure of entertainment, and the flood of entertainment and leisure options on the market during this time period, it is not clear how to interpret the lack of a trend in the entertainment scale economy.[13]

The size of the scale economy in entertainment in 1990 was .0087, which is larger than any of the historical estimates, and suggests that entertainment has become and increasingly private good over time. This would be consistent with the growth of the entertainment industry in general, and the increasing segmentation of the entertainment industry over time in particular. Part of the decrease in the scale economy in entertainment from 1888 to 1917 could be due to the rapid increase of entertainment products on the market during that time, particularly movies, radio, and recorded music. The increasing scale economies since 1917 would be consistent with specialized, and therefore more likely private, entertainment options from the 1920s to today.

4.4 Scale Economies in Housing

Housing is a public good. As such, the estimates of scale economies for housing should be negative if housing is consistent with the Barten model. This is a check to see if the Barten model's predictions are consistent with a good on the other side of the public/private divide. Table 5 shows the scale economies in housing to be consistent with the Barten model. In every year, increases in household size are correlated with decreases in the share of expenditure devoted to housing.

As with the other expenditure categories considered, the scale economy in housing does change over time. As Table 5 shows, the scale economy estimate in 1888 is substantially larger than the 1917 estimate (in absolute value), and the 1917 estimate is more than twice the size of the 1935 estimate (in absolute value). In fact, the changes over time in scale economies are most dramatic for housing.

[12] See the appendix for more on the expenditures that comprise entertainment in each survey.

[13] For more on the difficulties of capturing a time consistent measure of entertainment see Costa (1999).

As with the other expenditure items, these differences are statistically significant.

Even more, housing behaves in a way that is consistent with the Barten model over time. Market expansion would lead to substitutes for housing expenditures in the market, such that the scale economy for housing would decline in absolute value over time as the income and substitution effects of savings on public goods diminish in size. The results of Table 5 are consistent with such a conjecture, and they also imply, given the dramatic declines in the scale economy, that there were numerous substitutes for housing by 1935. Improvements in the availability and performance of functions inside of the household such as heating and cooling would have a strong impact on the presence of household scale economies for housing.[14]

Estimates for the scale economy in housing for 1990 was -.0532, which is larger than the 1935 value of the scale economy. Since 1935, then, a reversal in the magnitude of the scale economy has occurred. A natural explanation for this reversal would be the increasing ease of home ownership, particularly with the advent of government insured mortgages in the post-war United States. As is well known, these sorts of public policies led to a general expansion of the housing market. All of this serves to decrease the cost of home ownership, and the income effect for this public good would most likely be large as a result. This decrease in the cost of home ownership most likely outweighs the increasing number of substitutes to housing in the market, explaining the reversal of the trend.

4.5 Scale Economies and the Income Distribution

There is an additional robustness check that can be performed on the scale economies considered above, and acts as an additional test of the Barten model. The scale economy should also change as a function of income, regardless of the year in which it is measured. Even more, the Barten model predicts that if poorer households have fewer substitutes for the private good they will increase consumption of the private good more than wealthier households. To test this prediction, I estimated the size of the scale economy for each expenditure category by income quartile for each survey year.

Since food in general is not consistent with the Barten model, it is not clear how it should behave as a function of income. If the general property that poor households have fewer substitutes for food than wealthier households holds, then poorer households should have less negative estimates of scale

[14] One could also argue that the cost of housing, relative to all other goods, decreased over time. Such a calculation, however, would have to take into account the cost of housing versus the cost of homeownership, where credit markets decrease the cost of homeownership but not the cost of housing itself.

economies in food than wealthier households. Table 6 shows this to be the case in every survey. Households in the first income quartile have household scale economies in food that are greater than the scale economies of households in the fourth income quartile. For clothing, the results are broadly consistent with the Barten model. In general, households in the first income quartile would increase their expenditures on clothing more than households in the fourth income quartile. With the general pattern of declining scale economies in clothing over time, however, the differences narrow, and by 1935 there are not statistically significant differences in the size of the clothing scale economy by income quartile.

In contrast to these findings, poorer households have the lowest increase in expenditures for entertainment with household size. This would be entirely consistent with entertainment being a luxury that poor households can ill afford, or poorer households choosing more public versions of entertainment. Housing expenditures, however, are more difficult to rationalize. While the 1888 results are consistent with poorer households having the largest scale economies in housing, the 1917 and 1935 results suggest that wealthy households have the largest scale economies in housing. This could be due to poorer households having more cheap substitutes to housing expenditures in the past. The results do show, however, that for the same income quartile, the scale economy in housing decreases over time. Overall, the income distribution results are broadly consistent with the predictions of the Barten model, such that the cross-section predictions about scale economies and the income distribution are supported by the data in most cases.

4.6 Does the past help us resolve the "food puzzle"?

Since the Barten model fails to hold in the past, when food expenditure was even more likely to increase with household size, we are left with two options: we can either abandon the idea that food is a private good, or we can try to uncover the reasons why food in particular does not fit to the predictions of the Barten model.[15] Specifically, how do we reconcile these historical results with the Barten model?

To begin, consider the classic Engel function $w\left(\frac{x}{n}, n\right)$ where w is the share of the budget devoted to food, x is expenditure, and n is the size of the household. We know from Engel's first law that $\frac{\partial w}{\partial \frac{x}{n}} < 0$ and empirically the results of Table 1 confirm that $\frac{\partial w}{\partial n} < 0$ both in the past and present. These

[15] It is important to note that these two options are not mutually exclusive.

two derivatives tell us that the share of the budget devoted to food is decreasing both in per capita expenditure and in household size. Engel measures of economies of scale, which were rejected earlier because of their lack of theoretical justification, use these two facts to derive estimates of economies of scale. Indeed, if $\frac{\partial w}{\partial n} < 0$ and $\frac{\partial h}{\partial n} < 0$ (where h is the budget share devoted to housing), it must hold that $\frac{\partial[1-w-h]}{\partial n} > 0$ and more generally that $\frac{\partial[1-w]}{\partial n} > 0$ by Walras' law. This implies that food is indeed less private than everything else if the sign of the derivative is an indication of household economies of scale. While the finding that $\frac{\partial w}{\partial n} < 0$ may present a theoretical puzzle in light of the Barten model, this has been a feature of Engel curves since their inception, and one of the reasons that Engel argued that larger households could be welfare-equated to smaller households with lower per capita expenditures. The true puzzle, it seems, is how such an assumption (or assertion) can be theoretically justified as being welfare equivalent.[16]

This puzzle seems to turn on the idea of welfare itself. If welfare equivalence is similar proportional expenditures, it would seem as if the Barten model fails and the Engel conjecture survives. If welfare equivalence is taken to mean equating consumption, however, the problem is more complicated—a model describing the household production of food is needed. It will be difficult to specify a model that would accurately describe the changes in household technology over this time period. While Engel assumed (implicitly) that households with more members would spend *less* per capita on food, perhaps because other factors in the food production process increase with household size, more than conjecture will be needed to generate the sorts of predictions that the Barten model gave for changes in economies of scale as a function of technological change.[17]

A factor that would obviously be related to food production would be time. In fact, because household time is strictly increasing in the size of the household, larger households can substitute time for expenditure on food while leaving food consumption unchanged. Vernon (2005) has recently argued that the "food puzzle" could be explained by time as an input into the food production function. The

[16] Going further, it is important to note what is meant by equating welfare of households of different sizes. This is not simply a semiotic task. If the issue is not equating food expenditure, but food consumption, the problem is less about the results and more about the production of food. Consider the following calorie production function $F(wx, O)$ where

$F(*)$ is the calories available to the household and O factors other than food purchases involved in the production of the food that lands on the plates from which we eat (time, cooking technology, food transportation and storing technology, etc.). Two households of different sizes are equally well off if $\frac{F(wx,O)}{n_i} = \frac{F(wx,O)}{n_j}$ where $n_i \neq n_j$. If the other factors

of food production increase with household size, then household expenditure on food must decrease with household size for households of different sizes to be equally well off– if not, larger households would be strictly better off.

[17] This has been argued in a similar context by Aguiar and Hurst (2005) and Gronau and Hamermesh (2001, 2006).

problem for the present analysis is that while there are models of time use in a household production function, time is not the only other factor that would be important– electrification, the availability of natural gas, household refrigeration, transportation innovations, changes in agricultural technology, and other factors all play a role in the production of food at home from the middle of the nineteenth century onward. Even more, some factors would be complements to time input while others would be substitutes– not all technological change was labor saving for household production. A question of whether the income or substitution effect dominates for food consumption will be embedded in a question of whether the complements or substitutes to time input win out in a food production model at a particular point in time.

While time as an input in the food production function may explain parts of the puzzle for contemporary populations, the market for prepared foods was small in the past, such that the extent of substitutability would not be as great in the past as it is today. All households had to contribute significant time to food preparation in the past.[18] Additionally, Cowan (1983) and Moykr (2000) have shown that time input in household production most likely *increased* during the time period considered here, despite the advent of (presumably) labor saving technology in the household.[19] Furthermore, while time is certainly an input into the production of food, time was also an input in the production of goods like clothing at that time. Hours spent in household production would imply that "puzzles" would exist for other private goods in the past that have time as a significant input, or at least a case must be made for why food would be different from other time intensive processes.[20] In general, empirical identification of the relevant factors from such models will be difficult given the historical data.

Another possibility is that the Barten model yields predictions which do not generalize to the more than two-good case. Both Horowitz (2002) and Gan and Vernon (2003) make points along this dimension, but Deaton and Paxson (2003) reformulate the Barten model to include multiple goods and

[18] See Byington (1910), Oddy (1990), Kertzer and Barbagli (2002) and Logan (2005, 2006) for more on household production of food in the past.

[19] Greenwood, et. al. (2005) argue that technological change freed women from time spent on household chores, but Moykr (2000) notes that hours spent on household chores increased from 50 in the late nineteenth century to 56 in the early twentieth century, and only began to decline after WWII– well after the time period considered here. The relationship between changes in household production technologies and time use is still a subject of debate in the literature.

[20] If this were true it would have to hold that poorer households would use time to substitute for expenditure more than wealhier households– for example, the opportunity cost of time is lower for poorer households. (Also note, however, that consumption for households could not be equated without an inverse relationship between time input and income since expenditure increases with income.) As such, the results in Table 6 would have to show that expenditure on food and clothing would decrease with household size more for poorer households than wealthier households; Table 6 shows exactly the opposite.

still generate the same predictions regarding economies of scale in food. Gibson (2002) has suggested that measurement error explains the "food puzzle" result, and he argues that the problem lay in the recall method use by expenditure surveys. Systematic measurement error in food, however, seems unlikely since all of the recall evidence (for food and other items) are measured at the same time. Given the fact that people make food purchases more often than other purchases, it seems unlikely that food expenditures would be measured with error and other expenditures would not be plagued by the same types of errors. It is not clear why food would not behave as a private good but the other expenditure categories would.

This historical evidence does, however, allow us to reject some potential explanations for the puzzle. Earlier, I noted that if direct economies of scale in food production explained this finding that the puzzle should intensify over time. Since the effect of household size on demand is stronger in the past, however, such as explanation is unlikely to resolve the issue. Similarly, if household inequality were the cause of the puzzle I posited that the effect should attenuate over time as household size declines. While in general the effect does lessen over time, it does not do so in a consistent fashion (as it does for clothing), suggesting that the effect of household size does not act in a consistent way over time with respect to food or in a way that responds to changes in household size. Overall, the evidence is not consistent with an inequality explanation. The findings here in regards to food help to eliminate some potential explanations, but do not resolve the food puzzle or the debates regarding the Barten model. All told, this look at historical evidence has sharpened the focus of how the puzzle may be resolved theoretically, the Deaton and Paxson puzzle remains.

5 Changing Household Scale Economies and Real Income

The previous section has established that household scale economies changed over time in the American past. For each expenditure category considered, the measures of scale economies varied from time period to time period. I consider one important implication of these changing scale economies–estimates of real income in the past. I consider the implications of changing household scale economies to CPI bias for two reasons. First, this application of the results in the previous section fits with the argument made earlier that household scale economies have important implications for the measurement of well-being over time. CPI bias would imply that income growth has been under or overstated, and the role that changing household scale economies would have in estimating CPI bias is an important and unexplored issue in the literature. Secondly, the implications of household scale economies to CPI bias is straightforward. Scholars have recently developed methods of estimating the extent of CPI bias with Engel curves, and since the estimates of scale economies are based on an Engel framework, the integration of the two follows with few caveats.

Below, I show how the current methodology used to estimate CPI bias with Engel curves assumes that household economies of scale are constant over time. Such an assumption, when considered against the empirical work of the previous section, could lead to biased estimates of CPI bias, particularly if changes in scale economies are omitted from the econometric specification. I estimate the extent of the omitted variable bias using estimates of CPI bias with and without controls for changing household scale economies. The results show that CPI bias estimates, while still statistically significant, decline dramatically once changes in household scale economies are controlled for.

5.1 Measuring CPI Bias

Using Engel curves to capture CPI bias hinges on the fact that Engel curves relate the budget share to real household income. If food's share of the budget moves more or less than we would predict given estimates of changes in prices (from, say, the Consumer Price Index [CPI]), then movements in real income, measured directly from the Engel curve, would tell us about mis-measurement in real incomes from sources such as the CPI.[21] Following Hamilton's (2001) and Costa's (2001) methodology for the measurement of CPI bias, we can capture CPI bias through Engel curves of the following form

$$w_{i,j,t} =$$
$$\phi + \varphi\left[\ln\left(1+\Pi_{F,j,t}\right) - \ln\left(1+\Pi_{N,j,t}\right)\right] + \beta\left[\ln Y_{i,j,t} - \ln\left(1+\Pi_{j,t}\right)\right] + X'\theta + \sum_{t=1}^{T}\delta_t D_t + \sum_{j=1}\delta_j D_j + u_{i,j,t}$$

where w is the share of the budget devoted to food, Π are the cumulative price changes for food (F), non-food (N), and overall price changes, Y is household expenditure, X is a vector of household characteristics, and D is a set of dummies for year (t) and region (j).[22] Any CPI bias will be captured in δ_t, since two households with the same inflation adjusted expenditures and demographic composition should have the same shares of the budget devoted to food, since changes in relative prices are accounted for and income has been deflated. In this way, any changes in the Engel curve would

[21] Food is not the only expenditure category that can be used to estimate CPI bias. The methodology is entirely general, any expenditure category could be used. The availability of price indicies for food over long time spans leads food to be the primary expenditure category used since changes in relative prices must be captured in the regression.

[22] For the derivation of this equation see the appendix.

be due to the mis-measurement of income over time– CPI bias. Implicit in this framework is the idea that Engel curves capture living standards and households of similar type should have the same welfare (the foodshare) over time, controlling for changes in prices and deflating income.

The issue of changing household scale economies concerns variables in the vector X, which does not contain any time varying covariates. To highlight the features of the model, we can assume that household size is n and that it can be disaggregated into a finite number of distinct groups, such that $n = \sum_{i=1}^{N} n_i$. Both Hamilton and Costa estimate the regression above with the following specification of the demographic variables

$$w_{i,j,t} = \phi + ... + \sum_{i=1}^{N} \theta_i n_i + ... + u_{i,j,t}$$

The functional form above controls for household composition and the effects of household size simultaneously. The modeling implicitly assumes that not only composition, but also household size induce the same change on the food budget share over time. The issue is that the Hamilton-Costa form cannot separate the effects of household size and composition. While one can change composition and not household size, one cannot change household size without changing the composition with this specification. In this way, it is impossible to estimate CPI bias while controlling for changes in the effect of household size on demand with the demographic modeling that Hamilton and Costa use. While one may want to assume that household composition has the same influence on demand over time, the empirical results above and the Barten model itself gives us strong evidence that the effect of household size on demand does vary over time. Since the effect of household size does vary with time, the estimates of δ_t that Hamilton and Costa attribute to CPI bias suffer from omitted variable bias because changing household scale economies are correlated with time.[23] Interacting all of the demographic covariates with time would allow for both composition and size effects to change over time, but the stated goal here is to control for household composition effects and to assume that they are time invariant to highlight the role that changes in household scale economies have on estimates of CPI bias.

Hamilton (2001) concedes that the method, which is indirect, attributes all movement in the Engel curve unexplained by the other covariates to CPI bias. If there are missing covariates from the

[23] Hamilton (2001) describes robustness checks to his specification, which included adding covariates, interacting income with other covariates, and an instrumental variables specification. None of these robustness checks interacted household demography measures with time. Interactions of household size with time are an additional robusteness check unexplored in the previous work.

regression, or if there are errors in variables, then estimates of CPI could be spurious, overstated, or understated depending on the particular specification problem. Fortunately, changing household scale economies can be incorporated into the Rothbarth model that was used to estimate the economies of scale. Since the Rothbarth regression model is an Engel curve (and differs from the Hamilton Costa form only in being in per capita terms and the way that demography is modeled) it, too, can be used to estimate CPI bias while at the same time controlling for changing household scale economies. Recall that in the Rothbarth model the regression took the form

$$w_f = \alpha + \beta \ln\left(\tfrac{x}{n}\right) + \gamma \ln n + \sum_{k=1}^{K-1} \delta_k \left(\tfrac{n_k}{n}\right) + \zeta z + \varepsilon$$

which disaggregates changes in household composition, $\left(\frac{n_k}{n}\right)$, and changes in household size, (n), on demand by design. The Rothbarth functional form can be easily augmented to estimate CPI bias by including terms for changes in relative price, deflating per capita income, and including variables for time and region.[24] Incorporating changes in the effects of household size in this model is straightforward. The regression now becomes

$$w_{i,j,t} = \alpha + \varphi\left[\ln\left(1+\Pi_{F,j,t}\right) - \ln\left(1+\Pi_{N,j,t}\right)\right] + \beta\left[\ln\left(\tfrac{x}{n}\right)_{i,j,t} - \ln\left(1+\Pi_{j,t}\right)\right] + \gamma \ln n + \sum_{k=1}^{K-1} \delta_k \left(\tfrac{n_k}{n}\right) + \lambda\left[(\ln n) * D_t\right] + \sum \delta_t D_t + \sum \delta_j D_j + u_{i,j,t}$$

so that changes in the Engel curve that derive from changing scale economies can be estimated separate from estimates of CPI bias. If changing scale economies have an effect over time on movements in the Engel curve (if λ is statistically and economically significant) then the specification above will capture it, and estimates of δ_t will not suffer from the omission of changing scale economies in the household.

It is useful to distinguish the issue here, about estimates of CPI bias that may suffer from omitted variable bias, from the general issue of modeling demographic variables in demand analysis. I am concerned with the fact that changes in household size may have a separate, distinct effect on changes in demand, and should therefore be included in estimates of CPI bias that seek to control for changes in household composition. A separate issue is the modeling, generally, of demographic variables in demand equations in a way that is theoretically consistent. See Pollack and Wales (1981) and Lewbel (1985) for classic references on this issue. While I make no claims about the proper modeling of

[24] Note that regional (state) effects were controlled for in the estimates of scale economies discussed in the previous section.

demographic variables in demand systems, it is important to note that the discussion above is an important example of the modeling of demographic variables in demand systems more generally. If Engel based estimates of CPI bias are sensitive to the effects of household size on demand, estimates of CPI bias should seek to purge the effects of household demography from estimates of CPI bias. In order to discover such trends, theoretical and empirical research into modeling of demographic variables in demand systems is needed.

5.2 CPI Bias and Household Scale Economies

To derive estimates of CPI bias, the surveys of two year must be combined so that changes in relative prices and income can be captured and controlled for. I estimate CPI bias from 1888 to 1917 and from 1917 to 1935 using the surveys described above. Table 7 considers the estimates of CPI bias with and without controlling for changing household scale economies. The only additional variable added to the model is the interaction of household size and a time dummy variable as described above. The calculation of CPI bias derives from the time dummy variable.[25] If there is CPI bias, the time dummy variable will be statistically different from zero.

As predicted above, estimates of CPI bias decrease once the changes in household size are included, and the differences in the estimates of CPI bias are striking, reduced by 25% or more. For 1888 to 1917, CPI bias overstated income by approximately 2.2% per year, but after controlling for changes in household size estimates of CPI are reduced to 0.74% per year, nearly a three-fold decrease in the extent of CPI bias from 1888 to 1917. For 1917 to 1935, CPI bias understated income by 2.4% per year, but controlling for changes in scale economies reduced the estimate of CPI bias to 1.9% per year, nearly a 25% decrease in the estimate of CPI bias. Controlling for changes in household size over time has a significant effect on estimates of CPI bias and real income in the past.

Table 7 also shows two interesting facts. First, the inclusion of household size change over time does not impact the effect of income on demand, so household changes do not appear to have an effect that works through income. This is analogous to saying that changes in household size appear to be uncorrelated with deflated income. Secondly, it is not true that changes in household size fully explain CPI bias. Even after controlling for changing household size, there is still a statistically significant effect of time that can be attributed to CPI bias. It is likely, however, that the inclusion of other time

[25] For more on how CPI bias is estimated using this functional form see the appendix.

varying covariates (such as changing household compositional effects) would further reduce estimates of CPI bias.[26]

6 Conclusion

Changes in household size and structure are important factors when measuring welfare in the past and present. This paper has investigated the effect of household size on demand from the late nineteenth to the middle of the twentieth century in the United States. Congruent with previous results, food expenditure per capita decreased with household size in the past. While the "food puzzle" first noted by Deaton and Paxson remains, the time trend reveals that food has not behaved in any systematic fashion in the past. The results here, when combined with the cross-country evidence of Deaton and Paxson, cast serious doubt on the possibility that food was, or will be in the future, a private good consistent with the predictions of the Barten model. Clothing and entertainment behave in a manner more consistent with the Barten model for private goods, where clothing and entertainment expenditures increased with household size. Housing is consistent with the predictions that the Barten model makes for public goods, where expenditures decreased with household size. Furthermore, the effect of household size for every consumption category changed significantly over time.

These changes in household size on demand have important implications. I explored here how estimates of CPI bias suffer from omitted variable bias if changes in household size over time are not accounted for. The results here suggest that estimates of CPI bias are reduced by at least 25% once changes in household size are controlled for. Much of what we may erroneously attribute to unaccounted changes in real income actually reflects the changes that household size has on real income. To that end, models, both theoretical and econometric, that estimate real income need to be modified to reflect the influence of changing household size over time.

[26] Indeed, when CPI bias estimates of the type described in this section were estimated with interactions on household composition (interacting the household shares with time), the effect of CPI bias decreased dramatically. For 1888-1917, the fully interacted model resulted in a "Year is 1917" coefficient estimate of 0.015, which was not statistically significant (p-value 0.11). For 1917-1935, the "Year is 1935" coefficient changes sign (0.029), but is still statistically significant (p-value 0.002). Overall, it appears that CPI bias estimates are sensitive to the modeling of household demography.

References

[1] Aguiar, Mark and Erik Hurst (2005). "Consumption versus Expenditure." *Journal of Political Economy* 113 (5): 919-948.

[2] Barten, Anton P. (1964). "Family Composition, Prices and Expenditure Patterns." in Peter E. Hart, Gordon Mills, and John Whitaker, eds. *Econometric Analysis for National Planning*. London: Butterworths.

[3] Byington, Margaret F. (1910). *Homestead: The Households of a Mill Town*. Philadelphia: W.M. Fell Co.

[4] Carter, Susan B., Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright, eds. (2006). *Historical Statistics of the United States*. New York: Cambridge University Press.

[5] Costa, Dora L. (1999). "American Living Standards: Evidence from Recreational Expenditures." NBER Working Paper No. 7148.

[6] Costa, Dora L. (2001). "Estimating Real Income in the United States from 1888 to 1994: Correcting CPI Bias Using Engel Curves." *Journal of Political Economy* 109 (6): 1288-1310.

[7] Cowan, Ruth S. (1983). *More Work for Mother*. New York: Basic Books.

[8] Deaton, Angus and John Muellbauer (1980). *Economics and Consumer Behavior*. New York: Cambridge.

[9] Deaton, Angus and Christina Paxson (1998). "Economies of Scale, Household Size, and the Demand for Food." *Journal of Political Economy* 106 (5): 897-930.

[10] Deaton, Angus and Christina Paxson (2003). "Engel's What? A Response to Gan and Vernon." *Journal of Political Economy* 111 (6): 1378-1381.

[11] Estes, Eugena and Bo Honore (1995). "Partial Regression Using One Nearest Neighbor." Unpublished Manuscript, Princeton University.

[12] Gan, Li and Victoria Vernon (2003). "Testing the Barten Model of Economies of Scale in Household Consumption: Toward Resolving a Paradox of Deaton and Paxson." *Journal of Political Economy* 111 (6): 1361-1377.

[13] Gibson, John (2002). "Why Does the Engel Method Work? Food Demand, Economies of Size and Household Survey Methods." Unpublished Manuscript, University of Waikato.

[14] Gorman, William M. (1976). "Tricks with Utility Functions." in M.J. Artis and A.R. Nobay, eds., Essays in Economic Analysis: Proceedings of the 1975 AUTE Conference Sheffield. Cambridge: Cambridge University Press.

[15] Greenwood, Jeremy, Ananth Seshadri and Mehmet Yorukoglu (2005). "Engines of Liberation." *Review of Economic Studies* 72 (1): 109-133.

[16] Gronau, Ruben and Daniel Hamermesh (2001). "The Demand for Variety: A Household Production Perspective." NBER Working Paper No. 8509.

[17] Gronau, Ruben and Daniel Hamermesh (2006). "Time vs. Goods: The Value of Measuring Household Production Technologies." *Review of Income and Wealth* 52 (1): 1-16.

[18] Hamilton, Bruce W. (2001). "Using Engel's Law to Estimate CPI Bias." *American Economic Review* 91 (3): 619-630.

[19] Horowitz, Andrew W. (2002). "Household Size and the Demand for Food: A Puzzle Resolved?" Unpublished Manuscript, University of Arkansas.

[20] Kertzer, David, I. and Marzio Barbagli, eds. (2002). *The History of the European Family, Volume 2 Family Life in the Long Nineteenth Century.* New Haven, CT: Yale University Press.

[21] Lewbel, Arthur (1985). "A Unified Approach to Incorporating Demographic and Other Effects Into Demand Systems." *Review of Economic Studies* 52 (1): 1-18.

[22] Logan, Trevon D. (2005). "The Transformation of Hunger: The Demand for Calories Past and Present." NBER Working Paper No. 11754.

[23] Logan, Trevon D. (2006). "Nutrition and Well-Being in the Late Nineteenth Century." *Journal of Economic History* 66 (2): 313-341.

[24] Moykr, Joel (2000). "Why 'More Work for Mother?' Knowledge and Household Behavior, 1870-1945." *Journal of Economic History* 60 (1): 1-41.

[25] Muellbauer, John (1977). "Testing the Barten Model of Household Consumption Effects and the Cost of Children." *Economic Journal* 87: 460-487.

[26] Nelson, Julie A. (1988). "Household Economies of Scale in Consumption: Theory and Evidence." *Econometrica* 56 (6): 1301-1314.

[27] Nicholson, J. Leonard (1976). "Appraisal of Different Methods of Estimating Equivalence Scales and Their Results." *Review of Income and Wealth* 22 (1): 1-11.

[28] Oddy, D. J. (1990). "Food, Drink, and Nutrition." In F. M. L. Thompson, ed. *The Cambridge Social History of Britain 1750-1950, Vol. 2 People and their Environment.* New York: Cambridge University Press: 251-278.

[29] Perali, Federico (2001). "The Second Engel Law and Economies of Scale: An Empirical Puzzle to be Resolved." Unpublished Manuscript, University of Verona.

[30] Pistaferri, Luigi, Todd Schoellman and Michele Tertilt (2005). "Household Size and the Demand for Private Goods." Unpublished Manuscript, Stanford University.

[31] Pollak, Robert A. and Terrence J. Wales (1980). "Comparison of the Quadratic Expenditure System and Translog Demand Systems with Alternative Specifications of Demographic Effects." *Econometrica* 48 (3): 595-612.

[32] Pollak, Robert A. and Terrence J. Wales (1981). "Demographic Variables in Demand Analysis." *Econometrica* 49 (6): 1533-1551.

[33] Vernon, Victoria (2005). "Food Expenditure, Food Preparation Time, and Household Economies of Scale." Unpublished Manuscript, Fashion Institute of Technology, State University of New York.

[34] United States Bureau of Labor Statistics (1951). *Handbook of Labor Statistics: 1950 Edition.* Bulletin No. 1016. Washington, D.C.: Government Printing Office.

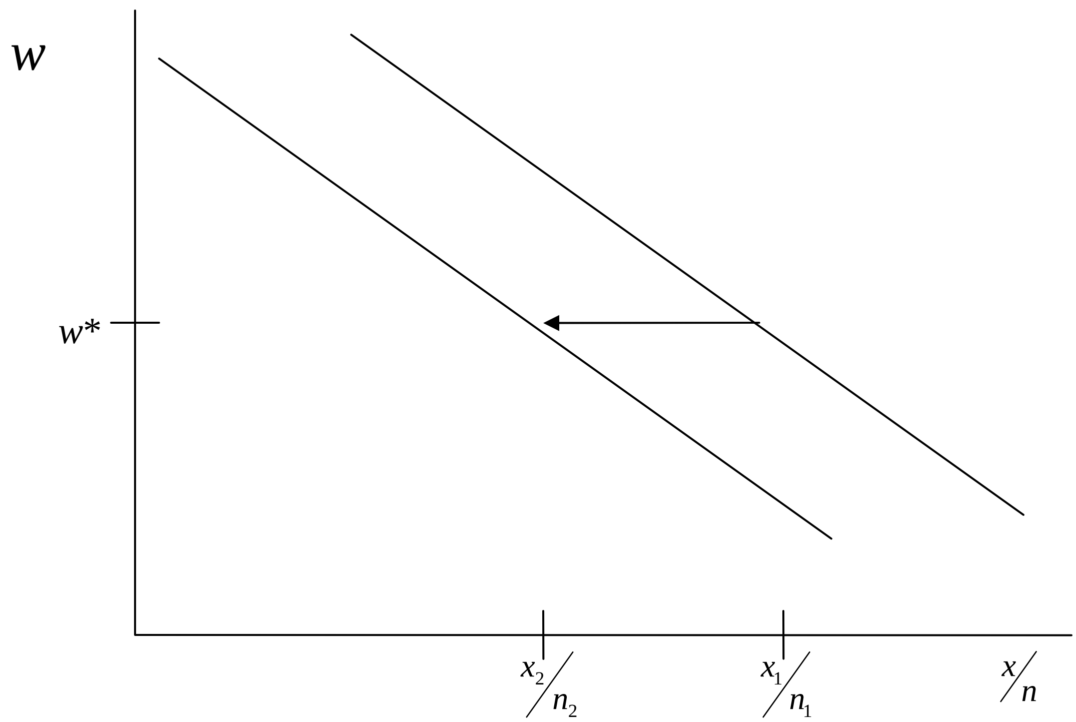
[35] United States Department of Labor (1986). *Cost of Living of Industrial Workers in the United States and Europe 1888-1890. ICPSR 7711.* Ann Arbor, MI: Inter-university Consortium for Political and Social Research.

[36] United States Department of Labor (1986). *Cost of Living in the United States 1917-1919. ICPSR 8299.* Ann Arbor, MI: Inter-university Consortium for Political and Social Research.

[37] United States Department of Labor and United States Department of Agriculture (1989). *Study of Consumer Purchases in the United States, 1935-1936. ICPSR 8908.* Ann Arbor, MI: Inter-university Consortium for Political and Social Research.

[38] Yatchew, Adonis (1997). "An Elementary Estimator of the Partial Linear Model." *Economics Letters* 57: 135-143.

Figure 1



Engel Measures of Economies of Scale

Table 1
The Effect of Household Size on Food's Share of the Budget 1888-1935

	I	II	III
Method	1888	1917	1935
Linear (OLS)	-0.023	-0.091	-0.040
	(5.6)	(32.39)	(3.36)
Fourier	-0.022	-0.089	-0.051
	(5.16)	(31.67)	(4.32)
First Differencing	-0.026	-0.090	-0.054
	(6.27)	(31.97)	(4.27)
IV	-0.024	-0.083	-0.038
	(5.67)	(28.33)	(3.06)
N	6809	12817	3534

Note:
Each entry is the coefficient estimate for the log of household size for that method, year pairing.
Each entry comes from a separate regression that includes the fraction of the household employed, the state of residence, the industry of the household head, and demographic shares of the household.
The dependent variable in each regression is the share of household expenditure devoted to food.
Robust t-statistics are listed under coefficient estimates in parenthses.

See section 3 of the text for details on the estimation procedure.

Table 2
The Effect of Household Size on Food's Budget Share by Consumption Type 1917-1935

	Food at Home		Food Away from Home	
	I	II	III	IV
Method	1917	1935	1917	1935
Linear (OLS)	-0.097	-0.046	0.006	0.008
	(34.35)	(4.5)	(5.84)	(2.39)
Fourier	-0.096	-0.044	0.007	0.008
	(33.72)	(4.32)	(6.08)	(2.27)
First Differencing	-0.096	-0.035	0.006	0.006
	(33.83)	(3.23)	(5.62)	(1.65)
IV	-0.089	-0.053	0.007	0.010
	(30.36)	(5.07)	(5.94)	(2.77)
N	12817	3534	12817	3534

Note:
Each entry is the coefficient estimate for the log of household size for that method, year pairing.
Each entry comes from a separate regression that includes the fraction of the household employed, the state of residence, the industry of the household head, and demographic shares of the household.
The dependent variable in each regression is the share of household expenditure devoted to food at home (I-II) and away from home (III-IV).
Robust t-statistics are listed under coefficient estimates in parenthses.

See section 3 of the text for details on the estimation procedure.

Table 3
The Effect of Household Size on Clothing's Share of the Budget 1888-1935

	I	II	III
Method	1888	1917	1935
Linear (OLS)	0.068	0.040	0.029
	(21.78)	(17.83)	(5.23)
Fourier	0.069	0.044	0.028
	(21.78)	(19.31)	(4.96)
First Differencing	0.063	0.048	0.028
	(19.87)	(21.31)	(4.91)
IV	0.082	0.049	0.035
	(24.91)	(20.99)	(6.08)
N	6809	12817	3534

Note:
Each entry is the coefficient estimate for the log of household size for that method, year pairing.
Each entry comes from a separate regression that includes the fraction of the household employed, the state of residence, the industry of the household head, and demographic shares of the household.
The dependent variable in each regression is the share of household expenditure devoted to clothing.
Robust t-statistics are listed under coefficient estimates in parenthses.

See section 3 of the text for details on the estimation procedure.

Table 4
The Effect of Household Size on Entertainment's Share of the Budget 1888-1935

	I	II	III
Method	1888	1917	1935
Linear (OLS)	0.007	0.004	0.005
	(5.75)	(9.63)	(1.93)
Fourier	0.006	0.004	0.005
	(5.1)	(10.0)	(1.94)
First Differencing	0.006	0.004	0.003
	(4.82)	(10.5)	(0.89)
IV	0.010	0.005	0.008
	(7.84)	(12.68)	(2.89)
N	6809	12817	3534

Note:
Each entry is the coefficient estimate for the log of household size for that method, year pairing.
Each entry comes from a separate regression that includes the fraction of the household employed, the state of residence, the industry of the household head, and demographic shares of the household.
The dependent variable in each regression is the share of household expenditure devoted to leisure/entertainment/recreation.
Robust t-statistics are listed under coefficient estimates in parenthses.

See section 3 of the text for details on the estimation procedure.
See the data appendix for the expenditure categories that comprise entertainment.

Table 5
The Effect of Household Size on Housing's Share of the Budget 1888-1935

	I	II	III
Method	1888	1917	1935
Linear (OLS)	-1.538	-0.068	-0.029
	(3.54)	(22.41)	(3.63)
Fourier	-1.560	-0.067	-0.025
	(3.59)	(21.85)	(3.17)
First Differencing	-1.666	-0.065	-0.022
	(3.86)	(21.4)	(2.72)
IV	0.787	-0.069	-0.035
	(1.72)	(21.89)	(4.31)
N	6809	12817	3534

Note:
Each entry is the coefficient estimate for the log of household size for that method, year pairing.
Each entry comes from a separate regression that includes the fraction of the household employed, the state of residence, the industry of the household head, and demographic shares of the household.
The dependent variable in each regression is the share of household expenditure devoted to housing.
Robust t-statistics are listed under coefficient estimates in parenthses.

See section 3 of the text for details on the estimation procedure.
See the data appendix for the expenditure categories that comprise housing expenditures.

Table 6
The Effect of Household Size on Budget Shares by Income Quartile, 1888-1935

Category	Income Quartile			
Food	1st	2nd	3rd	4th
1888	-0.007	-0.014	-0.032	-0.027
	(0.71)	(1.89)	(4.09)	(2.66)
1917	-0.075	-0.087	-0.105	-0.094
	(12.82)	(15.61)	(19.15)	(16.04)
1935	-0.026	-0.058	-0.072	-0.047
	(0.96)	(2.23)	(3.18)	(2.53)
Clothing	1st	2nd	3rd	4th
1888	0.075	0.065	0.057	0.054
	(10.43)	(11.34)	(9.51)	(7.16)
1917	0.050	0.053	0.039	0.022
	(12.0)	(12.33)	(8.8)	(4.0)
1935	0.022	0.033	0.032	0.036
	(1.97)	(2.93)	(2.82)	(3.28)
Entertainment	1st	2nd	3rd	4th
1888	-0.003	0.004	0.003	0.004
	(1.83)	(2.39)	(1.18)	(0.93)
1917	0.001	0.005	0.006	0.000
	(1.33)	(5.97)	(6.22)	(0.18)
1935	0.004	0.009	0.001	0.013
	(0.76)	(1.4)	(0.2)	(1.84)
Housing	1st	2nd	3rd	4th
1888	-5.259	-0.790	-0.457	0.062
	(4.26)	(0.95)	(0.6)	(0.08)
1917	-0.065	-0.060	-0.067	-0.082
	(11.4)	(10.25)	(11.02)	(11.53)
1935	-0.020	-0.034	-0.036	-0.053
	(0.86)	(1.66)	(1.89)	(2.97)

Note:
Each entry is the coefficient estimate for the log of household size for that income quartile, year pairing for that expenditure category, whose budget share is the dependent variable in the regression.
Each entry comes from a separate OLS regression that includes the fraction of the household employed, the state of residence, the industry of the household head, and demographic shares of the household.
Robust t-statistics are listed under coefficient estimates in parenthses.

Table 7
Estimating CPI Bias with and without Controls for Changing Household Size, 1888-1935

	I 1888/1917	II 1888/1917	III 1917/1935	IV 1917/1935
log real PCE	-0.132 (73.96)	-0.131 (73.11)	-0.159 (93.82)	-0.159 (93.89)
Year is 1917	0.065 (34.83)	0.026 (5.70)		
Year is 1935			-0.091 (4.42)	-0.069 (3.17)
Year is 1917 * Household Size		0.025 (9.36)		
Year is 1935 * Household Size				-0.016 (3.15)
R-Squared	0.393	0.396	0.477	0.479
N	19626	19626	16467	16467
Cumulative CPI Bias	-0.633	-0.219	0.435	0.351
Annual CPI Bias	-0.022	-0.007	0.024	0.019
% Difference in annual bias without household control		288%		124%

Note:
The dependent variable in all regressions is the share of household expenditure devoted to food.
Robust t-statistics are listed under coefficient estimates in parentheses. The regressions above include relative price changes between food and non-food, deflated household expenditure, regional dummies, household demographics, and the fraction of the household employed.

See section 5 of the text for details on the functional form in the CPI bias regression.
See the appendix for the derivation of the CPI bias estimate.

Appendix

1 Further Evidence on Household Economies of Scale in the Past

There are additional tests of the "food puzzle" that other researchers have used to investigate the problem. Gan and Vernon (2003) argued that the "food puzzle" resulted from improper specification of the predictions of the Barten model. Rather than the foodshare increasing with household size, they argue that food should be paired with other private goods, such as clothing. This would be a test of whether food was indeed a private good when compared to a good that behaved in a manner consistent with a private good in the Barten model (or, in Gan and Vernon's view "another good known to be more private than food." (pp. 1368-1369) This also requires that utility be separable with respect to the two goods combined together.). While this pairing of food and clothing shows that the food and clothing share is positively related to household size for their contemporary household surveys, and consistent with the idea that food and clothing are jointly private goods, the results do not hold for the historical household surveys used in this paper.[27] Table A1 shows the results, where the food and clothing share is negative in 1917 and in 1935. This implies that the negative correlation of household size and the foodshare dominates the positive relationship between household size and the clothing share– such that food and clothing jointly behave more like public goods in the past. Similarly, Gan and Vernon suggest that the share of food in food and shelter, $\left(\frac{f}{f+h}\right)$, would be positively related to household size, and find evidence for this in their contemporary household surveys. They take this as evidence that food is more private that housing. Table A1 shows that this was not always the case– food was more negatively related to household size than housing in the past. As such, Gan and Vernon's attempts to resolve the puzzle by grouping food with other items does not generate similar results with historical evidence.

2 Estimating CPI Bias

Estimating CPI bias from Engel curves begins with a number of assumptions. Decomposing food and non-food expenditures into a price index and quantity index requires that food be additively separable in the household's utility function. Furthermore, there must be homotheticity in the subutilities of food and non-food. With these conditions the bias of non-food does not effect the foodshare through complementarities of substitutabilities through some unmodeled channel. Hamilton (2001) further notes that food is chosen because (1) it has an income elasticity that is different from unity, and therefore sensitive to the measurement of income, (2) it is non-durable and therefore not subject to stock and flow effects (this would, naturally, be stronger in the past than today), (3) food does not involve the troublesome "definitional problems" of other expenditure categories and (4) because the Working-Leser Almost Ideal Demand System (AIDS) has a functional form that has successfully estimated the demand for food. It is also important to note that the method requires the dependent variable to be the budget share for food– food consumption and expenditure are likely to contain CPI bias themselves.

Beginning with the Almost Ideal Demand System for food

$$w_{i,j,t} = \phi + \varphi\left(\ln P_{F,j,t} - \ln P_{N,j,t}\right) + \beta\left(\ln Y_{i,j,t} - \ln P_{j,t}\right) + X^{'}\theta + u_{i,j,t}$$

where w is the share of the budget devoted to food, P is the true, unobserved price index for food (F), nonfood (N), and all goods, Y is household expenditure, X is a vector of household characteristics, and u is the error term. The true cost of living in year t, in place j, $P_{j,t}$, is a weighted average of the prices of food and non-food

$$\ln P_{j,t} = \alpha \ln P_{F,j,t} + (1-\alpha)\ln P_{N,j,t}$$

and those prices are measured with error (which is CPI bias) such that

$$\ln\left(P_{j,t}\right) = \ln\left(P_{j,0}\right) + \ln\left(1 + \Pi_{j,t}\right) + \ln\left(1 + E_{j,t}\right)$$

[27] Their surveys come from the United States (1990 Consumer Expenditure Survey), South Africa (1993 Living Standards Survey), and Russia (1994-1998 Russian Longitudinal Monitoring Survey).

where P_0 is the true price, Π is the CPI price, and E is the cumulative measurement error in the price index from year 0 to year t. Note that the measurement error would also apply to the prices of food and non-food in the same manner, and that aggregate error would also be a weighted function of the errors in food and non-food. Substituting the equation above into the Almost Ideal Demand System and rearranging terms yields

$$w_{i,j,t} = \phi + \varphi\left[\ln\left(1+\Pi_{F,j,t}\right) - \ln\left(1+\Pi_{N,j,t}\right)\right] + \beta\left[\ln Y_{i,j,t} - \ln\left(1+\Pi_{j,t}\right)\right] + X^{'}\theta + \varphi\left[\ln P_{F,j,0} - \ln P_{N,j,0}\right] - \beta \ln\left(P_{j,0}\right) + \varphi\left[\ln\left(1+E_{F,j,t}\right) - \ln\left(1+E_{N,j,t}\right)\right] - \beta\ln\left(1+E_{j,t}\right) + u_{i,j,t}$$

The functional form of estimating CPI bias (the Hamilton-Costa form)

$$w_{i,j,t} = \phi + \varphi\left[\ln\left(1+\Pi_{F,j,t}\right) - \ln\left(1+\Pi_{N,j,t}\right)\right] + \beta\left[\ln Y_{i,j,t} - \ln\left(1+\Pi_{j,t}\right)\right] + X^{'}\theta + \sum_{t=1}^{T}\delta_t D_t + \sum_{j=1}\delta_j D_j + u_{i,j,t}$$

follows directly and

$$\delta_t = \varphi\left[\ln\left(1+E_{F,j,t}\right) - \ln\left(1+E_{N,j,t}\right)\right] - \beta\ln\left(1+E_{j,t}\right)$$

is used to measure the extent of CPI bias. If we assume that the bias between food and non-food is constant and that both food and nonfood are equally biased it holds that

$$\ln\left(1+E_{j,t}\right) = \frac{-\delta}{\beta}$$

such that cumulative (percentage) CPI bias at t is

$$1 - \exp\left(\frac{-\delta}{\beta}\right)$$

For the 1888/1917 estimates of CPI bias, data on CPI measured relative price changes by region are unavailable. Therefore, estimates of relative price changes over time would collapse into the time dummy as there would be no regional variation. In this instance, the Engel cure used to estimate CPI bias is

$$w_{i,j,t} = \phi + \beta\left[\ln Y_{i,j,t} - \ln\left(1+\Pi_{j,t}\right)\right] + X^{'}\theta + \sum_{t=1}^{T}\delta_t D_t + \sum_{j=1}\delta_j D_j + u_{i,j,t}$$

where now

$$\delta_t = \varphi\left[\ln\left(1+\Pi_{F,j,t}\right) - \ln\left(1+\Pi_{N,j,t}\right)\right] + \varphi\left[\ln\left(1+E_{F,j,t}\right) - \ln\left(1+E_{N,j,t}\right)\right] - \beta\ln\left(1+E_{j,t}\right)$$

so that with the same assumptions as those above, and for a given value of φ and changes in relative prices, the cumulative CPI bias at t is

$$1 - \exp\left(\frac{\delta - \varphi\left[\ln(1+\Pi_{F,t}) - \ln(1+\Pi_{N,t})\right]}{-\beta}\right)$$

for the 1888/1917 estimates of CPI bias. I use the estimate of φ from the 1917/1935 CPI bias regressions to estimate the 1888/1917 CPI bias, which is the same methodology adopted in Costa (2001). It is worth noting that this method does not require income to be deflated. If income were not deflated then δ_t would be used to estimate the true cost of living rather than bias in that cost. The method does require estimates of the relative price changes over time, as these would have an effect on the demand for food generally.

3 Data Appendix

3.1 The Consumer Expenditure Surveys

I used three consumer expenditure surveys in this paper, covering the years 1888-1890, 1917-1919, and 1935-1936. For the 1888-1890 survey, the sample was selected only from the following nine industries: pig iron, bar iron, steel, bituminous coal, coke, iron ore, cotton textile industry, wool textile industry and glass. Sample families, limiting to those representing more than two persons, were chosen from employer records. Twenty-four states were covered. In total, nearly 7,000 American families were surveyed. For more on the sampling see Logan (2006).

The 1917-1919 data were obtained from the surveys over 12,000 families of wage earners or salaried workers. Sample families were chosen by such restrictions that there are only husband and wife with at least one child; the salary earners could only make less than $2,000 per year; families had to reside in the community at least one year prior to the interview; families could not have more than three boarders; families were not "slum" or charity; non-English-speaking families had to reside in the United States for more than five years. All the selections are from ninety-nine cities throughout 42 states.

In 1935-36, only native-born families living in the United States were selected. The sample collections covered 51 cities, 140 villages, and 66 farm counties throughout 30 states. Except for New York City, Columbus, OH, and the South, only white families were chosen. Families in large cities had to earn more than $500 a year and those in smaller localities had to earn more than $250 a year. Three complete samples were undertaken, the first of which included approximately 700,000 families, representing the populations of larger and smaller cities, small towns and rural areas. From this a sample of about 300,000 families with at least two members, with married for more than one year, and with less than ten boarders during the survey were solicited to provide income and housing information. From this group of 300,000 respondents, 61,000 were selected to provide comprehensive expenditure information. The data used in this paper comes from a random sample of 6,000 families from those who provided both income and expenditure information. Since the 1935-1936 survey was explicit in its desire to capture the expenditure of rural households, while the 1917-1919 and 1888-1890 selected almost exclusively on urban households, I used only the urban households from the 1935-1936 survey, which is more than half of the 6,000 observations. For the estimates of CPI bias, I used the rural data as well, although due to missing values this added only 116 households from rural areas from the 1935 survey. Table A2 shows the means of the expenditure categories and household size for each survey.

Construction of household expenditure for the three surveys was similar. While the construction of the clothing and food categories was straightforward, housing and entertainment vary somewhat by survey. Entertainment in 1888-1890 is comprised of expenditures on books, newspapers, vacations, and "other amusements." For 1917-1919 entertainment includes expenditures on movies, concerts, plays, lectures, dances, billiards, excursions, books, and "other amusements." For 1935-1936 entertainment includes movies, radios, sports clubs, social clubs, camping, fishing, hiking, sports (golf, baseball, horseback riding, tennis, etc.), bikes, skates, skis, billiards, boats, cameras, vacations, and "other recreational expenses." Housing in every survey year includes both rent and/or mortgage payments, lighting, and fuel expenditures. For 1917-1919 and 1935-1936, the list expands to include utilities such as electricity and sewage. I also constructed a housing expenditure variable that included expenditures on furniture and appliances, as these are likely goods to be used by and/or for multiple household members. The results in the text with regards to housing are robust to the inclusion of furniture and appliances, and other expenditures such as alcohol and tobacco prove to be consistent with the predictions for private goods in the Barten model (see Table A3).

3.2 Price Indices

Using weights from the consumer expenditure surveys, the Bureau of Labor Statistics (BLS) has measured the changes in retail prices of goods and services since 1913. Overall price change for 1888-1917 and overall and food price changes for 1917-1935 were calculated from the *Historical Statistics of the United States, Millennial Edition* (2006). For 1917-35, regional price indices were calculated using the *Handbook of Labor Statistics: 1950 Edition* (U.S. Bureau of the Census 1951) which contains price indices for 1917-1935 for food and all items for a sampling of cities in the United States. These were applied to the states from which the prices came, to construct a regional price index using the Census Bureau's regions (this gives four regions for the US). Assuming that the price index is a weighted sample of food and non-food, the price indices are used to create regional price indexes for food, non-food and all items for 1917-1935.

Table A1

The Effect of Household Size on Food and Clothing's Share of the Budget 1888-1935

	I	II	III
Method	1888	1917	1935
Linear (OLS)	0.045	-0.050	-0.016
	(10.25)	(15.11)	(1.25)
Fourier	0.047	-0.046	-0.024
	(10.75)	(13.65)	(1.89)
First Differencing	-0.026	0.020	0.003
	(6.85)	(7.17)	(0.23)
IV	0.057	-0.033	-0.003
	(12.56)	(9.53)	(0.24)
N	6809	12817	3534

The Effect of Household Size on Food in Food and Hosuing Expenditures 1888-1935

	I	II	III
Method	1888	1917	1935
Linear (OLS)	-0.017	0.048	-0.033
	(1.18)	(10.22)	(2.24)
Fourier	-0.017	0.047	-0.032
	(1.17)	(10.08)	(2.17)
First Differencing	0.001	-0.024	0.019
	(0.1)	(7.01)	(1.4)
IV	-0.092	0.053	-0.048
	(6.09)	(10.93)	(10.59)
N	6809	12817	3534

Note:
Each entry is the coefficient estimate for the log of household size for that method, year pairing. Each entry comes from a separate regression that includes the fraction of the household employed, the state of residence, the industry of the household head, and demographic shares of the household. The dependent variable in each regression is the share of household expenditure devoted to food and clothing (top panel) and the share of expenditure devoted to food from food and housing expenditure (bottom panel). Robust t-statistics are listed under coefficient estimates in parenthses.

See section 3 of the text for details on the estimation procedure.

Table A2

Summary Statistics from Historical Household Surveys, 1888-1935

	I	II	III
Variable	1888	1917	1935
Household Size	4.7	4.9	3.7
	(2.11)	(1.64)	(1.45)
Food Share	44.5%	39.2%	38.9%
	(.089)	(.079)	(.093)
Clothing Share	16.7%	16.2%	10.9%
	(.065)	(.050)	(.056)
Entertainment Share	1.9%	3.2%	3.5%
	(.024)	(.009)	(.027)
Housing Share	13.7%	13.6%	14.3%
	(.081)	(.069)	(.088)
N	6809	12817	3534

Note: Estimates are the mean values, based on Author's calculation.
Standard Deviations are listed in parentheses.

Table A3

The Effect of Household Size on Housing and Furniture's Share of the Budget 1888-1935

	I	II	III
Method	1888	1917	1935
Linear (OLS)	-1.476	-0.053	-0.026
	(3.41)	(15.01)	(3.04)
Fourier	-1.502	-0.052	-0.022
	(3.47)	(14.47)	(2.56)
First Differencing	-1.673	-0.052	-0.019
	(3.88)	(14.66)	(2.14)
IV	0.072	-0.056	-0.033
	(1.6)	(15.19)	(3.67)
N	6809	12817	3534

The Effect of Household Size on Alcohol and Tobacco's Share of the Budget 1888-1935

	I	II	III
Method	1888	1917	1935
Linear (OLS)	0.005	0.002	0.008
	(1.19)	(1.1)	(1.14)
Fourier	0.006	0.002	0.008
	(1.47)	(1.15)	(1.18)
First Differencing	-0.004	0.000	-0.001
	(1.37)	(0.33)	(0.11)
IV	0.008	0.002	0.007
	(2.08)	(1.11)	(0.88)
N	6809	12817	3534

Note:
Each entry is the coefficient estimate for the log of household size for that method, year pairing.
Each entry comes from a separate regression that includes the fraction of the household employed, the state of residence, the industry of the household head, and demographic shares of the household. The dependent variable in each regression is the share of household expenditure devoted to housing, furniture, and appliances (top panel) and share of expenditure devoted to alchohol and tobacco (bottom panel). Robust t-statistics are listed under coefficient estimates in parenthses.

See section 3 of the text for details on the estimation procedure.
See the data appendix for the expenditure categories that comprise housing expenditures.