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Understanding Post-War Changes in U.S. Household Production: A Full-Income Demand-System Perspective

By Wallace E. Huffman*

Abstract

This paper examines the changing structure of U.S. household production over the post-World War II period. We apply production theory in order to define a new set of inputs for U.S. households and use newly constructed data so as to examine with the aid of a relatively simple complete household aggregate demand system. The goal is to extend our understanding of the changing structure of the U.S. household sector over the post-World War II period, including the demand for inputs of women’s and men’s housework or unpaid household labor and seven other aggregate input categories. The econometric estimate of the demand system yields plausible price and income elasticities for nine input groups. The own-price elasticity of demand for women’s and men’s housework is shown to be sizeable and similar in size. Women’s and men’s housework are also shown to be complements, rather than substitutes, but the other seven input categories are substitutes for women’s and men’s unpaid housework. Purchased housework substitutes and household appliance services are shown to be much better substitutes for men’s housework than for women’s housework. Also, men’s unpaid housework, household transportation input, recreation input, and “other inputs,” which are largely men’s and women’s leisure time, are luxury goods; and women’s unpaid housework, food at home, housing input, and household appliance input are normal goods. Purchased housework substitute services have an income elasticity that is not significantly different from zero. These results are obtained while controlling for the impacts of trend dominated factors. The methodology applied here has implications for cost of living comparisons over the post-War II period.

Key Words: Complete-demand system, household production, housework, price elasticities, income elasticities, post-World War II.

*C.F. Curtiss Distinguished Professor and Professor of Economics, Iowa State University. I owe a large intellectual debt to T.W. Schultz, who first interested me in the topic and provided much early encouragement. W. Keith Bryant, Peter Orazem, Sonya Huffman, Walt Enders, Giancarlo Moschini, and an anonymous referee provided helpful comments. Diane Herz at the Bureau of Labor Statistics was very helpful in providing data on hours of work for women and men by age group, number of employed and not employed individuals, and on wage rates by age group for women and men. Dale W. Jorgenson shared his data on implicit prices and quantities for services of U.S. household durable goods, and Robert Eisner shared his data on hours of housework for men and women, and I am grateful to them. Several graduate students have worked on this project: Chiho Kim, Tubagus Feridhanusetyawan, Alan McCunn, Jingfing Xu, and Matt Rousu. Cindy Pease provided valuable editorial assistance. The Iowa Agriculture and Home Economics Experiment Station supported this project.
A major revolution in the household sector occurred in the 20th Century as a result of inventions of labor-saving electrical appliances, central heating, piped hot and cold water, flush toilets, manufactured clothing, processed foods, the falling relative prices of these goods, and adoption by households of new basic facilities, electrical appliances, and other new goods (see figure 1). At the beginning of the 20th Century, housework was hard physical work and consumed a large amount of woman’s time, but by the eve of the century it had been converted into modest amounts of relatively light work. A careful examination of these changes has been limited by a scarcity of needed data.1

World War II brought hardships to the household sector—resources, especially the production of durable goods, were diverted to produce tanks, planes, jeeps and guns to win the war. The stock of household appliances declined significantly over 1940 to 1945 (Greenwood et al., 2005). During the immediate post-World War II period, the production of durable goods was redirected to civilian uses, including household appliances, automobiles, and houses. The technology embodied in these goods also changed steadily. By the 1980s, computers were introduced into electrical appliances, which decreased greatly their need for direct personal attention as they carried out various tasks in the home. Jorgenson and Stiroh (1999) have shown that the U.S. household sector responded in the past 25 years in a predictable way to the dramatic decline in the relative price of computers and other information technologies.2

The objective of this paper is to examine the changing structure of U.S. household production over the post-World War II period by using relatively simple, but powerful, demand theory, and paying attention to conceptual issues in the derivation of empirical counterparts of key variables. I apply production theory in order to define a new set of inputs for U.S. households and use newly
constructed data so as to examine the changing structure of the U.S. household sector over the post-
World War II period, including the demand for inputs of women’s and men’s housework or unpaid
household labor and seven other aggregate input categories.\textsuperscript{3} The main hypotheses are that changes in
demand for and composition of inputs in U.S. household production over the post-War II period can
be explained by changes in relative input prices, real income, and a small set of other variables while
controlling for a time trend.\textsuperscript{4} Since the household sector is large relative to the market sector,
measured on an input our output basis (Benhabib et al. 1990), our research is particularly valuable to
macroeconomic economists who are attempting to better understanding the performance of the macro
economy, especially how homework substitutes for purchased inputs; see for example, Benhabib et
during the late 20\textsuperscript{th} Century, I show that this is not due to decreased leisure but most likely due to the
high real price of time by historic standards.

A generalized version of Becker’s productive household model, i.e., that inputs are used to
produce abstract commodities that are the source of utility to households, provides the basic
conceptual framework.\textsuperscript{5} However, given that the commodities/outputs are generally viewed as
unobservable, I follow Jorgenson and Stiroh (1999), systematically applying production theory to the
inputs going into household production and focusing the discussion on the demand for inputs and not
on commodities. That is, labor and capital services and intermediate goods are inputs into household
production, and purchased capital goods or investments in consumer durables are not (Jorgenson and
Stiroh 1999). The new labor inputs are unpaid housework and leisure of a household’s adult
members. Capital services are proportional to the stock of consumer durables, but aggregation
requires weighting the stocks by rental prices rather than acquisition prices for assets. The rental
price for each asset incorporates the rate of return, the depreciation rate, and the rate of decline in the
acquisition price. Hence, households demand housework, leisure, nondurable consumption goods and services, and the services of household durable goods (Becker 1965, Michael and Becker 1976, Gronau 1977, Committee on National Statistics 2000).

Using newly constructed data, I show that during the post-World War II period, the price of women’s and men’s housework rose relative to the prices of all inputs in household production (Schultz 1972, Council of Economic Advisors 2001); and for women’s housework, the rise was most dramatic from 1948 to 1980 and minimal thereafter. Results from econometric estimates of an aggregate complete household demand system for nine input categories show women’s and men’s unpaid housework are complements rather than substitutes, but the other seven input categories are substitutes for women’s and men’s housework. Substitute inputs for unpaid housework include purchased substitute services (laundry and dry clean services, domestic services and food away from home) and household appliance services, but my results show that these inputs are more highly substitutable for men’s than women’s unpaid housework. Also, I find men’s unpaid housework, household transportation input, recreation input, and “other inputs,” which are largely men’s and women’s leisure time, are luxury goods; and women’s own housework, food at home, housing input, and household appliance input are normal goods. Purchased housework substitute services have an income elasticity that is not significantly different from zero. Two fundamental changes in the demographic attributes of the U.S. population over the post-War II period have been in the age distribution—share under age 5 and over age 65—and in the metro-nonmetro location, and they have affected the structure of household demand. Our estimates of price and income elasticities are not dominated by trend, because we find statistically significant price and income elasticities after allowing for a linear time trend that controls for trend dominated factors in each demand equation.
The paper begins with a discussion and assessment of time uses by U.S. women and men over the post-World War II period. Section two and three present the economic model of consumer demand and the econometric model, the data, and the variables. Section four presents the empirical results and their interpretation, and the final section presents conclusions and implications.

**Background on Time Allocation**

Time allocation of U.S. women who are not in school has changed significantly over the post-World War II period. The changes for men have been modest. Legal and social restrictions on married women’s work in the labor market, i.e., “self-protection” legislation, existed from roughly 1850 to 1950 (Goldin 1990). They greatly reduced the effective supply of female labor to the U.S. labor market for a century. Although this restriction was temporarily loosened during World War II, it was not until about 1950 that long-term job opportunities for married women started to open up, including those for regular part-time work. For married women with children under age 6, the labor force participation rate was under 10 percent in 1948, but since then it has risen, especially after 1970, to the rate for all women of over 60 percent. This represents a dramatic increase in the supply of female labor in the market.

Bryant (1996) presents one of the few consistent early comparisons of the hours of women’s housework. He estimates that in the mid-1960s the average amount of time U.S. *married women* allocated to housework—time allocated primarily to food preparation and cleanup, house and garden care, care of clothing and linens, care of family members, and marketing and management—was 44.2 hours per week (6.31 hours per day). This was a reduction from 51.5 hours per week in 1925 (7.35 hours per day), and all major categories of housework declined except for management and marketing, which increased by 20 percent. Juster and Stafford (1991) report that the average amount of housework of *U.S. women*, 25-64 years of age, was 41.8 hours per week in 1965 (6 hours per day),
and it decreased to 30.5 hours (4.4 hours per day) in 1981, or by 31.5 percent. Average hours of labor market work, including commuting, increased from 20.5 hours per week in 1965 to 25.9 hours in 1981. Hence, their data show women’s hours of leisure time rose over this time period.

For men, fewer estimates of housework exist. Juster and Stafford report that in 1965 housework for men 25 to 64 years averaged 11.5 hours per week (1.64 hours per day), and it increased to 12.8 hours per week (1.83 hours per day) in 1981. Men’s average weekly hours of market work, including commuting, was 56.2 hours in 1965 and declined to 47.5 hours in 1981. Juster and Stafford’s data show that men’s housework relative to women’s housework and men’s leisure increased over 1965 to 1981.

Robinson and Godbey (1997, pp. 329) provide the most extensive data, starting in 1965, on housework for U.S. women and men, 18-64 years of age and for age 65 and older. Focusing on women 18-64 years old, they report average weekly hours of housework of 40.3 (5.76 hours per day) in 1965, 32.9 (4.70) in 1975, 30.7 (4.39) in 1985, and 27.4 (3.91) in 1995. In contrast to women, their data for men 18-64 years show an increase in average weekly hours of housework over time: 11.3 (1.61 hours per day) in 1965, 12.3 (1.76) in 1975, 15.7 (2.24) in 1985 and 15.6 (2.23) in 1995. Thus, for women the most dramatic change was the 7.4 hours per week or 20 percent reduction from 1965 to 1975, which is also a time period when the number of children per adult was declining steadily and dramatically (see figure 2). For men, the rate of change is positive but slow. In conclusion, these prior studies suggest that the hours of women’s household work have declined, especially over 1965 to 1975, and the hours of housework of men have generally risen since 1965.

Now firms use a diverse set of skilled women’s (and men’s) labor and other inputs and economies of scale to produce and market consumer and producer goods, services, and durables. Services of new consumer durable and other consumer goods and services substitute largely for
women’s housework and reduce the drudgery of doing laundry and ironing, carrying water, doing spring house cleaning, and speed up the preparation of meals and many other things (Bryant 1986; Greenwood et al., 2005).

Major changes in households include less time allocated by women to preparing meals and meal clean up at home and more meals consumed away from home. Frequently, workday lunches are purchased and eaten at school or work, and weekend dinners are eaten in restaurants. When meals are at home, ready-to-eat food is frequently purchased at fast-food restaurants, grocery delis, or other restaurants (take-out) and taken home to be eaten. When meals are prepared at home, microwave ovens with timers and electric and gas ranges with thermostatically controlled burners and ovens speed cooking and give control over the temperature with low supervision, which leads to a higher quality product. These appliances are technically advanced relative to the coal, wood, kerosene, and LP gas burning cooking stoves of the late ‘40s (Bryant 1986).

Fifty years ago married women allocated significant time to making and caring for clothing and linens, but new technologies (see figure 1) have been substituted for this work. “To make” versus “to buy” was an important decision in 1948, but today, ready-to-wear clothing is the norm, which is a major labor saver for women, and hand-made is the exception. In the late forties, U.S. households used relatively primitive motorized clothes-washing machines with wringers. Doing the laundry involved handling heavy wet clothing, including carrying it outside in baskets to be hung on elevated clotheslines to dry in the open air, with perhaps in sun. Today, almost all households have an automatic clothes washer and dryer (figure 1) or access to a Laundromat, and wash-and-wear or non-wrinkle (and hence, non-iron) fabrics are available, and “casual dress” for work has become acceptable dress. Doing the laundry, which remains largely women’s work (Robinson and Godbey 1997), requires little time and only modest human effort relative to the more distant past (Bryant
Mechanical and electrical power (see figure 1) have been substituted for women’s time and effort. Also, automatic clothes washers and dryers, having enhanced performance attributes associated with a broader range of water and fabric settings. Hence, the quality of these services continues to change and improve with the introduction of new goods. Modern dishwashers, also, have been adopted by households, and they are both a time and human energy saver, and facilitate sanitizing at the same time, which is a quality improvement.

Leisure time, or time allocated primarily to leisure activities, has a traditional meaning of pleasurable time (Robinson and Godbey 1997; Committee on National Statistics 2000, pp. 15-18; Gronau 1977). There is also low substitutability between own time and market inputs in leisure activities relative to household production. During the past half-century, the capital intensity of leisure-time activities has increased, too, but leisure activities remain relatively human-time intensive. In the 1950s individuals engaged in time-intensive leisure activities—active conversation with family members, relatives, and friends; reading books; playing games; participating in social organizations; and less than 10 percent of households had a television. Today, however, approximately 50 percent of leisure time is allocated to television viewing, video games, and surfing the web (Robinson and Godbey 1997). Furthermore, major technical advances in television sets have occurred—from small black and white TV sets receiving an average of 3 to 4 stations in the 1950s and 1960s to today, where household’s consume TV services on large-screen color TVs, frequently connected to cable or satellite reception and VCRs or DVDs, and providing a large number and range of viewing opportunities. Most have remote control electronic devices for changing channels and sound volume without leaving an easy chair. In the 1950s and 1960s these changes had to be made manually by an individual walking to the TV and turning a knob. Hence, technology and services of consumer-durable goods have also been substituted for human time in leisure-time activities.
The Economic Model: Consumer Demand for New and Other Goods

Consider consumer welfare in a market economy where new goods are being introduced and the quality of old goods are changing regularly (Fisher and Griliches 1995; Hausman 1996; Boskin et al. 1998). These three papers show that excluding “new goods” from the cost of living index can cause major biases. In particular, if the good is truly new and excluded for some time from the cost of living index, but later added, the measured cost of living index will generally overestimate the true cost-of-living and underestimate increases in social welfare. The main reason is that a new good is in some sense available at a very high shadow price (Fisher and Griliches 1995; Hausman 1996). The point we will make is that excluding the price of women’s and men’s housework (and leisure time) from cost of living indexes is analogous to excluding the price of a “new” good from the cost of living index, i.e., this practice causes a major bias in cost of living.

Designate as the virtual (or implicit) price $p^V_1$ for a “new” good $X_1$ or goods that are initially excluded from the cost of living index, we can consider the consumer’s optimal and voluntarily chosen level of $X_1$, which might be zero:

$$X_1 = x^V_1 (U_0, p^V_1, p_2).$$

That is, the virtual price is an implicit function of the zero quantity of a new good (housework, leisure and services of consumer durables), prices of the market-supplied goods and services, and utility $U_0$. Given the virtual price $p^V_1$, the Hicksian demand functions with zero quantity available ($x^V_2$) equal the Hicksian-demand functions without free availability ($x^{Re}_2$):

$$0 = x^{Re}_2 (U_0, p_1, p_2, X_1) = x^V_2 (U_0, p^V_1, p_2).$$
Virtual Prices and Consumer Demand

The virtual-price or shadow-price demand system presented below is developed using a modification of the cost function associated with the almost-ideal-demand system (AIDS) and draws on previous work by Deaton and Muellbauer (1980b), Fisher and Griliches (1995) and Huffman and Johnson (2004). The virtual-price form of the cost function of the almost-ideal demand system (AIDS) in logarithmic form is:

\[
\log C(U_0, p_1^V, p_2) = (1 - U_0) \log [a(p_1^V, p_2)] + U_0 \log [b(p_1^V, p_2)],
\]

where \( C(U_0, p_1^V, p_2) \) is the cost function, \( p_2 \) is an \( h \)-vector of market prices, \( p_1^V \) is a \( k \)-vector of virtual prices (prices of rationed goods), where \( h + k = n \), and \( U_0 \) is the utility level. For \( a(p_1^V, p_2) \) and \( b(p_1^V, p_2) \) specific functional forms are given, which are positive, linearly homogeneous, and concave in prices. Following Deaton and Muellbauer (1980b), a translog flexible-functional form is chosen for \( a(p_1^V, p_2) \) which depends both on market and virtual prices. That is,

\[
\log a(p_1^V, p_2) = \alpha_0 + \sum_{j=1}^{k} \alpha_{ij} \log p_{1j}^V + \sum_{j=k+1}^{n} \alpha_j \log p_{2j}
\]

\[
+ 1/2 \left[ \sum_{i=1}^{k} \sum_{j=1}^{k} \gamma_{i}^{**} \log p_{i}^V \log p_{1j}^V \right]
\]

\[
+ \sum_{i=k+1}^{n} \sum_{j=k+1}^{n} \gamma_{ij}^{**} \log p_{2i} \log p_{2j}
\]

\[
+ \sum_{i=1}^{k} \sum_{j=k+1}^{n} \gamma_{ij}^{**} \log p_{i}^V \log p_{2j}
\]

\[
+ \sum_{i=k+1}^{n} \sum_{j=1}^{k} \gamma_{ij}^{**} \log p_{2i} \log p_{1j}^V.
\]
Compared to the standard AIDS model, the linear portion contains an extra term, 
\[ \sum_{j=1}^{k} \alpha_{ij} \log p_{1j}^{V} \], involving virtual prices, and the quadratic part includes extra cross-product terms. The function \( b(p_{1}^{V}, p_{2}) \) is defined as

\[ \log b(p_{1}^{V}, p_{2}) = \log a(p_{1}^{V}, p_{2}) + \prod_{j=1}^{k} p_{1j}^{V} \beta_{ij} \prod_{j=k+1}^{n} p_{2j}^{V}. \]  

(5)

Substituting the expressions for \( a(p_{1}^{V}, p_{2}) \) and \( b(p_{1}^{V}, p_{2}) \) into the cost function (3) and applying Shepard’s lemma yields the budget/expenditure shares (Deaton and Muellbauer 1980a). Note that these shares are derived from the virtual-cost function (3). Therefore, they are themselves conditional upon the vector of virtual prices, in addition to being functions of market prices and utility. Substituting the expression for utility from the cost function into the virtual-share equations gives an equation for the expenditure share denoted as \( w_{i} \mid p_{j}^{V} \):

\[ w_{i} \mid p_{j}^{V} = \alpha_{i} + \sum_{j=1}^{k} \gamma_{ij} \log p_{1j}^{V} + \sum_{j=k+1}^{n} \gamma_{ij} \log p_{2j}^{V} + \beta_{i} \log \left[ I^{V} / a(p_{1}^{V}, p_{2}) \right], \quad \text{for } i=1 \text{ to } n, \]  

(6)

where \( \gamma_{ij} = 1/2(\gamma_{ij}^{*} + \gamma_{ij}^{*}) \), and \( \gamma_{ij} = 1/2(\gamma_{ij}^{*} + \gamma_{ij}^{*}) \). If \( \log a(p_{1}^{V}, p_{2}) \) is replaced by the Stone price index \( \log P(p_{1}^{V}, p_{2}) = \sum_{i=1}^{k} w_{i} \log p_{1i}^{V} + \sum_{j=k+1}^{n} w_{j} \log p_{2j}^{V} \), the virtual-share equations become linear,

\[ w_{i} \mid p_{j}^{V} = \alpha_{i} + \sum_{j=1}^{k} \gamma_{ij} \log p_{1j}^{V} + \sum_{j=k+1}^{n} \gamma_{ij} \log p_{2j}^{V} + \beta_{i} \log \left[ I^{V} / P(p_{1}^{V}, p_{2}) \right], \quad \text{for } i=1 \text{ to } n. \]  

(7)

Qualitative demographic or “translating” variables, which are related to equivalence scales (Muellbauer 1977; Deaton and Muellbauer 1980a), are introduced into the demand systems to incorporate effects associated with the changing age distribution of the population over the post-War II period and its metro-nonmetro composition:
\[ w_i \mid p_i^v = \alpha_i^{**} + \sum_{j=1}^{k} \gamma_{ij} \log p_{1j}^v + \sum_{j=k+1}^{n} \gamma_{ij} \log p_{2j} + \beta_i \log \left[ I^v / P(p_i^v, p_j) \right], \] (8)

where \( \alpha_i^{**} = \alpha_i + \sum_{s=1}^{S} \delta_{is} D_s \), \( D_s \) are the translating variables, and the following restrictions are imposed on the demand system: homogeneity of degree zero of prices and income or

\[ \sum_{j=1}^{k} \gamma_{ij} + \sum_{j=k+1}^{n} \gamma_{ij} = 0 \text{ for } \forall i; \]

symmetry of cross price effects or \( \gamma_{ij} = \gamma_{ji} \) and \( \gamma_{ij} = \gamma_{ij} \); and adding

\[ \sum_{i=1}^{n} \alpha_i^{**} = 1, \sum_{i=1}^{n} \delta_i = 0, \sum_{i=1}^{n} \gamma_{ij} = 0 \text{ for } \forall j, \text{ and } \sum_{i=1}^{n} \beta_i = 0, \]

which implies that the coefficients of one of the demand equations can be recovered residually.

The responsiveness of the demand for inputs into household production are summarized by income/expenditure and price elasticities. The income/expenditure elasticity of demand for the \( i \)-th input is

\[ \eta_{IE} = 1 + \beta_i / w_i \text{, } i = 1, \ldots, n. \] (9)

The Hickian compensated own price elasticities are

\[ \xi_{ii} = \gamma_{ii} / w_i + w_i - 1, \text{ } i = 1, \ldots, n, \] (10)

and the compensated cross-price elasticities are

\[ \xi_{ij} = \gamma_{ij} / w_i + w_j, \text{ } i, j = 1, \ldots, n. \] (11)

The income elasticity of any input group can be positive, negative or zero. However, the expenditures-share weight income/expenditure elasticities must sum to unity. To be consistent with demand theory, the compensated own-price elasticity of demand must be negative. The cross-price elasticities are positive for substitutes and negative for complements. Letting all input prices change by 1 percent and focusing on the demand for the \( i \)-th input, the expenditure share weighted compensated price elasticities is zero.
Cost-of-Living Indexes

Modern treatments of social income or national income accounting date back to Hicks (1939, p. 172). He states, “The purpose of income calculations in practice is to give people an indication of the amount which they can consume without impoverishing themselves.” In this framework, consumption and investment are largely limited to legal goods and services that pass through the marketplace. This means that they miss output associated with household production, leisure, rising life expectancy, changes in the quality of resources and the environment. It is production-based because it attempts to measure the rate of production at a given time (Nordhaus 2003, p. 9-13; Becker et al. 2005).

The most commonly used measure of the cost-of-living in the United States is the U.S. Department of Labor’s consumer price index (CPI) (Boskin et al. 1998; Fisher and Griliches 1995; Diewert 1976). This is essentially a Laspeyres price index—\( L(p^1, p^0) = \frac{\sum p^1 x^0}{\sum p^0 x^0} = \frac{\sum p^1 x^0}{I_0} \), where \( p_0 \) and \( p_1 \) are the prices under the two different time periods, and \( x_0 \) is the quantity for the beginning period. The Laspeyres price index gives an upward biased estimate of the cost-of-living, because in keeping constant weights for the base-period basket of goods as relative prices changed, it does not account for substitution among commodities (Boskin et al. 1998; Deaton and Muellbauer 1980a). In short, the Bureau of Labor Statistic’s CPI is a relatively crude instrument for measuring the impact of the treatment of housework, leisure and durable household goods on welfare. The implicit price deflator for personal consumption expenditures (IIPD) of the Bureau of Economic Analysis (BEA) is somewhat better than the CPI for long-term comparisons because it is a superlative price index (Diewert 1976), and the BEA makes regular revisions backward and forward associated with new information on quality change and introduction of new goods. The CPI is never revised backward; new procedures only go forward.
Following Deaton and Muellbauer (1980a), the true-cost-of living index, when there are “new goods” can also be obtained by invoking the theory of consumer demand. It is derived from the consumer expenditure function as the ratio of the minimum expenditures in two different time periods necessary to maintain a given utility level (as opposed to a constant basket of goods as in the Laspeyres price index). The base-period-weighted true-cost-of-living index is

\[
P(p^0, p^1, U^0) = \frac{C(U^0, p^1)}{C(U^0, p^0)},
\]

(12)

where \( U^0 \), the base utility level, is equal to \( \log \frac{I^V}{a(p^0)}/\log \frac{b(p^0)/a(p^0)}{a(p^0)} \), \( p^0 \) is a vector of market and virtual prices for the base period, and \( p^1 \) is a vector of market prices for the current period.

The true cost-of-living index can be calculated from the cost/expenditure function \( C(U, p) \). From the estimated complete system of demand equations, I can find the cost function. Using the estimated parameters from the virtual AIDS model, the indirect utilities can be derived from the functional forms in equations (4) and (5) and, finally, the virtual cost-of-living indices from equation (12). The cost-of-living indices show the impacts of the introduction of new goods or quality change in “old goods” between the base and current period.

With the estimated coefficients from the virtual AIDS and the standard AIDS, indirect utility can be calculated. The compensating variation given by the difference in cost functions or \( CV = C(p^1, U^0) - C(p^0, U^0) \) can be evaluated directly. Positive differences indicate that households experienced a welfare loss as a result of the introduction of new goods. Finally, the change in real total income/expenditure can be used to show the total welfare change during a period of introduction of “new goods” or quality change in old goods resulting from private and public R&D.

**The Econometric Model, Data and Variables**

A brief discussion of the econometric model, data, and results follows. In the econometric model, I take the heroic step of specifying a relatively simple complete household demand system. A
description of the refinements of the data are next presented, the model is fitted and then key econometric results are presented and interpreted.

**The Econometric Model**

The empirical specification of the full-income household AIDS demand system to be fitted to U.S. aggregate data is derived from equation (8), including symmetry, homogeneity, and adding-up restrictions, and presented here

\[
 w_{it} = \alpha_{i0} + \sum_{s=1}^{S} \delta_{is} D_{s} + \sum_{j=1}^{k} \gamma_{ij} \log p_{1ji} + \sum_{j=k+1}^{n} \gamma_{ij} \log p_{2ji} + \beta_{i} \log \left( \frac{I_{i}}{P(\ p_{1i}, p_{2i})} \right) + \phi_{it} + u_{it}, \tag{13}
\]

where \( \alpha_{i0} \) is a time-invariant unobserved effect for input \( i \), \( p_{1ji} \) is the price of nontraditional inputs, e.g., housework, leisure, and of services of household durable goods, \( p_{2ji} \) is the price of traditional inputs, e.g., food at home, housing, \( \phi_{it} \) represents the effects of time trend-dominated factors on input \( i \), \( u_{it} \) is a random disturbance term that captures other effects on the demand for input \( i \) and year \( t \), \( i = I, ..., n \) denotes the input categories, and \( t = I, ..., T \) denotes the years (Wooldridge 2002, p. 251-258). \( ^{11} \) Trend \( (t) \) controls for the effect of other trend dominated factors, for example, changes in schooling, life expectancy, marriage and divorce and single parent family rates, share of the population that are immigrants and air quality and hence, improves the quality of the estimates of the \( \gamma \)s and \( \beta \), which are central to price and income elasticity computations. With the n-expenditure shares being endogenous and expenditure shares summing to one, one of the share equations can be deleted. Its parameters can be recovered from the other (n-1) estimated equations and the parameter restriction on the AIDS demand system.

How do we know that the estimated coefficients of the ln(relative prices) and ln(real income/expenditure) are identifying a demand system? If, for example, the supply of each input is perfectly elastic, then shifts in the supply curves would identify the demand curves. For example, if
the household sector were a small sector in the complete U.S. economy for each of the input groups or inputs are purchased in an international market, this would support a perfectly elastic interpretation of supply elasticities and identification. The international market interpretation might apply to nonperishable foods, clothing, shoes, and automobiles, but unpaid housework, housing services and recreation seem likely to be “nontraded goods.” Although we will impose a set of restrictions (located under equation (8)) that are consistent with our set of equations being a demand system, this does not guarantee that all own-price elasticities will be negative. Hence, one consistency check on our econometric model is that it yields negative own-price elasticities. Finally, one might think of the household sector being one part of a much more complicated market oriented economy this is undergoing technical change. This, however, would greatly complicate our analysis, and we leave this exercise to later research.

Equation (13) has two random unobserved terms—$\alpha_{i0}$ and $u_{it}$. Furthermore, $\alpha_{i0}$ may be correlated with the other regressors and $u_{it}$, and if the system were estimated in level form, this would, in principle, bias all the estimated coefficients. The additive disturbance terms $u_{it}$ in equation (13) satisfies the usual stochastic assumptions (having a zero mean, finite variance, first-order autoregressive process over time, and contemporaneous correlation across share equations). To remove unobserved heterogeneity in each demand equation and to fully accommodate the time-series properties of the demand system, the (n-1) expenditure-share equations are treated as a system of first-order difference equations (i.e., $\rho$, the autocorrelation coefficient in each equation, is one) with a commodity-specific constant term (the $\phi_i$ in equation (13)). After removing the unobserved effect $\alpha_{i0}$ from each demand equation and transforming the disturbance term in the difference equations, the model is almost certainly covariance stationary (see Wooldridge 2002; Enders 1995, pp. 216–224; and Bemdt and Savin 1975). Hence, even if we use trend or linear interpolation to derive average
daily hours of housework for women and men between benchmark years, estimating the first-difference version of equation (13) means that a time trend cannot be a major factor determining our resulting price and income elasticity estimates. Moreover, in the differenced version of equation (13), the intercept terms become the coefficient of trend in the expenditure share equations, or \( \phi_i \). The differencing of equation (13) does mean that we elevate the relative importance of “noise” and measurement error in the fitted equations (Wooldridge 2002).

The (n-1) differenced demand equations can be configured as a stacked system of difference equations having the form of the seemingly unrelated regression model with contemporaneous cross-equation correlation of disturbances (Greene 2003, pp. 340-350). The iterative feasible generalized least-squares estimator is consistent, asymptotically efficient, and asymptotically equivalent to the maximum likelihood estimator (Barten 1969). The latter results are invariant to the equation dropped or residually computed to accommodate the singularity of the error covariance matrix. The share equation for the n-th commodity group, which is of secondary interest to this study, will be deleted in this application, and its parameters recovered using the restrictions on the parameters. The estimation is conducted using the ISUR procedure in SAS applying Gauss.

**The Data**

Econometrically, I am limited on the total number of major input categories across full-expenditures or parameters of the demand system that can be estimated from an annual time series, but aggregation or formation of groups is somewhat arbitrary. I am interested in the extent to which men’s housework, services of household appliances, housing, purchased consumer goods and services substitute for women’s housework. I minimize aggregation problems by using the Tornqvist index formula (Diewert 1976) to aggregate components within major input quantity and price groups.
Major input groups. The major types of products for personal consumer expenditures in the National Income and Product Accounts are: durable goods (motor vehicles and parts, furniture and household equipment, and other durable goods), nondurable goods (food, clothing and shoes, fuel, and other nondurables), and services (housing, household operation, transportation, medical care, recreation, and other services). (See the U.S. Department of Commerce). Guided by the objectives of this study and limits on the total number of parameters that can be estimated for an aggregate demand system, I define nine major and comprehensive input groups: (i) women’s (unpaid) housework, (ii) men’s (unpaid) housework, (iii) food-at-home, (iv) purchased housework SUBSTITUTE services (domestic services, laundry and dry-cleaning services, and food away from home), (v) housing services (for owner occupied and rental), (vi) services of household appliances (including imputed services from computers and furnishings owned and household utilities), (vii) transportation services (imputed services of transportation capital owned, purchased transportation services, and fuel for transportation), (viii) recreation services (imputed services of recreation capital owned and recreation services purchased), and (ix) other goods and services (largely men’s and women’s leisure and other purchased services; see U.S. Department of Commerce).

Clearly since the major objective of the study is to understand the changing demand for inputs in household production over the post-War II period when the use of men’s and women’s time tend to be allocated to different types of housework and the use of their time in housework was moving in the opposite direction over the post-War II period, it makes no sense to aggregate men’s and women’s housework together. In this study, the so-called “new goods” are women’s and men’s housework and leisure which have traditionally been excluded from household demand systems, and the imputed services of consumer durables that replace purchases of consumer durable goods. However, I use current- and constant-dollar consumer expenditure components on nondurable goods
and services taken directly from the National Income and Production Accounts (U.S. Dept. of Commerce).

**Human Time: housework, market work, leisure time, and other time.** I choose to scale down the average daily time endowment from 24 hours and define a modified time endowment of 14 or 15 hours per day by excluding time allocated to sleep, personal care, and eating (i.e. personal care). No evidence exists of significant trend in time allocated of personal care by women and men, i.e., personal care time is unresponsive to prices and income or even trend (see Robinson and Godbey 1997, pp. 337). Ramey (2005) also uses the same type of modified time endowment in her research. Each individual of aged 16 and older who is not in school is assumed to allocate his/her modified time endowment among unpaid housework, market work, including commuting, and leisure. Housework is defined as time allocated primarily to food preparation and clean-up; house, yard, and car care; care of clothing and linens; care of family members; and marketing and management; which is considerably broader than what is frequently labeled as “core housework”—cooking, cleaning and washing dishes, doing the laundry, and cleaning and straightening the house. Market work includes work for pay and commuting time to work. Time allocated to leisure or free time is time allocated primarily to social organizations, entertainment, recreation, and communications. It, however, is defined residually for each individual as his/her allocatable time endowment less hours of housework and hours of market work.

The (modified) time endowment is set as follows. For women and men aged 16 to 64 who are not enrolled in school, the modified endowment is assumed to be 14 and 15 hours per day, respectively. The size of these modified time endowments is based on information presented in Robinson and Godbey 1997, pp. 337, and the average size of these gender differences is also supported by the information presented by Juster and Stafford (1991, p. 477) for U.S. men and
women in 1965 and 1985. For women and men who are 65 years of age and older, the modified time endowment is assumed to be 13 and 14 years, respectively. In deriving aggregate average hours of paid work and of unpaid housework, a distinction is made between employed and not employed women and men (not in school), because from 1948 to 1996 these shares have changed significantly. (See Appendix A, figure 1)

The annual hours of unpaid housework for working and nonworking women and men aged 16-64 who are not in school were derived as follows. First, benchmark values for average daily hours of housework were derived from the literature and are summarized below for 1950, 1965, 1975, 1985, and 1995. See Appendix A for details. Second, average daily hours of housework for years between benchmark years were obtained by linear interpolation daily hours between benchmarks years. Third, to extend the series back to 1948, I assume that the average rate of decline in hours of housework over 1948-1950 was twice the rate for 1950-1965 because of the rapid post-war construction of new housing at this time and then worked backward from the 1950 benchmark. Fourth, the series on average daily hours of housework were extended to 1996 by linearly interpolating over 1995-1996 at the average annual rate of change over 1985-1995. Fifth, annual hours of housework per person aged 16-64 and not in school were obtained my multiplying average daily values by 365 days per year (see figure 3). A national total number of hours of housework for employed and not employed women and men aged 16-64 was obtained by multiplying annual hours of housework by the Census Bureau number of persons who were in the civilian population net of those enrolled in school (see Appendix B, figure 1). Figure 3 presents a plot of our final estimates of annual average hours of housework for employed and not employed women and men aged 16-64 and not in school.
Although U.S. Department of Labor data may not be perfect for deriving data on hours of work for pay (for example, paid vacation and sick leave may be included) they provide a large amount of detailed data. They include average weekly hours of work for pay for women and men by age group (16-19, 20-24, 25-34, 35-44, 45-54, 55-64, and 65 and older). I use the U.S. Department of Labor’s data to derive weighted average hours of work for pay for men and women who are employed and not enrolled in school. For employed women aged 16 to 64 (not in school), aggregate average weekly hours of work for pay were 37.6 in 1948, 35.1 in 1965, 35.2 in 1985, and 35.7 in 1996. For employed men aged 16 to 64 (not in school), aggregate average weekly hours for pay were 45.2 in 1948, 43.3 in 1965, 42.0 in 1985, and 42.3 in 1996. Thus, for employed women, average weekly hours declined early in the post-war period, and then a little after 1965. For employed men, the trend was downward to 1985, and then a slight increase. See Appendix B, figure 2 for a graphical summary of data on average hours worked for pay of men and women.

Although Robinson and Godbey (1997) provide a slightly different interpretation of hours of work for pay from 1965 to 1995 than the U.S. Department of Labor, they provide the most extensive data on commuting time. For 1965 to 1995, I use Robinson’s and Godbey’s estimates of average amount of commuting time to work for employed women and men. For 1948-1964, I make minor adjustments in the data from 1965, and they are converted to an annual basis.

Figure 4 summarizes my estimates of hours of women’s and men’s leisure computed as the adjusted time endowment less hours of housework, hours of work for pay including time for commuting to work. See figure 4. They show that women on average have less leisure time than men, but for men and women, the average amount of leisure time rose to 1975, and then decreased a little bit.
**Price for women’s and men’s unpaid housework.** The price of women’s and men’s housework and leisure is taken to be the average opportunity cost or wage. For employed women and men, the Bureau of Labor Statistics data on average hourly wage rates by age group (16-19, 20-24, 25-34, 45-54, 55-64, and 65 and older) are used to construct a weighted-average market-wage rate. For not-employed men and women, I apply the procedures of Smith and Ward (1985) to obtain an opportunity wage by age group, adjusted for selection into the not-employed group. Then the average opportunity wage rate is constructed as a weighted average opportunity wage rate over all age groups for not-employed men and women. See figure 5 for the information on hourly nominal opportunity wage of employed and not employed women and men. Finally, an average nominal wage rate for men and women was constructed as the weighted-average of the average nominal wage rate for employed and not-employed men and women, respectively.

**Services of Household Durable Goods.** Consumers purchase nondurable goods and services for consumption and acquire consumers’ durables in order to obtain a flow of services to use in household production. The treatment of consumers’ durables here is the one employed by Jorgenson and Stiroh (1999), and it is the same as for the private business sector (Jorgenson 2001). Capital services are proportional to the stocks of assets, including computers, but aggregation requires weighting the stocks by rental prices rather than acquisition prices for assets. The rental price for each asset incorporates the rate of return, the depreciation rate, and the rate of decline in the acquisition price. The Bureau of Economic Analysis (BEA) provides data on purchases of 12 types of consumer durable goods used in the construction of service measure for household durable goods.

**Creating price indexes for inputs.** In the latest National Income and Product Accounts, the BEA uses superlative index numbers (Diewert 1976) to construct quantity and price indexes for consumer goods. I also use a superlative index, the Tornqvist index (Diewert 1976; Deaton and Muellbauer
1980a, p. 174-175), in all of my construction of price and quantity indexes for input categories. This index permits substitution within major input categories to occur as relative prices of subcomponents change. The overall price index for the nine-input group making full-expenditures is, however, the Stone price index over the nine input groups (Stone 1954).

I employ the following demographic translating variables: the share of the U.S. resident civilian population who are (i) less than age 5, (ii) 65 years of age or older, and (iii) who have a non-metropolitan residence.21 Data on the services of household durables were constructed by Dale Jorgenson, and they include quality adjustments. However, disembodied technical change might also occur over time in the U.S. household sector, even after adding housework, leisure time, and services of durable goods to the input set. To account for this, I construct a household technology index as the stock of U.S. patents of consumer goods (Griliches 1990; Huffman and Evenson 2006). This index is the summation of patents of consumer goods obtained from the U.S. Patents and Trademarks Office and aggregated over time using trapezoidal-shaped timing weights that sum to one over a 26-year time period.22 If the introduction of “new goods” is immediate and the quality change for existing goods fully reflected in the National Income and Product data, then the stock of patents will not have a significant effect on expenditure shares. The null hypothesis is of no effect.

Patterns in Key Variables

Using the modified time endowment, full-income based consumption or expenditures per capita in 1987 dollars were $3,667.6 in 1948 and $10,085.4 in 1996 with a mean value of $7,858.8. Hence, the average annual rate of growth of full income based consumption per capita over the sample period was 2.06 percent, which is slightly lower than the 2.25 percent per year growth of real per capital personal consumption expenditures in the NIPA (BEA). The level and trend in eight of the nine expenditure shares, 1948-1996, using a (modified) full income concept are displayed in figure 6.
The full-income expenditure share for women’s housework is 16 percent in 1948, and it displays a long-term negative trend with a slight reversal during the 1980s. The net decline over a half-century is about 7 percentage points. The share for men’s housework is 8 percent in 1948, and it declines slowly to 1960, as major technical advances are made in home heating equipment, and then shows almost no change from 1960 to 1975. It, however, rose from 1975 to 1985, and then declined slightly. The net decline over the half-century is about 1 percentage point. Hence, during the post-War II period there has been a narrowing of the differential in the housework cost shares for men and women.

The expenditure share for food-at-home was 8 percent in 1948 and then declined steadily over the half-century, ending at 3.5 percent. The expenditure share for housework-purchased-substitute (laundry and dry clean services, domestic services, and food away from home) services was about 1.7 percent in 1948, declined slowly until the mid-70s and then rose slightly, ending essentially where it started. Although some may have the conception that the expenditure share on this item has risen dramatically over the sample period, it has not changed. A major factor is the steady technical advance in fabrics used in making clothing, making them easier to care for, and wages of domestic servants and restaurant workers that have remained low due to immigration of low skilled workers since 1980 relative to all U.S. workers.

Turning to input services, the full-income expenditure share for housing was 3.5 percent in 1948; it rose slowly and steady to 1970, remained essentially unchanged from 1970 to 1980, and then rose slowly and steadily to 1996. The net change is an increase of 2.3 percentage points. Although the share of full income spent on food at home is larger in 1948 than for housing, this is reversed by 1980, and in 1996, the share spent on housing is about twice as large as for food at home.\(^\text{33}\) The share for household appliance input rose initially with the massive investment in new housing during
the late 1940s and 1950s, and then displays a slow decline to the mid-70s, thereafter rising very slowly. However, the net change over the half-century was negligible. The share spent on transportation input was 3.4 percent in 1948, rising steadily to 1965, and then essentially remaining unchanged to 1975. From 1975 to 1996 it rose slowly, ending at 5 percent. The share spent on recreation input was 2 percent in 1948, had a slight negative trend to the mid-70s. It then reversed course with a slow increase to 1996, ending the Century 1.3-percentage points higher than at the beginning.

In summary, some of the nine expenditure shares show major changes over the last half-century—women’s housework, men’s housework, food-at-home, and transportation inputs—but the others vary much less. Since this is the first extensive examination of structural change in the aggregate U.S. household sector over the post-War period, I am limited in the type of comparisons that I can make. When housework and leisure are excluded from the expenditure system, very different expenditure shares result. For example, using personal income as the budget constraint, Costa (2001) gives the share of income spent on food-at-home as 15 percent in 1950 and 7 percent in 1994, and her expenditure share for recreation rose from 6 to 8 percent over the same period. These shares are much larger than I report. Deaton and Muellbauer (1980a), Jorgenson and Slesnick (1990), and Moschini (1998) also present expenditure shares using aggregate data with traditional measures of household consumption.

The relative input prices (nominal prices deflated by the Stone price index, Stone 1954) constructed from the 9 price indexes for major input groups, 1948 to 1996, are displayed in figure 7, and they show a large amount of variation over the period. When homogeneity of the demand functions in nominal prices and income is imposed, these real or relative prices become the prices for which percentage changes are taken to create the prices used fitting the AIDS demand system. Some
distinguishing features of patterns in these relative prices are as follows. *The relative price of women’s housework rose steadily over 1948 to 1980 for a total of 30 percent and, thereafter, remained roughly unchanged.* For men’s housework, the relative price rose about 27 percent over 1948 to 1972 and then declined, but stayed roughly 20 percent higher over the remainder of the period. The relative price of food-at-home has a strong negative trend, except for the world food-crisis years of the early 1970s, declining by about 60 percent over the last half-century. The relative price of housework-purchased-substitute services declined slowly over 1948 to 1967, rose slowly over 1967 to 1991, and then leveling off. The net increase in the last half-century is an increase of about 10 percent. The relative price of housing services declined steadily cumulating into a 45 percent decline from 1948 to 1975 and then reversed its trend to increase slowly until 1996. The relative price of the household appliance input declined dramatically from 1948 to 1975, moved irregularly but trending upward over 1975 to 1985, and then declined again. The net decline over the half-century was a dramatic 80 percent. The relative prices of transportation input moved in an irregular pattern over time and had a net decline over the whole period of 20 percent. The relative price of recreation input rose from 1948 to 1958, declined steadily 1958 to the mid-80s, and then rose slightly. The net decline over a half-century was, however, 20 percent. The relative price of “other inputs” rose very slowly over the half-century. Thus, over 1948 to 1996, my time series data on major household input categories show large relative price variation that can be an aid in estimating the parameters of the complete household demand system.

**The Empirical Results and Their Interpretation**

In this study, nine expenditure shares are the endogenous variables, and they are explained by nine real or relative input prices, by real income or total expenditures, share of the population under age 5 and over age 65, share living in non-metropolitan areas, and the consumer patent stock, and
trend. However, because expenditure shares add up to one and within and cross-equation restrictions are imposed in equations (8) and (13), we only need to estimate eight input demand equations with the associated restriction suggested by the theory. In the differenced form, the unknown parameters in the household demand system are: eight constant terms that are commodity-specific coefficients for trend, 24 coefficients of the translating variables; 8 coefficients of the disembodied technical change variable; 36 price coefficients; and 8 income coefficients. I fit the first-difference form of the AIDS of equation (13) to 49 observations, 1948-1996, subject to symmetry, homogeneity and adding up conditions to estimate a total of 84 unknown parameters using the iterative seemingly unrelated regression (ISUR) estimation routine in SAS using Gauss.

**Results for the Demand System**

Estimated coefficients of the AIDS-household demand system with nine input groups are reported in table 2, and the estimated compensated price and income/expenditure demand elasticities, evaluated at the sample means of the variables, are reported in table 3. The impact of per-capita total income, demographic characteristics, and own-price effects are estimated relatively precisely. The impacts of cross-price effects are estimated less precisely, but this is to be expected because they represent price effects that are of secondary importance and about which we know much less. The coefficients of the patent stock variable are non-zero; some are significantly different from zero, and hence we reject the hypothesis of no effect of disembodied quality change in the full-income household demand system. The demand system explains a large share of the variance in the household’s expenditure shares for women’s and men’s housework, food-at-home, housing input, and “other inputs.” Given that we are estimating the first-difference version of equation (13), which is a stiff test, the results look quite good, although there is some evidence of near multi-collinearity.
The estimates of the intercept terms of the first-difference version of the AIDS demand equations provide estimates of the impact of a linear time trend on the expenditure shares for each input group or $\phi_i$. Looking at table 2, a positive trend exists in the expenditure share for women’s housework, food-at-home, purchased housework-substitute services, housing, appliance services, and transportation services. A negative trend exists in the expenditure share for men’s housework, recreation input, and other inputs. However, given that we do not know the exact factors represented by trend, we do not want to place too much emphasis on the differences across input groups.

In spite of trend effects discussed in the preceding paragraph, I find strong own-price and income effects as reflected in the price and income elasticities. Point estimates of these elasticities are obtained by evaluating equations (9)-(11) at the sample mean of the expenditure shares (table 1). Z-values are computed for each own- and cross-price and income elasticity, taking the respective shares as given.\textsuperscript{25} The Hicksian own-price elasticity for each of the nine input groups is negative, statistically significant at the 1 percent level and plausible, at -0.49 for both women’s and men’s housework, -0.55 for food-at-home, -0.63 for recreation input, -0.76 for housing input, -0.88 for both housework-purchased-substitute services and appliance input, and -0.09 for transportation. Also, the own-price elasticity of demand for “other inputs,” i.e., largely men’s and women’s leisure, is –0.34.

It is an empirical issue as to whether women’s and men’s housework are substitutes or complements. My empirical results, however, show that women’s and men’s housework are complements, having a compensated cross-price elasticity of -0.16, which is significantly different from zero at the 5 percent level. Hence, given that the summation across all compensated price elasticities for women’s housework is zero (Deaton and Muellbauer 1980, p. 43-44), the other inputs on average must be substitutes and the average size of their compensated cross-price elasticity must be 0.09 (and cannot be zero). In fact, table 3, row 1, shows that all seven of these input categories are
substitutes for women’s housework. An explanation for women’s and men’s housework being complements is that women and men perform different types of housework and that these tasks complement rather than substitute for one another. Within married couples, housework continues to be specialized by gender. Women have continued over recent decades to perform the core housework—traditionally “female” tasks like cooking and cleaning—while men report traveling to stores, shopping, cooking, and doing repairs. Hence, men’s contributions to core housework remain small relative to women’s contribution. Men participate most in yard and home maintenance, where women contribute relatively little (Robinson and Godbey 1997; Bianchi et al. (2000); Aguiar and Hurst 2006, table 2 and 3).26

Although purchases-housework substitute services and appliance services are substitutes for women’s housework as anticipated, they are also substitutes for men’s housework (table 3). The respective cross-price elasticities between these two input categories are in fact much larger for men’s housework than women’s housework. Hence, these market substitutes for housework are “better” substitutes for men’s than women’s housework. Not too surprising, food–at-home and recreation inputs are complements to men’s housework, and the other four major input groups are substitutes.

Housing and transportation inputs are shown to be complements to food-at-home, which are all key inputs to a family’s enjoyable meals at home, and the other five input groups are substitutes. For housing, food at home, purchased housework substitute services, and household appliance services are complements. These four inputs contribute to an enjoyable home environment. For the appliance input, all of the other input groups are substitutes, except for housing. For recreation input, food at home, housing input, and transportation input are complements, (and other inputs are substitutes). The strongest substitute for the household’s (material) recreation input, however, is
“other inputs” with a compensated cross-price elasticity of 1.0 and significantly different from zero at the 1 percent level. Hence, we take this result to mean that a strong substitution effects exist between the “goods” component of recreation and the “own-time” component.

The cross-price elasticities among the nine input groups imply numerous margins where other inputs have been substituted for women’s and men’s housework as the real or relative price of time rose in the post-War II period (see figure 7). As seems reasonable, a small number of input groups substitute for the “other inputs” category, which is dominated by own leisure time.

Evaluated at the sample mean of the data, the expenditure/income elasticities of demand for women’s housework is 0.713, for men’s housework is 1.136, for food at home is 0.793, for purchased housework substitute services is -0.420, for housing input is 0.480, for household appliance input is 0.392, for transportation input is 1.151, for recreation input is 1.579, and for “other inputs” is 1.133. Hence, transportation, recreation, and “other inputs” are luxury goods, having expenditure/income elasticities greater than one. Women’s housework, food-at-home, housing, and appliance inputs are normal goods and have positive income elasticities that are less than one. Only housework-purchased-substitute services are inferior, having a negative expenditure elasticity, but the elasticity is not significantly different from zero at the 5 percent level. This latter income elasticity may be surprising, but readers can easily confuse price and income effects here. Increased use of this input category over the post-War II period is largely due the rising price of own time and not due to rising real nonlabor income.

On the whole, this set of expenditure/income elasticities has considerable appeal. In particular, with rising real nonlabor income over the post-War II period, our results suggest relatively large rightward shifts in demand due to income for men’s housework, transportation input, recreation input and “other inputs.” With the income elasticity of demand for both men’s and women’s
housework being positive and their time endowment being fixed, rising nonlabor income may have been one force behind a raising shadow price of human time, or making human time seem more “scarce” (Linder 1970; Robinson and Godbey 1997).

The impact of disembodied technical change in the household sector is not zero. The precise impact is on the demand for each major input group is \( \delta_j/s_j \). The impact on all input groups, including household appliances, is positive, except for housing and transportation. The impact measured as an elasticity at the sample mean of the expenditure share is largest (0.29 to 0.45) for men’s housework, food-at-home, appliance input, and women’s housework. For two of these four input groups, the actual introduction of new goods has been larger significant, and Fisher and Griliches (1995) and Hausman’s (1996) have shown that traditional methods used by the Labor Department for treating these goods tends to bias upward cost of living indexes. Also, due to a rising real price of own time over the post war II period, innovations in consumer goods may have been targeted toward substitutes for women’s and men’s housework. For transportation, the elasticity with respect to patents is -0.45, and over the long term, hedonic pricing techniques were first applied to automobiles as a method for adjusting for quality change (Boskin et al. 1998; Fisher and Griliches 1995; Griliches 1971). The result suggests that technical change in the household sector reduces the demand for women’s housework relative to housing, transportation, and “other inputs,” and increases the demand for women’s housework relative to food-at-home and men’s housework. No significant change in the demand for women’s housework relative to housework-purchased-substitute services, appliance input, and recreation occurs due to patenting activity.

The impacts of a change in the share of the population that is aged 5 years or less is 2.3 times larger for women’s housework than for men’s housework, and the impact of an change in the share of the population 65 years of age and older is 2.2 times larger on women’s housework than on men’s
housework. Hence, the demand for women’s unpaid housework is more responsive to the changing age composition of the U.S. population than is men’s housework.

Although we would like to have micro household level data to examine the changing structure of household production over the post-War II period, they do not exist. Although aggregate data on the household sector are in some sense second best, they are first best with respect to the feasibility of constructing them. Hence, we believe annual aggregate data provide useful insights into post-War II adjustments of U.S. household’s to input demand due to price and income changes.

Cost-of-Living Comparisons

The estimate parameters of the AIDS model of household demand from table 3, input prices as displayed in figure 7, and equation (12) are used to construct a new cost of living index (CLI) over 1948-1996. The resulting full-income based CLI is displaced in figure 8, and, for comparison, the implicit price deflator for personal consumption expenditures (IPD) of the Bureau of Economic Analysis is also presented. Over 1948-1996, my CLI increases at an average compound rate of only 2.1 percent per year, but the IPD increases by a much higher rate of 3.5 percent per year.

This comparison shows that the treatment of women’s and men’s housework (and leisure) and of household durable goods is important to cost of living comparisons. Recall that we are using services of durable goods rather than investments in new durable goods are the inputs producing commodities for consumption. Hence, failing to include own housework and leisure and including durable goods rather than their services, have biased the IPD upward significantly. Looking at figure 8, we see that the cumulative effect of this bias over a half-century is large. Both indexes start at one in 1948, but in 1996, my CLI is only 2.69 and the IPD is 5.25. The bias is large over the whole period, but especially so from 1980 to 1996. During this latter period of generally higher rates of CPI
inflation, the IPD rose at an average of 8.8 percent per year, but the social CLI rose by only 4.1 percent. Hence, over the last 16 years the bias has been almost 5 percent per year.

For comparison, these differences are much larger than the Boskin *et al.* Commission report of an upward bias of about 0.6 percent per year in the official CPI due to inadequate adjustments for quality changes, and Costa’s estimate of CPI bias of less than 1 percent over our study period. The difference between Costa’s and my estimates is especially large over the latter part of the period. Her estimate of a bias of 0.6 percent per year from 1982-1994 is much smaller than my estimate of a 5 percent per year bias from 1980-1996. The reasons for the difference is the much broader set of “goods” included in my social cost-of-living index that in Costa’s, and the fact that the relative price of human time changed very little over the 1980 to 1996 period (figure 7), but complex cross-price effects and quality improvements in consumption goods were operating to reduce the demand for women’s housework. Also, the demand for women’s leisure was growing. Moreover, the upward adjustments in the standard of living due to my computations from systematic use of a productive household model, but ignoring improvements in life expectancy, are significantly larger than those suggested by Nordhaus (2003, pp. 27) due to rising life expectancy from 1950-1995. Hence, when relative prices are changing over time for a broad set of consumption goods and real income is rising, the size and composition of the consumption market-basket is quite important to cost of living and real income/welfare estimates. This point was also emphasized earlier by Fisher and Griliches (1995).

**Conclusions and Implications**

Given that annual micro-level household expenditure data do not exist over the post-War II period, annual aggregate input measures of hours of unpaid housework and leisure were derived using the best available data and plausible assumptions. This information was merged with information from Jorgenson on services of household durable goods and GNP account information on
other household expenditures. With this refined data organized into nine input categories, an aggregate almost-ideal-demand system was fitted with appropriate controls and new estimates of price and income elasticities of household input demand were obtained. Macro-economists continue to be interested in these issues, and my methodology is in contrast to the approach taken by Greenwood et al. (2005). They developed a calibration model for the aggregate U.S. economy, including the household sector, and then used it to simulate impacts of aggregate price, income and technical change on household production over the 20th Century. Arguably, my approach is superior because it gives much greater latitude for the data to inform the size of key parameters—at least for the post-World War II period—where better data are available.

The study showed that the opportunity cost of women’s and men’s unpaid housework rose markedly relative to the price of all household inputs from 1948 to 1980, and then remained relatively unchanged to 1996 (figure 7). The expenditure share for women’s housework was relatively large in 1948 (16 percent), and fell dramatically during the first half of the period by 7 percentage points (figure 6). For men’s housework, the share was much smaller in 1948, and it fell until the mid-1970s and then rose, ending approximately where it began. The gender differential in unpaid housework has narrowed over the past five decades, but it has not been eliminated. Particular types of housework remain gender differentiated at the end of the 20th Century. Women continue to perform a large share of core housework and men perform a large share of housework associated with yard and car care and home maintenance.

The new U.S. data, grouped into nine major input categories and controlling for trend dominated factors, supports a flexible complete aggregate, but otherwise relatively simple, household demand system. The estimated parameters of the AIDS were used to evaluate compensate own- and cross-price and expenditure elasticities. All nine own-price elasticities and most of the nine
expenditure/income elasticities were statistically significant, even as we controlled for a linear time trend in model estimation. Seven major input groups were shown to be substitutes for women’s (and men’s) housework, except for men’s (women’s) housework, which is a complement. Hence, during the period from 1948 to 1980 when the relative price of women’s housework was raising dramatically, market inputs were substituted for women’s (and men’s) housework, and in the U.S., marketization of women’s work occurred—women’s work moved from the household to the labor market by roughly equal amounts. U.S. households adopted new facilities and electrical appliances that were manufactured using industrial technologies and marketed by private firms to household and technical change in manufacturing of these goods might have been stimulated by the rising relative price of human time. The services of these inputs substituted for women’s (and men’s) housework. This in particular released some of women’s time for work in the labor market. The increase in the consumer patent stock, a proxy for quality of consumer goods, also tended to reduce the relative intensity of women’s and men’s housework compared to other inputs. The growth over some subperiods in the demand for men’s unpaid housework is due to a large income elasticity of demand.

The AIDS-cost or expenditure-function associated with the AIDS complete-demand system in this study shows a remarkable picture of changes in the cost-of-living for the U.S. in the post-World War II period. These parameters were estimated holding constant key demographic attributes, technical change in the household sector, scale of the household sector, and a time trend. Over the post-war period, my full-income based cost-of-living index grew at an average rate of 1.4 percent per year slower than the BAE’s implicit-price deflator for personal consumption expenditures, and from 1980 to 1996, it grew about 5 percent per year slower. Hence, U.S. households’ standard of living or real welfare was rising over the post-World War II era much faster by 1.4 to 5 percent per year, than traditional cost of living computations led one to believe. Although I may not have directly controlled
for everything of importance to social welfare that was changing over the post-War II period, my time trend does a good job on trend dominated factors like family structure, crime rates, pollution, educational attainment of adults, and life expectancy, and hence, my results are informative about how the treatment of human time and durable goods affects cost of living comparisons over the last half of the 20th Century.

For example, I find the rise in the real price of women’s and men’s time over the study period caused substitution toward other inputs, including appliance services, purchased substitute services, housing, and transportation. In contrast, Greenwood et al. rely heavily upon labor-saving technical change to explain the reduction in the demand for women’s housework. Hence, our results support Jorgenson (2001) results for the general economy, that is, relative price changes have been large for many input groups over time and these price changes account for much of the resource adjustments that has occurred over time.

Although trends between benchmark years were used in deriving new data on women’s and men’s unpaid housework and leisure, the main econometric results—estimates of own-price and income elasticities—are surprisingly strong econometrically, given that we controlled for all trend dominated variables in estimating the underlying parameters. Hence, the new price and income elasticity estimates reported in this paper cannot be dominated by time trends! One might attempt to complicate the model by expanding the set of outcomes that are modeled. This, however, seems likely to raise simultaneity issues, which raise a whole new set of issues. Other useful routes of investigation, however, may exist for the 20th Century, and they are left to future research. The new American’s Use of Time survey by BLS, which started in the 21st Century, provides micro level data on time allocation that can be examined for this 21st Century, but it has nothing to offer for the 20th century, where this paper focuses.
References


BEA. “National Income and Product Accounts.” Available at: http://www.bea.gov/bea/dn/nipaweb


<table>
<thead>
<tr>
<th>Variable</th>
<th>Definitions</th>
<th>Sample Mean</th>
</tr>
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<tr>
<td>$s_1$</td>
<td>Expenditure share for women’s housework</td>
<td>0.119</td>
</tr>
<tr>
<td>$s_2$</td>
<td>Expenditure share for men’s housework</td>
<td>0.069</td>
</tr>
<tr>
<td>$s_3$</td>
<td>Expenditure share for food at home</td>
<td>0.052</td>
</tr>
<tr>
<td>$s_4$</td>
<td>Expenditure share for housework purchased substitute services</td>
<td>0.015</td>
</tr>
<tr>
<td>$s_5$</td>
<td>Expenditure share for housing input</td>
<td>0.048</td>
</tr>
<tr>
<td>$s_6$</td>
<td>Expenditure share for household appliance input</td>
<td>0.030</td>
</tr>
<tr>
<td>$s_7$</td>
<td>Expenditure share for transportation input</td>
<td>0.047</td>
</tr>
<tr>
<td>$s_8$</td>
<td>Expenditure share for recreation input</td>
<td>0.025</td>
</tr>
<tr>
<td>$s_9$</td>
<td>Expenditure share for “other inputs” (men’s and women’s leisure and other consumer goods and services)</td>
<td>0.595</td>
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<td>AGE &lt; 5</td>
<td>Share of the resident population that is less than five years of age</td>
<td>0.090</td>
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<tr>
<td>AGE $\geq$ 65</td>
<td>Share of resident population that 65 years of age and older</td>
<td>0.104</td>
</tr>
<tr>
<td>Non-metro</td>
<td>Share of resident population living in non-metropolitan areas</td>
<td>0.132</td>
</tr>
<tr>
<td>Consumer patents</td>
<td>The stock of patents of consumer goods, trapezoid weights over 26 years</td>
<td>3,262.7</td>
</tr>
<tr>
<td>$F/(N)$</td>
<td>Average household expenditure per person</td>
<td>4,369.5</td>
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<td>$P_1$</td>
<td>The price of women’s housework, or the opportunity wage</td>
<td>0.528</td>
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<tr>
<td>$P_2$</td>
<td>The price of men’s housework, or the opportunity wage</td>
<td>0.541</td>
</tr>
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<td>The price index of food at home</td>
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<td>The price index of purchased housework substitute services</td>
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<tr>
<td>$P_5$</td>
<td>The price index of housing input</td>
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<td>$P_6$</td>
<td>The price index for household appliance input</td>
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<td>$P_7$</td>
<td>The price index for transportation input</td>
<td>0.611</td>
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<td>$P_8$</td>
<td>The price index for recreation input</td>
<td>0.660</td>
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<td>$P_9$</td>
<td>The price index for “other inputs” (e.g., men’s and women’s leisure, medical services, and other outlays)</td>
<td>0.552</td>
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<td>$P$</td>
<td>The Stone price index</td>
<td>0.556</td>
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Table 2. ISUR Estimate of U.S. Household Demand System for Inputs: AIDS (Shares) 1948-1996 (Asymptotic Standard Errors in Parentheses)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Women’s housework</th>
<th>Men’s housework</th>
<th>Food-at-home</th>
<th>Purchased-substitute services</th>
<th>Housing input</th>
<th>Appliance input</th>
<th>Transportation input</th>
<th>Recreation input</th>
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<td>Constant</td>
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<td>-0.300</td>
<td>0.066</td>
<td>0.254</td>
<td>0.348</td>
<td>0.180</td>
<td>0.131</td>
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<td>(0.236)</td>
<td>(0.264)</td>
<td>(0.147)</td>
<td>(0.129)</td>
<td>(0.156)</td>
<td>(0.236)</td>
<td>(0.120)</td>
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<td>AGE ≤ 5</td>
<td>0.424</td>
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<td>0.118</td>
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<td>0.062</td>
<td>0.073</td>
<td>-0.026</td>
<td>-0.053</td>
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<td></td>
<td>(0.157)</td>
<td>(0.125)</td>
<td>(0.144)</td>
<td>(0.087)</td>
<td>(0.080)</td>
<td>(0.093)</td>
<td>(0.146)</td>
<td>(0.075)</td>
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<td>AGE ≥ 65</td>
<td>-0.360</td>
<td>-0.161</td>
<td>-0.240</td>
<td>0.229</td>
<td>0.311</td>
<td>0.025</td>
<td>-0.024</td>
<td>0.021</td>
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<tr>
<td></td>
<td>(0.282)</td>
<td>(0.223)</td>
<td>(0.261)</td>
<td>(0.146)</td>
<td>(0.131)</td>
<td>(0.155)</td>
<td>(0.243)</td>
<td>(0.122)</td>
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<td>Non-metro</td>
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<td>-0.065</td>
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<td>(0.04)</td>
<td>(0.03)</td>
<td>(0.04)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.03)</td>
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<td>ln(Con. patent stock)</td>
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<td>(0.014)</td>
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<td>lnP₁</td>
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<td>lnP₂</td>
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<tr>
<td></td>
<td>(0.010)</td>
<td>(0.011)</td>
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<td>-0.012</td>
<td>0.021</td>
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<tr>
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<td>(0.008)</td>
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<td>lnP₄</td>
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<td>0.015</td>
<td>0.004</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.005)</td>
<td>(0.004)</td>
<td>(0.005)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln P₅</td>
<td>0.003</td>
<td>0.008</td>
<td>-0.008</td>
<td>-0.004</td>
<td>0.009</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(0.006)</td>
<td>(0.006)</td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.007)</td>
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<tr>
<td>ln P₆</td>
<td>0.003</td>
<td>0.004</td>
<td>-0.001</td>
<td>0.004</td>
<td>-0.009</td>
<td>0.002</td>
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<td>(0.004)</td>
<td>(0.003)</td>
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<tr>
<td>ln P₇</td>
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<td>0.002</td>
<td>-0.003</td>
<td>-0.003</td>
<td>0.007</td>
<td>-0.001</td>
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<td>(0.004)</td>
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<td>(0.003)</td>
<td>(0.003)</td>
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<tr>
<td>ln P₈</td>
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<td>-0.008</td>
<td>-0.000</td>
<td>0.008</td>
<td>-0.007</td>
<td>-0.000</td>
<td>-0.003</td>
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<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.004)</td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.004)</td>
</tr>
</tbody>
</table>

| R²                 | 0.996              | 0.969           | 0.989        | 0.707                          | 0.990         | 0.832           | 0.874                | 0.981            |

1 System estimated after taking first-differences, which is consistent with ρ = 1 for a first-order autoregressive assumption for the disturbance in the original share equations.

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<th>Commodity/Input groups (i)</th>
<th>Prices (j)</th>
<th>Income/Expenditure Elasticity</th>
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<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>compensated ((e_{ij}^*))</strong></td>
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<td></td>
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<tr>
<td>1) Women’s housework</td>
<td>-0.493</td>
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<tr>
<td></td>
<td>(4.29)</td>
<td>(1.99)</td>
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<tr>
<td>2) Men’s housework</td>
<td>-0.283</td>
<td>-0.489</td>
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<tr>
<td></td>
<td>(1.99)</td>
<td>(3.14)</td>
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<td>3) Food at home</td>
<td>0.253</td>
<td>-0.154</td>
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<tr>
<td></td>
<td>(1.81)</td>
<td>(1.35)</td>
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<tr>
<td>4) Purchased housework substitute services</td>
<td>0.330</td>
<td>1.019</td>
</tr>
<tr>
<td></td>
<td>(0.90)</td>
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<td>5) Housing input</td>
<td>0.173</td>
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<td>(1.93)</td>
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<tr>
<td>6) Household appliance input</td>
<td>0.211</td>
<td>0.202</td>
</tr>
<tr>
<td></td>
<td>(1.30)</td>
<td>(1.45)</td>
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<tr>
<td>7) Transportation input</td>
<td>0.217</td>
<td>0.113</td>
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<tr>
<td></td>
<td>(1.95)</td>
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<tr>
<td>8) Recreation input</td>
<td>0.032</td>
<td>-0.236</td>
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<tr>
<td></td>
<td>(0.15)</td>
<td>(1.21)</td>
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<tr>
<td>9) “Other inputs”</td>
<td>0.058</td>
<td>0.048</td>
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<tr>
<td></td>
<td>(1.68)</td>
<td>(1.73)</td>
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</table>


Figure 1. The Diffusion of Basic Facilities and Electrical Appliances through the U.S. Economy

Source: Greenwood et al., 2005, p. 111.
Figure 2. Number of Children per 100 Adults, 1920-1996

The graph shows the percentage points of children under 5 and under 16 per 100 adults in the age group 16-64 over the years from 1910 to 2000. The data indicates fluctuations in the percentage points over time, with peaks and troughs that reflect changes in the population demographics during this period.
Figure 3. Average Annual Hours of Unpaid Household Work of Employed and Not Employed Men and Women, Aged 16-64: 1948-1996
Figure 4. Average Annual Hours of Leisure for Employed and Not Employed Men and Women, Aged 16-64: 1948-1996
Figure 5. Hourly Opportunity Wage for Employed and Not Employed Men and Women: 1948-1996
Figure 6. U.S. Household (Modified) Full-Income Based Expenditure Shares, 1948-1996
Figure 7. Relative Prices of Inputs for U.S. Household, 1948-1996
Figure 8. Comparisons of the AIDS cost of living index and implicit price deflator for personal consumption expenditures, 1948-1996
Appendix A

Procedures for Determining Benchmark Values for Unpaid Housework

The details of deriving benchmark values for average daily hours of unpaid housework are as follows. Considerable more data exist on time allocated to housework starting in 1965, and we first establish benchmarks years in the interval 1965 to 1995. My 1965 benchmark estimates for average daily hours of housework for women aged 16 to 64 (not enrolled in school) is 7.34 for not employed women and 3.72 for employed women. For men aged 16-64 (not enrolled in school) average daily hours is 2.17 for those who not employed and 1.58 for those who are employed. The weighted average across working and non-working women and men aged 16-64 is 5.71 hours per day and 1.62 hours per day, respectively. When converted to a weekly basis, these averages are the same as for Robinson and Godbey (1997, p. 105) use for total housework of individuals aged 18-64 (40.0 and 11.3 for women and men, respectively, and very close to the averages reported by Juster and Stafford (1991, p. 477) for total household work in 1965 for individuals aged 25-64 in urban households.

My 1975 benchmark estimates for average daily hours of housework for women aged 16 to 64 (not enrolled in school) is 5.73 for not employed women and 3.38 for employed women. For men aged 16-64 (not enrolled in school) average daily hours is 2.29 for those who not employed and 1.52 for those who are employed. The weighted average across working and non-working women and men aged 16-64 is 5.71 hours per day and 1.62 hours per day. When converted to a weekly basis, these are the average values of housework reported by Robinson and Godbey (1997, p. 105).

My 1985 benchmark estimates for average daily hours of housework for women aged 16 to 64 (not enrolled in school) is 5.56 for not employed women and 3.65 for employed women. For men aged 16-64 (not enrolled in school) average daily hours is 2.89 for those who not employed and 2.07 for those who are employed. When converted to a weekly basis, these are also the average values of housework reported by Robinson and Godbey (1997, p. 105) for 1985.

My 1995 benchmark estimates for average daily hours of housework for women aged 16 to 64 (not enrolled in school) is 5.21 for not employed women and 3.21 for employed women. For men aged 16-64 (not enrolled in school) average daily hours is 2.89 for those who not employed and 2.07 for those who are employed. When converted to a weekly basis, these are the average values of housework reported by Robinson and Godbey (1997, p. 105) for 1995; 26.0 and 15.3 for women and men, respectively.

Now we return to the harder task of setting a benchmark for hours of unpaid housework for 1950. Bryant (1996) presented an estimate of average daily hours of housework for married women in the mid-1920s of 7.35 which is similar to my 1965 benchmark for not employed women. On average, married women have more hours of housework than non-married women, so this is clearly an overestimate of the average for all women 16-64. For married women, a significant amount of housework is associated with children and child care, and I show in figure 2 that the average number of children, both less than age 5 and less than aged 16, per 100 adults (age 16 to 64) did not follow a linear trend over 1920 to 1960 but completed a full cyclical swing. In 1920, there were 17.7 children under age 5 per 100 adults, but this number declined to a trough of 11.8 in 1938, which is a 40 percent decline. The number of children less than age 16 also declined—from 54.4 in 1920 to a trough of 39.6 in 1942, a 32 percent decline. Hence, over this roughly 20-year period the demand for women’s housework must have declined significantly because the technology of household production was improving slowly.

Starting in the early 1940s the number of children per adult rose steadily until the early 1960s, when it reached a peak of 19.4 for children under age 5 and 57.4 for children under age 16. Hence,
over this period the demand for women’s housework associated with caring for children must have increased. However, after 1962 the number of children under age 5 per adult declined steadily, reaching a trough of 11.5 in 1977 and then remaining approximately unchanged until 1996. The number of children younger than age 16 per adult showed a stronger cyclical downturn from 1962 to 1988, reaching a trough of 35.1. However, in the early 1920s, 1950, and the mid 1960s the number of children under age 5 per 100 adults was approximately the same as at age 16 (figure 2). Based on this information, I assume the 1950 benchmark value for average daily hours of housework for women age 16 to 64 (who are not in school) was 8.70 hours for not employed and 4.46 hours for employed women or a weighted average of 7.21 hours.

For men, pre-1965 information on aggregate average hours of housework is less readily available than for women. However, when home heating was by noncentral heating equipment as much of it was before World War II (see figure 1), men’s housework included handling wood and coal and sometimes chopping and sawing wood to burn in fireplaces and stoves and disposing of ashes (Bryant 1986). As technical change in natural-gas and oil-fired central furnaces occurred and availability of low cost natural gas and heating oil increased, men’s work associated with home heating declined and was eventually eliminated in most homes.

The Census data on home heating equipment extend back only to 1940 (U.S. Dept. of Commerce 1943). They show that in 1940 only 40.6 percent of U.S. housing units had central heating, and 76 percent of noncentral heating equipment used wood or coal. After World War II there was a large investment in new housing units with improve basic facilities in the U.S., and by 1950, central heating had increased to 49.5 percent of housing units, and the use of wood and coal in noncentral heating units had declined to 67 percent (U.S. Dept. Commerce 1953, 1954). With the rapid construction of new housing units that occurred in the 1950s, central heating increased to 66 percent of housing units in 1960 and then to 77 percent in 1970 (U.S. Dept. Commerce 1961, 1973).xix In 1960, only 50 percent of noncentrally heated housing units used wood or coal.

Giving the changes in the technology of home heating from 1940 to 1970, the demand for men’s housework associated with home heating must have declined over this period. Hence, in 1950 for men aged 16 to 64 (not enrolled in school), I set my benchmark for aggregate average daily hours of housework at 2.52 for not employed men and 1.81 for employed men. Weighting across employed and not employed men, this gives an overall average 1.87 hours per day of housework, which is 14 percent larger than in 1965.xxx

For women and men aged 65 and older we applied the following benchmarks values. For 1950, averaged daily hours of housework for not employed women was 6.6 and for employed women was 3.0; for 1965, 6.29 and 3.15; for 1975, 4.90 and 2.87; for 1985, 4.76 and 3.10; and for 1995, 4/47 and 2.73. The estimates for the 1965-1995 benchmark values are heavily based on estimates by Robinson and Godbey (1997). For men aged 65 and older, we used the same benchmark values as for men aged 16-64.
Appendix B

Figure 1. Population of Employed and Not Employed, Ages 16-64: 1948-1996
Figure 2. Annual Hours Worked for Pay of Men and Women 16 Years of Age and Older: 1948-1996
ENDNOTES TO THE TEXT

1 For example, Greenwood et al. (2005) use a calibration rather than an econometric model to derive plausible adjustments hours of housework, leisure, and market work in the U.S. household sector over the 20th Century. Aguiar and Hurst (2006) have use evidence from various time allocation surveys from 1965 to 2003 to assess trends in leisure time use. They separate time for household production from leisure time in their analysis. Bianchi et al. (2000) examine the trends in adult women’s and men’s housework, excluding child care, over 1965 to 1995. In other related work, Ramey and Francis provide rough estimates of time allocated to housework and leisure time over the who 20th century. Thus, other authors have found it useful to distinguish housework from leisure time in time uses studies.

2 Eisner (1989) has suggested extending the national income accounts to include the household sector, but he does not report demand function estimates.

3 In contrast, Bianchi et al. (2000) who are sociologists use a different set of variables to explain changes in women’s and men’s housework in micro-survey data across 1965, 1975, 1985, and 1995. Their set of regressors include parental and employment status, age, education, and marital status.

4 One can either view that housework or unpaid household labor contributes to utility by producing commodities that are the ultimate sources of satisfaction or contributes directly to utility (Michael and Becker 1976; Pollak and Wachter 1975; Gronau and Hamermesh 2006).

5 See Gronau and Hamermesh (2006) for an attempt to define a comprehensive set of commodities that are consumed by households and identify their time and goods intensities.

6 The 1981 data contain an appropriate number of rural households but the 1965 data were for urban households only (Juster and Stafford 1991), which suggests a slight underestimate for the aggregate average.

7 Robinson and Godbey’s time use data are derived from time diary information, but the population being sampled contains some heterogeneity over time periods surveyed. This could affect the comparability of their estimates.

8 Joint use of inputs in household or home production is no more prevalent than for farms, and agricultural economists have successfully applied production theory there (e.g., see Griliches 1965; Huffman 1980; Huffman and Evenson 1989; Mundlak 2000).

9 The virtual price concept was developed by Neary and Roberts (1980) for a demand system under rationing. The virtual price $p_1^V$ for the rationed good $x_1$ at which the consumer optimally and voluntarily chooses the rationed good in a demand system containing non-rationed goods $x_2$ is $x_1 = x_1^C(U_0, p_1^V, p_2)$. The virtual price is an implicit function of the rationed quantity, prices of the non-rationed goods $p_2$, and utility $U_0$. Given the virtual price $p_1^V$, the Hicksian demand function without rationing is equal to the demand function with rationing: $x_1^{RC}(U_0, p_1, p_2) = x_1^C(U_0, p_1^V, p_2)$. Hence, the virtual price is conceptually sound and widely accepted by consumption and demand theorists. Virtual prices are a device to enlighten the discussion of the likely impact of “missing prices” on the cost of living.
The AIDS is a flexible function form. Other flexible functional forms for a demand system include the translog (Jorgenson and Slesnick 1990) and Rotterdam models. The AIDS and translog are similar (Moschini 1999), but the AIDS is most popular.

Marginal tax rates on income and purchased goods could be incorporated into our model of demand for inputs by households. However, in the almost-ideal-demand system, the terms involving the tax rate become a separate variable from the ln prices and ln income terms. If the tax rates are roughly constant over time, they will be differenced out of the econometric demand system in the next step. Hence, I choose to exclude explicit treatment of tax from my model of household demand.

Also, including commodity-specific constant terms can detract from the contribution of real per capita expenditures on demand.

We have only one price for men’s and one for women’s time, and hence, we cannot include leisure time as a separate input. Since leisure time is not the central focus of this study, men’s and women’s leisure are included in the other inputs category, but they account for more than 85% of expenditures in this category.

Bianchi et al. (2000) report that gender segregation of household tasks has continued in U.S. household over recent decades. This provides another reason for keeping men’s and women’s housework separate.

However, technical change associated with showering/bathing—soaps, shampoos, deodorants, shaving equipment—has made possible steady increases in the quality of personal hygiene, with a roughly unchanged average amount of time spent on personal care.

Tendencies to engage in more than one activity at a time, sometimes called joint production or time deepening, are partly reflecting growing scarcity of time, but they are also the source of personal stress and accidents. I stick to primary purposes of time use for allocation purposes.

All computations assume a 365-day and 52-week year.

Our estimates of annual average hours of labor market work are consistent with the Census year estimates presented by McGrattan and Rogerson (2004).

For 1965, Juster and Stafford’s estimate for commuting time is similar to those of Robinson and Godbey (1997).

A superlative price (quantity) index is one that gives a perfect aggregation for a household that faces fixed prices and has a utility function that is a flexible functional form. Laspeyres and Paasche price (quantity indexes) use fixed weight indexes, either using beginning or ending period weights, but the Tornqvist price (quantity) index uses moving average weights (Fisher and Griliches 1995).
I do not include a variable for the share of single parent households, age at first marriage, labor force participation status, and educational attainment. My perspective is that these outcomes are either determined by the relative prices, including the relative price of women’s and men’s household labor, and income in the demand system or trend dominated factors. See for example (Goldin 2006). Much of the impact of these variables on household input demand will be captured by the male and female wage rates and trend, which are included as regressors in my demand system.

This patent stock index is a proxy for the true household patent stock index. Since we do not have the true index, the inclusion of the proxy will reduce the omitted variables problem (Wooldridge 2002, p. 61-71). Furthermore, because the rate of patenting of household goods dropped dramatically during World War II, our patent stock index is not well approximated by a linear trend. Furthermore, the household patent index is a control for disembodied technical change, and its inclusion can be expected to improve the quality of the estimated parameters of the other variables in the demand system.


There are of course other dimensions of demographic change that one might control for, e.g., employment status, age at first marriage, share of single parent households, education level of heads of household, and share of population who are immigrants. However, the fact that equation (13) contains a time trend means that all trended dominated factors are already accounted for. The tendency for single parent household, which is related to divorce and teenage pregnancy rates, may also be affected by the rate of growth of women’s wages relative to men’s and the price of housework-purchased substitute services. Finally, the changing age structure, due to increased longevity, and rural-urban composition of the population, which affects congestion and housing and air quality, seem to be the most basic of demographic attributes for which one should control over the study period (Juster and Stafford 1991; Robinson and Godbey 1997).

Because we have fitted the expenditure share equations in first-difference form, we do not have estimates of the “intercept term” in each of the share equations. Hence, it is impossible to compute the standard error of the predicted expenditure share for each input.

Any changes in standards of housework quality are assumed to be well represented by a linear time trend.

Of course this index does not include the direct impacts of changing life expectancy, family status, environmental noise, pollution, climate change or crime, which also impact social welfare, if they are not trend dominated or determined by other included variables. (Nordhaus 2003, Murphy and Topel 2003).

If the comparison was to the CPI, the differences would be even larger. The reasons are that the CPI has fixed beginning period weights, and when the methodology is revised, e.g., in 1983 and again in the late 1990s, the new procedures go forward but not backward. Hence, the reported CPI is not constructed using the same procedures over time.
Upgrading home heating equipment from noncentral to central heating was accomplished primarily with the construction of new housing units. The number of new U.S. housing starts during 1920 to 1929 was high by early 20th Century standards, averaging 703 thousand units per year; but they returned to the pre-1920 rate during the Great Depression, Recovery, and World War II years of 1930 to 1947, averaging only 358 thousand per year (U.S. Bureau of Census 1966). The big push on new housing came after the end of World War II, and over 1947 to 1964 the average annual number of new housing starts was at the fantastically high rate of 1.218 million.

The large investment in new housing units over 1947 to 1964 that had technically advanced central heating, piped hot and cold water, soot-free electric lighting (Bryant 1986; Nordhaus 1998, pp. 63) and insulated, relatively tight construction was a major factor permitting women’s hours of housework to decline over 1948 to 1965 even in the face of an increasing number of children.