Families as roommates: Changes in U.S. household size from 1850 to 2000

ALEJANDRINA SALCEDO
Banco de México

TODD SCHOELLMAN
Arizona State University

MICHÈLE TERTILT
University of Mannheim, NBER, and CEPR

Living arrangements have changed enormously over the last two centuries. While the average American today lives in a household of only three people, in 1850 household size was twice that figure. Furthermore, both the number of children and the number of adults in a household have fallen dramatically. We develop a simple theory of household size where living with others is beneficial solely because the costs of household public goods can be shared. In other words, we abstract from intrafamily relations and focus on households as collections of roommates. The model's mechanism is that rising income leads to a falling expenditure share on household public goods, which endogenously makes household formation less beneficial and privacy more attractive. To assess the magnitude of this mechanism, we first calibrate the model to match the relationship between household size, consumption patterns, and income in the cross section at the end of the 20th century. We then project the model back to 1850 by changing income. We find that our proposed mechanism can account for 37 percent of the decline in the number of adults in a household between 1850 and 2000, and for 16 percent of the decline in the number of children.

KEYWORDS. Household size, living arrangements, roommates, economies of scale, household public goods, fertility decline.

1. Introduction

Over the last century and a half, family structure and living arrangements in the United States have undergone significant changes. Today's average household is 50 percent smaller than in 1850. The decline in fertility explains part of this change, as the average household today contains two fewer children of the head. However, virtually all other forms of cohabitation have become less common as well. The average household has fewer parents, fewer siblings, fewer grandchildren, and fewer other relatives of the household head. While in 1850 almost every household included a married couple, today less than half of all households do. Even the number of nonrelatives has declined by about one person per household.

One way to understand changing living arrangements is to model each form of cohabitation separately, focusing on the specific trade-offs and institutions most relevant to that form. In this paper, we explore an alternative view. Given that *all* forms of cohabitation have become less common, we propose a model that explicitly abstracts from specific forms of cohabitation or institutions and focuses on the economic trade-offs common to all forms of living together. In our model, the decline in cohabitation is an optimal response to growing incomes. When we calibrate the model, we find that about one-third of the decline in household size since 1850 can be attributed to rising incomes alone. Thus, our analysis suggests that a substantial part of the decline in living together may be understood as a common response to growing incomes. On the other hand, we explain only a part of the total decline, leaving room for alternative mechanisms or for models with a richer focus on one particular form of cohabitation.

In this paper, we think of households as collections of roommates living together to share the costs of household public goods. The larger a household, the less each roommate pays for public goods such as housing. The mechanism we propose is based on the idea that private goods have a higher income elasticity than public goods. Therefore, as people get richer, the household public goods become relatively less important. This changing consumption pattern reduces the economies of scale of living with other people and endogenously decreases the optimal household size. Hence, optimally changing consumption bundles provide the link from income to household size. In other words, the optimal number of roommates is decided through a simple cost–benefit analysis, with costs and benefits changing endogenously as income changes.

While literal roommates constitute only a small fraction of all households, we believe that decisions to form, alter, or dissolve families are also influenced by the same cost and benefit analysis. For example, adult children have the choice of whether to leave their parents' home. For those who stay, a driving consideration is cost. Elderly parents often move in with their adult children to save money. Similarly, when couples contemplate a divorce, they consider whether establishing two separate households is affordable.[1] On

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[1] On July 13, 2009, the front page of the *Wall Street Journal* featured a story about couples who delayed the decision to dissolve their marriages due to the current recession.

the other hand, there are also happily married couples who choose to live apart because they can afford to do so. Sociological and demographic research has studied the rise of living apart together (LAT) relationships—couples who identify their relationships as stable but choose not to live together (Roseneil (2006), Strohm, Seltzer, Cochran, and Mays (2009)).

Our story implies that richer households are smaller and spend a lower fraction of their budget on public goods relative to private goods. We provide evidence that these two implications are indeed observed in the data. Using U.S. Census Data, we show a strong negative relationship between income and household size. We then document that there is a negative relationship between income and the ratio of households' public to private consumption expenditures. To do so, we classify expenditures from the Consumer Expenditure Survey (CEX) and from the National Income and Product Accounts (NIPA) as household public goods or private goods. In the cross section from the CEX, the highest income quintile has a ratio of public to private consumption expenditures that is around 20 percent lower than that of the poorest quintile. In the time series from the NIPA, we note that over the last 50 years the aggregate ratio of household public to private consumption has fallen by 40 percent.

An overlapping generations model formalizes our story. Adults have preferences over a private good, a household public good, and the number of their own children in the household. They can choose to live with roommates, who help bear the cost of the household public goods, but finding roommates and maintaining good relationships takes time. The optimal number of roommates and the consumption of household public goods are linked: households with more roommates find it optimal to consume more household public goods due to the low price, and adults who want more household public goods find it optimal to have more roommates to share the costs. If the utility function displays more curvature in public than in private goods, then higher incomes lead to a higher expenditure share on private goods in our model. Relatively lower public consumption decreases the benefit of living with adults, so household sizes fall. A similar channel applies to children: over time, parents devote a higher share of their expenditures to private goods for their children, effectively making children more expensive and leading to a decline in the number of children per household. Thus, the model features a quality–quantity trade-off with respect to children that is directly tied to the (changing) composition of the consumption basket.

We calibrate the model using the cross-sectional data on the relationships among income, household size, and relative consumption of public to private goods. We then change incomes exogenously over time (e.g., due to technological progress) and ask to what extent rising incomes alone could have caused the fall in household size. In the data, the number of adults per household fell by 1.2 between 1850 and 2000, while the number of children per household fell by 1.9. The model predicts a decline of about half an adult and a third of a child over the same time horizon. Thus, the model can account for about one-third of the observed change in the number of adults and one-sixth of the observed change in the number of children in the household. We computed these results, assuming a constant age composition of the population over time. Adjusted for the changing age composition of the population, the model predicts a larger decline of

0.64 adults and of 0.55 children. These findings suggest that rising demand for private goods may have contributed significantly to the changes in the living arrangements of Americans over the last century and a half.

Our quantitative model also has implications for the resources saved given the changes in living arrangements. We find that the time spent meeting roommates and maintaining relationships in 2000 corresponds to 7 percent of gross domestic product (GDP). Given today's smaller households, this figure is about 25 percent lower than in 1850. We also find that the total cost of a child (time plus goods) has increased by about 20 percent over the same time span. The reason is that richer parents choose to tilt their consumption bundles toward more private consumption, for themselves and also for their children.

Most of the theoretical literature on household formation focuses on a particular margin of family formation such as marriage, divorce, fertility, or the importance of the extended family. A rare exception is Burch and Matthews (1987), who pointed to a general trend toward "simpler" households and argued in favor of a general theory of household formation. Another notable exception is Ermisch (1981), who built and estimated a static model of household formation. However, no attempt has been made to assess how well the model can account for changes in living arrangements over time. Fernández, Guner, and Knowles (2005) and Greenwood, Guner, and Knowles (2003) also studied several margins of living together in models that emphasize the importance of income and search frictions. Their papers do not seek to explain the long-term patterns documented here. Beresford and Rivlin (1966) were probably the first to emphasize a rising "demand for privacy" as a factor in changing living arrangements, but they provided no formal model. Byalsky, Keren, and Levhari (1999) argued that a shift from public to private services may have caused a decline in optimal kibbutz size in Israel during the 20th century.

In contrast, analyses that focus on a particular change in family arrangements (and thus household size) abound. Quantitatively, the most significant change has been the fertility decline. A strong (negative) relationship between fertility and income exists, both over time and in the cross section (Jones and Tertilt (2008)). A large literature investigates changes in fertility patterns over the last two centuries, some focusing on the overall decline and some focusing on the baby boom.[2] It is often argued that the negative income–fertility relationship is due to parents trading off quantity of children for quality of children, which typically means more human capital or time investment per child (Becker and Lewis (1973)). Our model introduces an interesting variant to the quantity–quality theory by suggesting that parents are choosing endogenously to allocate more private goods to their children while having fewer children.

A small body of work exists that analyzes other margins of family formation. Several authors focused on the age at which young people leave their parents' homes, and

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[2]See, for example, Galor and Weil (1996) on women's wages, Doepke (2004) on human capital and child labor laws, Greenwood and Seshadri (2002) on the role of new household technologies, and Jones and Schoonbroodt (2010) on changes in mortality. Papers on the baby boom include Albanesi and Olivetti (2009), Greenwood, Seshadri, and Vandenbroucke (2005), and Doepke, Hazan, and Maoz (2007). This literature has grown greatly in recent years; see Jones, Schoonbroodt, and Tertilt (2011) for a survey.

pointed to earnings of young adults and house prices as the main factors (Haurin, Hendershott, and Kim (1994), Ermisch and Di Salvo (1997), Fogli (2004)). Income (particularly old-age pensions) also seems to play a role in the increased tendency for the elderly to live alone (Costa (1997, 1999), McGarry and Shoeni (2000), Bethencourt and Ríos-Rull (2009)). Other authors analyzed the decline in marriage and the increase in divorce. For example, Greenwood and Guner (2009) offered a model to explain the decline in marriage and the increase in divorce, arguing that technological progress in the home production sector made people increasingly more able to live in smaller households. Brien, Lillard, and Stern (2006) studied the determinants of cohabitation, marriage and divorce in a model with frictions and heterogeneous match quality. Regalia and Ríos-Rull (2001) explored the rise of single female and single mother households in the United States based on the increase in relative wages of women.

Each of these papers emphasizes specific features of a particular form of cohabitation. Some of these papers also analyze how rising incomes affect that particular form of cohabitation. Our approach differs primarily in modeling income as a factor that affects *all* forms of cohabitation simultaneously. Since the rise in income has been large and widespread, we find it useful to ask how far one can go with a model that abstracts from specific relationships between household members and instead focuses on the factor common to all forms of cohabitation: the sharing of public goods. Our results suggest that about one-third of changes in household size can be understood with this model. This leaves the remaining two-thirds to be explained by other factors or changes in specific institutions such as the introduction of social security, changes in divorce laws, or changes in tax laws affecting the incentives to get married.

The next section documents changes in household size in the United States. In Section 3 we present evidence for the channel proposed in this paper. Section 4 sets up the model and derives some basic theoretical results. The calibration is described in Section 5, while Section 6 presents our results. Section 7 concludes. Additional details on the data are provided in the Appendix.

2. Changes in household size and composition

Economic development is strongly associated with smaller households. Kobrin (1976) documented that household sizes in the United States have been falling since 1790. Laslett (1969) documented a similar phenomenon in England, although arguing that the decline did not start until the early 20th century. Kuznets (1978) used cross-country data to show that more developed countries tend to have smaller households.

In this section we use Census data to shed more light on changes in household size and composition in the United States over the last century and a half.[3] Using microdata allows us to distinguish between family and household size, to analyze household size over the life cycle, and to document changes in household composition. Microdata also enable us to analyze the relationship between household size and income in the cross

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[3]We use the publicly available data from the Integrated Public Use Microdata Series (IPUMS) (Ruggles et al. (2009)). See Ruggles and Brower (2003) for a description. A more detailed description of the data analysis is presented in Appendix A.1.1.
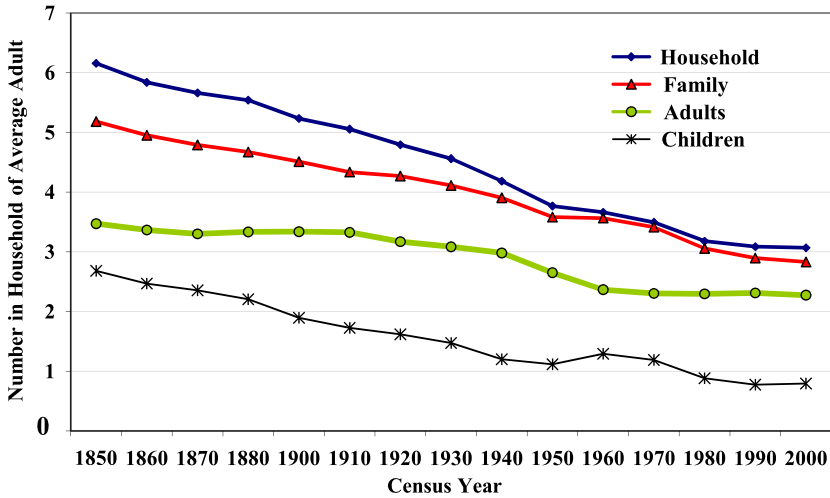
FIGURE 1. *Household size: number of members*. Calculations based on U.S. Census. Excludes group quarters. The unit of observation is an adult, so that each point represents the average household size across adults.

section. We use adults (18 years of age or older) as the unit of observation. Focusing on the average adult, instead of on the average household, helps us avoid any underrepresentation of people living in large households. Even more importantly, it allows us to perform analyses by age without looking only at households heads.[4]

Figure 1 shows the dramatic decline in household size from 1850 to 2000. The total number of household members for the average adult fell by about 50 percent, from 6.2 in 1850 to 3.1 in 2000. But this drop is not just another illustration of the fertility decline of the 19th century. To see this, we decompose average household size into adults (18 years of age and above) and children (under 18 years of age). The number of adults declined by more than one person, from 3.5 to 2.3, while the number of children decreased by almost two children, from 2.7 to 0.8. One might think that the decline in adult household members was driven mostly by changes in the family structure.[5] While changing family structure played an important role, it should be noted that nonfamily living arrangements declined as well. The number of nonfamily members is simply the gap between household and family members in Figure 1. While in 1850 the average person lived with one nonfamily member (i.e., a person not related by blood, marriage, or adoption), such arrangements had become almost nonexistent by 2000. In other words, sharing households with unrelated individuals, a common practice in the 19th century, essentially had disappeared by the middle of the 20th century.

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[4]This distinction is important because most people are not household heads most of the time, and heads of households have different household sizes from that of the average American. For example, in 2000, only 39 percent of 25 year old persons were household heads. While the average 25 year old person lived in a household of size 3.3, the average household size for heads of households aged 25 is only 2.5. The difference is greater the older the Census is. Furthermore, the fraction of individuals heading their own household at a given age has exhibited significant changes over time.

[5]Families in the U.S. Census are subsets of households that are related by blood, marriage, or adoption.
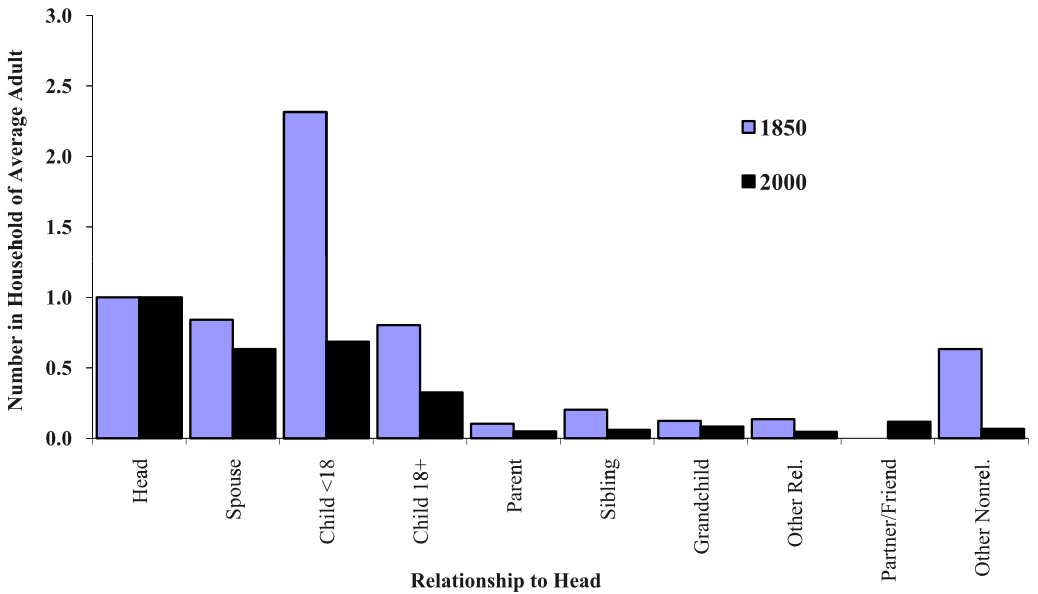
FIGURE 2. *Household members, 1850 and 2000*. Calculations based on U.S. Census. The unit of observation is an adult. Each bar represents the mean number of household members in each category.

To confirm further that the trend is not only a decline in marriage and fertility, we also decompose household size into different member categories, classifying each person according to his or her relationship to the household head. Figure 2 shows this decomposition for the years 1850 and 2000. The figure shows a decline in household members in almost every category: in 2000, there were fewer spouses, fewer children (both minors and adult children), fewer parents, siblings, grandchildren, other relatives, and nonrelatives in the household, compared to 1850. The only exception is the category "partners, friends, and visitors," which reflects the recent rise in nonmarried partners. This increase, however, is more than offset by the decline in spouses.

The reduction in household size has occurred at all stages of the life cycle. In Figure 3 we plot the number of household members by age group for each census year. Age groups span 5 years and are labeled by the middle year. The main point here is that the entire profile has shifted down almost uniformly. Young adults (18–22) live in larger households than 23–27 year old adults. Persons in their mid-40s have the largest households and the elderly have the smallest. We have also constructed a life cycle profile following cohorts across different censuses (not reported here), which confirms the downward shift in the household size–age profile.

In sum, the number of household members for the average adult has decreased by half over the last 150 years. The average adult lives in a household with fewer members of every type: fewer spouses, young children, adult children, siblings, and especially fewer nonfamily members. The decline has occurred at all ages. Given the universality of the decline, we believe it is worthwhile to pursue an analysis of household size that abstracts
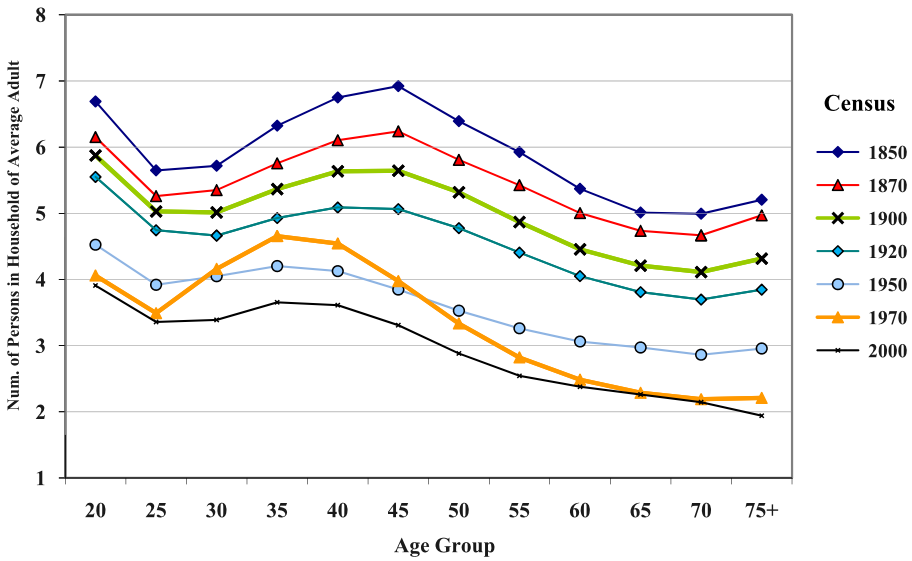
FIGURE 3. *Average household size by age for various censuses*. Calculations based on U.S. Census. The unit of observation is an adult, so that each point represents the average household size across adults. Age groups are composed of 5 years and are labeled by the middle year.

from specific events such as marriage, divorce, and children moving out of the household, and focuses instead on the common elements of all these decisions.

3. INCREASING DEMAND FOR PRIVATE CONSUMPTION

The idea we pursue in this paper is that people form households in part to share public goods. If the income elasticity of public goods is lower than that of private goods, then public goods become relatively less important as incomes increase, which causes a decline in optimal household size. We use cross-sectional data to investigate the presence of this mechanism. First, if income is an important determinant of household size, then one would also expect richer people to live in smaller households at any point in time. Second, if the mechanism works through differential demand for household public goods, then one would expect the ratio of public to private goods to vary systematically across people with different income levels.

We start by analyzing the relationship between income and household size. We find a strong negative relationship between per capita income and size. In fact, poorer adults live with more adults *and* more children. Specifically, we use 2000 U.S. Census data to compute the household size by age group and income quintile.[6] For almost all age groups, we find that adults in the highest income quintile live with fewer adults and fewer children than do adults at the bottom of the income distribution.[7] Table 1 presents

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[6]Income for each adult is measured as household income divided by the number of adults in the household.

[7]A negative relationship between income and household size has been noted previously in the literature. Early work by Brady (1958) and Beresford and Rivlin (1966) used data tabulations to support such a relation-

TABLE 1. Average household size by income quintiles, 2000.[a]

	23–27 Year Old Persons				28–32 Year Old Persons			
Quintile	Total	Family	Adults	Children	Total	Family	Adults	Children
1	3.95	3.26	2.72	1.23	4.12	3.58	2.49	1.62
2	3.94	3.27	2.80	1.14	4.13	3.59	2.57	1.56
3	3.56	3.02	2.60	0.96	3.80	3.40	2.38	1.42
4	3.09	2.65	2.40	0.69	3.33	3.03	2.15	1.18
5	2.75	2.38	2.31	0.44	2.81	2.58	1.99	0.82

[a]Calculations based on U.S. Census data. The unit of observation is an adult. Income for each adult is computed as income per capita for adults within the household.

household sizes for two age groups, 23–27 and 28–32. We find that average household size differs by more than one adult between the top and the bottom quintile. The relationship is essentially monotone across all quintiles.[8] Furthermore, the negative relationship is present for various measures of household size: adults only, children only, family members only, as well as nonfamily members.

Above we documented that the decline in household size over time has been visible across all categories of household members (see Figure 2). One might wonder to what extent the same holds true in the cross section. In fact, as in the time series, richer individuals in the cross section share a household with fewer adult children, parents, siblings, grandchildren, other relatives, partners, and friends, as well as with fewer nonrelatives (see Figure 4). The two exceptions are the categories spouses and children under age 18, which are both higher numbers for richer households. The reason is that we are not controlling for age in this figure, and that both children in the household and income are hump-shaped over the life cycle. Once we control for age, the relationship between income and children in the household is negative, as shown in Table 1. In sum, while the time series and cross section do not line up perfectly, they do display a lot of similarities.

Moving to the second part of the hypothesis, we show some direct evidence on the increasing demand for private goods. To do so, we compute measures of public and private goods in the data, and analyze how much they vary with income—both over time and in the cross section. To do this, we classify consumption goods as public or private. We perform this classification on aggregate data from the National Income and Product Accounts (NIPA) for which we have a time series starting in 1929. We also use the Consumer Expenditure Survey (CEX) for which we have more detailed information on consumption items and which allows us to relate expenditures to household characteristics.

ship. More detailed work was provided by Michael, Fuchs, and Scott (1980) and Pampel (1983), who used cross-state variation and individual microdata to study the relationship between income and household size. Ermisch (1981) provided evidence of the same relationship in the 1973 and 1976 General Household Surveys of Britain, where he estimated an income elasticity of household size of −0.20.

[8]In some instances, the size in the first quintile is smaller than in the second, but the difference is very small.
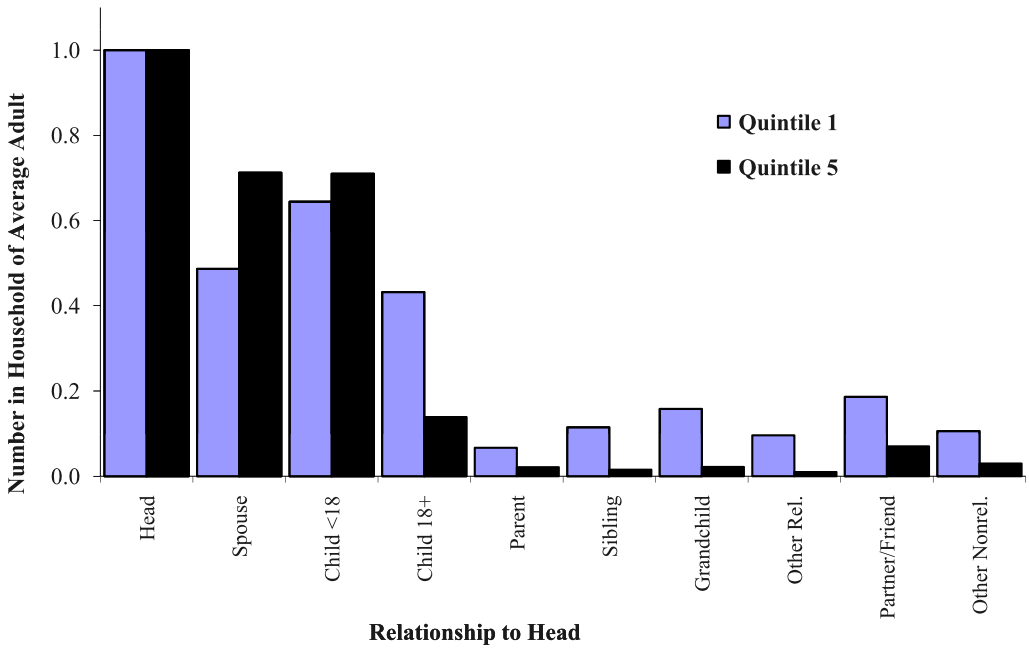
FIGURE 4. *Household members by income quintile, 2000.* Calculations based on U.S. Census data. The unit of observation is an adult. Each bar represents the mean number of household members in each category.

Classifying goods into private and public is not trivial; many goods have some private and some public characteristics. However, to map the data into our conceptual framework, we need to categorize goods into these two extremes, and doing so requires strong assumptions. The overarching principle we use is to classify goods based on "technology of usage," essentially asking the question, "Can a good be used by several individuals at the same time?" For some goods, such as movie or bus tickets, the answer is clearly no and they are classified as private. For more complicated situations, we assume that any good that could be shared is public *unless* typically it is not shared for one of the following five reasons: timing, depreciation, hygiene, taste, or fit.[9] The method is described in more detail in Appendix A.1.2. Using these principles, we classify the following categories as private goods: school tuition, health expenditures, personal care, clothing, public transportation, and food away from home. Public goods include housing, utilities, most durables, cars and related expenditures, and household appliances. We also classify food consumed at home as a public good. We do so because Deaton and Paxson (1998) and several subsequent papers found that food consumed at home has public good characteristics (Gan and Vernon (2003), Deaton and Paxson (2003)). This finding seems to apply to historical and recent data on expenditure patterns (Logan (2010)).

[9]For example, while toothbrushes could, in principle, be shared, most people do not share them for hygienic reasons; a bed could, in principle, be shared, however, most people do not take turns using a bed since they would need it at the same time; clothing could, in principle, be shared, however, this is unlikely to be practical because of fit. All of these goods are thus classified as private.
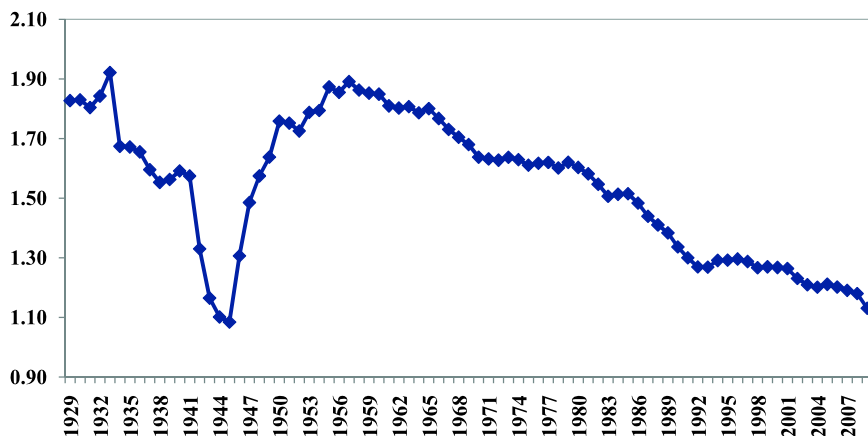
FIGURE 5. *Personal consumption expenditures: the ratio of public to private goods.* Calculations are based on National Income and Product Accounts.

In particular, larger households spend less per capita on food when total expenditures are kept constant. One potential explanation is that there are unmodeled economies of scale in food production. Finally, note that we do not consider whether (or not) a given household actually shares the goods classified as public.[10] If richer people use public goods in a more private fashion, then our estimate of the income elasticity of the ratio of public to private consumption would be a lower bound on the actual elasticity, implying that the channel could be more important than indicated by our analysis.

We start by using NIPA data published by the Bureau of Economic Analysis to analyze the long-term trend in the ratio of public to private expenditures. Unfortunately, these data are available only after 1929. Figure 5 presents the behavior of the ratio, which has declined from 1.8 in 1929 to 1.1 in 2009.[11] This is a drop of close to 40 percent. The main item driving the increase in private goods over the entire period is medical care, which has increased from 3 percent of total expenditures in 1929 to 16 percent in 2009. Expenditure shares of other private goods including education, recreation, and personal care also have increased. In contrast, the clothing expenditure share has fallen over time. As for public goods, the main item is food (purchased for off-premise consumption), which has decreased from 19 percent of total expenditures in 1929 to 7 percent in 2009.

The decrease in the ratio of public to private goods shown by the historical aggregate series provides suggestive evidence in favor of our mechanism. However, this phenomenon could also be explained by changing relative prices. To circumvent this problem, we compare expenditure patterns along the income distribution in a cross section, where relative prices are fixed. We use data from the Consumption Expenditure Survey (CEX), which contains detailed information on household expenditure. We pool data from 1995 to 2000 and treat it as a single cross section. Given the finer classification

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[10]For example, we are not considering whether some years ago household members shared a television while today each member may have his own.

[11]The dip during World War II is due to the government slowing or halting production of housing and consumer durables to redistribute resources toward the war effort.
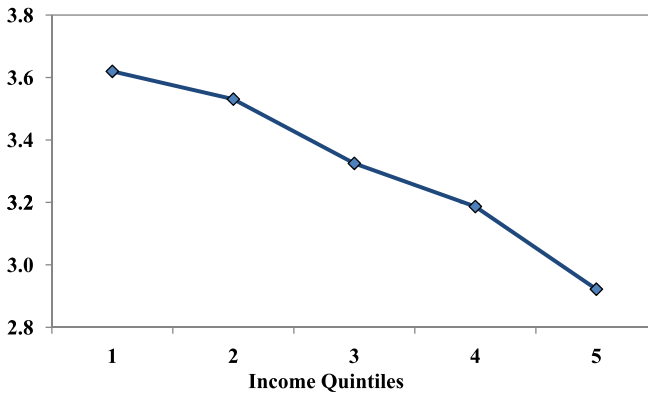
FIGURE 6. *Ratio of expenditures on public to private goods by income quintile, 1995–2000.* Calculations are based on CEX data, 1995–2000. Income quintiles are calculated separately for each age group. Mean values of expenditures on public and private goods are computed for each quintile.

of goods in the CEX compared to the NIPA data, we can break down goods more carefully into public and private categories. As before, we use adults as the unit of observation. Our measure of income is household income per adult, and we classify adults into different age groups (of 5 years each).[12] Figure 6 presents the ratio of public to private goods expenditures by income quintile, averaged across age groups. The ratio is lower for higher quintiles, supporting our hypothesis. For the poorest quintile, it is 3.6 compared to 2.9 for the richest quintile—a 24 percent difference.[13] We also find that for all age groups, the income elasticity of the ratio of expenditures in public to private goods is negative. The average elasticity across all 12 age groups is -0.091. See Table A.3 in the Appendix for more details. As in the Census data, we find a strong negative relationship between income and household size in the CEX. Consistent with Table 1, which was based on Census data, in Table A.2 we also find a strong negative relationship between income and household size in the CEX data. The average income elasticity across all ages is -0.073 for adults and -0.142 for children. Overall then, people in the lower quintiles have larger households and spend relatively more on public goods, while people in higher quintiles have smaller households and spend relatively more on private goods.

Some of the choices we made to classify goods might be arguable. We address the most obvious criticisms in a series of robustness checks reported in the Appendix. We exclude some of the most controversial goods from our analysis entirely and find similar patterns. We classify care services (such as babysitting and adult care) as private and obtain slightly lower elasticity estimates. Interpreting public goods generously by including all goods that have the potential to be shared reduces the elasticity estimate by roughly a quarter. Finally, reclassifying car products and car services as private lowers the elasticity estimate the most. However, we find negative elasticities for each of the robustness checks. While the exact magnitudes differ across the different robustness exercises, the

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[12]See Appendix A.1.3 for a discussion of the income measure and robustness exercises.

[13]There is a level difference between the NIPA and CEX data because the NIPA data include all of GDP, while the CEX data include only consumers' out-of-pocket expenditures.

fact that the ratio of public to private goods decreases systematically with income is extremely robust.

4. The model

We use an infinite horizon overlapping generations model. There are children and adults in the model, but only adults make choices. Adults decide each period whom to live with and what quantities of private and household public goods to consume.

4.1 *Households*

Households are collections of roommates (adults and children) who live together for the purpose of sharing the costs of household public goods. The trade-off is that living with others takes time that could otherwise be spent in the labor market. In each period, each adult imposes a cost of B units of time on each other adult in the household. This cost represents the time it takes to find roommates and to maintain the necessary relationships. In each period, each child imposes a cost of B^k units of time on his parent.[14] In this case, these costs capture the time it takes to care for a child. We also allow the costs of living with other people to vary by (own) age: B_a and B_a^k, where a is the age of the adult. The differing costs by age capture life cycle effects. For example, B_a might be low for young people, as everyone else is single too and finding a partner or roommate is easy. Older people will spend a lot more time searching for roommates. We can also capture the fact that fecundity declines with age by letting B_a^k increase in age.

Households, then, are clubs comprised of adults and children sharing household public goods. Generally, this approach introduces two problems. Modeling the optimal sorting of people with different tastes into local clubs is difficult.[15] Similarly, with heterogeneous household members, specifying how members bargain over spending on public versus private goods would be quite difficult. We get around these issues by assuming that only identical types, that is, adults of the same age and productivity (and their children), can live together. This is a strong assumption and prevents the analysis of some dimensions of household heterogeneity (such as the rise in two earner couples). However, for analyzing aggregate trends in household size, it is a useful simplifying assumption because it allows us to abstract from club formation and household bargaining. We also abstract from issues of enforceability or possible free riding. Further, we assume that households can be formed and dissolved each period at no cost. That is, there is no fixed cost of setting up a household and no household capital stock that links household size over a person's life. Again, we make this assumption mostly for simplicity. Age variation in the costs of living together can be thought of as one way to capture this capital stock.

Since we make a distinction between consumers and households, we use uppercase letters to denote quantities per household, and lowercase letters to denote per capita quantities.

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[14]For simplicity, and as is standard in the fertility literature, we assume there is only one parent per child. Essentially a household in our model is formed by adults who live together as roommates, each bringing along their own children.

[15]See Lam (1983, 1984, 1988) for an analysis of households as clubs.

4.2 *Consumers*

Adults derive utility from two distinct consumption goods. The first consumption good is denoted by v and is assumed to be consumed privately by a particular adult. The second consumption good is denoted by H and is a local public good, that is, it can be shared nonrivalrously with all household members. The assumption is that v and H are two very distinct types of goods, some that are inherently difficult to share (such as health care and education) and others that are inherently easy to share (such as housing and other durables). Given this specification, an adult who lives alone also consumes both types of goods, even though there are no economies of scale in the consumption of H for a one-person household.

Adults also derive utility from the number and well-being of their own children. The number of children of a given adult is denoted by k (for kids). Children, like all other people in the household, derive utility from consuming the household public good, H, but also from their allocation of private goods, v^k. People care about other adults in the household only indirectly: they help finance the cost of the public good. There is no reason for living together other than that it is cheaper. Let S be the number of adults in a household. In equilibrium, all adults make the same decision about how many children to live with, so there are $K = Sk$ total children in the household.

Let $U(v, H, k, v^k)$ denote the period utility function of an adult. Throughout this paper, we assume the functional form

$$U(v, H, k, v^k) = \frac{H^{1-\sigma}}{1-\sigma} + \omega \frac{v^{1-\phi}}{1-\phi} + \delta k^{\alpha} \left\{ \frac{H^{1-\sigma}}{1-\sigma} + \omega \frac{(v^k)^{1-\phi}}{1-\phi} \right\}.$$

Note that adults care about their own and their children's consumption bundles in the household in the same way. The relative weight that adults put on children's utility is denoted by $\delta > 0$. We allow for decreasing marginal utility from additional children through the exponent $\alpha \in (0, 1)$.[16] The nonhomothetic formulation (when $\sigma \neq \phi$) allows for nonlinear Engel curves, which are important for capturing expenditure patterns seen in the data. Finally, $\omega \geq 0$ is a parameter that determines the relative importance of public versus private consumption goods.

In the previous section, we documented strong patterns in household size by age and income, so we allow for two corresponding dimensions of heterogeneity. First, we assume a finite number of productivity types, denoted by i. Labor productivity is a function of the type (capturing differences in ability across people) and year (capturing general technological progress as well as capital accumulation). We denote productivity of a consumer of type i in year t by $z(t, i)$.[17] Second, people differ in their age. Each consumer is indexed by his or her birth year τ. Consumers live for a finite number of ages, indexed by $a \in \{0, \ldots, A\}$. Thus, a consumer who is born in year τ is $a = t - \tau$ years old in year t.[18]

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[16]$\alpha = 1$ would mean that adults care about the sum of utilities across all children.

[17]For simplicity, we abstract from human capital accumulation over the life cycle. The implied life cycle earnings profiles are increasing, but only in line with increases in GDP per capita.

[18]Note that we do not model the transition from childhood to adulthood explicitly here. Our model is simply a model of adults who choose also how many children to have in the household, but there is no fertility choice that determines the number of adults in the next generation.

An adult in this economy maximizes lifetime utility by choosing a basket of consumption goods (v, H, v^k) and a household size and composition (S, k) for each point in his or her life cycle, subject to a lifetime budget constraint. We denote consumption of the private good of a person of type i, born in year τ, at age a by $v(\tau, a, i)$. The same notation is used for all other goods as well as for the household sizes. We also assume fully functioning asset markets, and denote the price of consumption in period t by $p(t)$. We can then write the consumer problem as

$$\max \sum_{a=0}^{A} \beta^{\tau+a} U(v(\tau, a, i), H(\tau, a, i), k(\tau, a, i), v^k(\tau, a, i))$$

$$\text{s.t.} \quad \sum_{a=0}^{A} p(\tau+a)\left[\frac{H(\tau, a, i)}{S(\tau, a, i)} + v(\tau, a, i) + v^k(\tau, a, i)k(\tau, a, i)\right]$$

$$\leq \sum_{a=0}^{A} p(\tau+a)z(\tau+a, i)\left[1 - B_a(S(\tau, a, i) - 1) - B_a^k k(\tau, a, i)\right] \quad (1)$$

$$k(\tau, a, i) \geq 0 \quad \forall a \quad \text{and} \quad S(\tau, a, i) \geq 1 \quad \forall a$$

$$v(\tau, a, i), H(\tau, a, i), v^k(\tau, a, i) \geq 0.$$

The constraint $S(\tau, a, i) \geq 1$ indicates that all adults have to live at least with themselves. Further, we assume there is no cost of living alone.

Note that the budget set for this problem is nonconvex. Define $h = \frac{H}{S}$ as per-adult expenditures on the public good and $V^k = kv^k$ as total child expenditures. With this change of variables, the budget constraint is linear, while the redefined utility function is

$$U(v, h, S, k, V^k) = \frac{(Sh)^{1-\sigma}}{1-\sigma} + \omega\frac{v^{1-\phi}}{1-\phi} + \delta k^\alpha \left\{ \frac{(Sh)^{1-\sigma}}{1-\sigma} + \omega\frac{\left(\frac{V^k}{k}\right)^{1-\phi}}{1-\phi} \right\}.$$

The parameters of this utility function are restricted in several ways in our calibration. First, we focus our attention on the standard Barro–Becker case, $0 < \alpha < 1$ and $\sigma, \phi < 1$.[19] Second, we need further conditions to ensure that the utility function is concave; $\sigma > 0.5$ is necessary for concavity in h and S. Furthermore, $0 < \phi < 1$ and $1 < \alpha + \phi < 2$ are sufficient (although not necessary) for concavity in k; our calibration satisfies these parameter restrictions. Finally, for our story to hold, it is necessary that $\sigma > \phi$. We provide intuition to this effect below, and use the data to inform us about the relative values of these two parameters.

4.3 *Equilibrium*

We assume a small open economy, so that the interest rate r_t is given exogenously. An equilibrium is then simply defined as follows.

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[19]An alternative well defined parameter specification could start with $\alpha < 0$ and $\sigma, \phi > 1$ (Jones and Schoonbroodt (2010)).

DEFINITION 1. An equilibrium is an allocation $\{v(\tau, a, i), H(\tau, a, i), v^k(\tau, a, i)\}_{\tau, i, a}$, a household composition $\{S(\tau, a, i), k(\tau, a, i)\}_{\tau, i, a}$, and prices $\{p(t)\}_t$ such that the following statements hold:

(i) Each agent (τ, i) maximizes problem (1).

(ii) $\frac{p_t}{p_{t+1}} = 1 + r_{t+1}$ for all t.

4.4 *Model properties*

Letting λ be the Lagrange multiplier on the budget constraint and, for ease of exposition, omitting the type, cohort, and age indicators, the first order conditions are

S: $\frac{H}{z} = S^2 B_a$,

v: $\beta^{\tau+a} \omega v^{-\phi} = \lambda p$,

v^k: $\beta^{\tau+a} \delta k^{\alpha-1} \omega (v^k)^{-\phi} = \lambda p$,

H: $\beta^{\tau+a}(1 + \delta k^\alpha) S H^{-\sigma} = \lambda p$,

k: $\beta^{\tau+a} \delta \alpha k^{\alpha-1} \{\frac{H^{1-\sigma}}{1-\sigma} + \omega \frac{(v^k)^{1-\phi}}{1-\phi}\} = \lambda p[v^k + z B_a^k]$.

The first equation shows that the marginal benefit of an additional adult in the household is higher, the higher is the consumption of the public good H. The second equation gives the costs and benefits of private goods consumption, v. When income is higher (a lower multiplier on the budget constraint), households consume more private goods, v. The next two first order conditions display similar effects for the other two consumption goods, v^k and H. However, things are a little more complicated here, as the number of children, k, and adults, S, also enter. The marginal benefit of additional v^k consumption declines in the number of children, as children and per-child consumption are substitutes in the utility function.[20] In contrast, the marginal utility of public consumption increases in the number of both adults and children in the household, since more people benefit from the public consumption good. The last equation shows that an increase in the marginal cost of children ($pv^k + pzB_a^k$) reduces the optimal number of children. Finally, in this setup, the marginal cost of an additional child increases in desired private child consumption, v^k.

Combining the first order conditions with respect to H and S, we can derive an equation that relates optimal number of adults at two different ages, denoted by a and a' here:

$$S(a) = \left(\frac{p(\tau + a)}{p(\tau + a')} \beta^{a'-a}\right)^{1/(1-2\sigma)} \left(\frac{B_a z(\tau + a)}{B_{a'} z(\tau + a')}\right)^{\sigma/(1-2\sigma)}$$
$$\times \left(\frac{1 + \delta k(a')^\alpha}{1 + \delta k(a)^\alpha}\right)^{1/(1-2\sigma)} S(a'). \tag{2}$$

This expression shows how the optimal number of adults is related to its cost. Assuming the optimal number of children does not vary much with B_a, we can see that adult

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[20]Note, however, that in this formulation, children and total child consumption, kv^k, are complements. See Jones and Schoonbroodt (2010).

household size is higher precisely during those ages when the cost is lower (recall that $\sigma > 0.5$).

To gain some additional intuition on the workings of the model, consider a simplified version of the model with $\delta = 0$ (i.e., without children) and assume people live for one period only. The last assumption makes the budget constraint and feasibility coincide, and hence it is easy to solve the model explicitly. In particular, using the first order conditions and the one-period budget constraint, one can collapse the problem into one equation and one unknown:

$$z^{(\sigma-\phi)/\phi}(B^\sigma\omega)^{1/\phi}S(z)^{(2\sigma-1)/\phi} + 2BS(z) = 1 + B.$$

Using the implicit function theorem, we can derive conditions under which an increase in income leads to a decrease in household size:

$$\frac{dS}{dz} = \frac{-\dfrac{\sigma-\phi}{\phi}(\omega B^\sigma S^{2\sigma-1}z^{\sigma-2\phi})^{1/\phi}}{\dfrac{2\sigma-1}{\phi}(\omega B^\sigma z^{\sigma-\phi}S^{2\sigma-1-\phi})^{1/\phi} + 2B}.$$

We have already assumed $\sigma > 0.5$, so $\sigma > \phi$ guarantees that this expression is negative. When $\sigma > \phi$, Engel curves are nonlinear and private goods are a relative luxury good. Higher income households devote a higher fraction of income to private goods, so the incentives to form households decline.

In equilibrium, the ratio of total private versus public consumption can be expressed as

$$\frac{V}{H} = \frac{Sv}{H} = (\omega(B_a z)^{\sigma-\phi}S^{2\sigma-\phi-1})^{1/\phi}. \tag{3}$$

We have already shown that S falls in income when $\sigma > \phi$. If, in addition, $\phi > 2\sigma - 1$, then the right hand side increases directly through the increase in z and indirectly through the decrease in S, so that households with higher incomes are guaranteed to have higher private to public consumption ratios. It is easy to show that the same result applies for expenditure shares, $\frac{Sv}{Sv+H}$ and $\frac{H}{Sv+H}$.

While the formal results are derived only for the special case without children, numerical exploration of the model shows that the same logic applies more broadly. Generally, under the parameter restrictions derived above, higher income leads to a higher expenditure share on private goods and accordingly smaller (adult) household sizes. This finding holds for different types within a cohort, across cohorts, and over the life cycle. We also confirm numerically that as long as $\sigma > \phi$, Engel curves are such that v^k increases faster than H, which makes children endogenously more costly. This leads to a fall in the number of children. Thus, our model features a quality–quantity trade-off that works through the endogenous choice of private goods for children.

5. Calibration

In this section, we calibrate the model to measure the quantitative importance of our channel over the last 150 years. We calibrate the parameters to match a rich set of mo-

ments based on Census and CEX data from 2000 and 1995–2000. In particular, the calibration uses the variation in income and household size in the cross section to pin down parameter values. We use the calibrated model to simulate changes in income and then evaluate the effects on household size and the associated change in expenditures on public and private goods. In other words, we project the model back to 1850, when income was lower, and assess what fraction of the overall decline in living together can be accounted for by the model.

A model period is 5 years. We set $A = 12$, corresponding to age bins 18–22, 23–27, ..., 68–72, 73+ in the data. We use an annual discount factor of 0.97, which, given our model period of 5 years, implies $\beta = (0.97)^5$. We set the exogenous interest rate equal to 4.89 percent annually. This is the interest rate that would arise endogenously in a model with logarithmic utility, a discount factor of 0.97, and the average annual growth rate of 1.74 percent that we use, as we explain below. It is also within the range of interest rates reported in the data.[21]

We use income per capita as our measure of labor productivity, z. Since we are interested in long-term trends, we feed in the average growth rate rather than annual variations. On average, GDP per capita has been growing at 1.74 percent annually over the last century and a half.[22] We assume there are five types of agents, i, each corresponding to an income quintile. We assume workers stay in the same quintiles over their lifetime. Furthermore, we assume that the relative positions of these five quintiles are constant over time. We construct the relative income of the five quintiles based on per capita household income across quintiles in the CEX data (as described in Appendix A.1.2 and reported in Table A.2). This method gives the following multiples of average income for the five quintiles: $(z_1, z_2, z_3, z_4, z_5) = (0.20, 0.55, 0.83, 1.20, 2.23)$. Then $z(\tau, a, i)$ is set equal to $z(\tau, a, i) = z_i Y_{\tau+a}$, where $Y_{\tau+a}$ is GDP per capita in year $\tau + a$.

Finally, we calibrate five parameters of the utility function $(\alpha, \delta, \omega, \sigma, \phi)$, and 24 cost parameters $(\{B_a, B_a^k\}_{a=1}^{12})$ using a rich set of moments from the 2000 U.S. Census and from the Consumer Expenditure Survey (1995–2000). One set of moments consists of the cross-sectional values for the number of adults (S) and children (K) in the household for each age group, which are obtained from Census data. We also include income elasticities for the number of adults and children by age group, which we constructed using CEX information. The next set of moments consists of the income elasticities of the ratio of public to private expenditures also using CEX data, as described in Section 3. Since we estimated the elasticity separately for each age group, this gives an additional 12 moments. Last, we use that the average child requires about 4 percent of an adult's

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[21]Good interest rate data are notoriously difficult to obtain and estimates vary widely depending on which measure of interest rates is used. For example, short-term returns on U.S. government securities yield an average interest rate around 1–1.5 percent (Cochrane (2001)). Rupert and Gomme (2007) argued that the return to capital is a more appropriate measure of interest rates for calibration purposes. Long-term returns on equity for developed countries average 7.1 percent (Barro (2006)), while Prescott (1986) argued that standard calibrations of real business cycle models imply a real interest rate of 4 percent. The number we use is close to the midpoint of the range of reported numbers.

[22]This number is based on Johnston and Williamson (2006).

TABLE 2. Calibrated parameters.

Parameter	α	δ	ω	σ	ϕ
Value	0.334	0.123	4.082	0.735	0.690

time budget.[23] A complete list of the moments, together with the model analogues, is presented in Table A.4.

In total, we have 61 moments—S, K, and the income elasticities of S, K, and $H/(V + V^k)$, for each of the 12 age groups—plus average time spent on children. Given that we have 29 parameters, this results in an overidentified system where we cannot match each moment exactly. Instead, we minimize a weighted least-squares loss function. The exact loss function is described in Appendix A.2. Intuitively, the average levels of S and K by age group pin down the cost parameters (B and B^k). The elasticities of S, K, and $H/(V + V^k)$ help identify the parameters in the utility function α, σ, ϕ, and ω. Finally, the average child care time helps pin down δ separately from the level of time costs B_a^k.

Table 2 gives the calibrated parameters (α, δ, ω, σ, ϕ).[24] The procedure yields $\sigma > \phi$, which is consistent with the hypothesized nonhomotheticity in preferences for private and public goods, although the difference between the two parameters is relatively small. Figure 7 shows the time costs of having adults and children in the household. The cost of an additional adult increases almost linearly with age. The cost of children is tied closely to (lagged) biological constraints faced by parents, particularly mothers.

5.1 Fit

The calibrated model generally fits the data well. In particular, the model does well at matching the number of children and adults in the average person's household (within 0.9 percent, on average). It also does well at matching the average S, K, and H/V elasticities across age groups (within 1.1, 3.7, and 3 percent). However, it does less well at matching the profile of elasticities across ages. Our model has no strong channels that would generate such heterogeneity. Furthermore, the data include some anomalous moments, such as positive income elasticity of S for only the youngest age group, which are difficult for our model to match. Finally, the model does well at matching the time spent with children (within 3 percent).

[23]The Bureau of Labor Statistics (2004) provided data on time spent with children drawn from the 2004 American Time Use Survey (ATUS). Based on their estimates, we calculate two notions of the time cost of children. Direct time is only the time spent caring for and helping children, as denoted by the respondents. Indirect time is the difference between time spent on all household tasks for households with and without children. ATUS separates households into those with and without children under 6; we use the 2000 Census to weight these two observations together and to transform total time into average time per child. We then divide by 16 working hours per day to find an estimate of the fraction of the time budget. For direct time, the resulting estimate is 3.84 percent; for indirect time, it is 4.73 percent. We use 4 percent in our calibration.

[24]Our calibration shows that the objective function is fairly flat: a number of different parameterizations fit nearly as well. However, they also yield similar results.
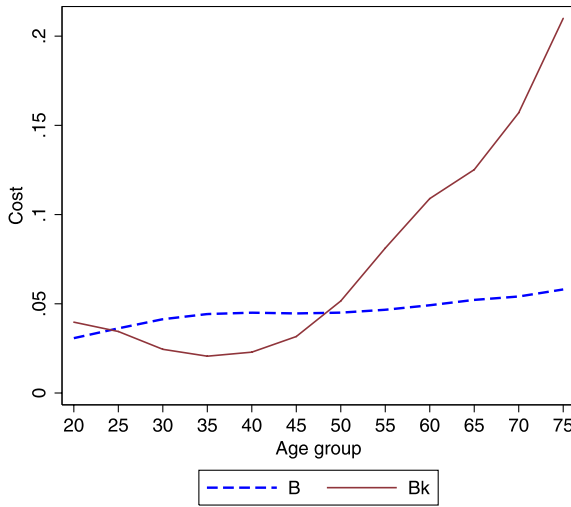
FIGURE 7. *Costs of household formation over life cycle: time cost of adults (B) and children (B^k).*

Figure 8 compares the model-predicted profiles of S and K by age with the data. The data and model series agree closely. The shape by age group is determined by the full set of B and B^k parameters.

The critical element of our calibration is the relationship between income and the choice variables, which led us to target the cross-sectional elasticities as our main moments. The model should fit the cross-sectional relationship between income and S, K, and $H/(V + V^k)$ reasonably well before it is used to assess the mechanism in the time series. Figure 9a shows the log of the $H/(V + V^k)$ ratio by income quintile, averaged

FIGURE 8. *Cross-section profiles of household size: number of adults and children by age group, actual and predicted.*

(a) $H/(V + V^k)$ by Income Quintile

(b) Number of Adults and Children by
Income Quintile

FIGURE 9. *Actual and predicted relationships with income.*

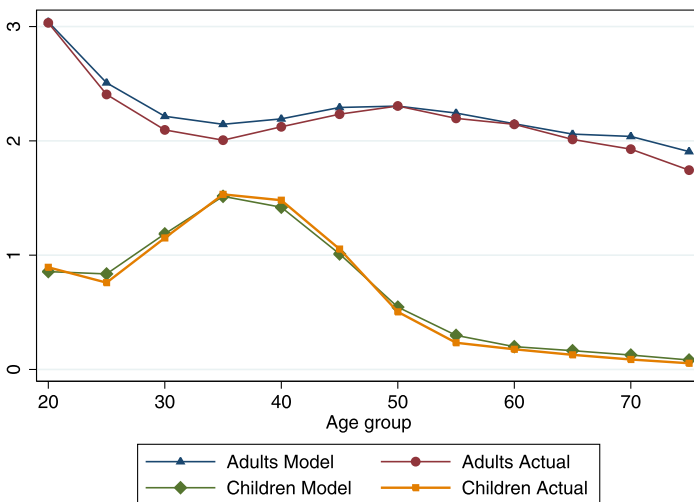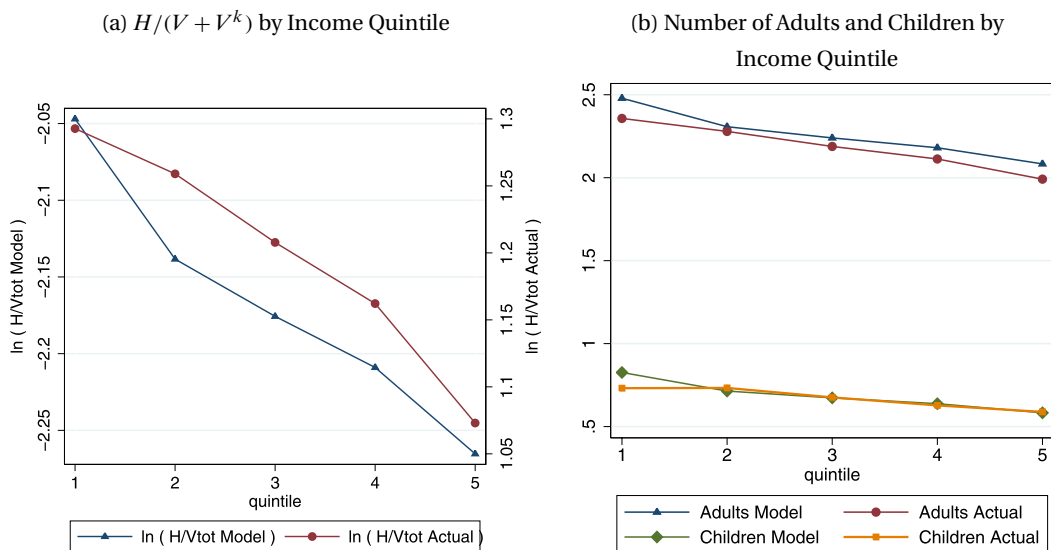across all ages for each income quintile. The model fits the data elasticities quite closely. The values for the model and the data are shown on different scales, indicating that the levels of the two are quite different. Given that the level was not included in our calibration targets, the poor fit here is not surprising. We do not see this as a major weakness, as what matters for our mechanism is the elasticity rather than the level.[25]

Figure 9b shows adult and child household sizes by income quintile, averaged across all ages. It demonstrates that the model matches the negative relationship between income and size quite well on average, indicating a good fit of the elasticity. The model and data values for each individual moment are presented in Table A.4.

6. RESULTS

We project the model back to 1850, assuming income has grown at an annual rate of 1.74 percent between 1850 and 2000. Figure 10a presents the results for the number of adults in the household, S. We include both the time series for the actual data and the results from the model. In the data, the number of adults decreased from 3.5 in 1850 to 2.3 in 2000. The model predicts a decrease of about half an adult, which is 37 percent of the actual fall.

Figure 10b shows the results for the number of children in the household, K. The data indicate that in 1850 there were 2.7 children per household, while in 2000 there were 0.8. The model generates a change of 0.31 children, that is, it captures 16 percent of the total difference between 2000 and 1850.

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[25]In experiments not reported here, we have tried to include the level as a calibration target. The resulting better match comes at the cost of fitting the elasticities more poorly. This trade-off is not surprising in an overidentified model.

(a) Number of Adults in Household

(b) Number of Children in Household
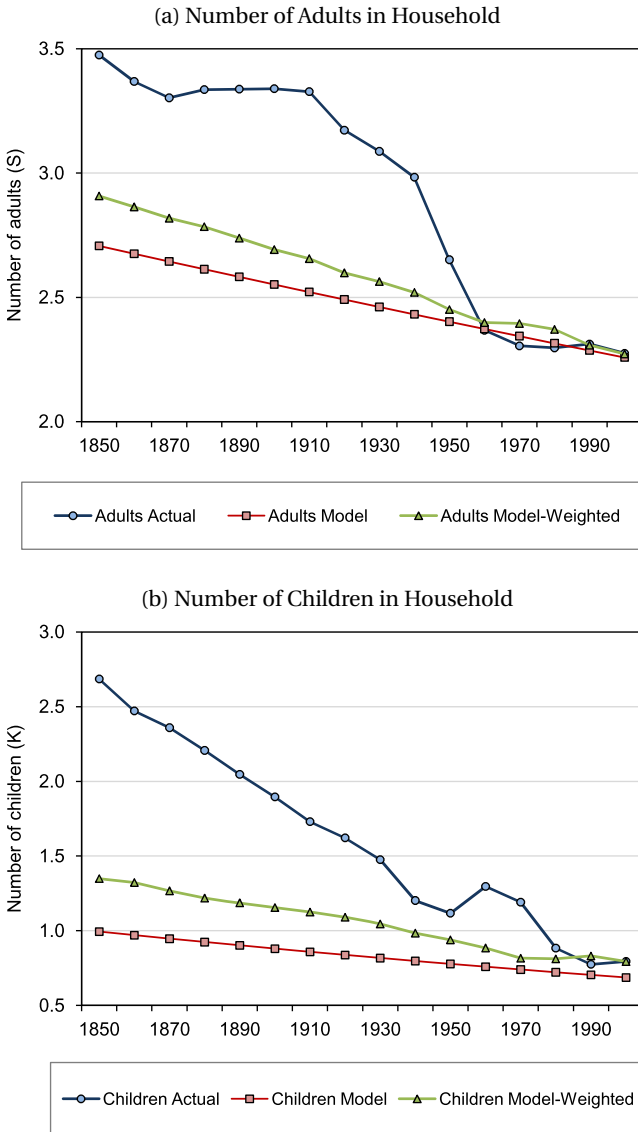
FIGURE 10. *Actual and predicted household size.*

An additional factor that has been left out of the analysis so far is the changing age structure of the population. Falling mortality has led to population aging, which is relevant because the elderly generally live with fewer adults and fewer children. To account for this effect, we obtain the actual age composition of the population for each reported year. We use it to construct weighted results that take into consideration changes in the demographic composition. These results are shown in Figures 10a and 10b under the label Model-Weighted. Allowing for changes in mortality, the model accounts for 53 percent of the change in the number of adults between 1850 and 2000, and 29 percent of the change in the number of children in the same period. Hence we conclude that one-third

TABLE 3. Actual and predicted change in S and K for subperiods.[a]

	Adults Δ			Children Δ		
	Actual	Model	$\frac{\text{Model}}{\text{Actual}}$	Actual	Model	$\frac{\text{Model}}{\text{Actual}}$
$\Delta_{1850-2000}$	1.20	0.64	0.53	1.89	0.55	0.29
$\Delta_{1900-2000}$	1.06	0.42	0.39	1.10	0.36	0.33
$\Delta_{1920-2000}$	0.90	0.33	0.36	0.83	0.30	0.36
$\Delta_{1950-2000}$	0.38	0.18	0.47	0.32	0.15	0.45
$\Delta_{1970-2000}$	0.03	0.12	4.08	0.40	0.02	0.06

[a] Predicted figures correspond to the weighted version of the model.

to one-half of the observed change in the number of adults, and one-sixth to one-third of the observed change in the number of children, can be attributed to our mechanism where increases in income endogenously decrease economies of scale within the household.

Our model also makes concrete predictions about the timing of the fall in household size that we can compare to the data. Table 3 compares the model's predicted decline in household size to the data for different start dates of the comparison. We again break the figures out into those for the number of adults and the number of children in the average person's household. What we can see is that the model does roughly as well at explaining the decline in household size since 1900, 1920, or 1950 as it does at explaining the decline in household size since 1850 in terms of the ratio of predicted to actual change in the number of adults or children. However, the model does not perform as well at explaining the more recent decline in household size. In part, this is because of a divergence of trends: while the number of adults in the household has stabilized, the number of children fell as the baby boom ended. Our model overpredicts the decline in the number of adults and underpredicts the decline in the number of children.

Figure 11 compares the actual and predicted ratios of expenditures on public goods to those on private goods ($H/(V + V^k)$). The actual ratio is based on U.S. NIPA data, as in Figure 5. Both series are normalized to take a value of 1 in 1930. In the data, the
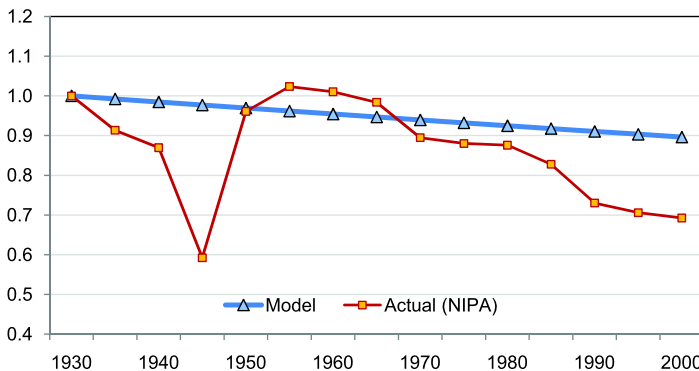

FIGURE 11. *Ratio of expenditures on public to private goods, actual and predicted.*

TABLE 4. Actual and predicted change in S and K (1850–2000).

	Adults $\Delta_{1850-2000}$			Children $\Delta_{1850-2000}$		
	Actual	Model	$\frac{\text{Model}}{\text{Actual}}$	Actual	Model	$\frac{\text{Model}}{\text{Actual}}$
	(1)	(2)	(3)	(4)	(5)	(6)
Baseline	1.20	0.45	0.37	1.89	0.31	0.16
Weighted	1.20	0.64	0.53	1.89	0.55	0.29
Homothetic ($\sigma = \phi$)	1.20	0.00	0.00	1.89	0.00	0.00
No children ($\delta = 0$)	1.20	0.43	0.36	1.89	0.00	0.00
One adult (large B)	1.20	0.00	0.00	1.89	0.04	0.02

$H/(V + V^k)$ ratio in 2000 is 70 percent that of 1930, while in the model it is 90 percent. In sum, the drop in the ratio of public to private consumption is about three times larger in the data compared to what the model would imply. This is perhaps not surprising, given that other channels probably contributed to the decline in public consumption. For example, falling prices for household public goods seem a likely candidate.[26] The model also cannot replicate the dramatic fall in the ratio of public to private goods in 1944. This particular drop is related to World War II, an event that is clearly outside of our model.

6.1 Understanding the mechanism

In our model, agents make decisions about the number of adults they want to live with, their number of children, and a consumption basket composed of private and public goods. We are interested in understanding how these components interact. To disentangle the different effects, we conduct three experiments. In the first, we set $\sigma = \phi$, which implies homothetic preferences and, therefore, shuts down our proposed channel. In experiment two, we set $\delta = 0$, which means that there is no utility value in having children. In experiment three, we set $B = 0.25$, which is a large enough cost to make all adults want to live alone.

Table 4 presents the results of the three different experiments. For comparison, the first row presents the baseline results and the second row gives the weighted benchmark numbers. The experiments each give unweighted results, so they should be compared to the first row. Column 1 reports the actual change in the number of adults between 1850 and 2000. Column 2 gives the implied change in the number of adults that results from the calibrated model. Column 3 reports the proportion of the actual change that can be explained by the model. Columns 4–6 present the analogous results for children. In the first experiment, we set $\sigma = 0.69$ so that it is equal to the calibrated ϕ. When preferences are homothetic, the ratio of public to private goods consumed ($H/(V + V^k)$) is unresponsive to changes in income. This implies that economies of scale within the

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[26]The importance of falling prices of household durable goods for changes in marriage and divorce was emphasized in Greenwood and Guner (2009). See Section 6.3 for a discussion on the impact of prices in our estimations.

household will not be affected, which yields a constant optimal household size. There is no change in the number of adults (column 2) or in the number of children (column 5).

The fourth row of Table 4 gives the results for the experiment with $\delta = 0$. There is obviously no change in number of children (column 5). Eliminating children implies that adults have some free resources that they allocate optimally between private and public goods. Because adults are richer in this sense, they choose to live with fewer adults. This effect is larger in 1850 (where there are more children in the baseline case) than in 2000. Therefore, the fall in adult household size in this experiment is smaller compared to the baseline decline. However, quantitatively the difference is very modest. The model generates a decline of 0.43 adults in this experiment relative to 0.45 in the baseline. In other words, while there is some interaction in the model between the optimal child and adult household sizes, we find that this interaction explains little about the U.S. experience. One reason for the lack of interaction is that children are modeled as belonging to a particular adult, not to the entire household. Thus, each adult has to pay for the consumption of private goods for his or her children, and, therefore, living with other adults does not make children cheaper.

Finally, we explore the case where adults are forced to live alone. We set a high enough cost of living with other adults so that adults of all ages choose to live alone. Then, by construction, the number of adults never changes (columns 2 and 3 in Table 4). We find that the fall in the number of children in this experiment is very small; it explains only 2 percent of the change in the number of children between 1850 and 2000 (column 6). This shows that there is little direct effect of growing incomes on the number of children. The decline in children per household works primarily through a decline in adults per household, not a decline in children per adult.

These experiments teach several lessons about the mechanism of the model. First, nonhomothetic preferences are crucial for our story. Second, the mechanism is most useful for explaining adult living arrangements. The number of children also declines, but due mostly to an indirect effect that works through the number of adults. Finally, the reverse effect from children to adults is very small.

6.2 *Falling cost of roommates and rising child expenditures*

We now discuss some ancillary implications of the model. Our model emphasizes the cost of living with other people, which is time spent forming and maintaining relationships with roommates and children. Given that household sizes have fallen over time, we can use the model to back out the resources saved due to changes in living arrangements. In particular, we construct the value of time spent on household formation and maintenance costs relative to GDP. Figure 12 plots the average household cost taken across all age groups and quintiles. We find that the cost of living with other people is substantial; on average, the time spent dealing with roommates is valued at 7 percent of GDP. Furthermore, resources devoted to living arrangements have decreased by around 25 percent over the last 150 years. In other words, the model suggests that the decline in household size has been accompanied by substantial resource savings, about 2.5 per-
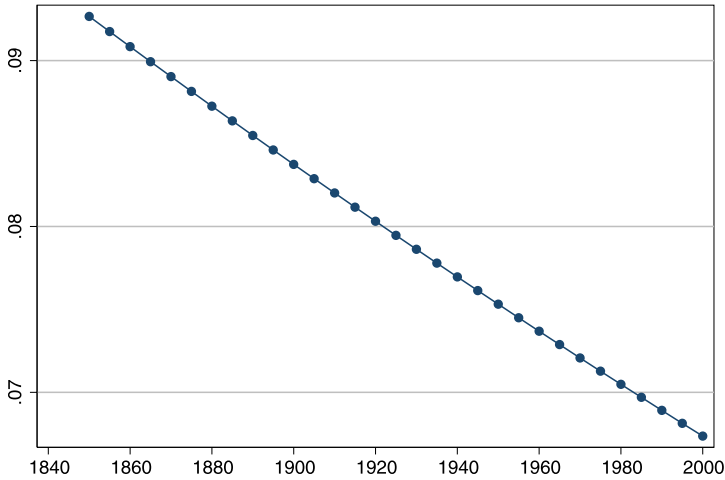
FIGURE 12. *Implicit household formation/maintenance costs relative to GDP*. Mean $z[B(S - 1) + B^k k]$, across all age groups and quintiles divided by the mean output, $z[1 - B(S - 1) - B^k k]$, also across all age groups and quintiles.

cent of GDP. While it is difficult to find direct evidence of such resource savings, time spent with family members has indeed been declining in the data.[27]

    While the pure time cost of children has decreased (due to fewer children), people choose to devote more resources to children, which leads to an increase in the total cost of children. This distinction is shown in Figure 13, where we report three different measures of the costs of children. The figure shows the results for the age group 28–32 in the third income quintile. The lowest line is simply the pure time cost of one child, B^k, which is constant by assumption. We then add the child's private consumption to construct a measure of the total cost of a child, which is plotted as the middle line. This total cost displays a substantial increase, from 7.6 percent of a parent's time to 9 percent. In other words, total child costs per child have increased by about 20 percent, which might be what people have in mind when they complain about the rising costs of raising children.[28] Rather than children becoming literally more expensive (which seems unlikely), our model suggests that parents voluntarily choose to spend more resources on children, making each child endogenously more expensive. Essentially there is a quantity–quality trade-off at work in this model, although the mechanism is different from the usual one. The typical story is that higher income parents invest more in their children or substitute consumption per child for number of children (Becker and Lewis (1973)). In our formulation, the quantity–quality trade-off arises naturally from the composition

[27]For example, Turcotte (2007) showed that time spent with family members fell in Canada between 1986 and 2005—from 250 minutes to 206 minutes a day—and that time spent alone increased from 133 minutes to 174 minutes a day over the same time horizon.

[28]The U.S. Department of Agriculture produces an annual report measuring expenditures on children; in real terms, expenditures increased about 20 percent between 1950 and 2008 (Lino and Carlson (2009)). This rise is often reported as rising costs of children. See, for example, the November 12, 2007 *Business Week* special report, "Is Raising Kids a Fool's Game?"
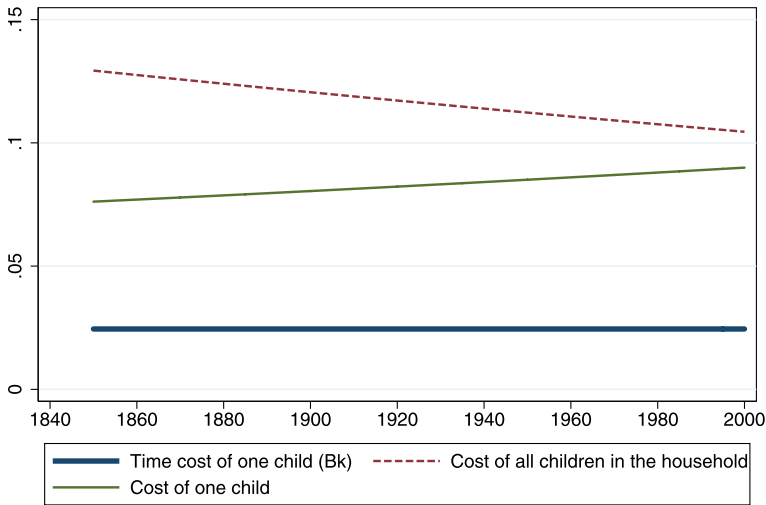
FIGURE 13. *Cost of children: fraction of time an adult would have to work to pay for the cost.* For age group 28–32 in the third income quintile. Cost of one child is equal to $(v^k + B^k z)/z$. Cost of all children in the household is equal to $(v^k + B^k z)K/z$.

of household consumption. While both public and private goods are normal goods, private goods are assumed to expand more quickly with income, raising the de facto cost of each child.

Finally, the total cost of all children in the household declines over time, as the top line in Figure 13 shows. This is not surprising since the total number of children in the household falls substantially over this period and more than compensates for the increased cost per child.

Spending 7 percent of GDP on dealing with household members might seem like a large figure and one might ask whether this is a plausible magnitude. One component of such a cost is domestic violence. Max, Rice, Finkelstein, Bardwell, and Leadbetter (2004) estimated the cost of intimate partner violence to be 8.3 billion dollars in 1995, which corresponds to about 1 percent of GDP in that year. In addition to extreme forms of family frictions such as violent conflict and suicide (Stevenson and Wolfers (2006)), conflict with adolescents is prevalent in most families (Montemayor (1983)), and even fighting over the remote control has been documented by researchers (Walker (1996)), just to name a few examples of such costs. Based on a 40-hour work week, our model would imply that people spend about 30 minutes a day on household maintenance costs. Using data from the American Time Use Survey (ATUS), we find that currently people spend 4 hours and 40 minutes daily (about 30 percent of their waking time) with other household members.[29] Surely most of this time is enjoyable, but some of it will also involve a cost in the form of reaching agreements, dealing with conflict, and foregone opportunities. Comparing our model implications with the ATUS data, our analysis suggests that

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[29]These figures are computed using pooled data for all available years (2003–2009).
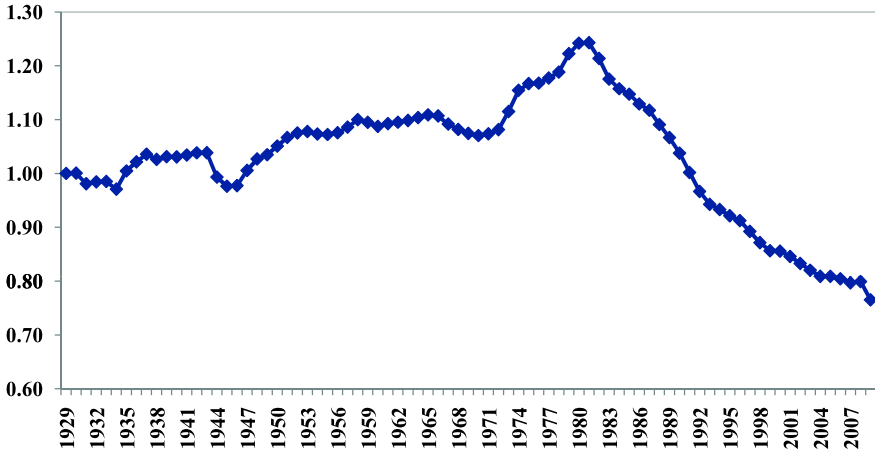
FIGURE 14. *Relative prices: public to private*. Calculations based on NIPA.

only a small part (about 11 percent) of the time spent with household members is costly. Therefore, we believe that the cost implications of the model are not unreasonable.

6.3 *Changes in relative prices*

In our analysis, we have assumed that relative prices between private and public goods are constant over time. The main reason is that the goal of the exercise is to quantify the importance of increasing incomes alone. But of course one would like to know whether changes in relative prices are large enough to cancel the effect of increasing incomes. To find an answer to this question, a long time series of relative prices is necessary. Unfortunately relative price data are not available as far back as 1850. However, more recent price data do exist and hence we can, to some extent, evaluate the effect of prices on our model. Based on the data from the NIPA, we classified production into private and public using the same categories as in Figure 5. We then compute chain-weighted price indices for public and private goods. Figure 14 shows the relative price index between 1929 and 2009. Public goods became relatively more expensive between 1929 and 1981, and have been continuously falling since. In our model this would imply that household size should have been falling until 1981, even if incomes had remained constant, and should have been increasing again (or the decline should have slowed down) from 1981 on, because the fact that public goods become cheaper makes larger household relatively more attractive. Whether this last mechanism is large enough to overturn the decline due to increasing incomes is a quantitative question. We thus conduct an experiment where we normalize relative prices in 2000 to 1 (so that the model implications in 2000 are identical to the benchmark) and then feed in the relative price series from the data for 1929–2000. Prior to 1929, we hold relative prices constant at their 1929 level.

In this experiment that considers changes in relative prices, we find that the implied decline in household size is only 0.4 adults and 0.35 children over the entire period. That is, this experiment explains 33 percent of the fall in adult household size, instead

of the 53 percent obtained in the baseline weighted model. For the number of children, the experiment explains 19 percent, which compares to the 29 percent in the baseline weighted model. The reason the implied fall is smaller now is because public goods became cheaper relative to private goods, which increases the benefits of living in larger households. Thus, the fall in optimal household size is somewhat dampened by the increasing relative prices of private goods. However, the remaining fall is still substantial.

In terms of the model implications around the early 1980s, the model is less successful. Because of the increase in the relative price of private goods, the model implies an increase in household size after 1981, which is contrary to the data. However, one should interpret this discrepancy with caution. The relative prices used here are from the NIPA and hence comprise a price index based on all goods that are part of GDP. One reason for the increase in the price of private goods after 1981 is the increase in the price of medical services. However, most medical spending is not paid for out of pocket by consumers and hence is irrelevant for the mechanism in our analysis.[30] Moreover, recall from Figure 1 that the data show a slowdown in the decline in adult household size starting from the 1960s and in child household size starting from the 1980s. This slowdown might be related to the increase in the relative price of private goods.

6.4 *Equivalence scales*

In our model, households enjoy economies of scale from public goods, which only have to be purchased once for everyone in the household. An existing literature on equivalence scales attempts to measure these economies of scale in various ways. Most commonly, equivalence scales measure how much more a household with S adults and K children would need to spend as compared to an adult living alone to achieve the same per-person consumption bundle. In the language of our model, these equivalence scales are defined as

$$ES(S, K) = \frac{H + Sv + Kv^k}{H + v}.$$

Note that equivalence scales depend on the level of H, v, and v^k chosen for the consumption bundle. Since the mix of public and private expenditures is endogenous in our model, so are the equivalence scales. For example, lower income households in our model spend relatively more on public goods, so they will have more economies of scale and lower equivalence scales. We further note that these equivalence scales are different from those that would hold welfare (rather than consumption bundles) constant. The main reason is that exogenously adding additional members to a household would lead the household to change its consumption patterns in our model.[31] Some

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[30]Using the same NIPA data as before, we find that medical care was 17.1 percent of total expenditures in 2000. By contrast, the weight on medical care in the consumer price index (CPI) was just 5.8 percent in the same year. Medical care is defined similarly in both groups to include medical goods, medical services, and health insurance services. Data for the weights used for the CPI are available from the Bureau of Labor Statistics website at ftp://ftp.bls.gov/pub/special.requests/cpi/Usri2000.txt.

[31]In addition, the household maintenance costs would go up, so that an additional compensation would be necessary to hold welfare constant.

TABLE 5. Equivalence scales: model versus empirical estimates.[a]

	Adults Only		2 Adults With Children		
	1 Adult	2 Adults	1 Child	2 Children	3 Children
Panel A: Empirical estimates by source					
OECD (1982)	1	1.70	2.20	2.70	3.20
National Academy of Sciences (1995)	1	1.62	2.00	2.36	2.69
Health and Human Services (1991)	1	1.34	1.68	2.02	2.37
Dept. of Commerce (1991)	1	1.28	1.57	2.01	2.37
Lazear and Michael (1980)	1	1.06	1.28	1.47	1.69
Nelson (1993)	1	1.06	1.17	1.24	1.30
Panel B: Model by income quintile, age, and year					
Quintile 1, ages 28–32, year 2000	1	1.75	1.81	1.86	1.92
Quintile 3, ages 28–32, year 2000	1	1.79	1.86	1.93	2.00
Quintile 5, ages 28–32, year 2000	1	1.81	1.89	1.97	2.05
Quintile 3, ages 63–67, year 2000	1	1.82	2.27	2.72	3.17
Quintile 3, ages 28–32, year 1850	1	1.71	1.76	1.81	1.86

[a]Figures for Panel A are taken from Table 3.2.1 in Fernandez-Villaverde and Krueger (2007). Panel B reports figures computed using estimates from the calibrated model.

work in the literature has attempted to compute equivalence scales that account for the unobserved, counterfactual changes in demand patterns (see, for example, Lazear and Michael (1980)).

Table 5 compares existing estimates of equivalence scales from the literature with those implied by our model. The results in the literature are in some cases derived from simple calculations and in some cases from economic theory. Each row corresponds to a different source, as summarized by Fernandez-Villaverde and Krueger (2007). The equivalence scales implied by our model depend on the characteristics of the household, so we present a range of estimates for different households.

The first thing to note from the table is that the model-implied equivalence scales are in the ballpark of the empirical estimates. For example, the model implies that expenditures need to rise 71–82 percent when adding a second adult to a household, which compares well to the figure of 70 percent from the Organization for Economic Cooperation and Development equivalence scales. Second, our model-implied equivalence scales vary depending on household type. Higher income households have higher equivalence scales because they tend to purchase relatively more private goods which lowers their economies of scale. This logic applies when comparing across income quintiles in 2000 as well as when comparing the figures for the third quintile between 1850 and 2000. Equivalence scales differ even more with age. For example, while a family of five (two adults and three children) needs to spend only twice the amount of a single adult of age 28–32, the factor would be more than 3 for a 63–67 year old adult. Interestingly, the empirical estimates of equivalence scales also differ widely. While such differences are typically attributed to different methodologies, our model raises the possibility that equivalence scales are simply not constant. According to our model, they depend on how households allocate expenditures between public and private goods, which in turn

depends on income and age of a household. This fact in turn raises questions about the usefulness of equivalence scales for the measure of poverty or other policy questions.

7. Conclusion

Over the course of 150 years, the household of the average American shrank by half. The decline was broad based, affecting all forms of cohabitation for Americans of all ages. The negative cross-sectional correlation between income and household sizes suggests that rising income might have been a key force. The evidence we present on consumption patterns indicates that higher incomes are accompanied by a greater relative preference for private over household public goods. Since the primary purpose of roommates is to share the costs of local public goods, the declining budget share of local public goods leads people to form smaller households endogenously. Hence, optimally changing consumption bundles provide the link from income to household size. This story is general to all living arrangements. Our approach abstracts from the specifics of relationships (other than the distinction between adults and children) so as to capture those elements that are common to all "roommate choices": living with parents, spouses, grandparents, aunts and uncles, adult children, servants, and so on.

The calibration exercise implies that changing demographics and consumption patterns account for one-half of the drop in the number of adults per household and one-third of the drop in the number of children per household. Thus, some of the changing structure of families, changing attitudes toward fertility, and changing consumption habits can be viewed as efficient responses to changing incomes. While there is some popular concern about the social costs of smaller households, we quantify the benefits: the value of time freed up from finding roommates and maintaining good relationships is equivalent to 2.5 percent of GDP. In our model, these changes are efficient and there is no need for governments to subsidize larger families.

Our mechanism explains only part of the observed change, which leaves room for other channels. Changes in institutions and social norms were probably significant factors. For example, relaxed divorce laws may have facilitated the decline in the number of spouses per household. Changes in female labor supply could be playing an important role. Likewise, the introduction of social security may have affected the living arrangements of the elderly, particularly elderly widows.

This paper also opens up several questions. For one, our model suggests that equivalence scales are endogenous, and hence are different across different household types, but also might be changing over time. Given this, what is an appropriate measure of equivalence scales, say, for constructing poverty scales? We leave this inquiry for future research.

Appendix

A.1 *Data*

The main sources of data for our analysis are the U.S. Census and the Consumer Expenditure Survey.

A.1.1 *Census*   First, we need to define a household. The Census definition of a household has always been related to a group of persons who share a dwelling and share some resources. The measure of resources used has changed somewhat over time: early Censuses emphasized shared income, but later ones used shared kitchens, shared dining tables, shared cooking equipment, or meals taken together to define a household. Although we suspect that the changes in the definition have little impact on our measures, there is no way to evaluate that assertion formally.

The U.S. Census classifies all housing units as households, group quarters, or vacant units. According to the Census documentation, "Group quarters are largely institutions and other group living arrangements, such as rooming houses and military barracks." We are interested in households, not group quarters like college dorms, jails, hospitals, or mental institutions, where living arrangements are largely involuntary. Unfortunately, the exact definition of group quarters has varied also across censuses. In the 1940–1970 censuses, households with five or more persons unrelated to the head are classified as a group quarter. For the 1850–1930 and 1980–1990 census, the condition is 10 or more persons unrelated to the head.[32] See Ruggles and Brower (2003) for more details.[33] The only way to construct a consistent measure of household is to consider as group quarters all housing units with five or more unrelated members. In other words, households can have at most four persons unrelated to the head. We call this the consistent definition of household. The main concern with this definition is that it may improperly classify large households as group quarters. To mitigate this problem, we have the "mixed" definition, where for censuses 1850–1930 and 1980–2000, the only households that are classified as group quarters are those with 10 or more unrelated persons, and for 1940–1970, those with five or more unrelated persons. Figure A.1 shows that the consistent and the mixed measures differ very little. The consistent definition gives slightly lower numbers, which is not surprising since it classifies some large households as group quarters. All numbers used in the paper are based on the mixed definition.

Two other potential problems are as follows. First, some individuals who were sampled but could not be associated to a group quarters or household are classified as fragments. We exclude these. Second, not all members from large households were interviewed in the early censuses. Before 1930, information on at most 30 members of the household was collected. This is not a concern given that less than 0.1 percent of the households have more than 30 members.

Table A.1 gives the exact figures used in the paper.

A.1.2 *CEX*   Our measures of consumption on private goods and household public goods are based on data from the Consumer Expenditure Survey (CEX) from 1995 to 2000. The CEX collects detailed data on the expenditure of American households as well as information on income and household characteristics. The data are collected by the U.S. Census Bureau for the Bureau of Labor Statistics. The CEX consists of two surveys,

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[32]In later years, this constraint is not binding. For example, in 2000 no households are classified as group quarters based on the number of unrelated members.

[33]These authors also describe some problems with the classification of household members according to their relationship to the head.
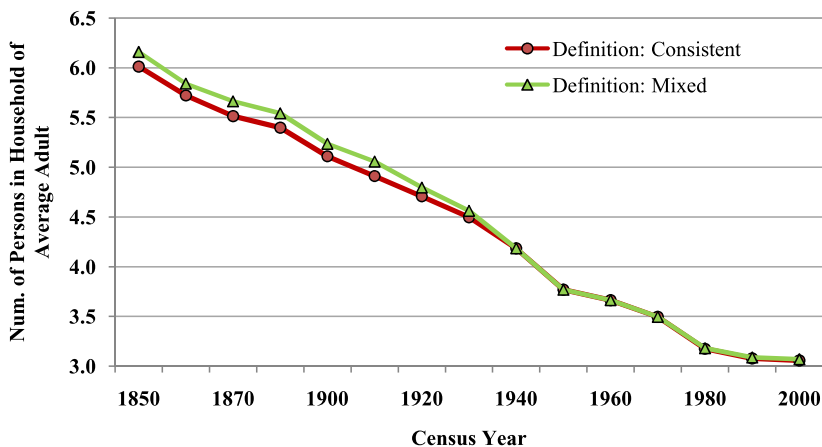
FIGURE A.1. *Household size by household definition.* Computed using U.S. Census data. "Mixed" indicates that for the 1850–1930 and 1980–1990 censuses households with more than 10 members unrelated to the head are classified as group quarters, as well as those with more than 5 unrelated members for 1940–1970. "Consistent" indicates that all households with more than five unrelated members are classified as group quarters (excluded from the household count).

the diary and the interview. The diary is designed to obtain expenditure data on small and frequently purchased items. The interview is a rotating panel that follows households for five quarters. It records information on about 95 percent of all expenditures (excluding expenditures for housekeeping supplies, personal care products, and non-

TABLE A.1. Different measures of household size.[a]

Census Year	Household Members	Family Size	Adults	Children	Observations
1850	6.16	5.18	3.47	2.68	99,016
1860	5.84	4.95	3.37	2.47	142,715
1870	5.66	4.79	3.30	2.36	201,914
1880	5.54	4.67	3.34	2.21	273,521
1900	5.23	4.51	3.34	1.90	436,140
1910	5.06	4.34	3.33	1.73	548,914
1920	4.79	4.27	3.17	1.62	634,416
1930	4.56	4.11	3.09	1.47	761,371
1940	4.18	3.91	2.98	1.20	886,961
1950	3.77	3.58	2.65	1.12	1,141,994
1960	3.66	3.57	2.37	1.30	1,106,337
1970	3.50	3.42	2.30	1.19	2,548,180
1980	3.18	3.06	2.30	0.88	1,569,017
1990	3.09	2.90	2.31	0.78	1,796,436
2000	3.07	2.83	2.28	0.79	2,011,639

[a]Computed using U.S. Census data. The unit of observation is an adult. Household members refers to all persons in the household. Family size includes only those related by blood, marriage, or adoption. Adults are individuals 18 years of age or older.

prescription drugs). In this paper, we use the interview survey, which also gathers information on income and sociodemographic variables such as number of household members. The first interview is considered a baseline and its main purpose is to obtain an inventory of household appliances. Data on consumption are collected on the second to fifth interviews and refer to expenditures made in the previous 3 months. Figures on income are collected only on the second and fifth interviews.

The main information that we obtain from the CEX is the consumption of public and private goods in the household. The survey identifies each consumption item by a universal classification code (UCC), and there are around 550 UCCs. We classify all consumption items into public and private at the UCC level.

The main characteristic of the goods that we take into account when classifying them is their intrinsic technology: whether a good *can* be used by several individuals at the same time. With this in mind, we construct some rules to give discipline to the classification of goods. The first rule is that if the good cannot be shared under any circumstances, then we classify it as private. This is the case with meals and beverages consumed in restaurants, public transportation (e.g., plane or bus tickets), health plans and medical expenditures, some recreational expenses (like club fees or tickets for events), and education. Second, we classify all goods that can be shared by taking turns as public unless they typically are not shared for one of the following five reasons: coincidence of usage, depreciation, hygiene, taste, or fit. Using these rules leads us to classify the following as private goods: linens (coincidence of usage), towels (coincidence of usage), jewelry (taste), personal care appliances (hygiene), magazines (taste), school supplies (fit), and clothing (fit) as private.

On the other hand, we classify the following as public goods. First, all housing and housing related expenditures including utilities are classified as public goods. A home typically is shared by all household members, and there is no particular feature of a house that typically is not shared for any of our five reasons. In other words, all household members benefit from a home. As part of household expenditures, we include rent for households that rent and an imputed rent for home owners. The annual imputed rent was estimated as 1/16 of the reported market value of the home, within the range of rental-price ratios reported in Davis, Lehnert, and Martin (2008).

Using the same logic, we also classify most durable goods as public. The nonrivalry characteristic is not as evident as in the housing case given that, for example, only one person can sit in a chair at a time. However, we consider that all household members can benefit from durables at home given that they suffer a very small depreciation when one person uses it. In this category, we include most furniture, dishwashers, dinnerware, appliances, TVs and the like, computers, pets, and recreational equipment. We use the same logic for cars and related expenditures. Another category we classify as public is food prepared at home. This classification is based on Deaton and Paxson (1998), who argued that there are economies of scale in the preparation of food consumed at home.

Summing up, goods that are identified as public are food at home, home related expenditures, utilities, laundry, kitchen utensils, most furniture, cars, car related expenditures, TV, DVD, other household appliances, newspapers and books, and contributions. Private goods include food away from home, linens, bedroom furniture, travel items,

TABLE A.2. Average household size by income quintiles, 1995–2000.[a]

Quintile (Relative Income)	23–27 Year Old Persons				28–32 Year Old Persons			
	Public/Private	Household Members	Adults	Children	Public/Private	Household Members	Adults	Children
1 (0.20)	3.60	3.60	2.65	0.95	4.21	3.79	2.40	1.40
2 (0.55)	3.80	3.43	2.56	0.87	3.65	3.61	2.17	1.44
3 (0.83)	3.49	3.23	2.33	0.91	3.57	3.16	2.07	1.10
4 (1.20)	3.21	2.90	2.30	0.60	3.45	2.91	1.97	0.94
5 (2.23)	2.99	2.66	2.19	0.47	2.92	2.75	1.88	0.88

[a]Calculations based on CEX data (1995–2000). The unit of observation is an adult. Income is computed as total income in the household divided by the total number of adults. We report relative incomes as a multiple of average income. Public/Private refers to expenditures on public goods as a proportion of expenditures on private goods. Household members denotes the total number of adults and children in the household.

clothing, transport (bus or plane), school tuition, health expenses, club or recreational lessons, and personal care. We excluded categories that are investment rather than consumption goods (such as home repairs). Other excluded items are finance charges and care for household members (babysitting and adult care centers). The classification at the UCC level is available from the authors upon request.

For all calculations, the sample is restricted to households that responded about their expenditures in the four interviews, so that there is information on their annual consumption. This restriction reduces our sample size to 40 percent of the households. Additionally, we retain only those households where there were no changes in the number of household members. This is the case for 85 percent of the households. Finally, given that we interpret income as a measure of productivity, we also drop households for which there is a missing or negative value for income. Because we are interested in the behavior of the variables for the average adult, the unit of observation is an adult (18 years of age or older). The final number of observations is 29,277 adults in 15,942 households. All dollar quantities are converted to real terms using the CPI.

We construct a measure of annual consumption (public and private) by adding information from the four interviews. Income is reported on an annual basis and we use the figure reported in the fifth interview. The income variable that we assign to each adult is total household income divided by the number of adults in the household.

For the calibration of the model (and other statistics presented in Section 3), we construct the ratio of public to private consumption expenditures. To do so we obtain the mean value of expenditures in public and private goods for adults of a particular age group. We take the ratio of these aggregates as our moment in the model and the data. Additionally, we compute the income elasticities of this ratio for our age groups. For each age group, we calculate the income elasticity of the public–private consumption ratio based on the five quintile observations. Table A.2 shows these measures for two of the age groups. It shows clearly how across quintiles the ratio of public to private goods falls and how, at the same time, both measures of household size (adults and children) decrease. Note that the household size numbers differ slightly from Table 1 since these numbers are based on the CEX rather than the Census.
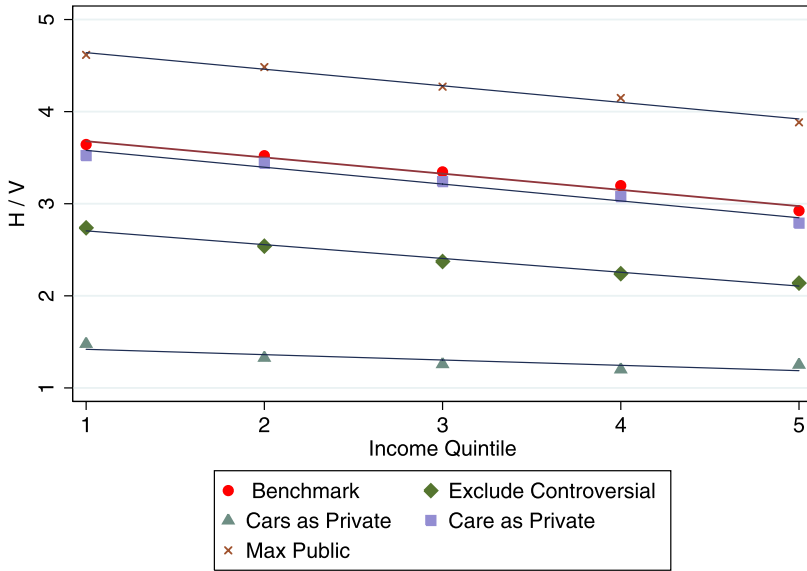
FIGURE A.2. *Ratio of public to private goods by income quintile.* Computed using data from CEX, 1995–2000. Results shown are average results for a quintile, across ages. The case "Exclude Controversial" does not consider all goods whose classification into public or private was controversial. "Cars as Private" reclassifies cars from public into private goods. "Care as Private" considers items like babysitting or adult care in the private category instead of excluding them. "Max Public" classifies as public all goods that can be shared in some way.

We have four robustness checks on the classification of goods into public and private. Figure A.2 presents the mean ratio H/V by income quintile, averaged across age groups for the baseline and each of the additional exercises. First, we exclude from the analysis expenditures on goods that are likely to have a controversial classification as either public or private goods. These items include cars, babysitting and adult care, videos, some games and toys, CDs, fishing and photo equipment, magazines, newspapers, and books. All were classified as public except photo equipment, which was private. Excluding controversial items decreases H/V for all quintiles and does not alter the main conclusion that richer people consume a smaller proportion of public goods. The income elasticity of H/V at the baseline for the 43–47 age group is -0.12, and excluding controversial items does not change it. In a second robustness check, we classify babysitting and adult care as private instead of excluding them ("Care as Private"). The difference from the baseline is very small (the elasticity is -0.13). The third exercise consists of classifying all goods that can be shared in some way, like taking turns, as public ("Max Public"). The main items that change classification are some furniture and clothing. In this case, as is shown in Figure A.2, H/V increases, but the elasticity only changes to -0.09. Finally, the largest drop in the ratio results from reclassifying cars as private instead of as public. This reduces the income elasticity to -0.05.

TABLE A.3. H/V elasticities.[a]

Age Group	Measure of Income		
	Income per Adult	Income per Worker	Income per Worker (Controlling for HH Size)
18–22	−0.143	−0.123	−0.113
23–27	−0.095	−0.097	−0.052
28–32	−0.155	−0.139	−0.115
33–37	−0.093	−0.080	−0.068
38–42	−0.072	−0.079	−0.070
43–47	−0.121	−0.139	−0.136
48–52	−0.076	−0.097	−0.105
53–57	−0.112	−0.111	−0.115
58–62	−0.096	−0.063	−0.040
63–67	−0.069	−0.104	−0.092
68–72	−0.044	−0.106	0.031
73+	−0.016	−0.005	−0.004
Average	−0.091	−0.095	−0.073

[a]Calculations based on CEX data (1995–2000). The unit of observation is an adult. HH stands for household.

A.1.3 *CEX robustness: Defining income*   To compute our various elasticities, we have to define our measure of income. Our preferred measure is income per adult because we think this is the most appropriate measure of how rich a household is on a per capita basis. Of course, it is not the case in reality that all household members work and earn the same income (as they do in our model). A particular concern we have is with home production. It seems plausible that larger households could find it more beneficial to allocate an adult to full-time home production. If this were true, then adults living in these households would also be recorded as having lower income per adult, simply because fewer adults work. In this case, household size causes income and not the other way around.

We provide three checks that suggest that our definition of household income does not drive our results. First, we note that in 65 percent of all households in our sample the number of earners is identical to the number of adults. Second, we reestimate the key H/V elasticity using income per earner rather than income per adult as our measure of household income. As can be seen in Table A.3, the estimated elasticities are similar to our baseline estimates for all age groups. We verified that this is also the case for household size elasticities (results not shown). Finally, we also reestimate the key H/V elasticity again using income per earner, but this time controlling for the household size. The results are available in the final column of Table A.3. Although they are modestly lower than the baseline results overall, they compare well. All three estimates yield similar results and suggest that our results are not an artifact of the definition of household income.

TABLE A.4. Moments in model and data.[a]

Moment	Data Value	Model Value	Moment	Data Value	Model Value
Average S, 18–22	3.051	3.041	Average K, 18–22	0.857	0.856
Average S, 23–27	2.519	2.508	Average K, 23–27	0.839	0.836
Average S, 28–32	2.209	2.215	Average K, 28–32	1.180	1.186
Average S, 33–37	2.137	2.145	Average K, 33–37	1.518	1.515
Average S, 38–42	2.192	2.193	Average K, 38–42	1.420	1.419
Average S, 43–47	2.300	2.292	Average K, 43–47	1.010	1.011
Average S, 48–52	2.328	2.304	Average K, 48–52	0.554	0.546
Average S, 53–57	2.255	2.243	Average K, 53–57	0.290	0.299
Average S, 58–62	2.183	2.150	Average K, 58–62	0.197	0.200
Average S, 63–67	2.101	2.059	Average K, 63–67	0.162	0.165
Average S, 68–72	2.021	2.039	Average K, 68–72	0.125	0.126
Average S, 73+	1.858	1.906	Average K, 73+	0.084	0.083
S elasticity, 18–22	0.009	−0.073	K elasticity, 18–22	−0.106	−0.145
S elasticity, 23–27	−0.096	−0.073	K elasticity, 23–27	−0.334	−0.145
S elasticity, 28–32	−0.116	−0.074	K elasticity, 28–32	−0.247	−0.148
S elasticity, 33–37	−0.084	−0.074	K elasticity, 33–37	−0.097	−0.150
S elasticity, 38–42	−0.118	−0.074	K elasticity, 38–42	0.021	−0.149
S elasticity, 43–47	−0.125	−0.073	K elasticity, 43–47	0.083	−0.145
S elasticity, 48–52	−0.110	−0.072	K elasticity, 48–52	−0.063	−0.138
S elasticity, 53–57	−0.074	−0.071	K elasticity, 53–57	−0.255	−0.131
S elasticity, 58–62	−0.063	−0.070	K elasticity, 58–62	−0.299	−0.126
S elasticity, 63–67	−0.026	−0.070	K elasticity, 63–67	−0.319	−0.123
S elasticity, 68–72	−0.035	−0.069	K elasticity, 68–72	−0.141	−0.119
S elasticity, 73+	−0.036	−0.070	K elasticity, 73+	0.056	−0.117
H/V elasticity, 18–22	−0.143	−0.091	Time spent with kids	0.040	0.039
H/V elasticity, 23–27	−0.095	−0.091			
H/V elasticity, 28–32	−0.155	−0.092			
H/V elasticity, 33–37	−0.093	−0.093			
H/V elasticity, 38–42	−0.072	−0.092			
H/V elasticity, 43–47	−0.121	−0.092			
H/V elasticity, 48–52	−0.076	−0.090			
H/V elasticity, 53–57	−0.112	−0.090			
H/V elasticity, 58–62	−0.096	−0.089			
H/V elasticity, 63–67	−0.069	−0.088			
H/V elasticity, 68–72	−0.044	−0.088			
H/V elasticity, 73+	−0.016	−0.089			

[a]Average S and K by age group are computed using the 2000 U.S. Census. Details are presented in Appendix A.1.1. Income elasticities for S, K, and $H/(V + V^k)$ by age group were computed using 1995–2000 CEX data as described in Appendix A.1.2. Time spent with kids is estimated based on Bureau of Labor Statistics information.

A.2 *Computational methods and calibration details*

Let ε denote elasticity. For example, $\varepsilon^D_{S,z}(a)$ is the income elasticity of adult household size S for people of age a in the data, while $\varepsilon^M_{S,z}(a)$ is the same elasticity in the model.

Using this notation, we minimize the loss function:

$$
L = \sum_{a=1}^{12} \left(\frac{\varepsilon_{S,z}^D(a) - \varepsilon_{S,z}^M(a)}{\frac{1}{12}\sum_{a=1}^{12} \varepsilon_{S,z}^D(a)} \right)^2 + \sum_{a=1}^{12} \left(\frac{\varepsilon_{K,z}^D(a) - \varepsilon_{K,z}^M(a)}{\frac{1}{12}\sum_{a=1}^{12} \varepsilon_{K,z}^D(a)} \right)^2
$$

$$
+ \sum_{a=1}^{12} \left(\frac{\varepsilon_{H/(V+V^k),z}^D(a) - \varepsilon_{H/(V+V^k),z}^M(a)}{\frac{1}{12}\sum_{a=1}^{12} \varepsilon_{H/(V+V^k),z}^D(a)} \right)^2
$$

$$
+ \sum_{a=1}^{12} \left(\frac{S_a^D(a) - S_a^M(a)}{\frac{1}{12}\sum_{a=1}^{12} S_a^D(a)} \right)^2 + \sum_{a=1}^{12} \left(\frac{K_a^D(a) - K_a^M(a)}{\frac{1}{12}\sum_{a=1}^{12} K_a^D(a)} \right)^2
$$

$$
+ \left(\frac{0.04 - \frac{\sum_{a=1}^{12} B_a^k K_a}{\sum_{a=1}^{12} K_a}}{0.04} \right)^2 .
$$

Note that the empirical average of 4 percent of time spent with children has been substituted in already.

References

Albanesi, S. and C. Olivetti (2009), "Maternal health and the baby boom." Mimeo, Columbia University. [136]

Barro, R. J. (2006), "Rare disasters and asset markets in the twentieth century." *Quarterly Journal of Economics*, 121 (3), 823–866. [150]

Becker, G. S. and H. G. Lewis (1973), "On the interaction between the quantity and quality of children." *Journal of Political Economy*, 81, 2 (Part 2), S279–S288. [136, 158]

Beresford, J. C. and A. M. Rivlin (1966), "Privacy, poverty, and old age." *Demography*, 3 (1), 247–258. [136, 140]

Bethencourt, C. and J.-V. Ríos-Rull (2009), "On the living arrangements of elderly widows." *International Economic Review*, 50 (3), 773–801. [137]

Brady, D. S. (1958), "Individual incomes and the structure of consumer units." *American Economic Review*, 48 (2), 269–278. [140]

Brien, M. J., L. A. Lillard, and S. N. Stern (2006), "Cohabitation, marriage, and divorce in a model of match quality." *International Economic Review*, 47 (2), 451–494. [137]

Burch, T. K. and B. J. Matthews (1987), "Household formation in developed societies." *Population and Development Review*, 13 (3), 495–511. [136]

Bureau of Labor Statistics (2004), "American time use survey—2004 results announced by BLS." Available at http://www.bls.gov/news.release/History/atus_09202005.txt. [151]

Byalsky, M., M. Keren, and D. Levhari (1999), "The kibbutz as a labor-managed club: Public and private goods, incentives and social control." In *Trade, Growth and Development—Essays in Honor of Professor T. N. Srinivasan* (G. Ranis and L. K. Raut, eds.), North-Holland, Amsterdam. [136]

Cochrane, J. H. (2001), *Asset Pricing*. Princeton University Press, Princeton, NJ. [150]

Costa, D. L. (1997), "Displacing the family: Union army pensions and elderly living arrangements." *Journal of Political Economy*, 105 (6), 1269–1292. [137]

Costa, D. L. (1999), "A house of her own: Old age assistance and the living arrangements of older nonmarried women." *Journal of Public Economics*, 72, 39–59. [137]

Davis, M. A., A. Lehnert, and R. F. Martin (2008), "The rent-price ratio for the aggregate stock of owner-occupied housing." *Review of Income and Wealth*, 54 (2), 279–284. [166]

Deaton, A. and C. Paxson (1998), "Economies of scale, household size, and the demand for food." *Journal of Political Economy*, 106 (5), 897–930. [142, 166]

Deaton, A. and C. Paxson (2003), "Engel's what? A response to Gan and Vernon." *Journal of Political Economy*, 111 (6), 1378–1381. [142]

Doepke, M. (2004), "Accounting for fertility decline during the transition to growth." *Journal of Economic Growth*, 9 (3), 347–383. [136]

Doepke, M., M. Hazan, and Y. Maoz (2007), "The baby boom and World War II: A macroeconomic analysis." Working Paper 13707, NBER. [136]

Ermisch, J. and P. Di Salvo (1997), "The economic determinants of young people's household formation." *Economica*, 64, 627–644. [137]

Ermisch, J. F. (1981), "An economic theory of household formation." *Scottish Journal of Political Economy*, 28 (1), 1–19. [136, 141]

Fernández, R., N. Guner, and J. Knowles (2005), "Love and money: A theoretical and empirical analysis of household sorting and inequality." *Quarterly Journal of Economics*, 120 (1), 273–344. [136]

Fernandez-Villaverde, J. and D. Krueger (2007), "Consumption over the life cycle: Facts from the consumer expenditure survey data." *Review of Economics and Statistics*, 89 (3), 552–565. [162]

Fogli, A. (2004), "Endogenous labor market rigidities and family ties." Mimeo, New York University. [137]

Galor, O. and D. N. Weil (1996), "The gender gap, fertility and growth." *American Economic Review*, 86 (3), 374–387. [136]

Gan, L. and V. 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. [142]

Greenwood, J., N. Guner, and J. Knowles (2003), "More on marriage, fertility and the distribution of income." *International Economic Review*, 44 (3), 827–862. [136]

Greenwood, J. and N. Guner (2009), "Marriage and divorce since World War II: Analyzing the role of technological progress on the formation of households." *NBER Macroeconomics Annual*, 23, 231–276. [137, 156]

Greenwood, J. and A. Seshadri (2002), "The U.S. demographic transition." *American Economic Review Papers and Proceedings*, 92 (2), 153–159. [136]

Greenwood, J., A. Seshadri, and G. Vandenbroucke (2005), "The baby boom and baby bust." *American Economic Review*, 95 (1), 183–207. [136]

Haurin, D. R., P. H. Hendershott, and D. Kim (1994), "Housing decisions of American youth." *Journal of Urban Economics*, 35, 28–45. [137]

Johnston, L. D. and S. H. Williamson (2006), "The annual real and nominal GDP for the United States, 1790—Present." Economic History Services. Available at http://eh.net/hmit/gdp/. [150]

Jones, L. E. and A. Schoonbroodt (2010), "Complements versus substitutes and trends in fertility choice in dynastic models." *International Economic Review*, 51 (3), 671–699. [136, 147, 148]

Jones, L. E., A. Schoonbroodt, and M. Tertilt (2011), "Fertility theories: Can they explain the negative fertility-income relationship?" In *Demography and the Economy* (J. Shoven, ed.), University of Chicago Press, Chicago, IL. [136]

Jones, L. E. and M. Tertilt (2008), "An economic history of the relationship between occupation and fertility—U.S. 1826–1960." In *Frontiers of Family Economics*, Vol. 1 (P. Rupert, ed.), Emerald Group Publishing Limited, Bingley, U.K. [136]

Kobrin, F. E. (1976), "The fall in household size and the rise of the primary individual in the United States." *Demography*, 13 (1), 127–138. [137]

Kuznets, S. (1978), "Size and age structure of family households: Exploratory comparisons." *Population and Development Review*, 4 (2), 187–223. [137]

Lam, D. (1983), *The Economics of Household Composition in Developing Countries*. Ph.D. thesis, University of California at Berkeley. [145]

Lam, D. (1984), "Household public goods and the shadow price of privacy: A framework for modeling the interaction of household composition and economic behavior." Paper presented at the annual meeting of the Population Association of America, Minneapolis. [145]

Lam, D. (1988), "Marriage markets and assortative mating with household public goods: Theoretical results and empirical implications." *The Journal of Human Resources*, 23 (4), 462–487. [145]

Laslett, P. (1969), "Size and structure of the household in England over three centuries." *Population Studies*, 23 (2), 199–223. [137]

Lazear, E. and R. T. Michael (1980), "Family size and the distribution of real per capita income." *American Economic Review*, 70 (1), 91–107. [162]

Lino, M. and A. Carlson (2009), "Expenditures on children by families, 2008." Miscellaneous Publication 1528-2008, U.S. Department of Agriculture, Center for Nutrition Policy and Promotion. [158]

Logan, T. D. (2010), "Economies of scale in the household: Puzzles and patterns from the American past." *Economic Inquiry*, 49 (4), 1008–1028. [142]

Max, W., D. P. Rice, E. Finkelstein, R. A. Bardwell, and S. Leadbetter (2004), "The economic toll of intimate partner violence against women in the United States." *Violence and Victims*, 19, 259–272. [159]

McGarry, K. and R. F. Shoeni (2000), "Social security, economic growth, and the rise in independence of elderly widows in the 20th century." *Demography*, 37, 221–236. [137]

Michael, R. T., V. R. Fuchs, and S. R. Scott (1980), "Changes in the propensity to live alone: 1950–1976." *Demography*, 17 (1), 39–56. [141]

Montemayor, R. (1983), "Parents and adolescents in conflict: All families some of the time and some families most of the time." *Journal of Early Adolescence*, 3 (1–2), 83–103. [159]

Pampel, F. C. (1983), "Changes in the propensity to live alone: Evidence from consecutive cross-sectional surveys, 1960–1976." *Demography*, 20 (4), 433–447. [141]

Prescott, E. C. (1986), "Theory ahead of business cycle measurement." *Carnegie-Rochester Conference Series on Public Policy*, 25 (1), 11–44. [150]

Regalia, F. and J.-V. Ríos-Rull (2001), "What accounts for the increase in the number of single households?" Mimeo, University of Pennsylvania. [137]

Roseneil, S. (2006), "On not living with a partner: Unpicking coupledom and cohabitation." *Sociological Research Online*, 11 (3). [135]

Ruggles, S. and S. Brower (2003), "Measurement of household and family composition in the United States, 1850–2000." *Population and Development Review*, 29 (1), 73–101. [137, 164]

Ruggles, S., M. Sobek, T. Alexander, C. A. Fitch, R. Goeken, P. K. Hall, M. King, and C. Ronnander (2009), "Integrated public use microdata series: Version 4.0 [Machine-readable database]." Minnesota Population Center [producer and distributor], Minneapolis, MN. Available at http://usa.ipums.org/usa/. [137]

Rupert, P. and P. Gomme (2007), "Theory, measurement and calibration of macroeconomic models." *Journal of Monetary Economics*, 54 (2), 460–497. [150]

Stevenson, B. and J. Wolfers (2006), "Bargaining in the shadow of the law: Divorce laws and family distress." *Quarterly Journal of Economics*, 121 (1), 267–288. [159]

Strohm, C. Q., J. A. Seltzer, S. D. Cochran, and V. M. Mays (2009), "'Living apart together' relationships in the United States." *Demographic Research*, 21 (7), 177–214. [135]

Turcotte, M. (2007), "Time spent with family during a typical workday, 1986 to 2005." *Canadian Social Trends*, 83, 2–11. [158]

Walker, A. J. (1996), "Couples watching television: Gender, power, and the remote control." *Journal of Marriage and Family*, 58 (4), 813–823. [159]