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Families as Roommates: Changes in U.S. Household Size from 1850 to 2000*

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Abstract: The size of the average American household has fallen dramatically -from six in 1850 to three in 2000. To explain this decline we model households as collections of roommates who share the costs of household public goods. If private goods are more income elastic than public goods, as we document in the paper, an increase in income endogenously leads to smaller households. We calibrate the model to match data from 2000. Changing incomes to their 1850 levels, we find that our mechanism can explain 37 percent of the observed reduction in the number of adults per household and 16 percent of the reduction in the number of children.
Keywords: Household size, living arrangements, roommates, economies of scale, household public goods, fertility decline.
JEL Classification: D10, E10, J11, N30, O10.

Resumen: El tamaño del hogar estadounidense promedio ha caído dramáticamente -de seis personas en 1850 a tres en 2000. Para explicar esta caída proponemos un modelo en el que vivir con otras personas es beneficioso únicamente porque los costos de los bienes públicos del hogar se pueden compartir. Si la elasticidad ingreso de los bienes privados es mayor que la de los públicos, como se documenta en este estudio, un aumento en el ingreso reducirá, endógenamente, el tamaño del hogar. Calibramos el modelo usando datos del año 2000. Cambiando el ingreso a su nivel de 1850 encontramos que nuestro mecanismo puede explicar 37 por ciento de la caída en el número de adultos por hogar y 16 por ciento de la caída en el número de niños.
Palabras Clave: Tamaño del hogar, arreglo familiar, economías de escala, bienes públicos del hogar, caída en la fertilidad.

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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 non-relatives 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 tradeoffs 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 tradeoffs 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 a 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 or not 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 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 (Sasha Roseneil 2006, Charles Q. Strohm, Judith A. Seltzer, Susan D. Cochran & Vickie M. 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 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 tradeoff 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 the 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

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

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. When adjusting 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 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 towards 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 Thomas K. Burch & Beverly J. Matthews (1987) who point to a general trend towards "simpler" households and argue in favor of a general theory of household formation. Another notable exception is John F. Ermisch (1981) who builds and estimates a static model of household formation. However, no attempt is made to assess how well the model can account for changes in living arrangements over time. Raquel Fernández, Nezih Guner & John Knowles (2005) and Jeremy Greenwood, Nezih Guner & John Knowles (2003) also study several margins of living together in models that emphasize the importance of income and search frictions. These papers do not seek to explain the long-term patterns documented here. John C. Beresford & Alice M. Rivlin (1966) are probably the first to emphasize a rising "demand for privacy" as a factor in changing living arrangements, but have no formal model. Michael Byalsky, Michael Keren & David Levhari (1999) argue 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 (Larry E. Jones & Michèle Tertilt 2008). A large literature investigates changes in fertility patterns over the last two centuries, some focusing on the overall decline, and some 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 (Gary S. Becker & H. Gregg 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 analyzing other margins of family formation. Several authors focus on the age at which young people leave their parents' homes, and point to earnings of young adults and house prices as the main factors (Donald R. Haurin, Patric H. Hendershott & Dongwook Kim 1994, John Ermisch & Pamela Di Salvo 1997, Alessandra Fogli 2004). Income (particularly old-age pensions) also seems to play a role in the increased tendency for the elderly to live alone (Dora L. Costa 1997, Dora L. Costa 1999, Kathleen McGarry & Robert F. Shoeni 2000, Carlos Bethencourt & José-Víctor Ríos-Rull 2009). Other authors analyze the decline in marriage and increase in divorce. For example, Jeremy Greenwood & Nezih Guner (2009) offer 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. Michael J. Brien, Lee A. Lillard & Steven N. Stern (2006) study the determinants of cohabitation, marriage and divorce in a model with frictions and heterogeneous match quality. Ferdinando Regalia & José-Víctor Ríos-Rull (2001) explore 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 U.S. In Section 3 we present evidence for the channel proposed in this paper. Section 4 sets up the model and derives some

[2]See for example Oded Galor & David N. Weil (1996) on women's wages, Matthias Doepke (2004) on human capital and child labor laws, Jeremy Greenwood & Ananth Seshadri (2002) on the role of new household technologies, and Larry E. Jones & Alice Schoonbroodt (forthcoming) on changes in mortality. Papers on the baby boom include Stefania Albanesi & Claudia Olivetti (2009), Jeremy Greenwood, Ananth Seshadri & Guillaume Vandenbroucke (2005) and Matthias Doepke, Moshe Hazan Hazan & Yishay Maoz (2007). This literature has grown greatly in recent years; see Larry E. Jones, Alice Schoonbroodt & Michèle Tertilt (forthcoming) for a survey.

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

Over the course of development, there has been a strong trend towards smaller households. Frances E. Kobrin (1976) documents that household sizes in the United States have been falling since 1790. Peter Laslett (1969) documents a similar phenomenon in England – although arguing that the decline did not start until the early 20th century. Simon Kuznets (1978) uses 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 micro data allows us to distinguish between family and household size, to analyze household size over the life cycle, and to document changes in household composition. Micro data also enable us to analyze the relationship between household size and income in the cross 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 under-representation 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 non-family living arrangements declined as well. The number of non-family members is simply the gap between household and family members in Figure 1. While in 1850 the average person lived

[3]We use the publicly available data from IPUMS (Steven Ruggles, Matthew Sobek, Trent Alexander, Catherine A. Fitch, Ronald Goeken, Patricia Kelly Hall, Miriam King & Chad Ronnander 2009). See Steven Ruggles & Susan Brower (2003) for a description. A more detailed description of the data analysis is presented in Appendix A1.1.

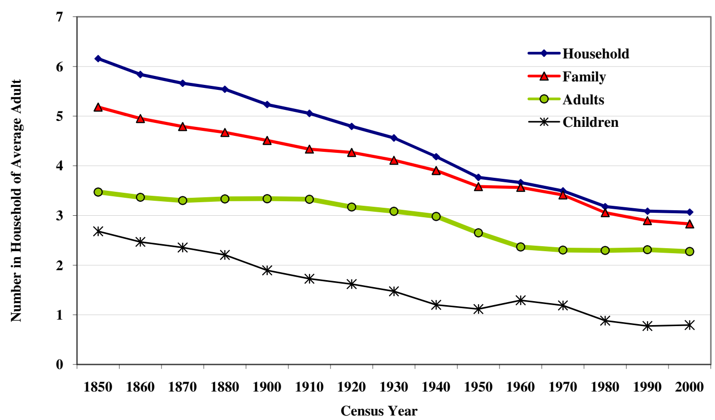
[4]This distinction is important because most people are not household heads most of the time, and heads of households have different household sizes from that of the average American. For example, in 2000, only 39% of 25 year old persons were household heads. While the average 25 year old person lived in a household of size 3.3, the average household size for heads of households aged 25 is only 2.5. The difference is larger 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.

with one non-family 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.

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, grand-children, other relatives, and non-relatives 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.

Figure 1: Household Size: Number of Members

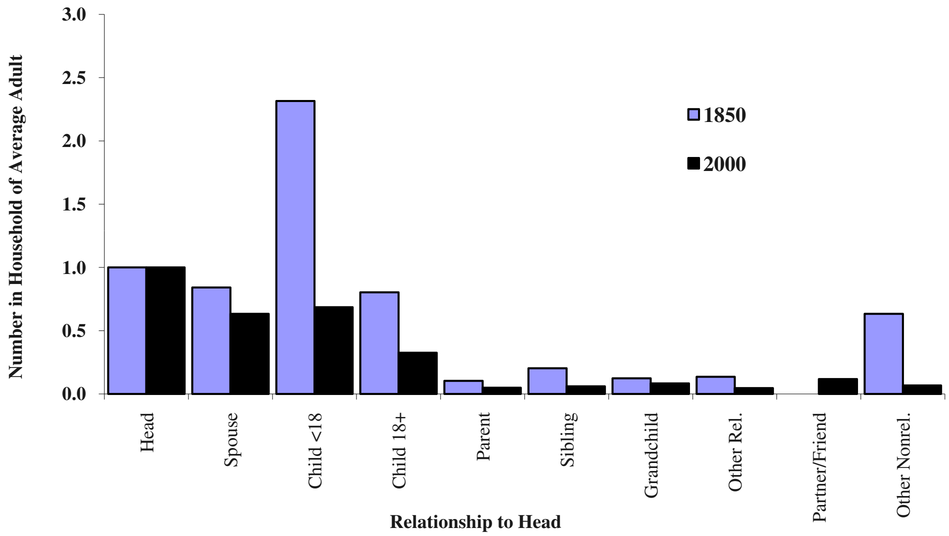


Source: U.S. Census. Excludes group quarters. The unit of observation is an adult, so that each point represents the average household size across adults.

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 five 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 to 22) live in larger households than 23-27 year old adults. Persons in their mid-40s have the largest households, and the elderly 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.

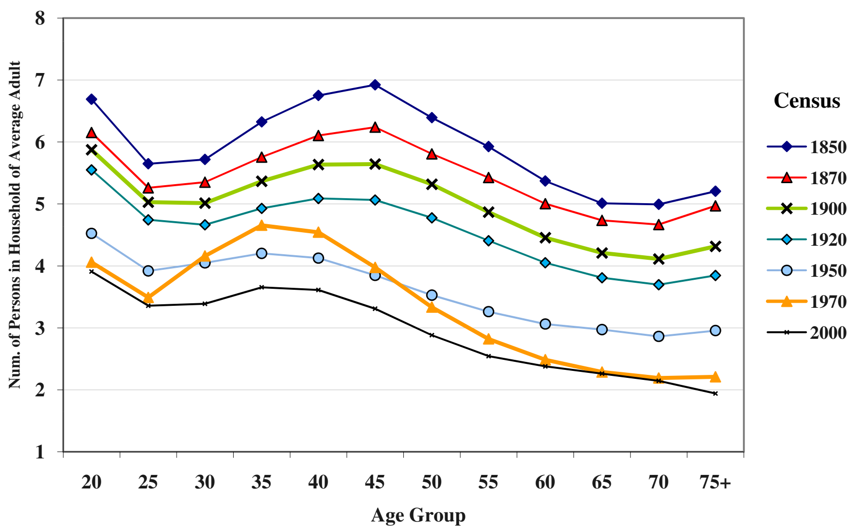
In sum, the number of household members for the average adult has decreased by half over the last 150 years. The average adult lives in a household with fewer members of every type: fewer spouses, young children, adult children, siblings, and especially fewer non-family members. The decline has occurred at all ages. Given the universality of the decline, we believe it is worthwhile to

Figure 2: Household Members, 1850 and 2000



Source: U.S. Census. The unit of observation is an adult. Each bar represents the mean number of household members in each category.

Figure 3: Average Household Size by Age
Various Censuses



Source: 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 five years and are labeled by the middle year.

pursue an analysis of household size that abstracts 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 household public goods are a key reason for living together, the benefit of a larger household being a lower cost (per capita) of the 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 would cause 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 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 bottom quintile. The relationship is monotone across all quintiles. Further, the negative relationship is present for various measures of household size: adults only, children only, family members only, as well as non-family members. The negative relationship holds for almost all age groups. The average income elasticity for the number of adults in the household is -0.10, while for children it is -0.05. The only exceptions are young adults (18-22 years) where we find a (small) positive relationship between income and adult household size, and older adults (38-47, and 73+) where we find a (small) positive relationship between income and number of children in the household. This exception might be due to the differential timing of child-bearing for women of different education levels (and hence income). More educated women typically have children later in life, which might explain why the number of children in the household for older Americans is positively correlated with income. Details are reported in Table A3.

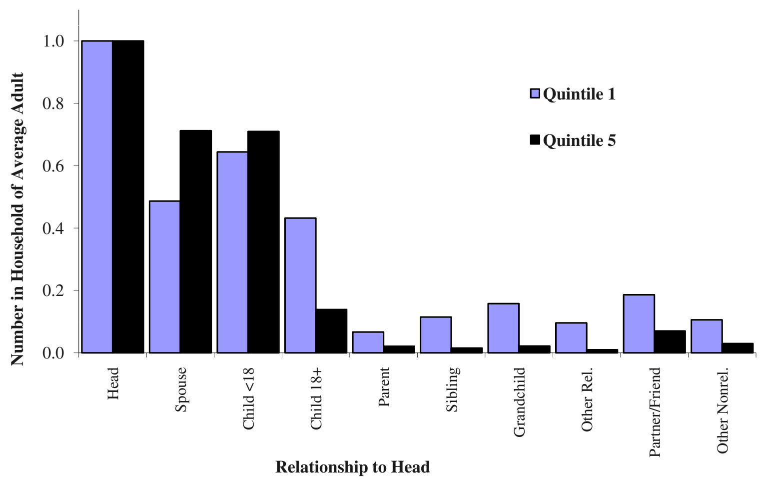
Above we documented that the decline in household size over time has been visible across all categories of household members (see Figure 2). One might wonder to what extent the same holds

[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 Dorothy S. Brady (1958) and Beresford & Rivlin (1966) uses data tabulations to support such a relationship. More detailed work is provided by Robert T. Michael, Victor R. Fuchs & Sharon R. Scott (1980) and Fred C. Pampel (1983), who use cross-state variation and individual microdata to study the relationship between income and household size. Ermisch (1981) provides evidence of the same relationship in the 1973 and 1976 General Household Surveys of Britain, where he estimates an income elasticity of household size of -0.20.

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, fewer parents, siblings, grand-children, other relatives, partners and friends, as well as with fewer non-relatives (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 controlling 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.

Figure 4: Household Members by Income Quintile, 2000



Note: Authors' 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.

Table 1: Average Household Size by Income Quintiles, 2000

	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

Note: Authors' 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.

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 Economic 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, but only for a short period of time. We also use the numbers found in the CEX data throughout the rest of the paper.

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.[8] The method is described in more detail in Appendix A1.2. Using these principles, we classify the following 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 Angus Deaton & Christina Paxson (1998) and several subsequent papers find that food consumed at home has public good characteristics (Li Gan & Victoria Vernon 2003, Angus Deaton & Christina Paxson 2003). This finding seems to apply to historical and recent data on expenditure patterns (Trevon D. Logan 2010). 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.[9] 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 2.0 in 1929 to 1.34 in 2006. This is a drop of about one third.[10] The main item driving the increase in private goods

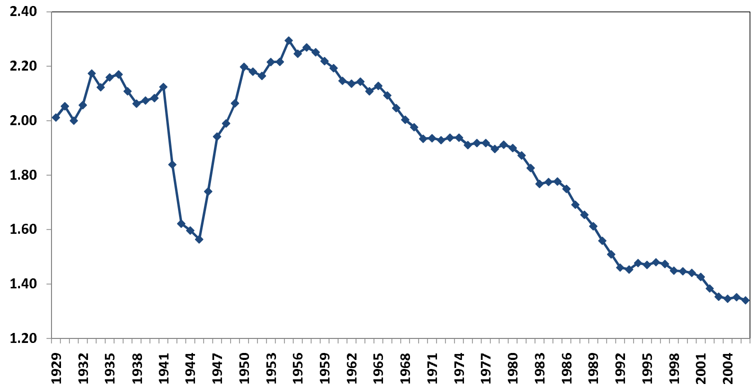
[8]For example, while tooth brushes could in principle be shared, most people do not share them for hygienic reasons; a bed could in principle be shared, however, most people do not take turns using a bed since they would need it at the same time; clothing could in principle be shared, however, this is unlikely to be practical because of fit. All of these goods are thus classified as private.

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

[10]There is a level difference between the NIPA and CEX data because the NIPA data include all of GDP while the

over the entire period is medical care, which has increased from 3% of total expenditures to 17%. 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% of total expenditures in 1929 to 8% today.

Figure 5: Personal Consumption Expenditures:
Ratio of Public to Private Goods



Note: Author's calculations based on National Economic Accounts.

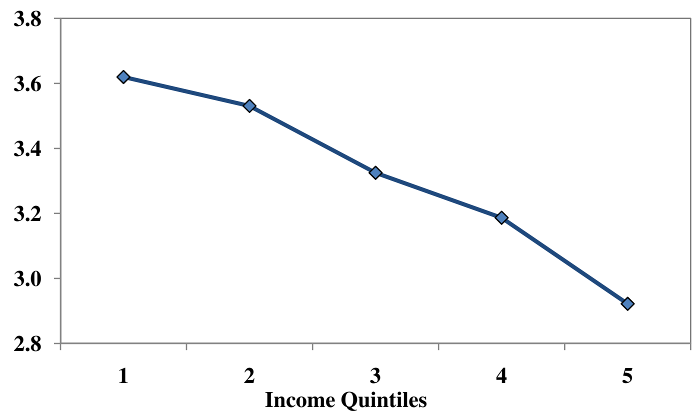
The decrease in the ratio of public to private goods shown by the historical aggregate series provides suggestive evidence in favor of our mechanism. However, this phenomenon could also be explained by changing relative prices. To circumvent this problem, we compare expenditure patterns along the income 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 of goods in the CEX compared to the National Accounts data, we can break down goods more carefully into public and private categories. As before we use adults as the unit of observation. For each adult we construct the ratio of expenditures on public goods to expenditures on private goods for the household. Our measure of income is household income per adult. Figure 6 presents the ratio of public to private goods expenditures by income quintile, averaged across ages. 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% difference. As in the Census data, we find a strong negative relationship between income and household size in the CEX. 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

CEX data include only consumers' out-of-pocket expenditures. The dip during World War II is due to the government slowing or halting production of housing and consumer durables to redistribute resources towards the war effort.

more on private goods. We perform the same exercise classifying adults into different age groups (of five years each) and find that in all cases 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 Appendix A1.2 for more details.

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 by most. However, we find negative elasticities for each of the robustness checks. While the exact magnitudes differ across the different robustness exercises, the fact that the ratio of public to private goods decreases systematically with income is extremely robust.

Figure 6: Ratio of Expenditures on Public to Private Goods
by Income Quintile, 1995-2000



Source: Authors' calculations based on CEX data, 1995-2000. Income quintiles, aggregate H, and aggregate V are calculated separately for each age; the quintile results in the Figure are the average across ages.

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 tradeoff 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.[11] 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.[12] Similarly, with heterogeneous household members, specifying how members bargain over spending on public vs. private goods would be quite difficult. We get around these issues by assuming that only identical types, i.e. 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.

[11]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.

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

Since we make a distinction between consumers and households, we use upper case letters to denote quantities per household, and lower case letters to denote per capita quantities.

4.2 Consumers

Adults derive utility from two distinct consumption goods. The first consumption good is denoted by v, and we assume it is consumed privately by a particular adult. The second consumption good is denoted by H and is a local public good, i.e. it can be shared non-rivalrously 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 the paper we will assume the following 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 $\alpha \in (0,1)$.[13] The non-homothetic formulation (when $\sigma \neq \phi$) allows for non-linear 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 vs. 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

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

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 $z(t,i)$.[14] 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.[15]

An adult in this economy maximizes life-time utility by choosing a basket of consumption goods (v,H,v^k) and a household size and composition (S,k) for each point in her life-cycle, subject to a life-time 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:

$$\begin{aligned}
&\max \sum_{a=0}^{A} \beta^{\tau+a} U\big(v(\tau,a,i),H(\tau,a,i),k(\tau,a,i),v^k(\tau,a,i)\big) \qquad (1)\\
&s.t. \sum_{a=0}^{A} p(\tau+a)\left[\frac{H(\tau,a,i)}{S(\tau,a,i)} + v(\tau,a,i) + v^k(\tau,a,i)k(\tau,a,i)\right]\\
&\quad \leq \sum_{a=0}^{A} p(\tau+a)z(\tau+a,i)[1 - B_a(S(\tau,a,i)-1) - B_a^k k(\tau,a,i)]\\
&\quad k(\tau,a,i) \geq 0\ \forall a \quad \text{and} \quad S(\tau,a,i) \geq 1\ \forall a\\
&\quad v(\tau,a,i),h(\tau,a,i),v^k(\tau,a,i) \geq 0
\end{aligned}$$

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

Note that the budget set for this problem is non-convex. 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

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

The parameters of this utility function are restricted in several ways in our calibration. First,

[14] 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.

[15] 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.

we focus our attention on the standard Barro-Becker case, $0 < \alpha < 1$ and $\sigma, \phi < 1$.[16] Second, we need further conditions to ensure that the utility function is concave. $\sigma > 0.5$ is necessary for concavity in h and S. Further, $0 < \phi < 1$ and $1 < \alpha + \phi < 2$ is 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:

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:*

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

2. $\frac{p_t}{p_{t+1}} = 1 + r_{t+1}$ *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

$$
\begin{aligned}
S: &\quad \frac{H}{z} = S^2 B_a \\
v: &\quad \beta^{\tau+a}\omega v^{-\phi} = \lambda p \\
v^k: &\quad \beta^{\tau+a}\delta k^{\alpha-1}\omega (v^k)^{-\phi} = \lambda p \\
H: &\quad \beta^{\tau+a}(1+\delta k^{\alpha}) S H^{-\sigma} = \lambda p \\
k: &\quad \beta^{\tau+a}\delta\alpha k^{\alpha-1}\left\{\frac{H^{1-\sigma}}{1-\sigma} + \omega\frac{(v^k)^{1-\phi}}{1-\phi}\right\} = \lambda p[v^k + zB^k_a]
\end{aligned}
$$

The first equation shows that the marginal benefit of an additional adult in the household is higher, the higher the consumption of the public good H is. The second equation gives the costs and benefits of private good consumption, v. When income is higher (a lower multiplier on the

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

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.[17] In contrast, the marginal utility of public consumption increases both in the number of 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 set-up 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.

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

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 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:

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

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

$$\frac{ds}{dz} = \frac{-\frac{\sigma-\phi}{\phi}(\omega B^{\sigma} s^{2\sigma-1} z^{\sigma-2\phi})^{\frac{1}{\phi}}}{\frac{2\sigma-1}{\phi}(\omega B^{\sigma} z^{\sigma-\phi} s^{2\sigma-1-\phi})^{\frac{1}{\phi}} + 2B}$$

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

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

households devote a higher fraction of income to private goods, so the incentives to form households decline.

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

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

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 moments 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 five 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% 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% that we use, as we explain below. It is also within the range of interest rates reported in the data.[18]

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% annually over the last century and a half.[19] 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. Further, 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 A1.2 and reported in Table A2). 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, as described in Section 3. Since we estimated the elasticity separately for each age group, this gives an additional 12 moments. Lastly, we use that the average child requires about 4% of an adult's time budget.[20] A complete list of the moments, together with the model analogues, is presented in Table A3.

In total, we have 61 moments: S, K, and the income elasticities of S, K, and $H/(V+V^k)$, for each of the twelve 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.

[18]Good interest rate data is 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% (John H. Cochrane 2001). Peter Rupert & Paul Gomme (2007) argue that the return to capital is a more appropriate measure of interest rates for calibration purposes. Long-term returns on equity for developed countries averages 7.1% (Robert J. Barro 2006) while Edward C. Prescott (1986) argues that standard calibrations of RBC models imply a real interest rate of 4%. The number we use is close to the midpoint of the range of reported numbers.

[19]This number is based on Louis D. Johnston & Samuel H. Williamson (2006).

[20]The Bureau of Labor Statistics (2004) provides 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%; for indirect time, it is 4.73%. We use 4% in our calibration.

Instead, we minimize a weighted least-squares loss function. The exact loss function is described in Appendix A2. 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 elasticity parameters in the utility function α, σ, and ϕ. Finally, the average child care time helps pin down δ separately from the level of time costs B_a^k.

Table 2: Calibrated Parameters

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

Figure 7: Costs of Household Formation over Life Cycle
Time cost of adults (B) and children (B^k)

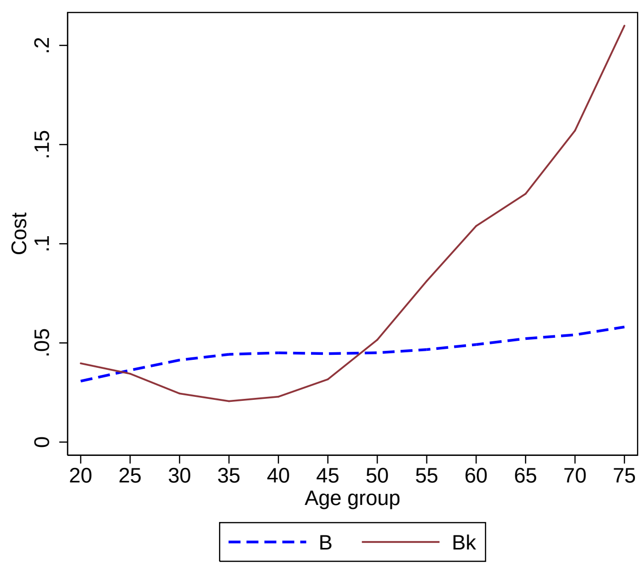


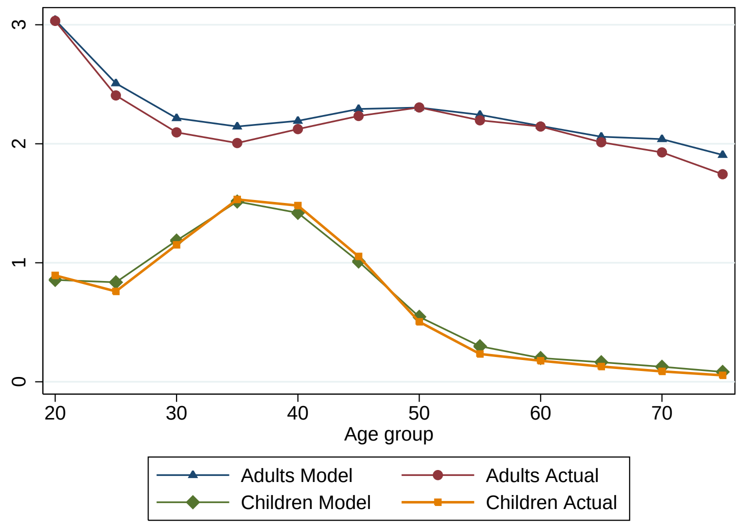
Table 2 gives the calibrated parameters $(\alpha, \delta, \omega, \sigma, \phi)$.[21] The procedure yields $\sigma > \phi$, which is consistent with the hypothesized non-homotheticity in preferences for private and public goods, although the difference between the two parameters is relatively small. 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.

[21]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.

5.1 Fit

The calibrated model generally fits the data well. 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.

Figure 8: Cross-Section Profiles of Household Size
Number of Adults and Children by Age Group
Actual and Predicted



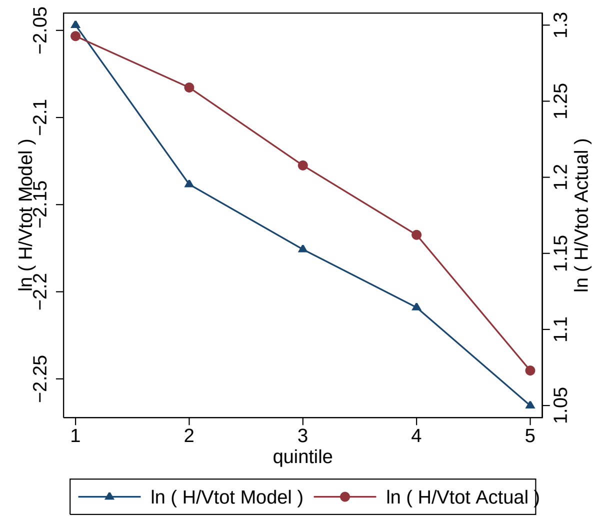
The critical element of our calibration is the relationship between income and the choice variables, which led us to target the cross-sectional elasticities as our main moments. The model should fit the cross-sectional relationship between income and S, K, and the $H/(V+V^k)$ reasonably well before it 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 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.[22]

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 A3.

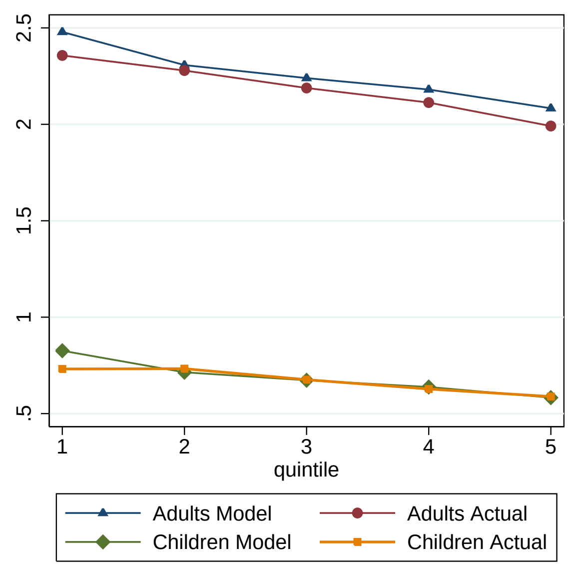
[22] In experiments not reported here, we have tried to include the level as a calibration target. The resulting better match comes at the cost of fitting the elastiticies more poorly. This tradeoff is not surprising in an over-identified model.

Figure 9: Actual and Predicted Relationships with Income

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



(b) Number of Adults and Children by Income Quintile



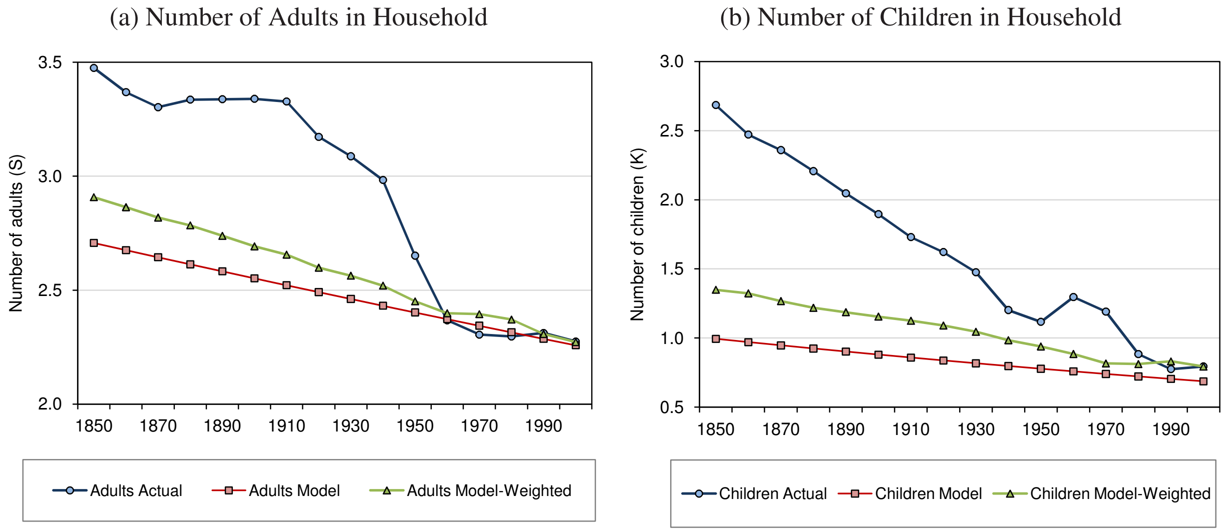
6 Results

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, i.e., it captures 16 percent of the total difference between 2000 and 1850.

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

Figure 10: Actual and Predicted Household Size



one-third 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.

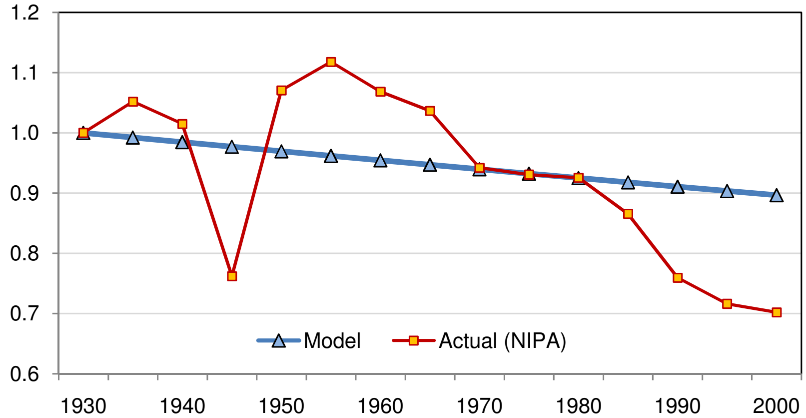
Figure 11 compares the actual and predicted ratios of expenditures on public goods to those on private goods ($H/(V+V^k)$). The actual ratio is taken from Figure 5, i.e. based on U.S. NIPA data. Both series are normalized to take a value of one in 1930. In the data, the $H/(V+V^k)$ ratio in 2000 is 70% that of 1930, while in the model it is 90%. 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.[23]

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

[23]The importance of falling prices of household durable goods for changes in marriage and divorce is emphasized in Greenwood & Guner (2009).

Figure 11: Ratio of Expenditures on Public to Private Goods
Actual and Predicted



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 3 presents the results of the three different experiments. For comparison, the first row presents the baseline results and the second one 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 to 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 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 4).

The fourth row of Table 3 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

Table 3: 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

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.

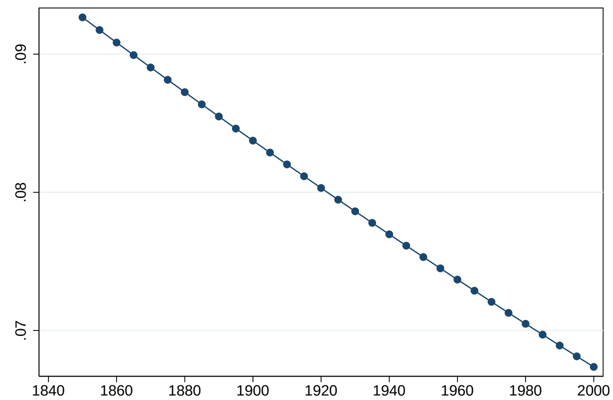
Finally, we explore the case where adults are forced to live alone. We set a high enough cost of living with other adults so that adults of all ages choose to live alone. Then, by construction, the number of adults never changes (Columns 2 and 3 in Table 3). We find that the fall in the number of children in this experiment is very small; it explains only two 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, non-homothetic 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. Further, 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 saving, about 2.5 percent of GDP.

Figure 12: Implicit Household Formation/Maintenance Costs Relative to GDP



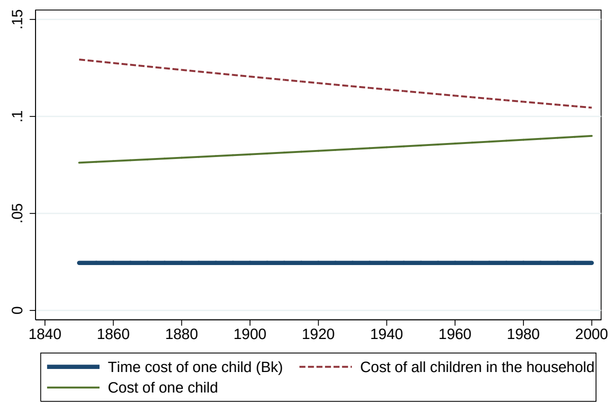
Note: Mean $z[B(S-1)+B^k k]$, across all age groups and quintiles divided by the mean output, $z[1-B(S-1)-B^k k]$, also across all age groups and quintiles.

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 to 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.[24] 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 & Lewis 1973). In our formulation, the quantity-quality tradeoff arises naturally

[24]The U.S. Department of Agriculture produces an annual report measuring expenditures on children; in real terms, expenditures increased about 20% between 1950 and 2008 (Mark Lino & Andrea 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?"

from the composition 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.

Figure 13: Cost of Children
Fraction of time an adult would have to work to pay for the cost



Note: For age group 28 to 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 $(v^k + B^k z)K/z$.

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.

7 Conclusion

Over the course of 150 years, the household of the average American has shrunk 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) in order to capture those elements that are common to all "roommate choices": living with parents, spouses, grandparents, 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 towards 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.

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Appendix

A1 Data

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

A1.1 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, and not group quarters like college dorms, jails, hospitals, or mental institutions, where living arrangements are largely involuntary. Unfortunately, the exact definition of group quarter has varied also across Censuses. In the 1940 to 1970 Censuses, households with five or more persons unrelated to the head are classified as a group quarters. For the 1850 to 1930 and 1980 to 1990 the condition is ten or more persons unrelated to the head.[25] See Ruggles & Brower (2003) for more details.[26] 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 ten or more unrelated persons, and for 1940-1970 those with five or more unrelated persons. Figure A1 shows that the consistent and the mixed measures differ very little. The consistent definition gives

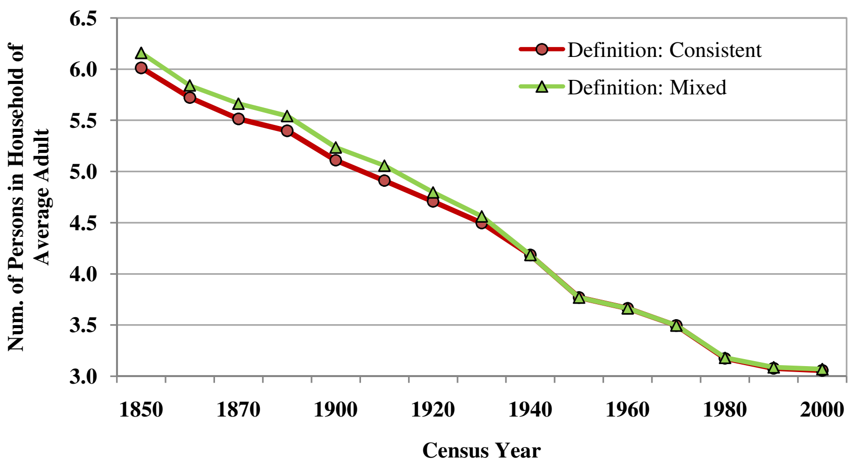
[25] In later years this constraint is not binding. For example in 2000 no households are classified as group quarters based on the number of unrelated members.

[26] These authors also describe some problems with the classification of household members according to their relationship to the head.

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 that were sampled but could not be associated to a group quarter 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.

Figure A1: Household Size by Household Definition



Note: Computed using U.S. Census data. "Mixed" indicates that for the 1850-1930 and 1980-1990 households with more than ten members unrelated to the head are classified as group quarters, as well as those with more than five 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).

Table A1 gives the exact figures used in the paper.

A1.2 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 is collected by the U.S. Census Bureau for the Bureau of Labor Statistics. The CEX consists of two surveys, 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 5 quarters. It records information on about 95% of all expenditures (excluding expenditures for housekeeping supplies, personal care products, and non-prescription drugs). In this paper we use the Interview survey, which also gathers information on income and

Table A1: Different Measures of Household Size

Census Year	Household Members	Family Size	Adults	Children	Obs
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

Note: 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.

socio-demographic 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 is collected on the second to fifth interviews and refer to expenditures made in the previous three months. Figures on income are collected only on the second and fifth interviews.

The main information that we obtain from 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. Secondly, 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), and 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 Morris A. Davis, Andreas Lehnert & Robert F. Martin (2008).

Using the same logic, we classify most durable goods also as public. The non-rivalry 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 & Paxson (1998) who argue 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, 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% 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% 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 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 A2 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.

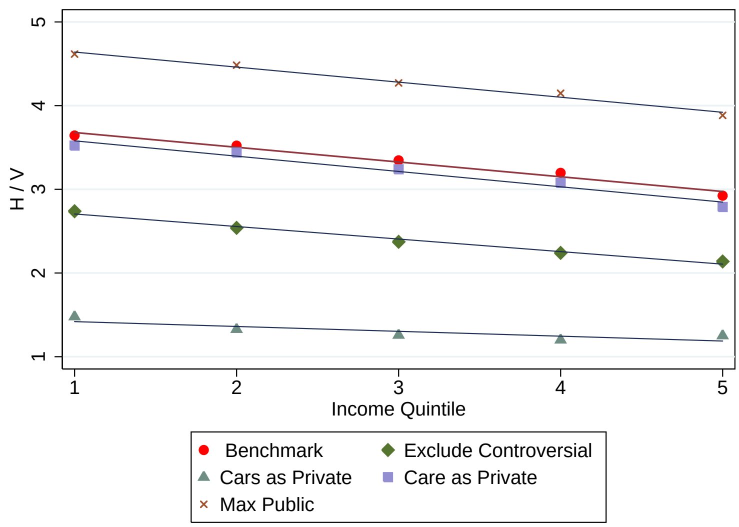
Table A2: Average Household Size by Income Quintiles, 1995-2000

Quintile (relative income)	23-27 year old persons				28-32 year old persons			
	$\frac{\text{Public}}{\text{Private}}$	HH members	Adults	Children	$\frac{\text{Public}}{\text{Private}}$	HH 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

Note: Authors' 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. HH members stands for the total number members of the household.

We have four robustness checks on the classification of goods into public and private. Figure A2 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 this 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 A2, 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.

Figure A2: Ratio of Public to Private Goods by Income Quintile



Note: 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.

A2 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 following loss function

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

$$+\sum_{a=1}^{12}\left(\frac{S^{D}_{a}(a)-S^{M}_{a}(a)}{\frac{1}{12}\sum_{a=1}^{12}S^{D}_{a}(a)}\right)^2 + \sum_{a=1}^{12}\left(\frac{K^{D}_{a}(a)-K^{M}_{a}(a)}{\frac{1}{12}\sum_{a=1}^{12}K^{D}_{a}(a)}\right)^2 + \left(\frac{\frac{\sum_{a=1}^{12}B^{k}_{a}K_a}{0.04-\sum_{a=1}^{12}K_a}}{(0.04)}\right)^2.$$

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

Table A3: Moments in Model and Data

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			

Note: Average S and K by age group are computed using the 2000 U.S. Census. Details are presented in Appendix A1.1. Income elasticities for S, K, and $H/(V+V^k)$ by age group, were computed using 1995-2000 CEX data, as described in Appendix A1.2. Time spent with kids is estimated based on BLS information.