The Household Revolution: Childcare, Housework, and Female Labor Force Participation*

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Abstract

Over the twentieth century, the allocation of womens' time changed dramatically. This paper explores the implications for the allocation of married womens' time stemming from: (1) the household revolution associated with the introduction of a variety of labor-saving devices in the home; (2) the remarkable increase in the relative wage of women; and (3) changes in childcare requirements associated with changes in fertility patterns. To do so, we construct a life-cycle model with home production and childcare constraints. The parameters of the childcare production function are estimated using micro evidence from U.S. time use data. We find that the increase in the relative wage of women is the most important explanation of the increase in married womens' market work time over the twentieth century. Changes in fertility had large effects up to 1980, but little effect thereafter. The declining price of durables has an appreciable effect only since 1980, an effect that is consistent with a broader interpretation of durable goods reflecting the marketization of home production.

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1 Introduction

Over the 20th century, the allocation of womens' time changed considerably, particularly for married women. In terms of market activity, the participation rate of women rose from 4.4% in 1900 to 59.1% in 2000. In contrast, the changes for men and for single women are far more modest. Women are also spending less time doing housework, although there is disagreement in the empirical literature as to the magnitude of this decline. Leading explanations for these changes include technological improvements in home production, changes in fertility, and the sharp increase in the wages of women relative to men. Greenwood, Seshadri and Yorukoglu (2005) attribute the bulk of the change in married womens' work time to innovations in home production while Jones, McGrattan and Manuelli (2003) assign almost no role to these innovations. Other studies attribute the increase in the second half of the century to increases in womens' relative wages (Attanasio, Low and Sanchez-Marcos, 2008 and Jones *et al.*, 2003), to a decline in childcare costs (Attanasio *et al.*, 2008) and/or human capital accumulation (Olivetti, 2006). Overall, there is little consensus on the role of the household revolution as a determinant of the dramatic increase in female labor participation throughout the 20th century.

In this paper, we construct a dynamic general equilibrium model to assess the role of changes in womens' relative wages, fertility, and home production technologies on the allocation of married womens' time. Unlike previous work in the literature, we center our analysis around the role that childcare constraints have played on married womens' decisions by including explicit childcare time constraints that match information from U.S. time use surveys. The time dimension of childcare has, as far as we know, never been included in a life-cycle model, nor has the durable goods revolution been examined alongside childcare constraints. This is surprising since the most important difference between married and single women is that married women are far more likely to have children than single women. The data also shows that life-cycle changes in market hours coincide with the childbearing years, although the specific pattern has changed over time.

In our model, each household solves a life-cycle problem. To capture the effects of the durable goods revolution, durables become cheaper over time and the home production function is such that durables are labor-saving. In the budget constraint, the relative wage of women rises as it does in the data. Finally, early in their life-cycles, households face childcare constraints which use up some of their time. Specifically, childcare takes as inputs primary childcare time (time spent exclusively caring for a child) and a secondary input given by secondary childcare time (time spent supervising a child, but for which the primary activity is not caring for a child) and daycare. In the model, secondary childcare time consists

of housework time and leisure. These constraints change over time owing to differences in fertility.[1]

To see the importance of the childcare constraint, and the importance of the distinction between primary and secondary childcare time, consider the effects of an increase in womens' relative wages. Absent childcare, the expected effects are an increase in market time coming at the expense of housework time and leisure. With childcare, such a fall in housework time and leisure implies a fall in secondary childcare. The household can satisfy its childcare constraint through a combination of more primary childcare time and increased purchases of daycare services. Increasing primary childcare time will diminish the response of market time to the higher relative wage while purchases of daycare act much like a tax on earnings. We expect that, in our model, women in their child-rearing years will be less responsive to the observed increases in their relative wage.

Next, consider what happens as the price of durables falls. Without childcare, the story runs as follows: Households buy up durables which frees up time out of housework. While households may increase their consumption of home goods, in general women will allocate more time to both leisure and working in the market. With childcare, the fall in housework time reduces secondary childcare time. The increase in leisure goes only part way in satisfying the childcare constraint. As above, we expect households to increase their primary childcare and purchases of daycare. Once more, the response of market time will be muted relative to the model without childcare.

The effects of an increase in childcare, coming about from an increase in fertility, are fairly straightforward. Such an increase will, generally, be accommodated through higher primary childcare, more secondary childcare time (housework time and leisure), and daycare purchases. These effects serve to reduce the time allocated to the market.

Relative to the existing literature, we are much more demanding in the breadth of evidence used to evaluate the model. First, we consider not just time allocated to market activity, but also housework, leisure, and primary and secondary childcare. Second, the model is evaluated on its ability to match life-cycle patterns implicit in U.S. time use surveys over the last third of the twentieth century. Third, we assess the model's ability to match up with aggregate time use over the entire twentieth century.

In general, the benchmark model does a good job replicating the life-cycle pattern of time use implied by U.S. time use surveys. When plotted against age, the model predicts that

[1]In our model, fertility is exogenous. In the world, realized fertility patterns are the product of a variety of factors, such as tastes for children, overall economic conditions, availability of birth control, and attitudes towards marriage and divorce. While the choice over the number of children is an interesting issue, for the purposes of looking at changes in the allocation of time, what presumably matters is realized fertility, whatever its causes.

market time initially declines, starts rising for women in their early 40s, then declining with women in their mid-50s. In this regard, the model best fits the 1965 time use survey which exhibits a similar pattern, although not as pronounced. Subsequent time use surveys display a flatter pattern (1975), then a hump-shaped pattern (1985 and 2006). The benchmark model does not predict such an evolution. Simulating the model without childcare yields profiles that decline monotonically with age, a pattern not seen the data. Thus, the inclusion of childcare is important in generating market time profiles that better resemble those seen in the U.S. The benchmark model does well in mimicking the age profiles of housework time and leisure, although it predicts too much housework time for the earlier time use surveys, and too little leisure. The model without childcare delivers similar profiles. The benchmark model also lines up well with regards to childcare time which is high for women until their early 40s.

The model is calibrated to aggregate data on market time in 1965 and 2006, and housework time in 2006. The model does reasonably well with regards to aggregate market time and housework time for the intervening time use surveys in 1975 and 1985. A more serious test of the model is how it performs early in the 20th century. Here, we are hampered by a dearth of data on married women. One of the few sources of data is from Wilson (1929, 1930) and U.S.Department of Agriculture (1944) for the 1920s (made available courtesy of Valerie Ramey). While the model predicts too little housework time, its predictions for leisure and market time are within the available range of estimates (albeit on the high side).

We evaluate the role of changes in relative wages, the declining price of durables, and changes in childcare over the 20th century. We do so by shutting down the effects of one factor at a time, then comparing the resulting simulated time series with those of the benchmark model. Focus on market time since it has received the most attention in the literature. We find that the bulk of the change in market time over the 20th century can be attributed to increases in womens' wages; this effect is $3\frac{1}{3}$ times larger than that of the household revolution. We see an even larger role for the rising wages of women when we exclude childcare from the model. Changes in childcare have a sizable impact over the period 1900 to 1980.

Curiously, our model finds that the bulk of the effect of the falling price of durables manifests itself since 1980; prior to that date, changes in married womens' market time is attributed to changes in wages and childcare. On the face of it, the fact that the model finds an important role for the price of durables only since 1980 seems problematic since most household appliances and consumer durables were in place by 1980. The one durable good to come onto the scene since then is the personal computer. Arguably, it is only since the advent of the internet and the ability to shop online that PCs have, potentially,

become time-saving devices, at least with regards to home production. We can make more sense of the model's predictions if we stretch the definition of durables to include some non-durables. Doing so does little violence to the model since a model period is sufficiently long that the depreciation rate is close to 100%. Over the last two or three decades, a variety of new time-saving goods have become available and facilitated home production, such as ready-made foods, frozen foods, pre-washed lettuce, semi-prepared meals, iron-free clothing and sheets, and new cleaning products. This interpretation of durables is consistent with the marketization of home production (the move from home to market goods) described by Ngai and Pissarides (2008) and Rogerson (2008). Using this broader interpretation of inputs to home production, our results support Greenwood *et al.*'s (2005) hypothesis that improvements in home technologies are important, but shifts their effects to a later period.

As previously mentioned, we are not the first to look at the time allocations of women over the 20th century. Broadly speaking, there have been two approaches. The first has looked at the roles of relative wages and the price of durables, excluding the effects of childcare and fertility. Greenwood *et al.* (2005) build a life-cycle model with home production and a durables adoption decision. They find that the durable goods revolution is the prime driver of changes in womens' market time and that its effects are roughly three times those of changes in relative wages. Jones *et al.* (2003) use a home production model more similar to ours. Since 1950, they find that most of the action in womens' market time is due to increases in the relative wage; changes in the price of durables play only a small role. Our results are consistent with those of Jones *et al.* in that we find little role for the durable goods revolution up to 1980.[2]

The second approach in the literature has combined rising wages of women with childcare (thus ignoring the durable goods revolution), and has analyzed the latter part of the 20th century. Attanasio *et al.* (2008) also model childcare although they do not model the time dimension of childcare. They find that a combination of higher wages and lower daycare costs can explain the changes in womens' market time since 1980. While Attanasio *et al.* do an admirable job in mustering evidence in favor of a fall in the price of daycare, the evidence is not clear cut. Our model provides an alternative interpretation of this time period in which higher wages and lower prices of durables account for the rise in womens' market

[2]The home production function in the core model of Greenwood *et al.* (2005) is Leontief and adopting durables is modeled as a shift to a new home production function with higher home labor productivity and a larger durable good. Greenwood *et al.* also present results for a model similar to ours except that the representative household is infinitely lived; in this case, they still find a large role for the durable goods revolution. In an appendix, we re-examine the Greenwood *et al.* (2005, Section 6) model. Our analysis suggests that this model either (a) implies a large role for the durable goods revolution but an implausibly large expenditure share on durables, or (b) an empirically plausible expenditure share on durables but a near non-existent role for the durable goods revolution.

time. Simulating our model with lower daycare costs as in Attanasio *et al.*, our model predicts an implausibly large decline in primary childcare time; see Section 6.2. Olivetti (2006) attributes the rise in womens' market time between the 1970s and 1990s to increases in the returns to work experience. Her model also implies a large decline in maternal care which, if we think of 'maternal care' as corresponding to primary childcare time, has not been observed. If, instead, we interpret maternal childcare as including secondary childcare time, then our model provides a means to square Olivetti's results with the data. Prior to the 2006 ATUS, secondary childcare time is not well measured. Nonetheless, it is plausible that secondary childcare time has fallen since its two chief components, leisure and housework, have declined. Thus, our distinction between primary and secondary childcare time can help reconcile results like those of Olivetti with the available facts.

In the literature, few (if any) papers have treated childcare time separately from home production. This seems surprising since, as Aguiar and Hurst (2007) note,

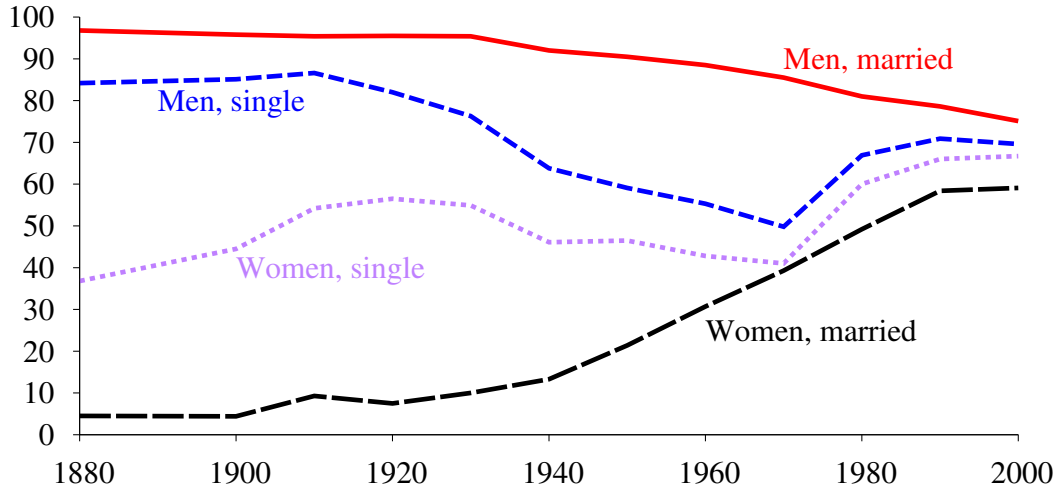
> there are certain elements of child rearing for which market goods and parental time are not good substitutes. This proposition is supported by the fact that hardly anyone uses market substitutes to raise their children completely. For this reason, we feel it appropriate to analyze childcare separately.

Recent empirical evidence also suggests that childcare constraints limited the impact of the household revolution. Dinkelman (2011) examined the impact of rural household electrification on employment in South Africa. She found that the impact of changes in household technology on market work is larger for women in their 30s and 40s, and less important in areas with a higher percentage of young children. Cardia (2012) found that modern appliances in the U.S. significantly increased labor force participation rates of married women with school age children, and to a lesser extent the participation of married women with pre-school children.[3]

The remainder of the paper is organized as follows: in Section 2 we examine census data and the micro data from the U.S. time use survey; in Section 3, we describe the model; in Section 4 we discuss the calibration of the model. Solving the model is difficult owing to the number of potentially non-binding constraints; see Section 5. In Section 6 we examine the results of the simulations. For an empirically plausible elasticity, the model finds essentially no role for the durable goods revolution to affect the allocation of womens' time. Section 7 concludes.

[3] Coen-Pirani, León and Lugauer (2010) and Cavalcanti and Tavares (2008) provide empirical evidence that support Greenwood *et al.*'s (2005) suggestion that improvements in home technology have contributed significantly to increasing womens' labor market participation rates.

Figure 1: Participation Rates by Sex, by Marital Status



2 Historical Facts: Female Labor Force, Housework and Childcare

In this section we use data from the U.S. Census and U.S. time use surveys to examine trends in married womens' market work, housework, childcare and leisure. The term married woman is used as a shorthand to include not only married women but also women with a domestic partner.

Labor force participation rates of married women rose markedly over the 20th century, from 4.4% in 1900 to 59.1% by 2000; see Figure 1. Participation by single women also rose, but not as dramatically, from 44.5% to 66.7%. In contrast, participation rates of men, whether married or single, have fallen modestly over the same time period.[4]

Figure 2 reports the observed changes in the allocation of time of married women to market work over the second half of the twentieth century. The data come from the 1965, 1975 and 1985 Time Use Surveys (TUS) and the 2006 American Time Use Survey (ATUS). Figure 2 suggests that in the 1960s, children significantly affected the amount of time that married women spent working in the market, and that this effect has since diminished. In 1965, married women in the age bracket 24-29 spent 89.97 minutes a day in market work versus 163.08 minutes spent by married women in the 42-47 age bracket. In 1975, these figures were 135.79 and 171.49 minutes, respectively, and in 2006, 198.88 and 236.88 (the figures for 2006 are reported in Table 1).

[4]These participation rates are based on the authors' calculations from U.S. Census data. Here, "married" corresponds to the category "married, spouse present" while "single" refers to individuals who are "never married/single".

Table 1: From the 2006 ATUS: Married Women Allocation of Time

Age	Observations	Personal Care	Leisure	Market Work	Housework	Housework (broad)
18-23	71	620.75	243.51	112.64	140.09	159.01
24-29	321	571.50	218.52	198.88	136.73	163.55
30-35	605	552.74	215.41	190.54	154.17	185.5
36-41	644	545.59	196.85	222.27	154.92	187.48
42-47	579	551.23	214.77	236.88	168.23	197.42
48-53	407	551.13	251.52	245.13	166.80	193.54
54-59	320	568.04	248.10	215.52	164.13	193.08
60-65	224	556.86	309.43	164.39	162.67	186.54
66-71	163	579.61	356.40	26.60	218.56	245.14
72-78	113	577.36	403.07	31.92	184.73	208.77
18-78	3447	559.94	248.08	191.75	163.09	191.31

Age	Observations	Primary Childcare	Secondary Childcare	Secondary Childcare (with housework)	Secondary Childcare (with broad housework)	Secondary Childcare (with leisure)
18-23	71	97.30	377.00	101.00	108.50	140.70
24-29	321	104.72	302.23	87.64	103.12	92.54
30-35	605	110.20	357.30	103.96	120.62	107.27
36-41	644	89.53	309.47	84.19	97.65	82.63
42-47	579	42.27	172.81	53.10	58.63	53.20
48-53	407	13.41	49.40	16.16	17.91	13.25
54-59	320	2.86	15.60	4.41	5.00	3.62
60-65	224	2.75	5.11	0.84	0.89	2.21
66-71	163	0.52	4.64	0.97	0.97	1.85
72-78	113	0.0	0.00	0.00	0.00	0.00
18-78	3447	49.15	166.47	47.9	139.53	49.38

Figure 2: Married Females: Daily Minutes of Work (Time Use Surveys)

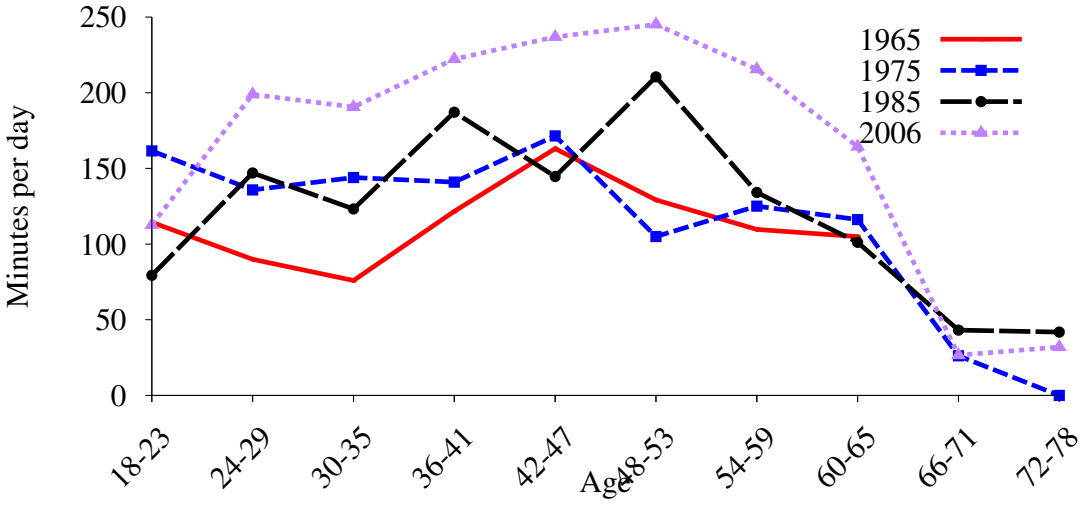


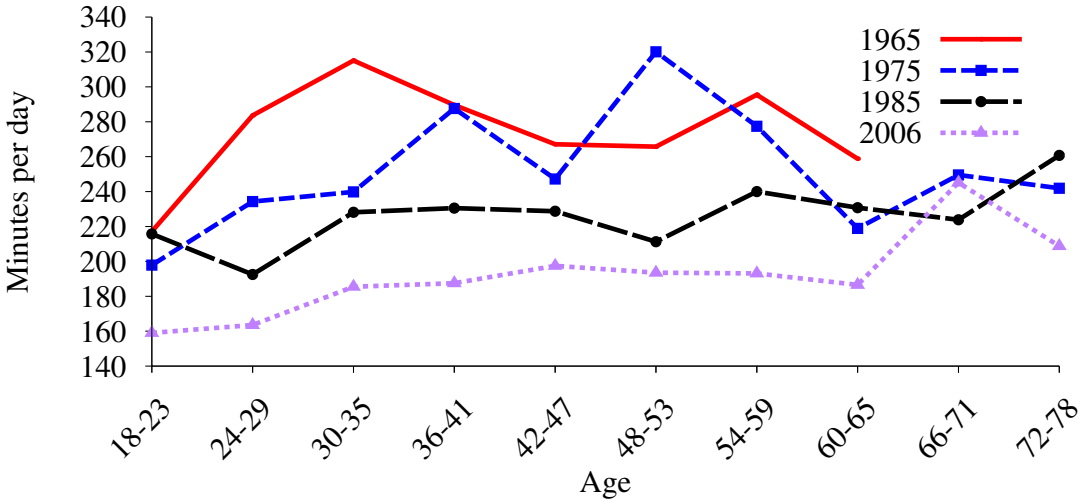
Figure 3 shows marked declines in housework between 1965 and 2006. For women in the age group 24-29, housework fell steadily from 283.63 minutes a day in 1965 to 136.73 minutes in 2006. The decline was similar for other age groups. On average, married women were spending 276.79 minutes a day in housework in 1965 versus 163.09 in 2006. While housework declined sharply after 1965, in principle, the supervision of a child required the same number of hours.[5] One concern with interpreting the decline in housework as time freed for either leisure or market work is that part of housework time was spent in providing child supervision in the form of secondary care. Unfortunately we do not have information about secondary childcare in the first half of the century, and the information we have from the Time Use Surveys prior to 2003 cannot be compared to the information collected in the more recent ATUS.

Since 2003 the ATUS has collected information about time spent during which a respondent had a household child under 13 in "his/her care" but is doing something else as a primary activity. The child need not be in the same room.[6] In addition, if the respondent reports providing both primary and secondary childcare, the time is attributed to primary care only. The responses from the ATUS are not directly comparable to earlier TUS since when respondents reported that they were engaged in secondary childcare, they were then asked "what else were you doing?" and so respondents may have under-reported passive supervision of children. The recent time use surveys (ATUS) give much higher estimates of

[5]It is possible that with less time spent on housework, childcare standards increased and more time is now spent supervising children than in the first half of the century.

[6]The time individuals spend providing secondary childcare to household children is restricted to the time starting when the first household member under the age of 13 woke up and ending when the last household child under 13 went to bed. It is also restricted to times when the respondent was awake.

Figure 3: Married Females: Daily Minutes of Housework (Time Use Surveys)



secondary childcare than previous time use surveys, suggesting that the question asked captured different notions of secondary childcare, with less passive child supervision captured in the earlier surveys.[7] For these reasons our figures report secondary childcare only for the 2006 survey but primary childcare for all four surveys. For both primary and secondary childcare,[8] we use only information about the respondent's own child/children and/or their spouse's child/children.

Table 1 reports for 2006 how many minutes per day married women spent on personal care, leisure, market work, housework, primary and secondary childcare.[9] It shows shows that married women spend almost three times more time on secondary childcare than doing primary childcare.

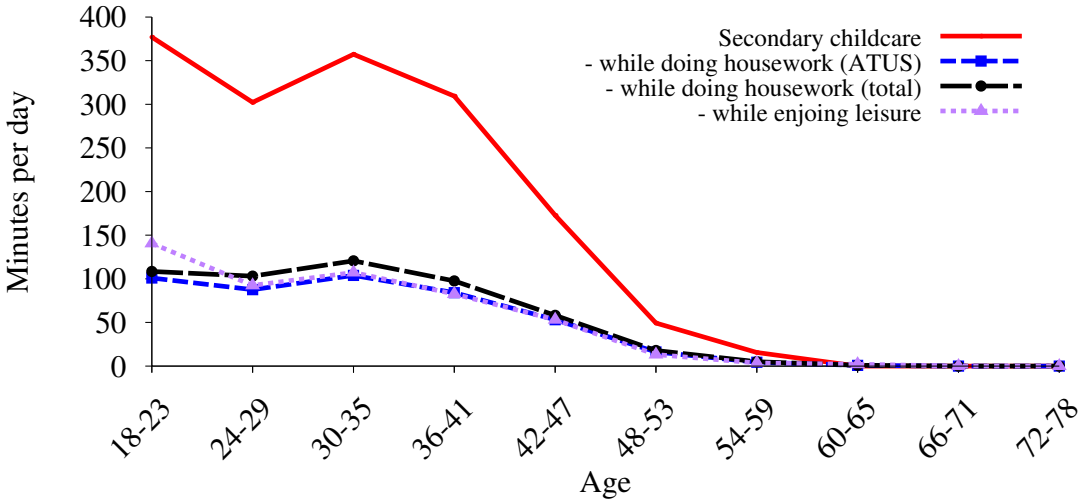
Figure 3 plots the total time married women spent on household chores while Figure 4

[7] Allard, Bianchi, Stewart and Wright (2007) describe the different measures of secondary childcare used in the surveys. They also compare the data from the 2003-2004 ATUS on primary and secondary childcare with the 2000 National Survey of Parents (NSP) conducted by the Survey Center at the University of Maryland. This is the most recent time-diary study that collects data on secondary activities. The NSP information about primary childcare is remarkably close to the information obtained from the 2003-2004 ATUS, but for secondary childcare the NSP reports much lower figures. Again, the difference is the more passive notion of childcare used in ATUS which aims at capturing the idea that the respondents may be doing something else, in a different room, not with the child, but nearby, with the knowledge of what the child is doing and capable of intervening if necessary. For primary childcare, however, the notion used in the different surveys provides very similar estimates.

[8] For secondary childcare we use the information under the flag trthh_ln

[9] The ATUS codes for personal care are: tutiercode1=01; for leisure: tutiercode1==12; for market work: work (tutier1code=05) + travel to work (tutier1code=18 + tutier2code=05); for housework: household activities (tutier1code=02); total housework housework + consumer purchases (tutier1code = 07, tutier2code=01+02+03)+ travel to make purchases (tutier1code=18, tutier2code=07)+ phone calls (tutier1code=16, tutier2code=01, tutier3code=04); for primary childcare: household children tutier1code=03, (tutier2code=01 + tutier2code=02 + tutier2code=03).

Figure 4: Secondary Care Time (2006 ATUS)



disaggregates, for 2006, secondary childcare time into its chief components (secondary childcare time while doing housework, and while enjoying leisure). Two measures of housework are used: one includes standard activities (code 02), while "total housework" also includes time spent purchasing groceries, food and gas, including time spent traveling and making phone calls related to purchases of consumption goods (see Table 1). These figures show that a considerable fraction of secondary childcare is done while mothers do household chores, particularly for married women younger than 41, and confirm the importance of the link between housework and childcare.

Figure 4 also shows secondary childcare while enjoying leisure. Both types of secondary childcare (joint with housework and with leisure) are of similar magnitude, each about a third of total secondary childcare. The other third of secondary childcare, which is not included as part of secondary childcare in our model and simulations, was done when the primary activity was some other activity such as grooming, eating a meal, or studying.[10] The large share of secondary childcare used to satisfy the childcare requirement suggest that the link between housework and childcare might have been even more important earlier on in the century, when housework was more time intensive.

Figure 5 shows the evolution of primary childcare over the second half of the twentieth century. The micro data do not reveal large changes in the amount of time spent on primary childcare between 1965 and 2006. However, if we exclude 1965 when childcare requirements were higher because of the baby boom, there is an increase in the time married women spend providing primary childcare to their children, about 40 minutes more a day in 2006 than in

[10]For example, in the 2006 ATUS survey a woman between the ages of 30 and 35 spent 39.84 minutes per day supervising the kids while eating a meal, and 26.88 minutes while the primary activity was traveling.

Figure 5: Married Females: Daily Minutes of Primary Childcare Time (Time Use Surveys)

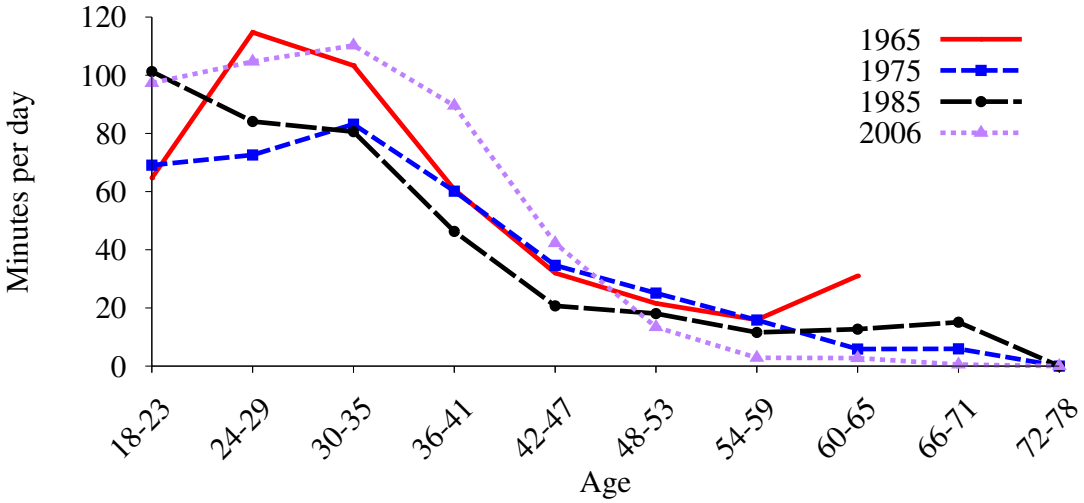
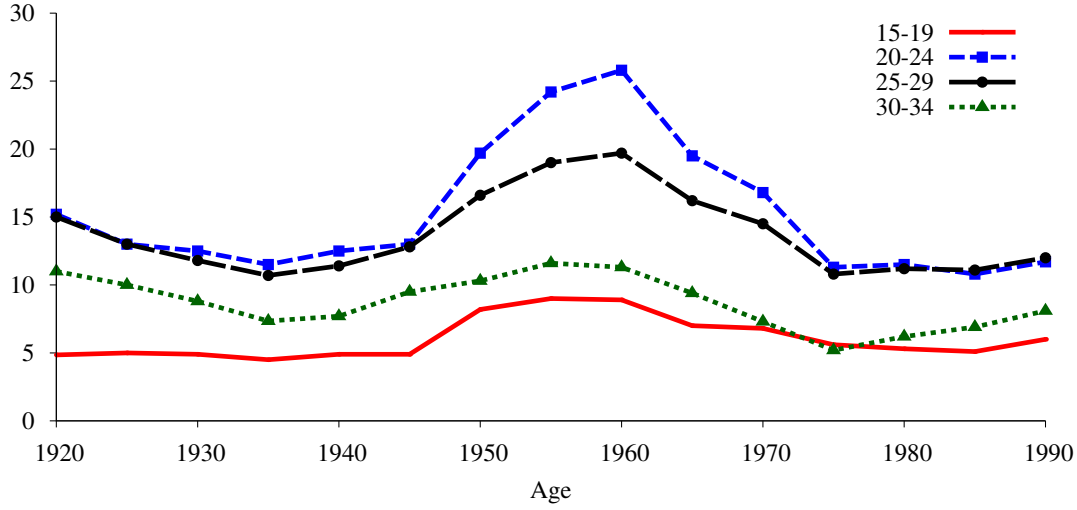


Figure 6: Live Births per 100 Women



1985 and 1975; a similar trend is reported in Aguiar and Hurst (2007).[11]

Finally, Figure 6 illustrates the importance of fertility changes throughout the twentieth century and particularly during the second half of the century. We will assess the role that changes in fertility, manifested as changes in childcare requirements, had on the allocation of married womens' time over the 20th century.

To recap, the evidence shows that there has been an increase in primary childcare time over the second half of the twentieth century. Secondary childcare time is much larger than primary childcare time, and roughly equal fractions of secondary childcare is done

[11]International data reveals similar patterns for childcare time. In Canada in the 1980s, for example, a couple with least one child under the age of five spent 4.1 hours a day in primary care and 12.3 hours in secondary care; see Harvey, Marshall and Frederick (1991).

while performing housework tasks and while enjoying leisure. What little we know about secondary childcare time in the 20th century comes only at the end of that century. From the ATUS, we know that roughly a third of secondary childcare time is spent doing housework. While the effects of the durable goods revolution and increases in the relative wages of women operate primarily through the trade-offs between market time, housework time, and leisure, it seems reasonable to think that there will be important effects operating through the time required for childcare. These are the avenues explored below.

3 Economic Environment

3.1 Households

The economy is populated by overlapping generations of households. Households within a cohort are identical and each is comprised of a married couple which splits its time among market work, housework, secondary and primary childcare, and leisure. While men always work a fixed number of hours, the household chooses how much women work. As in Greenwood *et al.* (2005), women earn a fraction of what men earn. A household 'formed' at date t has preferences summarized by

$$\max \sum_{i=0}^{T-1} \beta^i U(c^i_{mt}, c^i_{ht}, \ell^i_t) \tag{1}$$

where T is the 'lifetime' of the household, c denotes consumption, ℓ leisure, i superscripts refer to the *age* of the household, t superscripts denote the cohort (that is, the date of formation of the household), m subscripts pertain to *market* variables, and h subscripts indicate *home work* activities. Thus, c^i_{mt} is market consumption of a household of cohort t at age i (which means this consumption is enjoyed at calendar date $t+i$). The functional form for U is:

$$U(c_m, c_h, \ell) = \begin{cases} \ln C(c_m, c_h) + \omega \ln \ell & \text{if } \gamma = 1 \\ \frac{[C(c_m, c_h)\ell^\omega]^{1-\gamma}}{1-\gamma} & \text{if } \gamma \in (0,1) \cup (1, \infty) \end{cases} \tag{2}$$

where $C(c_m, c_h)$ is a consumption aggregator:

$$C(c_m, c_h) = \begin{cases} c_m^\psi c_h^{1-\psi} & \text{if } \xi = 0 \\ \left[\psi c_m^\xi + (1-\psi) c_h^\xi\right]^{1/\xi} & \text{if } \xi \in (-\infty, 0) \cup (0, 1). \end{cases} \tag{3}$$

Home goods, c^i_{ht}, are produced by combining durables, d^i_t, with time, n^i_{ht}:

$$c^i_{ht} = H(d^i_t, n^i_{ht}) \tag{4}$$

where

$$H(d, n_h) = \begin{cases} d^\eta n_h^{1-\eta} & \text{if } \zeta = 0 \\ \left[\eta d^\zeta + (1-\eta) n_h^\zeta\right]^{1/\zeta} & \text{if } \zeta \in (-\infty, 0) \cup (0, 1). \end{cases} \tag{5}$$

A key feature of the model is the childcare constraint:

$$c^i_{ct} \leq G(n^i_{pt}, n^i_{ht}, \ell^i_t, s^i_t) \tag{6}$$

where

$$G(n_p, n_h, \ell, s) = \begin{cases} n_p^\nu (n_s + s)^{1-\nu} & \text{if } \varphi = 0 \\ \left[\nu n_p^\varphi + (1-\nu)(n_s + s)^\varphi\right]^{1/\varphi} & \text{if } \varphi \in (-\infty, 0) \cup (0, 1) \end{cases} \tag{7}$$

where n_p is *primary* childcare time, n_s is *secondary* childcare time, and s is purchased daycare services. Secondary childcare time and daycare are assumed to be perfect substitutes. Secondary childcare is a fraction of leisure time, ℓ, and housework time, n_h:

$$n_s = \theta_\ell \ell + \theta_h n_h. \tag{8}$$

Childcare is a constraint in that a household of age i *must* provide total childcare services of c^i_c; the household does not directly value the provision of these childcare services. These services, in turn, are produced either with primary childcare time, n^i_p, or a secondary input (either secondary childcare time, n^i_s, or daycare, s^i_t). Consequently, when there are children in the household, home work time, n^i_h, produces two distinct goods: home consumption goods, c^i_h, and childcare, c^i_c.

The household's budget constraint is

$$c^i_{mt} + q_{t+i} x^i_t + p_{t+i} s^i_t + a^{i+1}_t = \overline{n} w_{t+i} + \phi^i_t n^i_{mt} w_{t+i} + r_{t+i} a^i_t \tag{9}$$

where x^i_t represents investment in durables by a household of cohort t at age i, a^i_t denotes this household's beginning-of-period market assets, $\overline{n}$ is the (fixed) amount of time that the husband works, w_{t+i} is the real wage, ϕ^i_t is the efficiency of the wife relative to the husband, r_{t+i} is the gross return on capital, q_{t+i} is the price of durables and p_{t+i} is the price of daycare. It is assumed that the price of daycare is a fraction ρ of the wife's wage: $p_{t+i} = \rho \phi^i_t w_{t+i}$.

The household faces a constraint on the *wife's* time,

$$n^i_{mt} + n^i_{ht} + n^i_{pt} + \ell^i_t = \tilde{T} \tag{10}$$

where $\tilde{T}$ is the time endowment. Notice that secondary childcare time does not appear in the time constraint since it is a byproduct of leisure and housework time.

There are a number of non-negativity constraints in the model. The important ones are on the allocations of time and purchases of daycare services. As well, a woman cannot work more than a 'standard' work week. These constraints are:

$$0 \leq n^i_{mt} \leq \overline{n}, \quad n^i_{ht} \geq 0, \quad n^i_{pt} \geq 0, \quad \ell^i_t \geq 0, \quad s^i_t \geq 0. \tag{11}$$

The law of motion for durables is

$$d^i_t = (1 - \delta_d) d^{i-1}_t + x^i_t. \tag{12}$$

The household faces the following boundary conditions:

$$d^{-1}_t = 0, \quad a^0_t = 0, \quad d^T_t \geq 0, \quad a^{T+1}_t \geq 0 \tag{13}$$

That is, the household starts with no durables and no real assets, and it ends with non-negative holdings of durables and real assets. Notice that the timing with respect to durables implies that durables purchased at age i are available for use at age i. This assumption means that durables are available for home production in the first period of the household's life.

The problem of the household is to maximize Eq. (1) subject to Eqs. (4), (6) and (9)–(13), taking as given prices.

3.2 Firms

Firms face the usual static problem of maximizing period-by-period profits, viz.

$$\max_{\{K_t, N_t\}} F(K_t, N_t) - \tilde{r}_t K_t - w_t N_t$$

where K_t is capital, N_t the labor input, $\tilde{r}_t$ the real rental rate of capital, and w_t the real wage. The relationship between $\tilde{r}_t$, above, and r_t in the household's problem is:

$$r_t = \tilde{r}_t + 1 - \delta_k$$

3.3 Market Clearing Conditions

Capital market clearing is given by

$$K_t = \sum_{i=0}^{T-1} a_{t-i}^i.$$

The right-hand side adds up the market assets of all individuals alive at date t. In reading through this equation, recall that the superscript on a is the household's age while the subscript denotes its cohort (when it was 'born').

Similarly, labor market clearing is

$$N_t = T\ \overline{n} + \sum_{i=0}^{T-1} \phi_{t-i}^i n_{m,t-i}^i.$$

Recall that male labor supply is constant at $\overline{n}$.

Finally, goods market clearing is written

$$\sum_{i=0}^{T-1} c_{m,t-i}^i + q_t \sum_{i=0}^{T-1} x_{t-i}^i + p_t \sum_{i=0}^{T-1} s_{t-i}^i + K_{t+1} = F(K_t, N_t) + (1-\delta_k)K_t$$

4 Calibration

Functional forms are given by Eqs. (2), (3), (5) and (7). The model's parameters are summarized in Table 2.

To start, a model period is set to 6 years. The reason behind this choice is that the TUS reports the number of children under 6, and the number aged 6-12. Setting the model period to 6 allows us to line up with the age ranges of children as reported in the TUS. The household 'lives' for 10 periods, or 60 years. In data terms, we are looking at households for which the respondent is aged between 18 and 78.

A number of the model's parameters are standard, and hopefully require little discussion. These parameters include: α, capital's share of income; δ_k, the depreciation rate of market capital; and δ_d, the depreciation rate of durables. The depreciation rates are consistent with results reported in Gomme and Rupert (2007). The initial price of durables, q_{1900} is chosen so that in 2006, the durables-output ratio is around 0.325 in 2006 – a value that is consistent with the data; again, see Gomme and Rupert. The price of durables declines at the rate 8.3% per annum, as in Greenwood *et al.*. Time spent working by men, $\overline{n}$, is 320 minutes per day (a 7.5 hour work day, 5 days a week). $\overline{n}$ is also the maximum amount of time that a woman can work in the market.

Table 2: Parameter Values

Time		
	Length of a period (years)	6
	Number of periods of 'life'	10
$\tilde{T}$	Time endowment (minutes per day)	680
Market production		
α	Capital's share	0.33
δ_k	Depreciation rate of market capital (annual)	0.07
Utility		
ω	Weight on leisure in utility function	0.6354
β	Discount factor (annual)	0.9821
Consumption aggregator		
ψ	Weight on market consumption	0.7450
ξ	CES parameter	-0.3
Home production		
η	Weight on durables	0.4590
ζ	CES parameter	0.35
δ_d	Depreciation rate of durables (annual)	0.2
q_{1900}	Initial price of durables, 1900	13
g_q	Change in price of durables	-8.3%
Childcare		
ν	Weight on primary childcare time	0.58347
φ	CES parameter	0.75715
θ_ℓ		0.6
θ_h		0.8
ρ	cost of childcare as a fraction of wages	0.5

Table 3: Childcare Production Function Estimates

Parameter	Estimate	Standard Error
p_{01}	159.74207	6.79635
p_{02}	171.81351	8.98634
p_{10}	213.92775	5.86796
p_{11}	239.36241	7.27665
p_{12}	235.77827	11.40349
p_{20}	256.11998	6.80167
p_{21}	251.56954	11.23365
p_{22}	229.29934	21.86333
ν	0.58347	0.01497
φ	0.75715	0.04515

Perhaps the most problematic parameters are those characterizing the childcare production function, ν and φ. The *model* says that for household i, childcare is

$$c_c^i = \left[\nu(n_p^i)^\varphi + (1-\nu)(n_s^i + s^i)^\varphi\right]^{1/\varphi}.$$

In order to estimate the parameters of the childcare production function, we assume that non-working married women use no daycare services. For such women, the estimating equation is of the form

$$0 = -\sum_{\substack{j=0,1,2 \\ j\neq j'}} \sum_{j'=0,1,2} p_{jj'} I_{jj'} + \left[\nu(n_p^i)^\varphi + (1-\nu)(n_s^i)^\varphi\right]^{1/\varphi} + \epsilon_i$$

where $I_{jj'}$ is an indicator function equal to 1 if the woman has j children under the age of 6 and j' children aged 6 to 12.[12] $p_{jj'}$ gives the childcare required if the number of children is given by the ordered pair, (j, j'). The parameters to be estimated are the $p_{jj'}$s, ν and φ. Conceptually, the values of ν and φ trace out different childcare isoquants while the $p_{jj'}$s index different isoquants.

The parameter estimates are summarized in Table 3. All of the parameters are fairly tightly estimated. What is most important is that the CES parameter, φ, implies a fair deal of substitutability between primary and secondary childcare. In other words, households will find it relatively easy to substitute, say, from primary to secondary childcare in order to satisfy their childcare requirement.

The childcare requirements, $p_{jj'}$, can now be used to calculate the amount of daycare working women have to provide to their children to ensure that the childcare requirements

[12] In the ATUS, very few women have more than 2 children under the age of 6, or more than 2 children aged 6 to 12.

are met.[13]

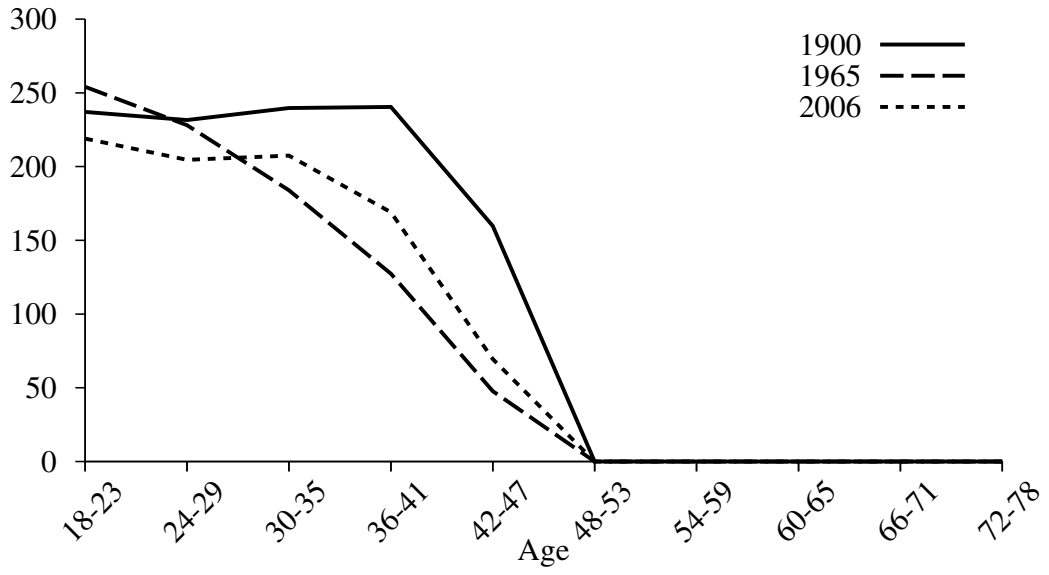
Going from the estimates of the $p_{jj'}$s to the childcare requirement for a 'typical' woman in a particular cohort is somewhat involved. First, fertility data is available at five year intervals from 1920 through 1995. For dates prior to 1920, the 1920 observation is repeated; for dates after 1995, the 1995 observation is repeated. The fertility data is available for the following age groups: 20–24, 25–29, 30–34 and 35–39. It is assumed that woman over the age of 40 do not give birth; as an empirical matter, their fertility rate is extremely low. This data is converted to annual using spline interpolation. Second, the fertility data is used to compute the number of newborns for each year, for each possible age of a woman; it is assumed that all woman in the same age group have the same fertility. Third, use the newborn data to figure out the number of children under the age of 6, at 6 year intervals. The same data, offset by 6 years, gives the number of children aged 6 to 12. Fourth, these 'child profiles' are adjusted to match the ATUS. The reason for this adjustment is that the fertility data is for all woman while from the ATUS we are interested in only married women. Finally, use the childcare requirement estimates, $p_{jj'}$, to compute the childcare requirement for each household cohort. Since a representative woman of a particular cohort will, in general, not have an integer number of children, it is necessary to interpolate the childcare requirement.

Figure 7 presents the childcare requirement profile for the 1900, 1965 and 2006 cohorts. Early in the twentieth century, the childcare requirement was fairly flat until the typical woman reached her mid-30s, falling off fairly shortly thereafter. The 1965 cohort, which is toward the end of the baby boom, saw a higher childcare requirement early in the life-cycle, but this requirement fell off fairly smoothly with age. By the end of the twentieth century, the typical childcare requirements of a woman early in her life-cycle had fallen, but were reasonably flat to her early-30s. One may well ask why the sharp increase in births associated with the baby boom – see Figure 6 – does not manifest itself in a sharper increase in childcare requirements for the 1965 cohort. The answer lies in the childcare requirement estimates in Table 3. Having two children under the age of 6, for example, does not double the childcare requirement, it increases it by 20%. In other words, the incremental effect of an additional child on the childcare requirement is relatively small once a woman already has a child.

Recall from Eq. (8) that secondary childcare time, n_s^i, is the sum of a fraction θ_ℓ of leisure time and a fraction θ_h of housework time. It is assumed that these fractions are constant: they do not vary with the age of the woman, nor with the age or number of children. The

[13] In principle, we should be using primary and secondary childcare time time for the household, not just the wife. Unfortunately, as discussed earlier, the ATUS only collects time use data for the respondent, not the household.

Figure 7: Childcare Requirement Profiles by Cohort



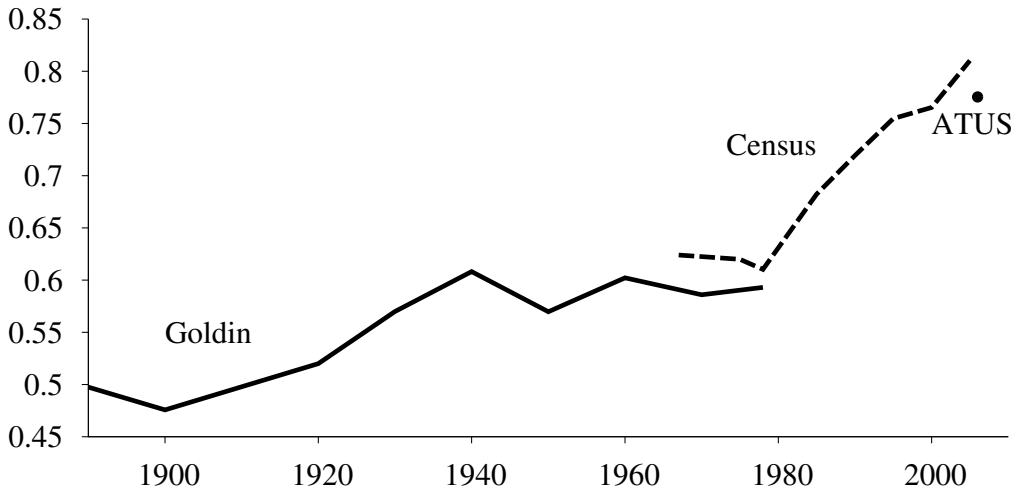
fractions are taken to roughly match observations from the ATUS data and are as reported in Table 2.

The parameter ρ is the cost of daycare as a fraction of a woman's wage. Its value is obtained as the ratio of average female domestic worker earnings to average female earnings using the 1950 Census.

For durables to be labor-saving, durables and housework time have to be fairly substitutable. Hence we set the CES elasticity of substitutions in the home production $\zeta = 0.35$ which implies more substitutability than Cobb-Douglas. This value for ζ is in the range estimated by McGrattan, Rogerson and Wright (1997) and Rupert, Rogerson and Wright (1995). Consider, instead, the setup in Greenwood *et al.* (2005). There, market time is indivisible, hours and durables are perfect complements (the home production function is Leontief), durables are indivisible, and by assumption, adopting the latest vintage of durables increases the productivity of housework time in a labor-embodied fashion. As the price of durables falls, a household eventually adopts the newest vintage of durables. While their model is quite suitable for analyzing the household durable adoption decision, our model is more appropriate for comparing the allocation of time between market work, housework, childcare and leisure.

The elasticity of substitution between market and home goods plays an important role in the analysis. As Jones *et al.* (2003) show, when market and home goods are good substitutes, improvements in home technologies induces a decrease in market hours; only when the two goods are highly complementary will market hours increase. Empirical evidence in McGrattan *et al.* (1997) and Rupert *et al.* (1995) suggest, instead, that home and market

Figure 8: Earning Gap: Female to Male Earnings



goods are substitutes, which implies that improvements in home technologies will decrease female market hours. As in Jones *et al.* (2003) we assume complementarity between the two goods so that improvements in home technology generate a positive effect on female market work. While Jones *et al.* (2003) set $\xi = -0.75$, which implies an elasticity of substitution between home and market goods equal to 0.57, we assume slightly more substitutability by setting $\xi = -0.3$ (an elasticity of 0.74).

The data for the earning gap for the period from 1900 to 1980 included, come from Goldin (1990) and for the period between 1985 to 2005, from various issues of the Census Statistical Abstracts. Both definitions use median full time earnings for white women and men. As Figure 8 shows, the earning gap increases sharply after 1980; similar increases are also found in Jones *et al.* (2003) and Attanasio *et al.* (2008).

The time endowment, $\tilde{T}$, requires some discussion. In the business cycle literature, the usual practice is to set the time endowment to discretionary time: total time less sleeping and personal grooming. In the business cycle model, this discretionary time is then split between working and leisure. Since there are no time series on aggregate leisure, the business cycle literature is not particularly interested in leisure per se. However, as shown in Table 1, what the business cycle researcher calls leisure is, in fact, a mix of many activities, only a small portion of which is leisure. If we took the total time endowment (1440 minutes per day), subtracted off personal care (from the ATUS, about 560 minutes per day), and matched the profiles for market work, housework and primary childcare time, then the model would predict far too much leisure time since, on average, women spend about 200 minutes per day on other activities. For the model, it is important to get leisure right since it is one of the inputs to secondary childcare. In order for the model to have a chance at matching the

observed life-cycle profiles, we treat this 'extra' 200 minutes per day as non-discretionary time. Alternatively, we can compute $\tilde{T}$ as the sum of average market time, housework time, primary childcare time, and leisure. Doing so gives a value of about 680 for $\tilde{T}$. Defining discretionary time in this fashion simply gives the model an opportunity to get average time allocations right, not the life-cycle patterns.

The remaining parameters are: ω, the weight on leisure in utility; β, the discount factor; ψ, the weight on market consumption in the consumption aggregator; and η, the weight on durables in the home production function. These parameters are chosen to roughly match the following observations:

1. From the 2006 ATUS, married women worked, on average, 198.28 minutes per day.
2. From the 1965 U.S. TUS, married women worked, on average, 113.6 minutes per day.
3. An annual real interest rate of 4%.
4. From the 2006 ATUS, married women on average performed 192.02 minutes of housework.

5 Solving the Model

There are a number of features in the model that make it difficult to solve using standard techniques, meaning solving sets of non-linear Euler equations and constraints. First, the fact that secondary childcare time and daycare services are perfect substitutes means that the non-negativity constraint on daycare sometimes binds. Second, there is sufficient substitutability between primary childcare time and secondary childcare that the non-negativity constraint on primary childcare time sometimes binds. These two problems are exacerbated by the fact that secondary childcare time is a 'cast off' of other activities, namely housework time and leisure. Third, the substitutability between durables and housework time mean that the non-negativity constraint on housework time may also bind. Finally, the inequality constraint on childcare may bind, particularly later in a woman's life-cycle when secondary childcare time may be more than sufficient to satisfy this constraint.

While a number of approaches were taken to solving the model, in the end a brute force maximization of lifetime utility subject to the various constraints and non-negativity constraints did the trick, with one modification: the Euler equations for asset and durables accumulation were included among the constraints.[14] In a sense, including these Euler equations amounts to blending a straight maximization of lifetime utility with solving Euler

[14]The actual optimization code (with inequality constraints) is due to Schittkowski (1985/86).

equations. The reason for including these Euler equations is that while the solution algorithm performed well in finding solutions for 'static' variables ('well' in the sense that these variables fit their relevant Euler equations), the same could not be said for the 'dynamic' variables.

Simulating the model proceeds as follows. First, conjecture a path for the capital-labor ratio. The capital-labor ratio then gives paths for the real wage and the return to capital. Second, solve the household's problem for each cohort. That is, given the path for factor prices, maximize each household's lifetime utility, subject to its constraints. Third, compute what the model implies for the path of the capital-labor ratio. If this computed path is sufficiently close to that conjectured, stop; otherwise, update the conjecture for the path of the capital-labor ratio and repeat the steps above.

Finally, we construct artificial time use surveys in exactly the same way that they are for the U.S. Specifically, we do not present the life-cycle profile for some cohort. Instead, we build up a model-based time use survey that corresponds to a snapshot of the time allocations of the generations that are alive at the time of the survey.

6 Results of the Simulations

The benchmark simulation incorporates the historical patterns in the earnings gap, the price of durables, and fertility (and so childcare requirements). The following counterfactual experiments are also conducted: (1) eliminate the effects of changes in home productivity by keeping the price of durables at their 1900 level; (2) keep the relative wage of women fixed at its 1900 level; (3) maintain fertility, and so childcare requirements, at their 1900 level; and (4) eliminate the childcare requirement.

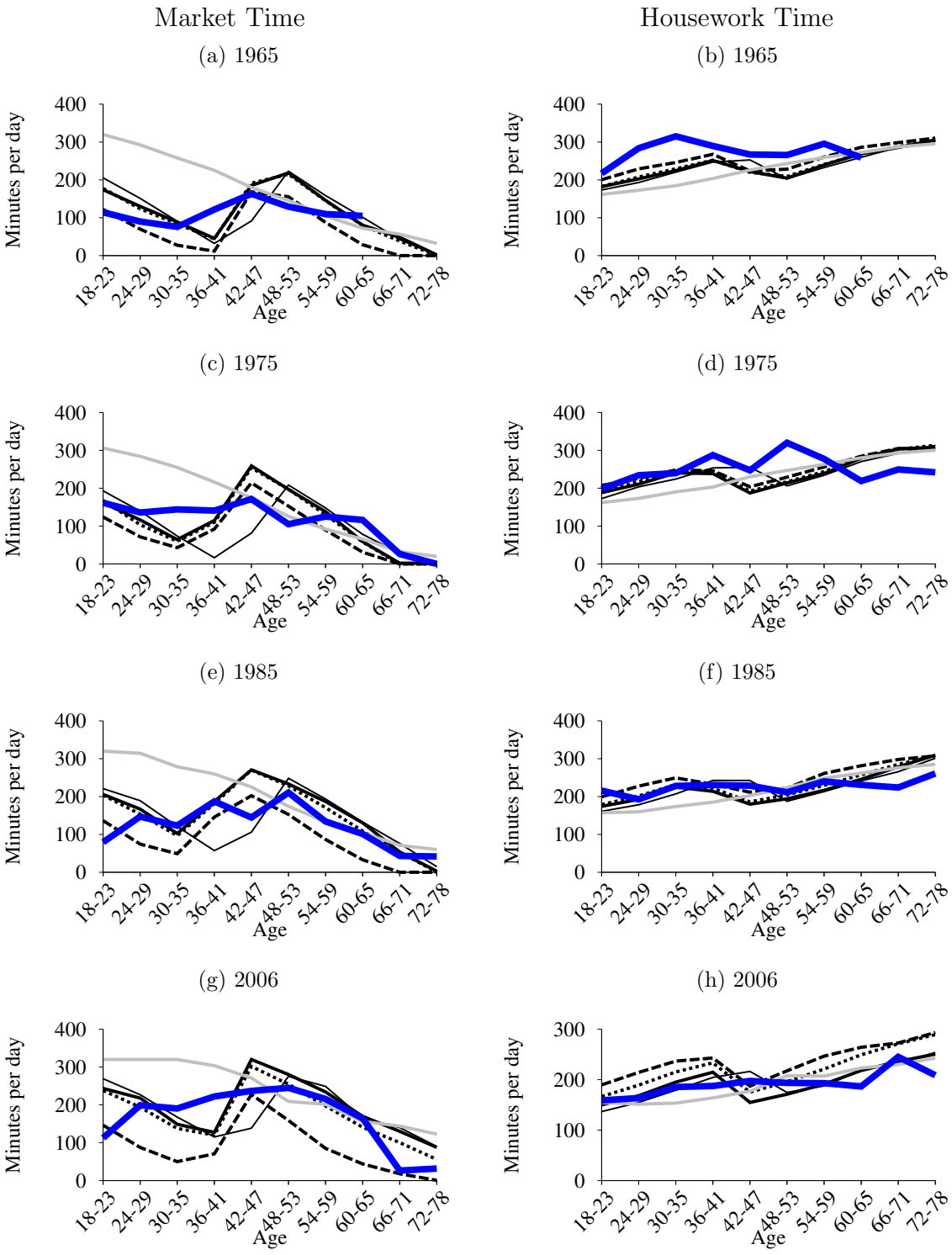
The model is evaluated in two ways. First, Figures 9–11 show how well the model performs with regards to the life-cycle profiles for the allocation of time as reported in various U.S. time use surveys. Second, Figure 12 examine the model's ability to mimic the observed behavior of aggregate time allocations. A final experiment, reported in Figure 15, considers the aggregate effects of a 15% reduction in the cost of childcare.

6.1 Life-cycle Patterns

Benchmark Model

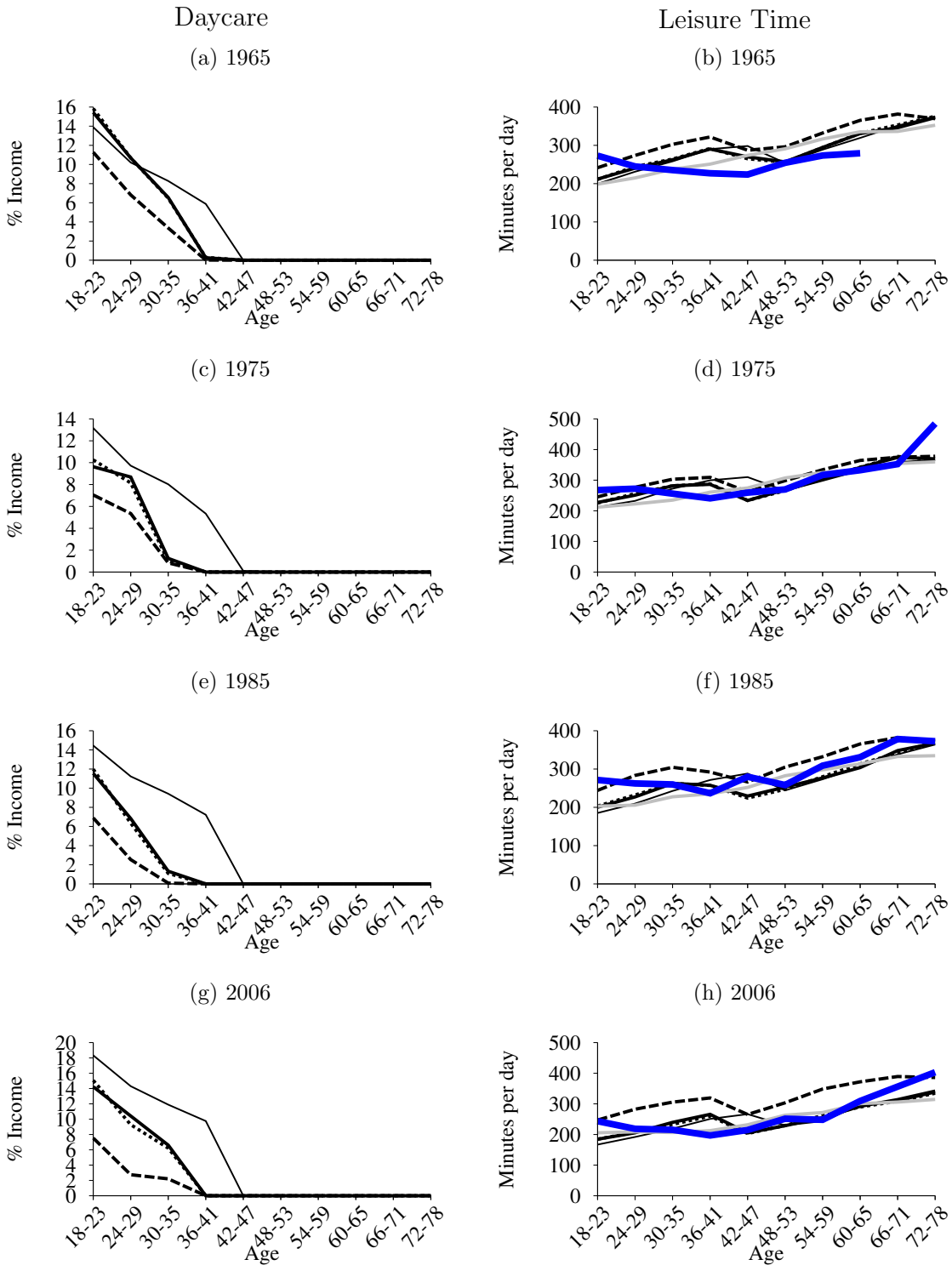
Data and model simulations for market work are presented in the left-hand panels of Figure 9. The heavy blue solid line corresponds to data from the time use surveys. In order to evaluate the role played by childcare in our model, it is useful to start by looking at a version of the model without childcare. This scenario is given by the gray line in Figure 9, the model

Figure 9: Simulations: Market Work and Housework



Legend: (1) heavy, blue solid line: U.S. Time Use Survey data (various years); (2) black solid line: benchmark model; (3) black dashed line: 1900 relative wage; (4) black dotted line: 1900 price of durables; (5) thin black line: 1900 childcare requirements; (6) gray solid line: no childcare.

Figure 10: Simulations: Leisure and Daycare

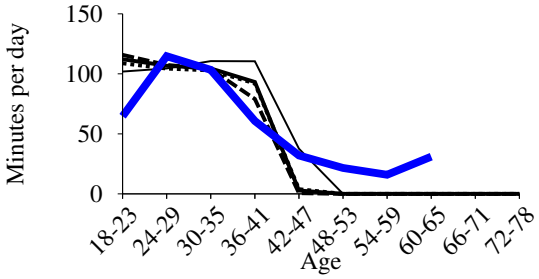


Legend: (1) heavy, blue solid line: U.S. Time Use Survey data (various years); (2) black solid line: benchmark model; (3) black dashed line: 1900 relative wage; (4) black dotted line: 1900 price of durables; (5) thin black line: 1900 childcare requirements; (6) Gray solid line: no childcare.

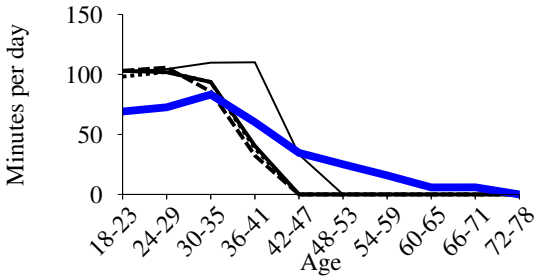
Figure 11: Simulations: Primary and Secondary Childcare

Primary Childcare Time

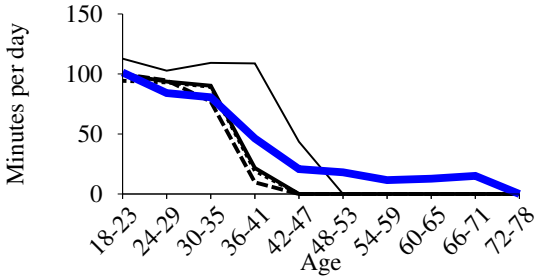
(a) 1965



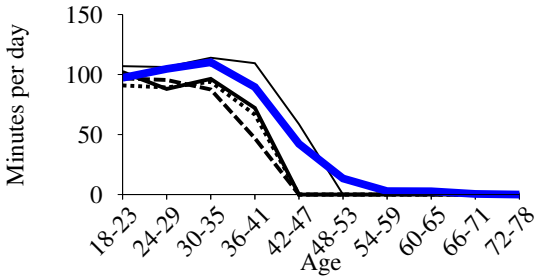
(c) 1975



(e) 1985

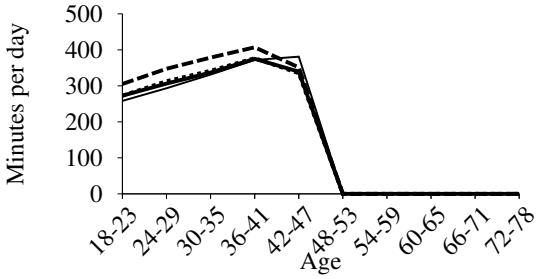


(g) 2006

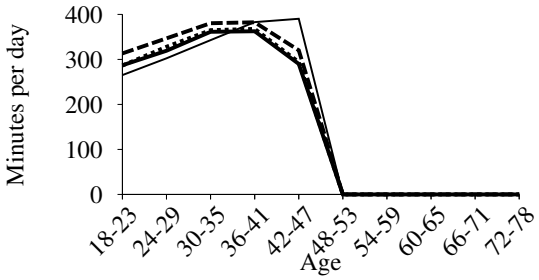


Secondary Childcare Time

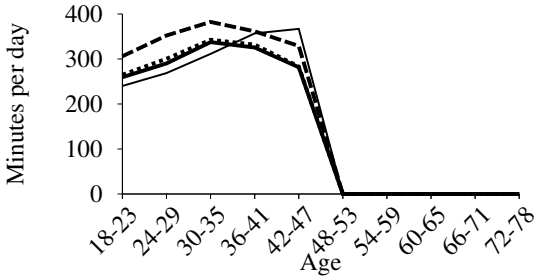
(b) 1965



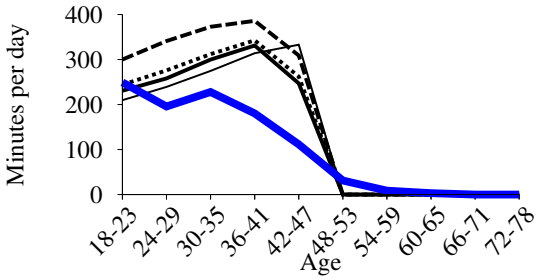
(d) 1975



(f) 1985



(h) 2006



Legend: (1) heavy, blue solid line: U.S. Time Use Survey data (various years); (2) black solid line: benchmark model; (3) black dashed line: 1900 relative wage; (4) black dotted line: 1900 price of durables; (5) thin black line: 1900 childcare requirements; (6) Gray solid line: no childcare.

predicts that young women allocate a lot of time to working in the market and that their allocation of time declines with age. Consequently, the model without childcare cannot reproduce the double peak life-cycle pattern observed for the 1960s nor the hump-shaped pattern observed in more recent years.

Figure 9 also reports market work for our benchmark model with childcare constraints (see the black solid lines), in addition to several other experiments which we discuss in the next subsection. The benchmark model predicts realistic life-cycle allocations even if quantitatively there are some discrepancies. It over-predicts market time for the youngest group of women (18 to 23): for 2006, the model predicts 243.5 minutes compared to 112.64 in the data. This discrepancy is not due to time spent on education: married women in this age group devote only 23 minutes per day to education. There are a number of anomalies concerning this age group that cannot be understood within the context of our model. As reported in Table 1, this age group spends substantially more time on personal care than the 24 to 29 age group: 620 minutes compared to 571. The younger age group also spends more time on leisure (243 minutes versus 218) than the next older age group. A further issue is that the number of observations for this youngest age group is much smaller than the other age groups.[15]

More importantly, the model under-predicts market time of women between the ages of 24 and 35, and over-predicts market time for those aged 42 to 47. One potential explanation for these discrepancies is that we have abstracted from human capital accumulation, and just as importantly, human capital depreciation when a woman is temporarily out of the market (see Olivetti, 2006 and Attanasio *et al.*, 2008). Were these elements included, women may find it preferable to juggle childcare to maintain their attachment to the market. Human capital considerations may also explain why the model over-predicts market hours for women in their early 40s since, in the data, these women experienced sizable depreciation of their human capital during their childbearing years.

It is also possible that we have overstated childcare costs, for which there is little information available (we used the ratio of female domestic wages to average female wages for 1950). For example, a significant number of women receive family help; see Cardia and Ng (2003). Using the 1992 release of the Health and Retirement Survey, they find that 42.5% of households with at least one child and grandchild spent more than 100 hours per year caring for grandchildren.[16]

[15]This youngest age group spends 93.4 minutes per day on secondary childcare while watching television compared to 52.7 minutes for the next oldest age group, and 23 minutes per day on education versus 74 for the next oldest age group.

[16]Other data sources likewise indicate that there are non-trivial intergenerational transfers of time. Using the National Longitudinal Survey of Labor Market Experience,Presser (1989) finds that grandmothers are

In all four time use surveys, housework and leisure are flat-to-rising over the life-cycle (see the right-hand side of Figure 9 and the left-hand side of Figure 10). The model also generates flat-to-rising profiles and matches the data quite well except for 1965 where the model under-predicts housework and over-predicts leisure. One explanation for this discrepancy between the model and the data for 1965 is that our model may underestimate the quantity of housework associated with larger families during the baby boom. While the calibration ensures that the model roughly matches *average* housework time in 2006, the life-cycle pattern was not targeted. That the model nearly reproduces the observed life-cycle pattern can be taken as independent evidence in favor of the model.

In the data, primary childcare starts off high for young women, then drops off gradually starting in a woman's late 30s; see the left-hand side of Figure 11. The model displays a similar pattern. Since the model over-predicts secondary childcare time for women in their 30s, the childcare production function and estimated childcare requirements necessarily imply that the model will under-predict primary childcare time for these women. Across all four time use surveys, the model under-predicts the amount of primary childcare time for women over the age of 40. There are two reasons for these disparities. First, we assumed that after the age of 40, women do not give birth. As an empirical matter, birthrates drop off sharply after age 35. In the model the 36–41 age group is the last one with young children; the 42–47 group has only older children (aged 6–12). Consequently, the older age groups face no childcare requirements. Yet, in the data, women in their 60s are still providing some primary childcare time. It is likely that the children being care for are grandchildren, a possibility that we have abstracted from. Second, for the 42–47 age group, the model predicts no primary childcare time. The reason for this is that this age group has more than enough secondary childcare time to satisfy their childcare constraint.

For secondary childcare, we focus on the 2006 survey since it seems to have better measured secondary childcare time. The life-cycle pattern for secondary childcare looks similar to that of primary childcare: it is high for young women, then falls for older women; see the right-hand side of Figure 11. The model exhibits a similar pattern although it over-predicts secondary childcare for women in their 30s. The model matches aggregate childcare requirements but is attributing more primary childcare than observed. The children production function and constraint necessarily implies that an over-prediction for secondary childcare time will be accompanied by an under-prediction for primary childcare time.

The model also makes predictions for daycare use; see the left-hand side of Figure 10. It predicts that the heaviest use is early in a woman's life, and that daycare drops off fairly quickly. In fact use of daycare goes to zero *before* the childcare constraint does; so does

the most common (23.9%) type of care for preschool children, averaging 27.1 hours per week.

primary childcare time. What is happening is that by the time a woman reaches her early 40s, there is more than sufficient secondary childcare time to satisfy the childcare constraint. This prediction follows from the assumptions that secondary childcare time and daycare are perfect substitutes, and that secondary childcare time is a good substitute for primary childcare time. In the model, in 2006, married women 30 to 35 years old spend 6.6% of family income on day-care – an expenditure pattern in line with Anderson and Levine (1999) who find that families with at least one child under 6 spend an average of 7.7% of their income on daycare.

Overall, while the match is not perfect, the model's predictions for the allocation of womens' time between market work, housework, leisure and children line up reasonably well with the time use surveys.

Counterfactuals

Figures 9–11 report three counterfactual experiments. The first asks what the second half of the twentieth century would have looked like without the durable goods revolution. We simulate this scenario by keeping the price of durables at its 1900 level. Except for 2006, the model predicts very modest changes in time allocations. For 2006, the model's results are qualitatively in accord with Greenwood *et al.* (2005): absent the durable goods revolution, married women would work less in the market and more at home; they would also allocate a little less time to primary childcare, and some more to leisure. The take-away message is that the model predicts little change in married womens' lives due to the durable goods revolution until after 1985.

The second experiment keeps the relative wage of women at its 1900 level. Not surprisingly, women substitute out of market work into other activities, chiefly housework and leisure. Owing to these increases in leisure and housework time, secondary childcare time rises. This latter increase leads to marked declines in both primary childcare time and daycare, again by virtue of their substitutability with secondary childcare time. Overall, the effects of lowering the relative wage of women is quite sizable, particularly in 2006 when the relative wage is much higher than the other survey years; see Figure 8.

The final experiment imposes the 1900 childcare requirement throughout the twentieth century. As reported in Figure 7, the principal effect of this change is to boost the childcare requirement of older women (between their mid-30s and mid-40s) since early in the twentieth century, women had more children and later into life. It is, then, not surprising that the effects of this experiment manifest themselves chiefly among women in their mid-30s to mid-40s. The model predicts that these middle aged women spend less time working in the market, more time doing housework and enjoying leisure (and so more time on secondary

childcare time). Primary childcare time and use of daycare by middle aged women are both much higher than under the benchmark calibration.

Overall, these experiments indicate sizable effects associated with fertility (as reflected in changes in childcare requirements), particularly among middle aged women; large effects over the entire life-cycle due to the increase in the relative wage of women; and fairly modest effects of the durable goods revolution, especially prior to the 2006 survey.

6.2 Aggregate Trends

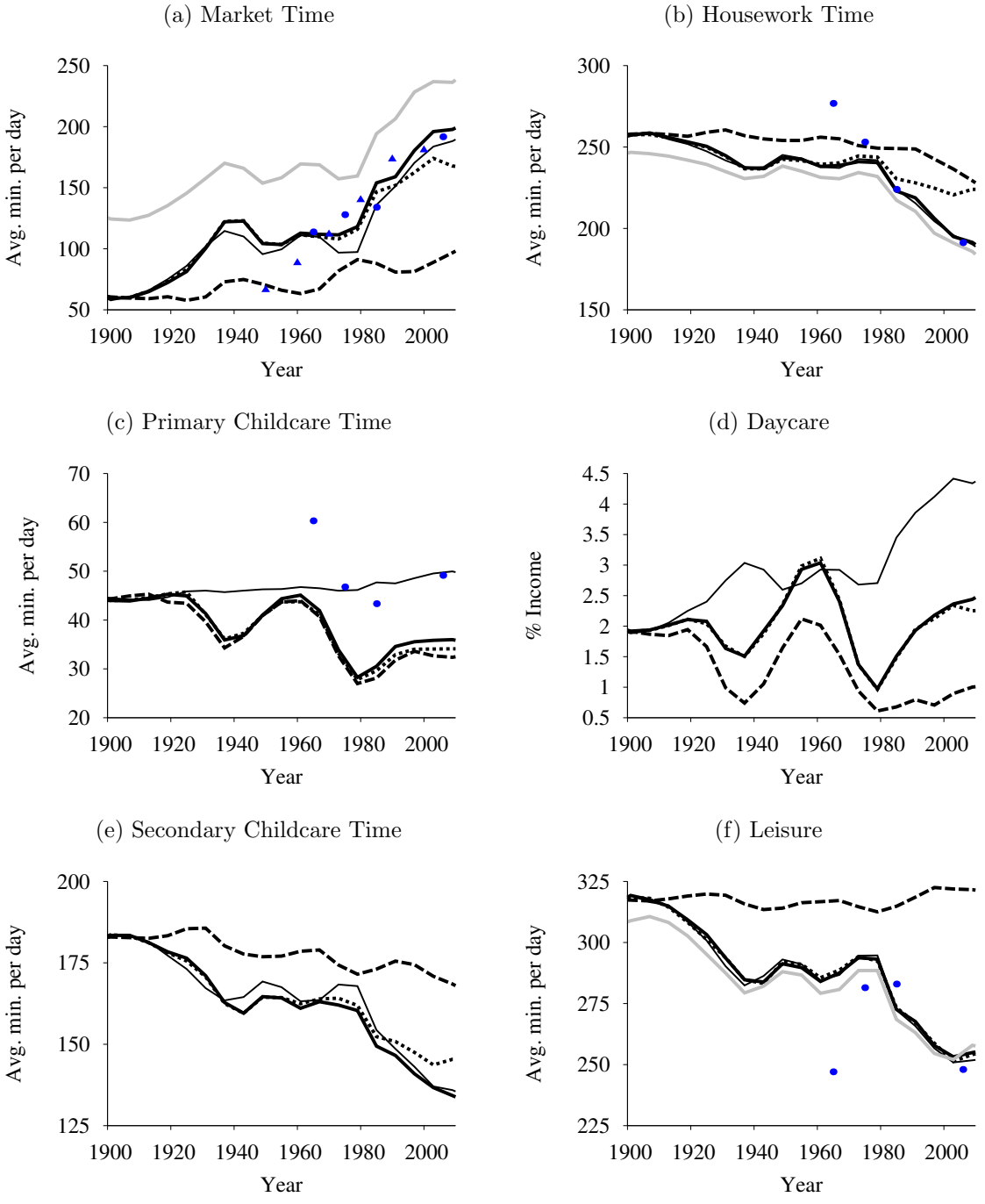
Figure 12 presents aggregated time allocations over the past century, with the same counterfactual experiments as in Section 6.1.

Recall that the model was calibrated to match average market time in 1965 and 2006. As shown in Figure 12a, the model does reasonably well in matching average market time as reported in the 1975 and 1985 time use surveys. A more rigorous test of the model is how it performs over the twentieth century as a whole. The benchmark model predicts a marked increase in the amount of time women spend worked in the market, from an average of 59.5 minutes per day in 1900 to 196 minutes in 2006, an increase of 136.5 minutes; see Figure 12a and Table 5. There is no comparable time allocation data for the U.S. going back to the early 20th century. Ramey and Francis (2009) find that for *all* women, market time increases from 82.2 minutes per day in 1900 to 162.1 in 2005. Their figures almost certainly understate the increase in market time of married women since few married women worked early in the twentieth century. Nonetheless, the model's predictions appear plausible. Survey results for the 1920s, reported in Wilson (1929, 1930), reveal that, on average, married women spent between 28.3 and 104.6 minutes a day working in the market, depending on where they lived; see Table 4 for details.[17] Our model predicts that in 1925, married women worked 81 minutes a day which is toward the upper end of the range reported by Wilson. The model's prediction for housework time (including care of family members) is considerably lower than the available estimates. On the other hand, its predictions for primary childcare time and leisure are within the range of estimates in Table 4.

The relative effects of wage changes, technological improvements in the home sector and fertility changes can be evaluated by keeping each of these elements, one at the time, constant at their 1900 level. To understand how we gauge the contribution of a factor, consider the relative wage. Figure 12a shows that when the relative wage does not change from its 1900 value, market time does not change as much as for the benchmark model. Intuitively, this observation suggests that the model assigns a large role to changes in the relative wage. The

[17] Valerie Ramey kindly provided us with the Wilson data.

Figure 12: Historical Trends



Legend: (1) blue dots: U.S. time use surveys; (2) black solid line: benchmark model; (3) black dashed line: 1900 relative wage; (4) black dotted line: 1900 price of durables; (5) thin black line: 1900 childcare requirements; (6) gray solid line: no childcare.

Table 4: Time-use of Married Women in the 1920s

Category	Homemaking (including care of family members	Care of family members	Work	Leisure
Wilson (1929, 1930): Married Homemakers, Oregon, 1926–27				
Farm	442.3	32.6	104.6	204.0
Country	470.6	42.9	51.4	225.4
Towns	441.4	55.7	28.3	261.4
U.S.Department of Agriculture (1944): Homemakers, 1924–28, 1930–31				
Farm	443.1	33.4	81.4	240.0
Non-farm rural	441.4	40.7	38.6	270.0
College-educated urban, cities $<$ 100,000	426.0	88.3	18.0	312.0
College-educated urban, cities $>$ 100,000	405.4	81.4	18.9	323.1
Model, 1925	295.4	44.9	81.3	303.3

Source: Data supplied by Valerie Ramey

percentage contribution of changes in relative wages is measured by the change in market time *not* attributable to changes in the relative wage (that is, the change according to the benchmark model, 138.2 minutes between 1900 and 2006, less the change when the relative wage is kept fixed, 36.2 minutes) divided by the change according to the benchmark model (again, 138.2 minutes). According to this calculation, 73.8% of the changes in market time were due to changes in the relative wage, 22% to the declining price of durables, and 5.6% to changes in fertility.[18] Absent childcare, the model makes similar predictions: relative wage changes account for 86.2% of the changes in market time while the durable goods revolution is responsible for 18.8%. While the role of fertility changes and childcare appear to be fairly modest when viewed across the entire twentieth century, the picture is somewhat different when we look at specific episodes like the baby boom, as discussed below.

For comparison with Greenwood *et al.* (2005), an exercise similar to the above, except stopping in 1980, can be performed. In this case, one would conclude that 47.7% of the change in married womens' market work time is attributable to changes in the relative wage of women, 4.6% to changes in the price of durables, and 32.5% to changes in fertility. Abstracting from childcare, the contributions are 73.1% due to relative wage changes and

[18]These percentages do not add up to 100% because we only change one factor at a time. Getting the contributions to add up to 100% can be achieved by holding first one, then two, then three factors constant; this latter calculation would require taking a stand on the order of the factors.

Table 5: Summary Statistics, Aggregate Female Market Time

	Minutes Per Day			Change from 1900		Contribution (%)	
	1900	1980	2006	1980	2006	1980	2006
Benchmark	59.5	118.1	197.7	58.6	138.2		
· Relative Wage	60.5	91.2	96.7	30.6	36.2	47.7	73.8
· Price of Durables	60.0	115.9	167.8	55.9	107.7	4.6	22.0
· Childcare	57.7	97.3	188.1	39.6	130.4	32.5	5.6
No Childcare	124.4	159.6	236.3	76.7	111.9		
· Relative Wage	122.3	128.4	149.0	20.6	26.7	73.1	76.2
· Price of Durables	121.1	150.0	212.0	62.1	90.9	19.0	18.8

19% owing to the falling price of durables. These figures stand in contrast to those reported in Greenwood *et al.* who find that the durable goods revolution has an effect three times larger than that of changes in the relative wage. As in Attanasio *et al.* (2008), after the 1980s, wage changes play an important role but are not sufficient in generating the observed increase in market work. They include a 15% decrease in child care cost, for which there is some evidence, and generate changes in market work consistent with the data. In our case, decreased fertility and technological improvements in home production explain a significant part of the increase.

The aggregate effects of housework time are summarized in Figure 12b. The benchmark model predicts a decline in housework time (including also primary childcare) of 24.5% which is close to the 35% decline reported in Ramey and Francis (2009) for all women 14 years old and older. While the model was calibrated to match average home hours in 2006, its predictions over the twentieth century provide a useful test of the theory. In 1925, the model predicts that married women spent 250.5 minutes per day doing housework, or 295.4 minutes per day on the combination of housework and primary childcare. These numbers are considerably smaller than those reported by Wilson: between 441 and 470 minutes per day. However, our model omits many aspect of home production that were relevant in the early twentieth century. For example, our model abstracts from technological improvements in reproductive medicine and infant formula which Albanesi and Olivetti (2007) suggest have, over the course of the twentieth century, reduced the time required for home production. In the 1920s, our model also predicts too much leisure. Taken together, these observations indicate that the model needs to better match the reallocation between home production and leisure, not market time. Between the mid-1920s and late-1960s, Bryant (1996) reports a 14% decline in housework time; over this period, the model predicts a fall of 5%, or a third of the total.

Performing a decomposition similar to that described for market time, between 1900 and

2003, the model assigns the largest role to changes in relative wages (45.2% of the total), a slightly smaller contribution from the durable goods revolution (41.2%), and a modest role to changes in fertility (14.9%).[19]

The benchmark model predicts a fall in leisure from 319.2 minutes in 1900 to 254.9 minutes in 2006, a drop of 20.1%; see Figure 12f. Table 4 reports that in the 1920s married women spent between 204 and 261.4 minutes a day in leisure activities. This is lower than our model's estimate of 303.5 minutes a day for 1925. For 2006, 1985 and 1975 the benchmark model comes close to the aggregates computed from the time use surveys. The model under-predicts the 1965 survey, mirroring the same mismatch we found in the previous section when examining life-cycle changes and in Figure 12b for 1965.

Almost all of the decline in leisure time over the twentieth century, 64.3 minutes per day, can be attributed to increases in the relative wages of women. Absent these increases, the model predicts a slight increase of 4.3 minutes per day in leisure which implies that changes in relative wages explain essentially all of the change in leisure. By way of contrast, shutting down either the fall in the price of durables or changes in childcare result in declines in leisure of 64.3 and 67.6 minutes, respectively, meaning that these changes account for virtually none of the change in leisure time.

For primary childcare time, the benchmark model generates a decline of 8 minutes. The small size of this decline is due, in part, to averaging over all women. Recall that of the 10 age groupings, only 5 have a positive childcare requirement, and of these the model predicts that only the first 4 actually allocate time to primary childcare. As a result, the average fall of 8 minutes corresponds to 20 minutes per day for those women who actually allocate time to primary childcare. Absent changes in the relative wages of women, primary childcare time would have fallen by 12 minutes. Shutting down the fall in the price of durables, primary childcare time would have fallen by 9.9 minutes. On the other hand, imposing the 1900 childcare requirement throughout would have required an extra 5.4 minutes of primary childcare time in 2006.

Given the results for housework time and leisure, it should not be surprising that the model attributes most of its predicted decline in secondary childcare time (49.2 minutes according to the benchmark model) to increases in the relative wage of women (70.7%) with a lesser contribution by the durable goods revolution (22.2%). It is perhaps surprising that changes in childcare requirements account for only 2.9% of the decline in secondary childcare time.

[19]These decompositions are computed for the sum of housework time and primary childcare. Similar numbers are obtained for housework time alone, although in this case the contribution of childcare is very small.

The model predicts a 0.52 percentage point increase in the expenditure share on daycare, from 1.92% in 1900 to 2.44 in 2006. Absent the increase in the relative wage of women, this expenditure share would have fallen by 0.91 percentage points. Without the durable goods revolution, the expenditure share on daycare rises by 0.34 percentage points, while imposing the 1900 childcare constraint throughout the twentieth century raises the expenditure share by 2.46 percentage points.

Figure 12a shows that the effects of fertility changes on market time were felt most strongly between the late 1930s and late 1950s, and 1970-2006 (especially the 1970s). Improvements in home production only started having an appreciable effect on market time starting around 1950, with the impact growing thereafter. The influence of changes in the relative wages of women are felt throughout most of the twentieth century, with particularly sizable effects from the mid-1930s to mid-1940s, and more recently since 1980 when the relative wage of women rose precipitously.

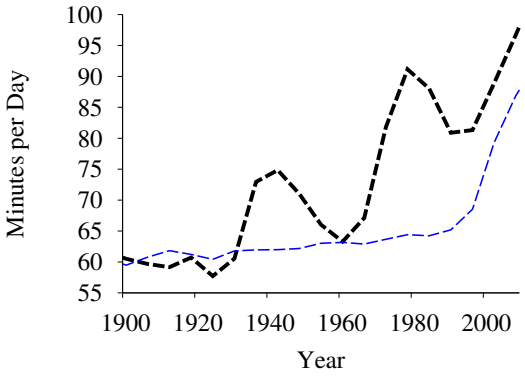
While the model does quite well in predicting changes in market work over the century, it has problems reproducing the aggregate pattern to housework in two periods: early in the twentieth century, and during the baby boom following World War II. Both periods correspond to times of high fertility. We suspect that these discrepancies may reflect extra housework time directly attributable to children that have been omitted from our model, such as extra laundry and food preparation. We already mentioned the potential role of progress in medical technologies, obstetric practices, and infant formula in reducing time spent in home production early in the twentieth century. During this period and the baby boom, there is a corresponding mismatch with regards to leisure time. To perform better, the model would have to capture the reallocation of extra housework time from leisure, not market time.

The model can also be used to assess the importance of childcare on the allocation of married womens' time. Figures 12a and 12b show that absent the childcare constraint, in 2006 women would have worked 38.6 more minutes per day in the market. This prediction accords reasonably well with evidence from the 2006 ATUS. For example, relative to a woman without children, a married woman aged $30-35$ with at least one child under the age of six works 60.7 fewer minutes in the market. The model does not do so well with respect to housework time, predicting that without childcare, a married woman would spent 5.6 fewer minutes per day doing housework. From the ATUS, women aged $30-35$ with children spend 55 more minutes per day doing housework than a woman without children. Over the entire twentieth century, childcare has an impact on changes in the time women spend on market work. The benchmark calibration predicts a rise in market work from 59.5 minutes per day in 1901 to 197.7 in 2003 – a 3.3 times increase. Without childcare, the model predicts a rise

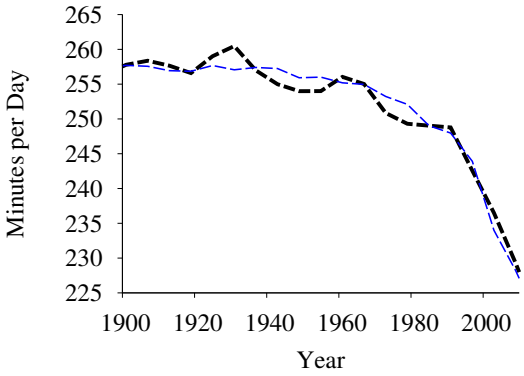
Figure 13: The Effects of Childcare

1900 Relative Wage

(a) Market Time

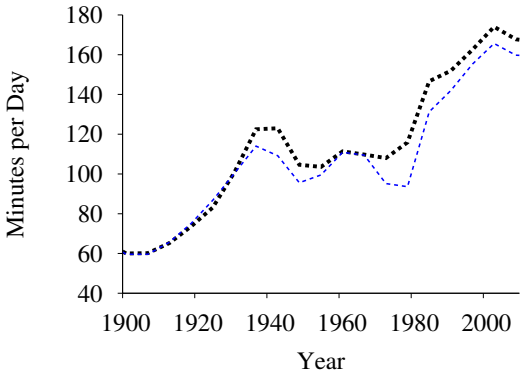


(b) Housework Time

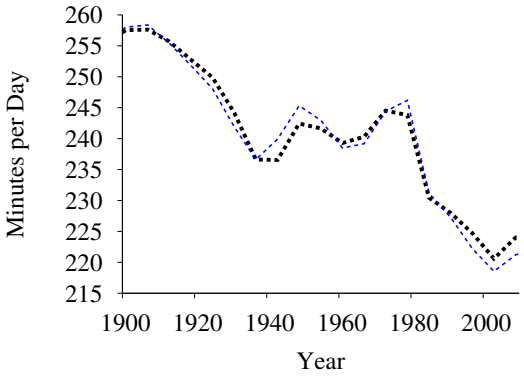


1900 Price of Durables

(c) Market Time



(d) Housework Time



Legend: (1) black dashed line: 1900 relative wage; (2) thin blue dashed line: 1900 relative wage and 1900 childcare; (3) black dotted line: 1900 price of durables; (4) thin blue dotted line: 1900 price of durables and 1900 childcare.

from 124.4 minutes per day in 1901 to 236.3 in 2003, or roughly 1.9 times larger.

In Figure 12, the effects of changes in childcare on the allocation of time tend to be masked by the effects of changes in the relative wage and the price of durables. Figure 13 attempts to remedy this situation. To start, Figures 13a and 13b suppresses changes in the relative wage. In addition, the thin blue line keeps childcare at its 1900 level. Consequently, the difference between the thick black line and thin blue line gives the contribution of childcare, holding fixed the relative wage of women. Thus, the two rises and falls in market time – the first from 1930 to 1960, the second from 1960 to 1900 – can be attributed to changes in childcare that are ultimately linked back to variation in fertility, interacted with the durable goods revolution. Thus, changes in fertility increased market time by as much as 13 minutes around 1943, and 27 minutes around 1979. The effects on housework time are much smaller:

a decrease of 2 minutes in 1943 that can be attributed to changes in childcare, and 3 minutes in 1979.

In Figures 13c and 13d, the price of durables is maintained at its 1900 value. In this case, the thin blue line gives the effect of changes in the relative wage only (that is, childcare is kept at its 1900 level) while the thick black line gives the effect of changes in both the relative wage and childcare. Once more, the difference between the two lines provides insight to the role of changes in childcare, interacted in this case with the rising relative wage of women. For market time, there are again two rises and falls in the differences between the thick black line and the thin blue line, one from 1930 to 1960, the other starting in 1960. The peak responses are again in 1943 (14 minutes) and 1979 (22 minutes). In this case, changes in childcare again tend to reduce housework time although the effects are again small: a decline of 3 minutes in 1943 and 2 minutes in 1979.

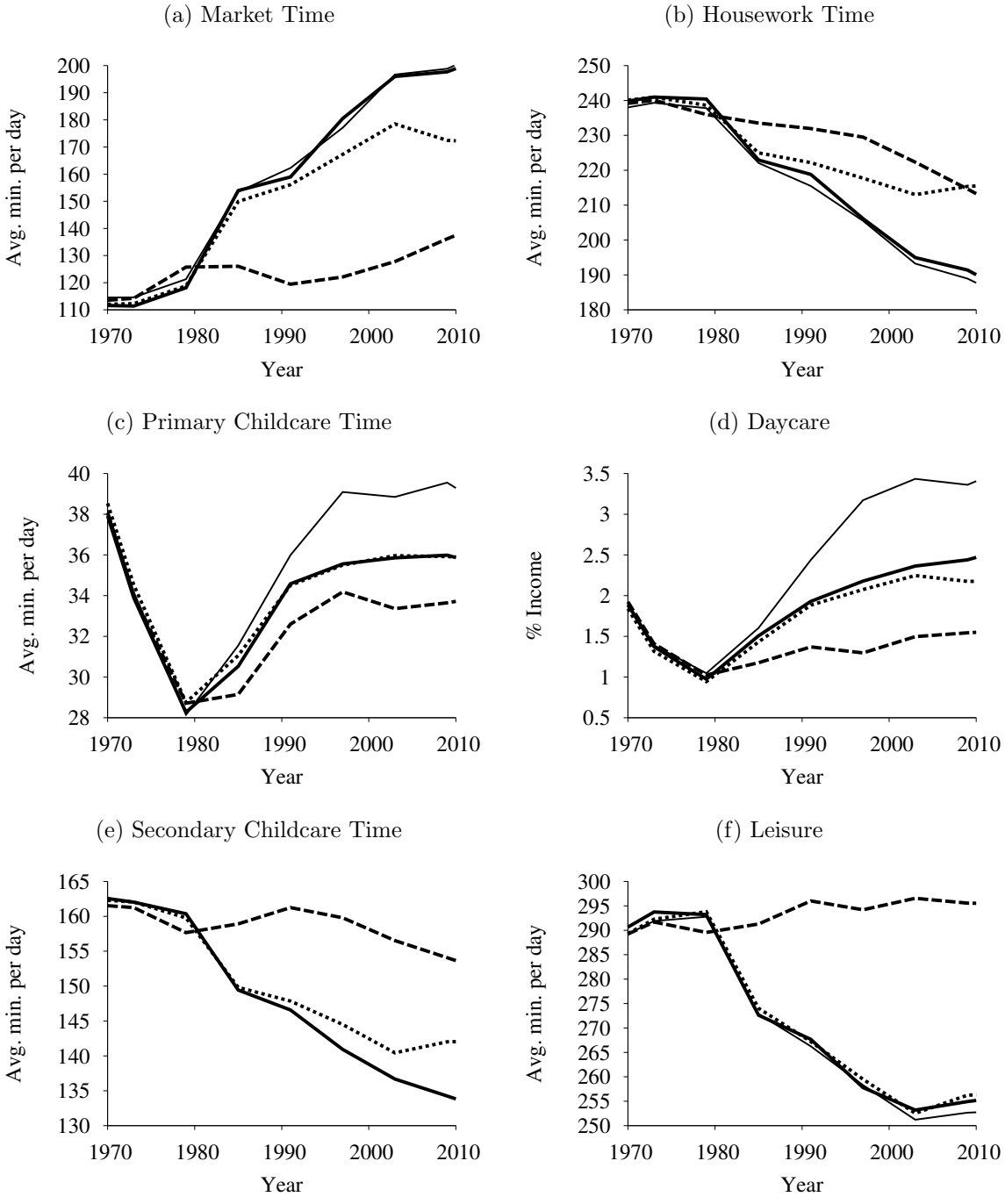
Post-1980

The period after 1980 is interesting for a couple of reasons. First, the relative wage of women rose quite rapidly after 1980; see Figure 8. Second, Figure 12 shows that this is the period when the model assigns a larger role to the falling price of durables. To analyze this period, we simulate the model: (a) holding the relative wage of women constant starting in 1980, (b) keeping the relative price of durables constant starting in 1980, or (c) maintaining the childcare requirements after 1980 constant for those cohorts born in 1980 or later.

As shown in Figure 14, changes in childcare requirements affect primary childcare time and purchases of daycare, but little else. Relative to the historical relative wage, when the relative wage of women stays at its 1980 level, there is only a modest increase in womens' market time, housework time does not fall as much, and leisure does not fall at all. Due to the responses of leisure and housework time, there is a more modest decline in secondary childcare time, and as a result households spend less of their income on daycare and allocate somewhat less time to primary childcare. The effects of holding the price of durables at their 1980 level are qualitatively similar to those of maintaining the 1980 wage gap, although the effects are smaller.

The effects on market time are examined in more detail in Table 6. The benchmark model predicts a rise in womens' market time of 79.6 minutes per day after 1980. Holding the wage gap at its 1980 level, the model predicts that market time would have changed by only 10.4 minutes, suggesting that the model assigns a large role to the observed changes in the relative wage in accounting for the increase in market time. Using the same calculation as above, the model attributes 86.9% of the increase in market time to changes in the relative wage of women. Holding the price of durables at its 1980 value, the model predicts an

Figure 14: Post-1980



Legend: (1) black solid line: benchmark model; (2) black dashed line: 1980 relative wage starting in 1980; (3) black dotted line: 1980 price of durables starting in 1980; (4) thin black line: 1980 childcare requirements for generations born starting in 1980.

Table 6: Aggregate Female Market Time, Post-1980

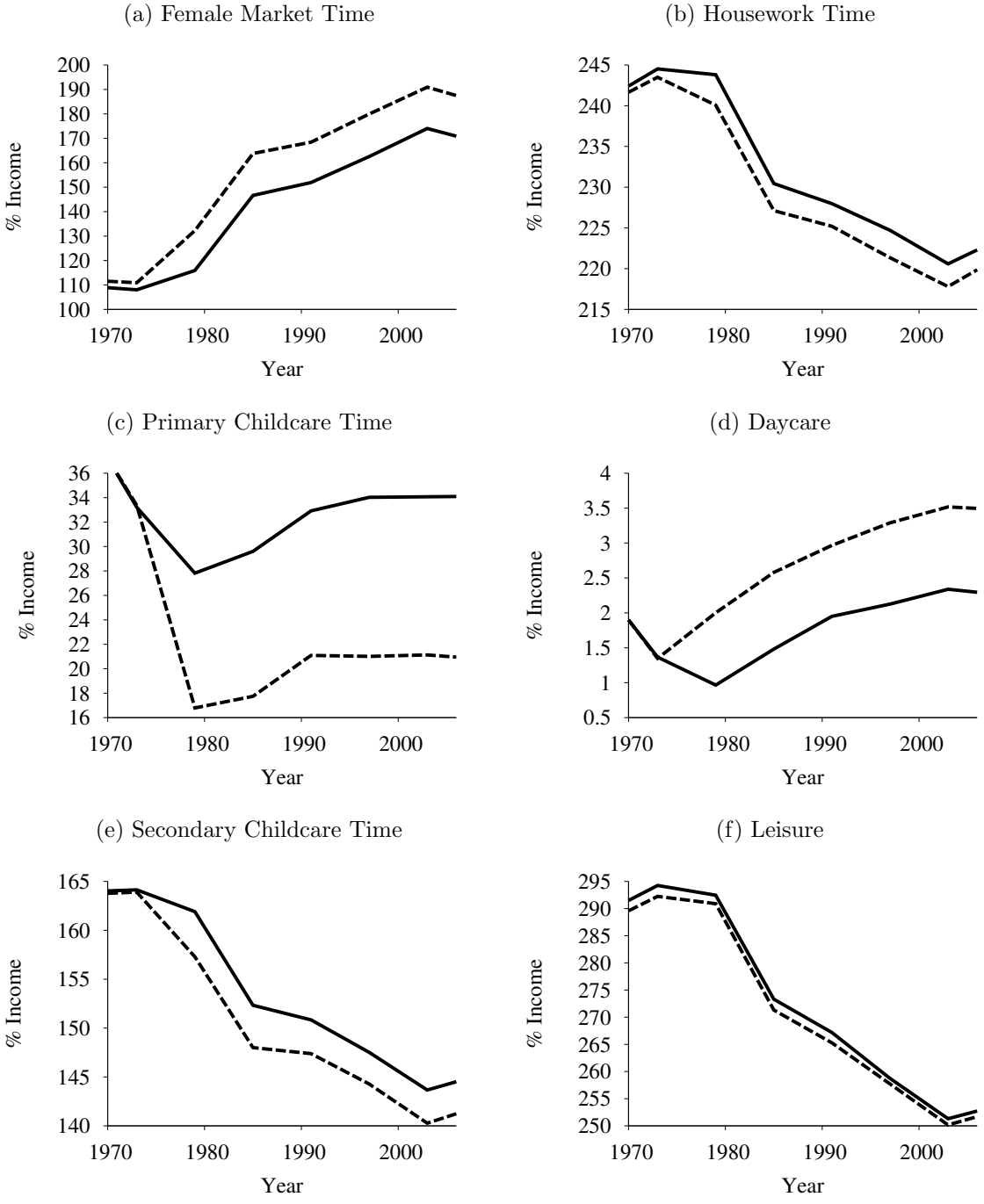
	Minutes Per Day		Change 1980 to 2006	Contribution to Change
	1980	2006		
Benchmark	118.1	197.7	79.6	
· Relative Wage	125.8	136.2	10.4	86.9
· Price of Durables	118.8	172.5	53.6	32.6
· Childcare	121.3	198.8	77.5	2.6

increase of 53.6 minutes; thus, the fall in the price of durables accounts for 32.6% of the total. Finally, keeping childcare of generations born after 1980 at the 1980 level leads to a 77.5 minute increase in market time, meaning that childcare accounts for a very modest 2.6% of the total. As above, these percentages do not add up to 100% because each factor is changed in isolation, not in sequence. If we normalize these contributions to add up to 100%, just over 71.3% of the increase in female market time in the benchmark model is due to changes in the relative wage, and 26.8% is due to the declining price of durables. In other words, the effect of relative wage changes is $2\frac{2}{3}$ times larger than that of the fall in the price of durables.

Cheaper Daycare

Attanasio *et al.* (2008) find that a combination of higher relative wages for women and lower childcare costs are needed to explain the rise in female labor force participation since 1980. We evaluate these effects in Figure 15. The model is simulated with the benchmark price of daycare (50% of the female wage), and with 15% cheaper daycare (that is, a price equal to 42.5% of the female wage) starting in 1979. In an attempt to stay true to the essence of Attanasio *et al.*'s model, the price of durables is kept at its 1900 value which has the effect of minimizing the role of the durable goods revolution. By 2006, cheaper daycare increases market time by 17 minutes (10%), decreases housework time by a scant 3 minutes, decreases primary childcare time by 13 minutes (38%), and increases the expenditure share on daycare by 1.2 percentage points (from 2.3% to 3.5%). That the expenditure share on daycare rises when its price falls reflects the greater quantity of daycare being used when it is cheaper. Viewed through the lens of our model, the cheaper daycare explanation of the increased market time of women in the late twentieth century leaves something to be desired. In particular, as shown in Figure 5, U.S. time use surveys simply do not exhibit a large decline in primary childcare time after 1980. To the contrary, primary childcare time in the 2006 ATUS is as high as it has been in any of the time use surveys (although this

Figure 15: Cheaper Daycare



Legend: (1) black solid line: benchmark model; (2) black dashed line: 1900 price of durables; (3) black dotted line: 1900 price of durables and 25% cheaper daycare starting after 1975.

evidence only comes on stream in 1965).

7 Conclusions

This paper investigated the effects of the rising relative wage of women, the declining price of durables, and the evolution of childcare requirements on the allocation of womens' time over the twentieth century. The innovative feature of our work was modeling childcare as a constraint on the allocation of womens' time. The parameters of the childcare production function were estimated using micro data from the 2006 ATUS, and the childcare requirement was computed from calculations based on the 2006 ATUS and observed fertility. Our estimates of the childcare production function may be of independent interest. Interestingly, our estimated elasticity of substitution between primary childcare time and secondary inputs (both time and daycare) is close to that used by Olivetti (2006) between maternal and paid daycare.

For the life-cycle profiles, we found that modeling childcare is important for understanding the pattern of market work. Specifically, a version of the model without childcare predicts that market time is monotonically declining with a woman's age; the data shows a flatter or even hump-shaped pattern, depending on the vintage of the time use survey. The benchmark model with childcare comes closer to matching the life-cycle patterns for market time, housework, primary childcare and leisure time.

In term of aggregates, the benchmark model predicts a rapid rise in the time that married women spent working in the market over the twentieth century. This rapid rise is broadly consistent with evidence on womens' work time. Our simulations support the results of Attanasio *et al.* (2008) and Jones *et al.* (2003) that increases in the relative wage of women are crucial in explaining the large increase in womens' market work time. As in Attanasio *et al.* (2008) wage changes are not sufficient to explain the dramatic increase in market work since 1980. According to our model, while the durable goods revolution plays a minor role in accounting for the increase in womens' market time from 1900 to 1980, it plays a larger role after 1980. Prior to 1980, the contribution of increases in the relative wage of women was more than 10 times larger than that of the falling price of durables; after 1980, the effect of relative wages is $2\frac{2}{3}$ times that of the price of durables. As discussed in the introduction, this prediction of the model that the effects of the durable goods revolution are felt most strongly since 1980 can be squared with the data if we think of durables as including not only consumer durables but also a variety of labor-saving goods that have become available over the past three decades.

Whether looking at time use surveys or aggregate data, the model tends to under-predict

housework time and over-predict leisure between 1900 and 1980. Since the model does a better job in matching up with market time, what is needed to a mechanism that will lead the model to shift time from leisure to housework. We speculate that part of the answer lies in the interaction between family size and housework. In particular, our model may understate the amount of housework associated with large families, thus accounting for why the model under-predicts housework time both early in the 20th century but also in the 1960s when family sizes were larger than around the turn of the millennium. Along similar lines, Albanesi and Olivetti (2007) suggest that technological change in reproductive medicine and infant formula have reduced the time needed for housework.

While the model does well in mimicking the double-humped-shaped pattern to the life-cycle pattern of market time as recorded in the 1965 U.S. time use survey, later surveys are either flatter or somewhat hump-shaped. The model does not capture these changes which suggests that changes in wages and prices of consumer durables alone cannot explain why women are increasing their market work while raising young children. We conjecture that elements like human capital accumulation and costs associated with entering and exiting the labor force may help account for the higher market work of these women.

Our model and proposed strategy to estimate the elasticity of substitution between types of childcare could be useful in evaluating the impact of family policies on children. The model predicts that daycare subsidies (a lower price of daycare) increase market time while leading to a sharp decline in primary childcare time. Given the importance of parental time inputs to child development, this decline in primary childcare time may have an important negative impact on child development.

Appendix A: Effects in a Standard General Equilibrium Model

In this appendix, we explore the impact of changes in the relative price of durables on female labor force participation in the context of a standard general equilibrium model with a log-linear utility function and a CES home production function with durables and labor as inputs. Greenwood *et al.* (2005, Section 6) show that this model produces predictions regarding the impact of the household revolution on the allocation of womensf time that are similar to those in their core model with an explicit adoption decision, a Leontief home production function, and a labor-embodied home productivity gain upon adoption. We show that while their calibration of the simpler model delivers a sizable impact of the durable goods revolution on market time of women, it does so only when the expenditure share on durables is implausibly large. When the model is recalibrated to deliver a more plausible durable expenditure share, the durable goods revolution has only a small impact on womensf time, as in our benchmark model in our main text, or as in Jones *et al.* (2003). In our earlier benchmark model, the durable goods revolution has little effect on the allocation of womensf time up to 1980. This appendix clarifies why our results, obtained using a fairly standard home production OLG model similar in flavor to the one used Greenwood *et al.* (2005, Section 6) are different, but does not question results obtained in more complex setting such as the ones described for their core model.

A.1 Model

In each period, the representative household consumes market goods, c_{mt}, home-produced goods, c_{ht}, and leisure, ℓ_t. Preferences are summarized by

$$\sum_{t=0}^{\infty} \beta^t U(c_{mt}, c_{ht}, \ell_t). \tag{A.1}$$

The household faces a budget constraint,

$$c_{mt} + a_{t+1} + q_t w_t x_t = w_t(\overline{n} + \phi_t n_{mt}) + r_t a_t. \tag{A.2}$$

The behavior of men is taken to be exogenous; their market work is given by $\overline{n}$. The wage rate is w_t and ϕ_t is the wage of women relative to men. The household's market beginning-of-period assets are denoted a_t and r_t is the gross return to those assets. Investment in durables is given by x_t and $q_t w_t$ is the time cost of acquiring durables.

Home production is

$$c_{ht} = H(d_t, n_{ht}) \tag{A.3}$$

where d_t is durables. The law of motion for durables is

$$d_t = (1 - \delta_d)d_{t-1} + x_t \tag{A.4}$$

where δ_d is the depreciation rate of durables. The timing in Eq. (A.4) allows us to consider the case in which durables fully depreciate within a period, as in Greenwood *et al.* (2005).

Finally, the household's time constraint is

$$n_{mt} + n_{ht} + \ell_t = 1. \tag{A.5}$$

The market-side of the economy is neoclassical with production given by

$$Y_t = F(K_t, N_t) \tag{A.6}$$

where $N_t = \overline{n} + \phi_t n_{mt}$. Factors are paid their marginal products, and the law of motion for capital is

$$K_{t+1} = (1 - \delta_k)K_t + I_t. \tag{A.7}$$

A.2 Calibration

For the benchmark model, utility is

$$U = \mu \ln c_{mt} + \nu \frac{c_{ht}^{\zeta}}{\zeta} + (1 - \mu - \nu)\frac{\ell_t^{\xi}}{\xi}, \quad \zeta,\ \xi < 1. \tag{A.8}$$

This utility function is a slight generalization of that in Greenwood *et al.* (2005) motivated by Greenwood and Guner (2009).

The home production function is

$$H = [\theta d_t^{\kappa} + (1 - \theta)n_{ht}^{\kappa}]^{1/\kappa}, \quad \theta \in [0, 1],\ \kappa < 1. \tag{A.9}$$

Market production is Cobb-Douglas,

$$F = K_t^{\alpha} N_t^{1-\alpha}. \tag{A.10}$$

Most of the calibration targets are taken from Greenwood *et al.* (2005). A model period is 5 years. The discount factor, β, is set to hit an annual real return of 4%. In the utility function, the two curvature parameters $\zeta = 0$ and ξ, are set to zero (meaning logarithmic).

θ, the share parameter in home production, is set to 0.3 while the curvature parameter, κ

is 0.35. This latter parameter is quite important. When κ is positive, durables and housework time are substitutes in production which allows durables to be labor-saving devices. As in Greenwood and Guner (2009), durables depreciate completely within a period: $\delta_d = 1$.

Capital's share of income in the market sector, α, is set to a fairly conventional value, 0.3, and the depreciation rate of market capital, δ_k, is consistent with a 10% annual depreciation rate.

The relative wage series, ϕ_t, is taken from Goldin (1990), extended through the end of the twentieth century using U.S. Census data. The price of durables, q_t, is given by

$$q_t = q_0 e^{-\gamma t}. \tag{A.11}$$

As in Greenwood *et al.* (2005), $\gamma = 0.083$ which incorporates not only the fall in the price of durables but also growth in the real wage.

There are three parameters yet to be assigned values. The preference weights on market consumption, μ, and home consumption, ν, are chosen so that the model's prediction for market in 1900 and 1980 match those reported in Greenwood *et al.* (2005), namely $0.05 \times (40/112)$ and $0.5 \times (40/112)$, respectively. The resulting parameter values are as in Greenwood *et al.*, namely $\mu = 0.47$ and $\nu = 0.27$. Finally, the initial price of durables, q_0, is set to 540 as in Greenwood *et al.* (2005).

A.3 Results

We solve for time paths for the period 1800 to 2100 as follows. The price of durables is assumed to start declining in 1900, and stop declining in 198-. Similarly, the relative wage of women is constant at its 1900 value throughout the 1800s, is given by history through the 1900s, then remains constant again through the 2000s. The model starts in an initial steady state, and ends in a steady state. We then solve for paths for the variables of interest between these two steady states.

A.3.1 Benchmark Model

Results for three sets of simulations are reported. The first is the benchmark model in which the relative wage of women is given by history, and the relative price of durables declines as described by Eq. (A.11). The second keeps the relative wage of women fixed at its 1900 value of 0.48 but allows the price of durables to decline. The final set fixes the price of durables at its 1900 value, but uses the relative wage given by history.

As in the body of our paper, when the prediction of a simulation differ from the benchmark, this indicates that the factor being held constant is an important driver for that

variable. So, the top panel of Figure 16 shows that changes in the relative wage of women are an important driver in the benchmark model's predicted rise in womens market time. Since simulated market time holding fixed the price of durables is generally closer to the benchmark simulation, the model assigns a smaller role to the durable goods revolution. Looking at around 1980, the model assigns roughly equal roles to changes in relative wages and the durable goods revolution. The model assigns a larger share of the change in housework time to the durable goods revolution than to changes in relative wages; see the middle panel of Figure 16.

However, as shown in the bottom panel of Figure 16, the benchmark calibration implies a rising expenditure share on durables. In 1980, this share is over 8%. This expenditure share tends to flatten out after 1980 only because the price of durables is assumed to be constant after 1980; simulations in which the price of durables continues to decline exhibit ever increasing durables expenditure shares. Is an expenditure share of 8 or 9% reasonable? Greenwood and Guner (2009) suggest that targeting the expenditure share on appliances is appropriate; they report this share as 0.5%. By this metric, the benchmark calibration's predicted expenditure share is far too high.

A.3.2 An Alternative Calibration

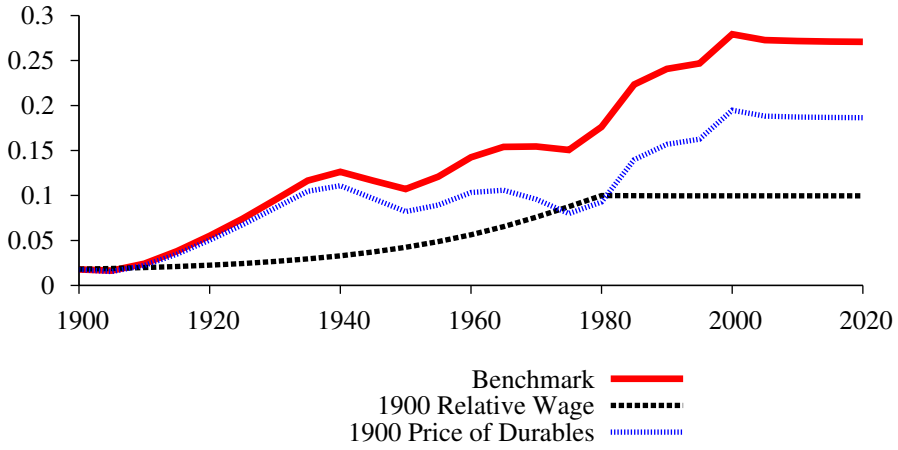
Of course, the results in Figure 16 do not necessarily imply that the Greenwood *et al.* (2005, Section 6) model requires a large durables expenditure share to generate a large role for the durable goods revolution in changing the allocation of womens' time. To explore this issue further, we recalibrated the model to the appliance expenditure share reported in Greenwood and Guner (2009): 0.5%. We attempted to do so by increasing the initial price of durables. Unfortunately, we were unable to solve the model for a sufficiently high initial price of durables to drive its expenditure share down to 0.5%. It appears that calibrating the preference parameters μ and ν to hit market work targets in 1900 and 1980 makes the expenditure share of durables very unresponsive to changes in the initial price of durables.

To get around this problem, instead calibrate μ and ν so as to match evidence on market and housework time for married women as reported in the 2006 American Time Use Survey (ATUS), namely 0.2065 for market time and 0.1625 for housework time (both measured in the ATUS by married women aged 18 to 65). With an initial price of durables $q_{1900} = 20,000$, μ is calibrated to be 0.54 while ν is 0.10. This calibration delivers a predicted durables expenditure share of 0.5% in 1980.

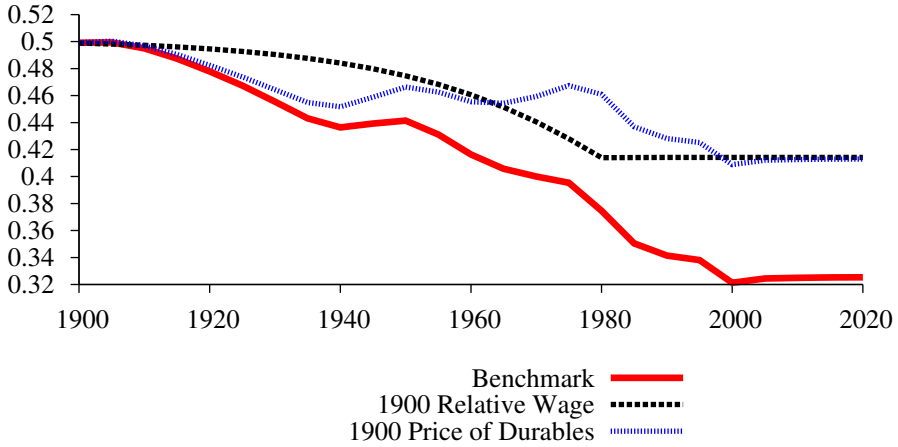
Simulations under this alternative calibration are summarized in Figure 17. From the perspective of this calibration, the changes in market time over the twentieth century are driven almost entirely by the increase in the relative wage of women. The same is true for

Figure 16: Benchmark Model

(a) Market Time



(b) Housework Time



(c) Expenditure Share on Durables

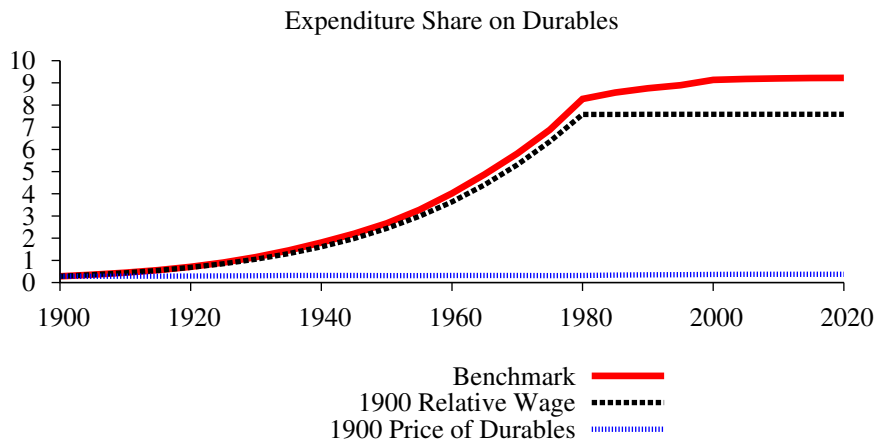
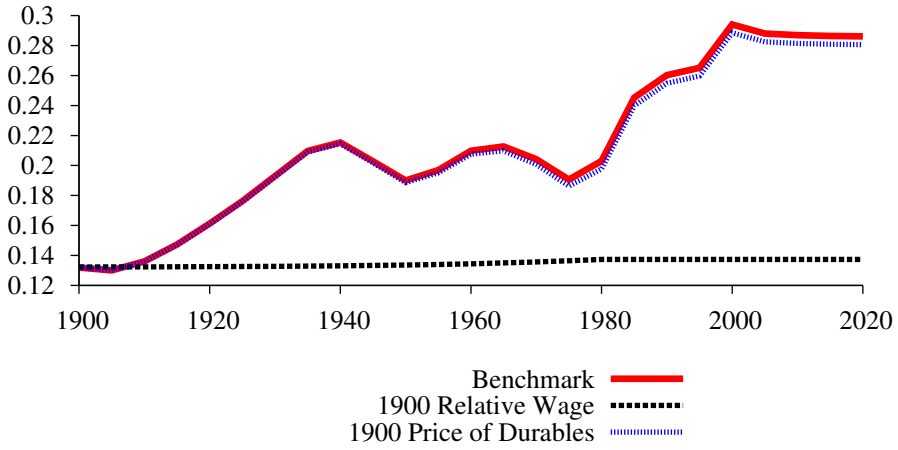
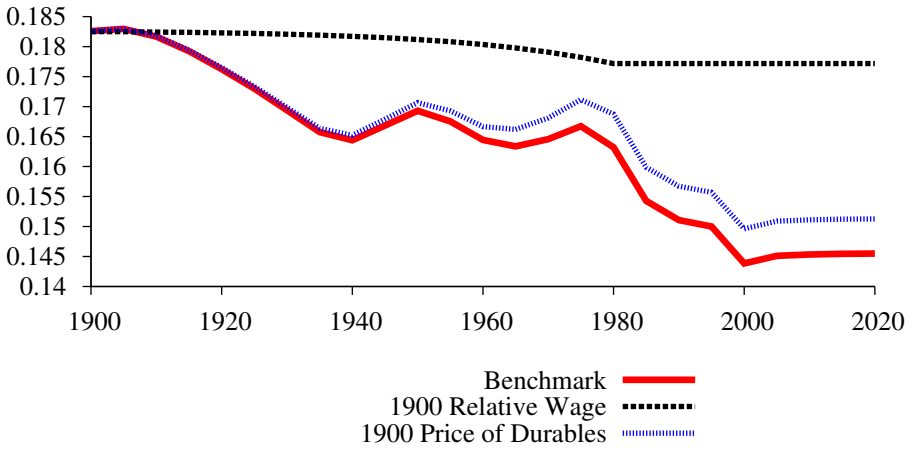


Figure 17: Alternative Calibration

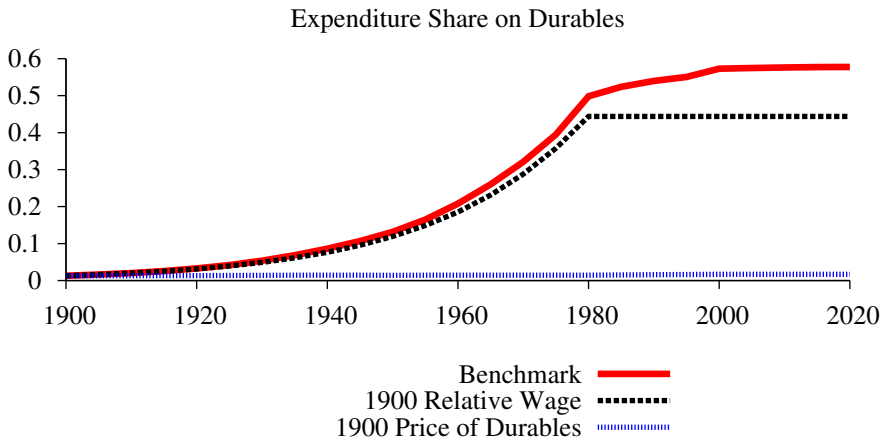
(a) Market Time



(b) Housework Time



(c) Expenditure Share on Durables



housework time. These findings are in accord with those of our benchmark model as well as those of Jones *et al.* (2003).

A.3.3 Discussion

There are not that many 'free parameters' in this model, and the model is fairly insensitive to reasonable changes in these parameters. The experiments we conducted were to change parameters (relative to the benchmark) as follows:

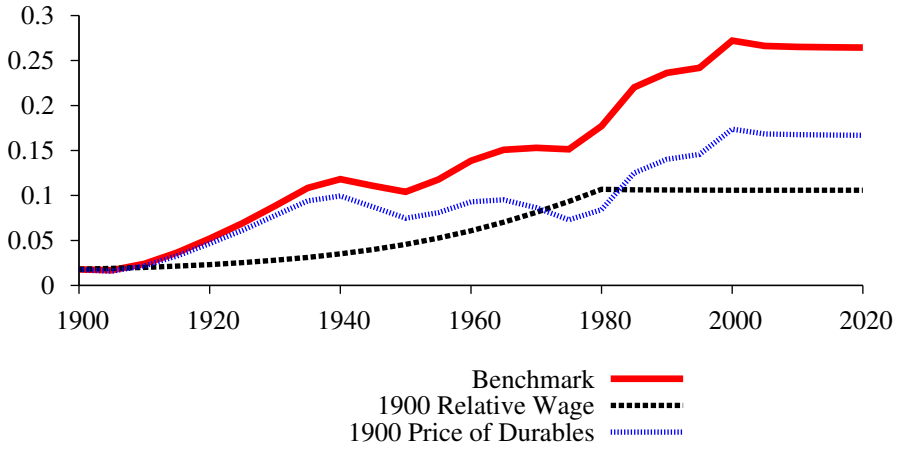
1. $\xi = -1$ which implies more curvature over leisure; see Figures 20 and 21.
2. $\zeta = -1.9$ as in Greenwood and Guner (2009) which puts more curvature on home consumption; see Figures 18 and 19.
3. $\theta = 0.206$ and $\kappa = 0.189$, the home production function parameters reported in McGrattan *et al.* (1997); see Figures 22 and 23.
4. Setting the depreciation rate for durables, δ_d, so that the annual depreciation rate is 20%see Figures 24 and 25.

In all cases, the story follows that above. Calibrating the model to match market hours of married women in 1900 and 1980 implies: (a) that the expenditure share on durables in 1980 is much too high, (b) that this share is quite insensitive to the initial price of durables, and (c) that the durable goods revolution has an important role to play in explaining the change in the time allocation of married women over the twentieth century. Alternatively, calibrating the model to the ATUS observations for 2005 (a) allows us to choose the initial price of durables to hit an expenditure share for durables in 1980 of 0.5%,[20] and (b) that the primary driver of changes in the allocation of married womens' time over the twentieth century was the rise in the relative wage of women.

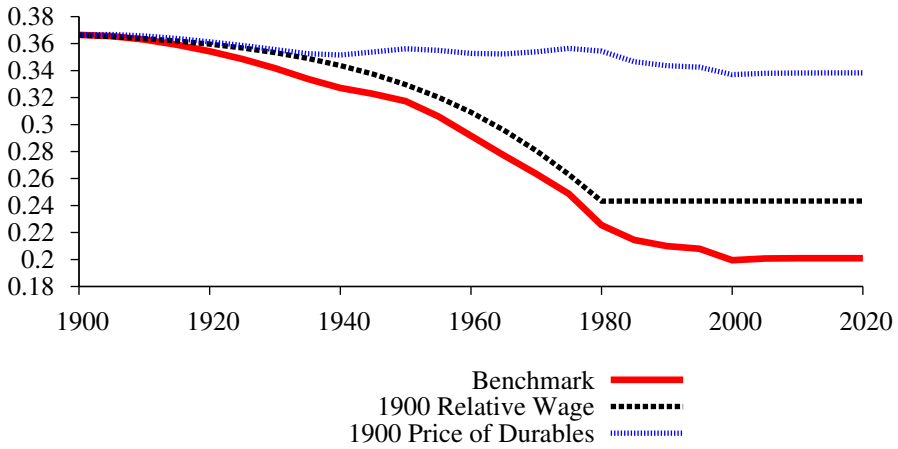
[20]The exception is when we change the home production function parameters for which a durables expenditure share in 1980 of 1% seems to be a lower bound.

Figure 18: $\zeta = -1.9$, 1900 and 1980 Market Time Targets

(a) Market Time



(b) Housework Time



(c) Expenditure Share on Durables

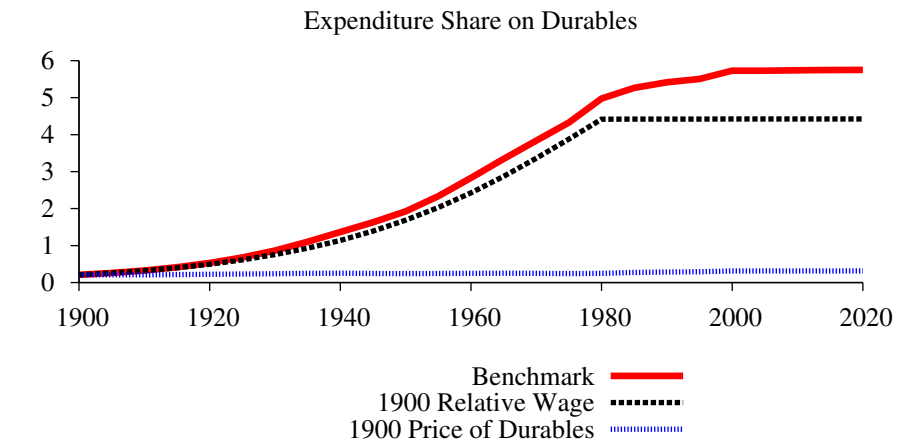
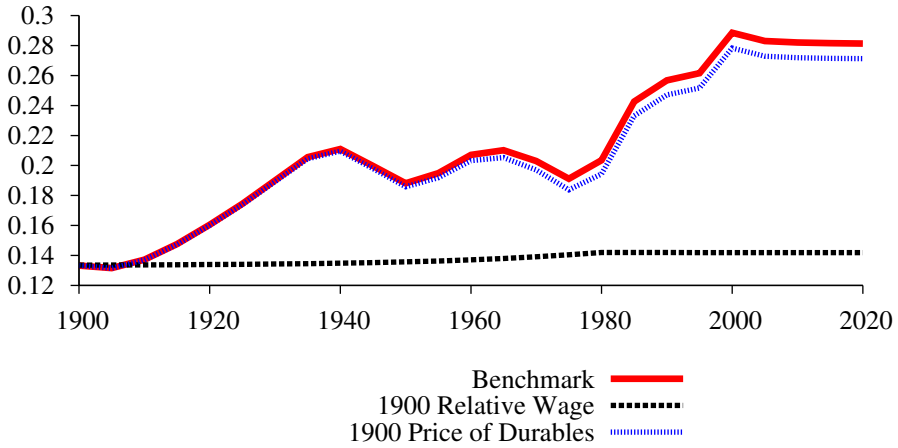
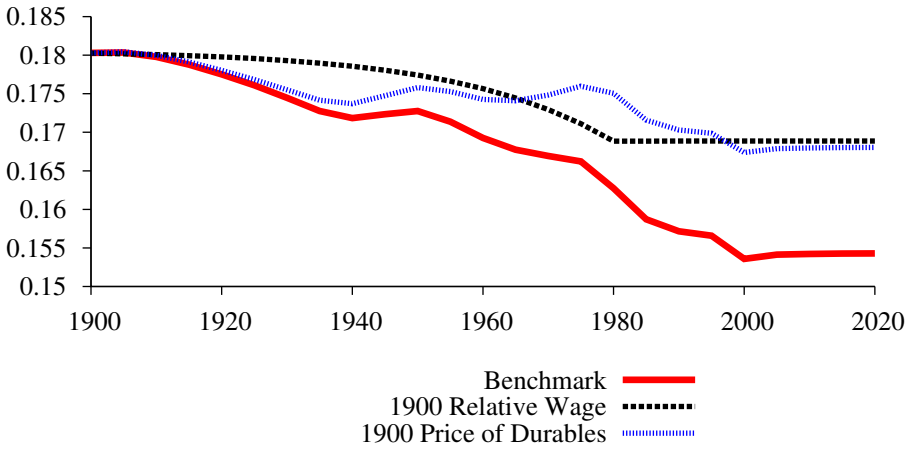


Figure 19: $\zeta = -1.9$, 2005 ATUS Time Targets

(a) Market Time



(b) Housework Time



(c) Expenditure Share on Durables

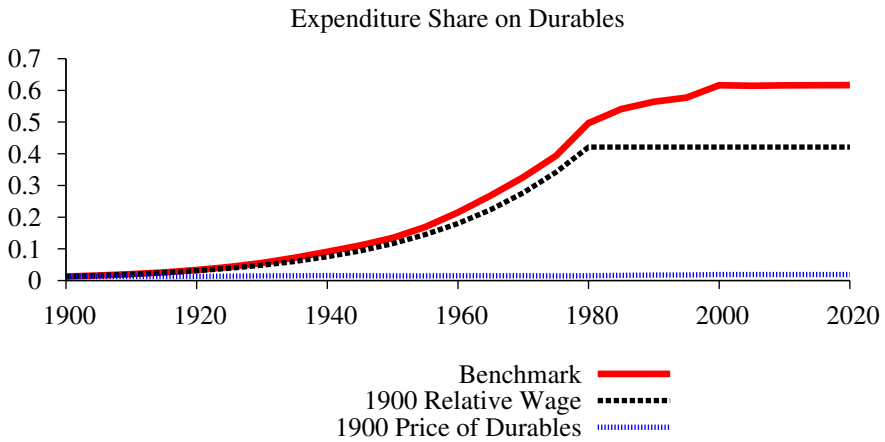
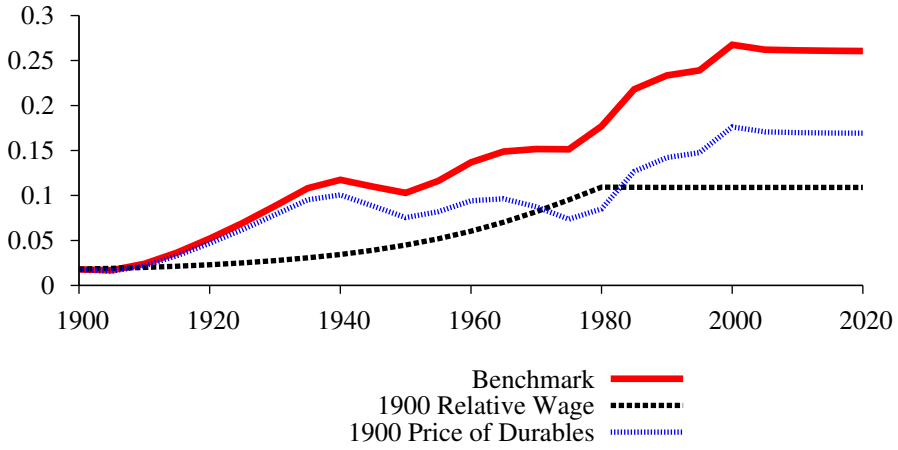
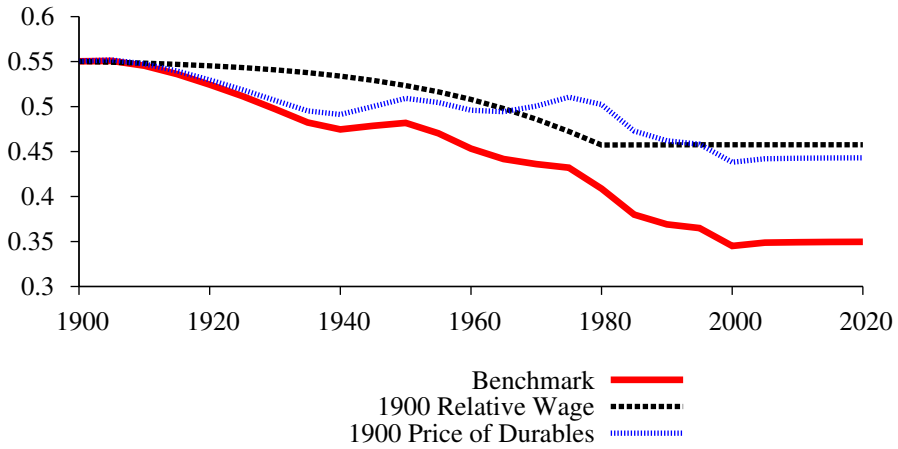


Figure 20: $\xi = -1$, 1900 and 1980 Market Time Targets

(a) Market Time



(b) Housework Time



(c) Expenditure Share on Durables

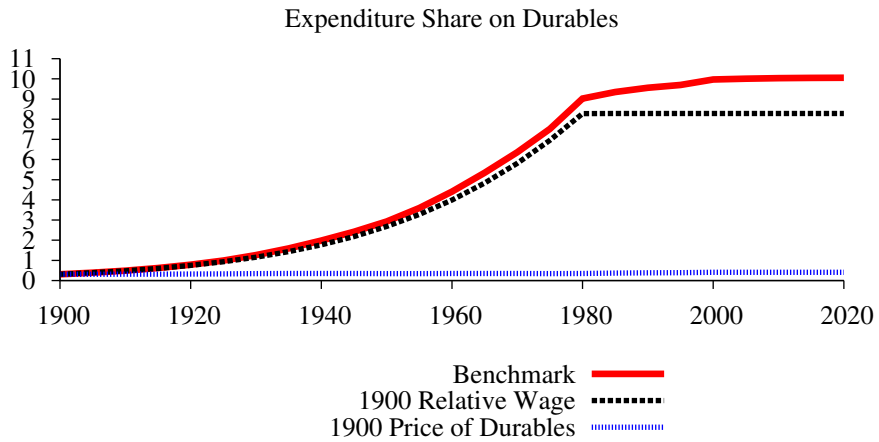
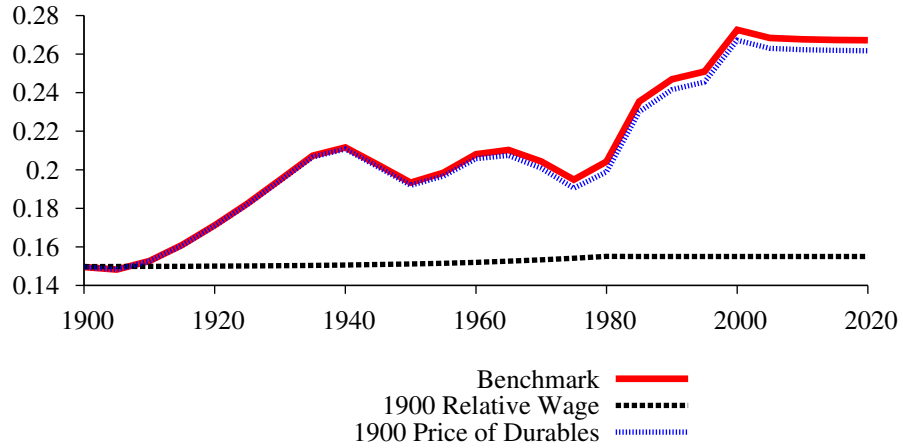
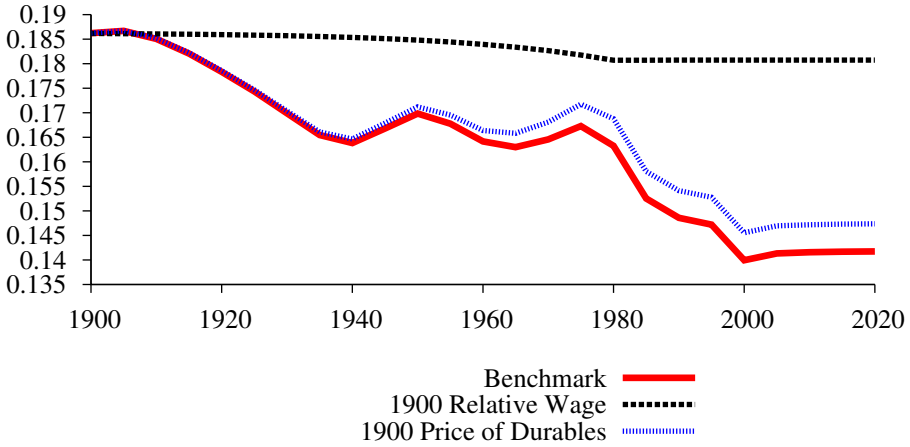


Figure 21: $\xi = -1$, 2005 ATUS Time Targets

(a) Market Time



(b) Housework Time



(c) Expenditure Share on Durables

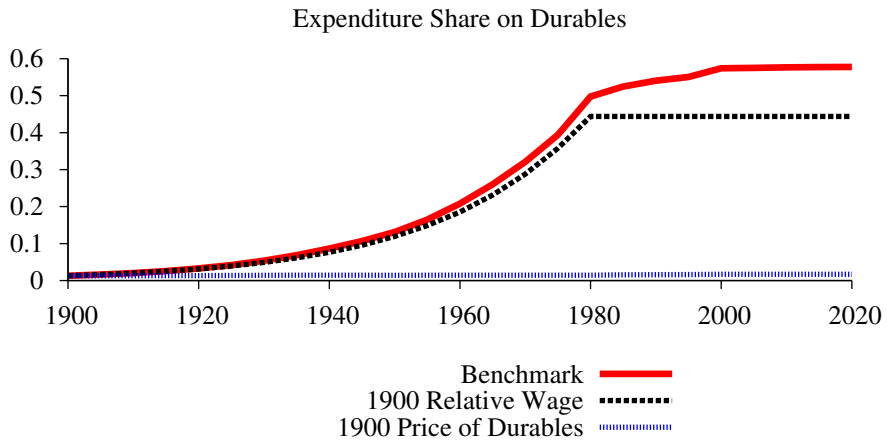
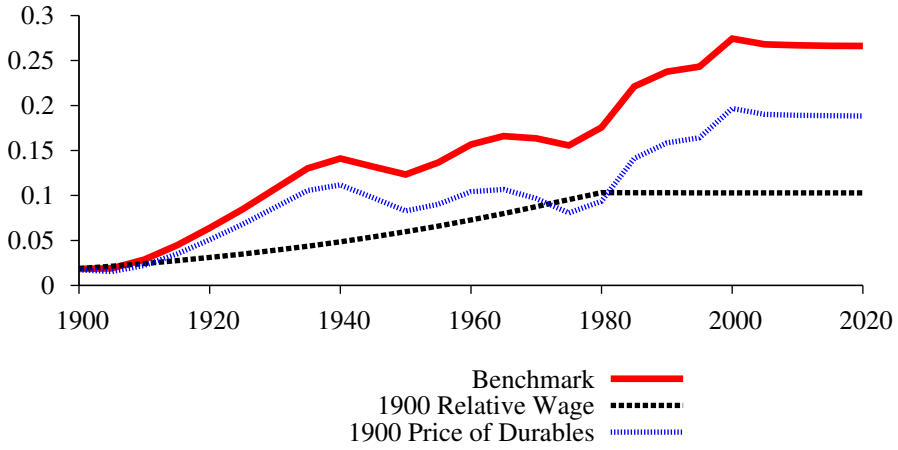
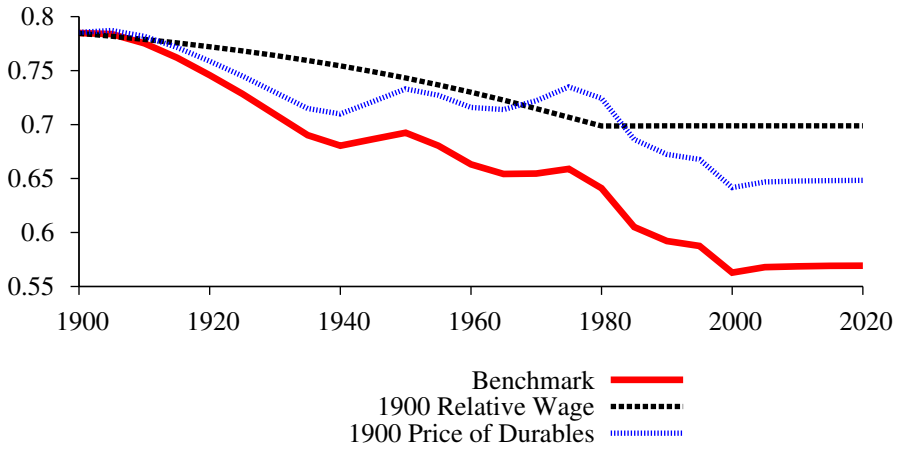


Figure 22: $\theta = 0.206$, $\kappa = 0.189$, 1900 and 1980 Market Time Targets

(a) Market Time



(b) Housework Time



(c) Expenditure Share on Durables

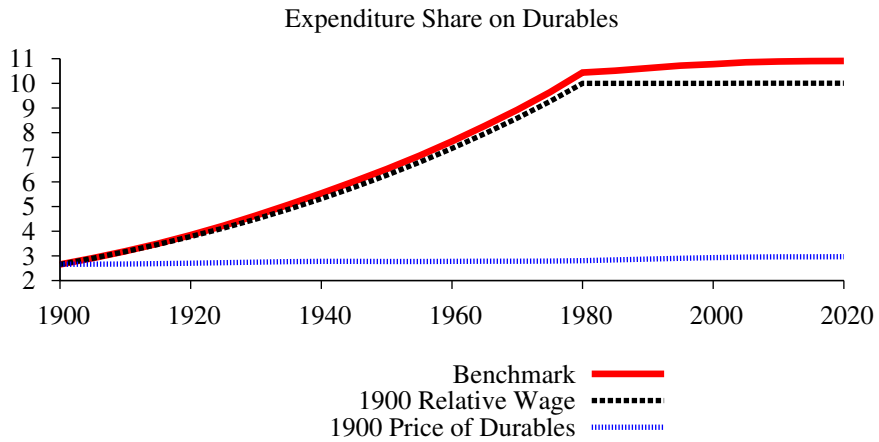
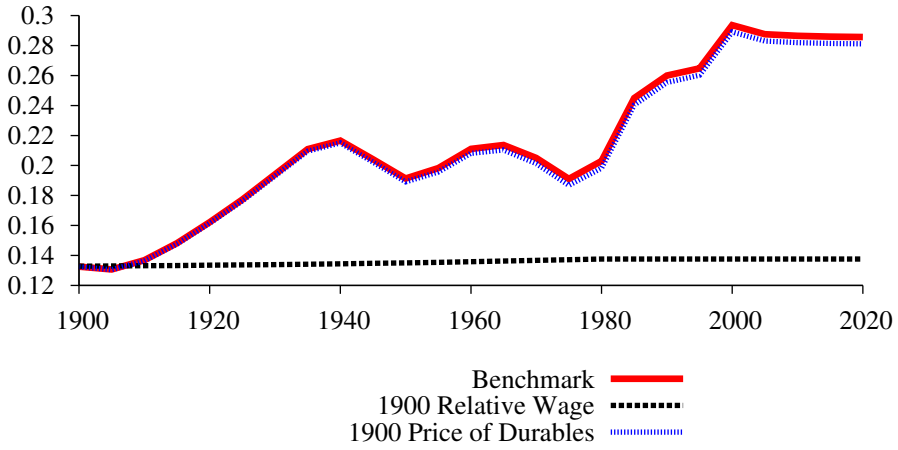
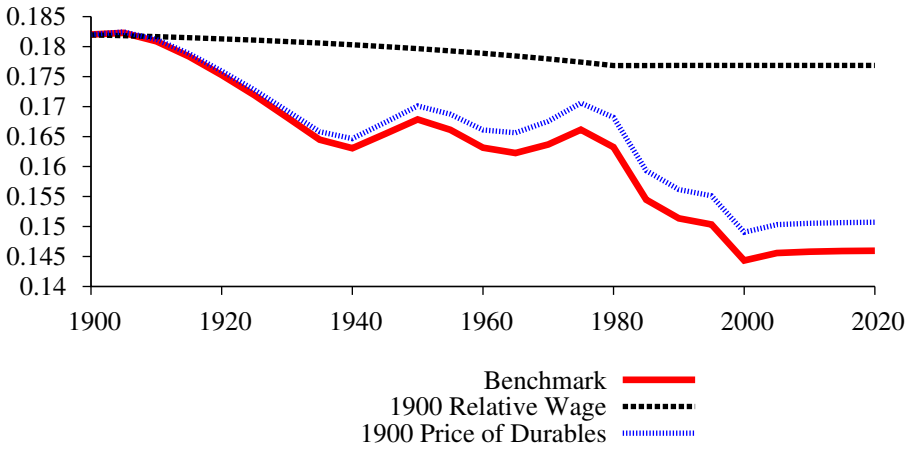


Figure 23: $\theta = 0.206$, $\kappa = 0.189$, 2005 ATUS Time Targets

(a) Market Time



(b) Housework Time



(c) Expenditure Share on Durables

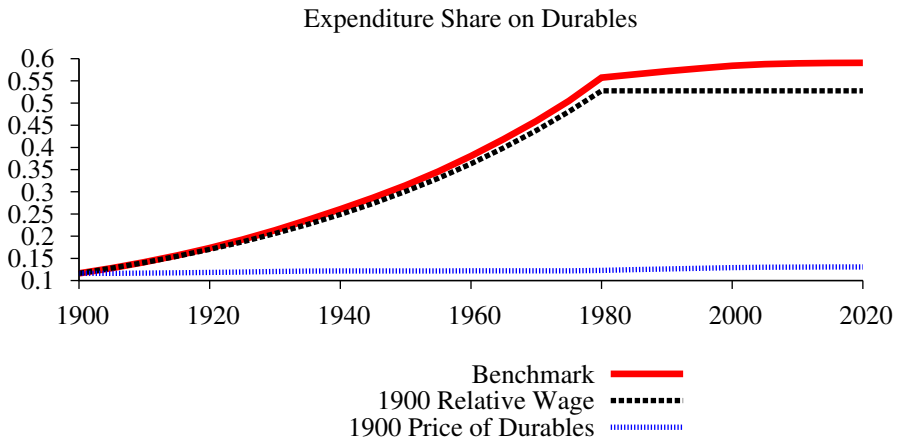
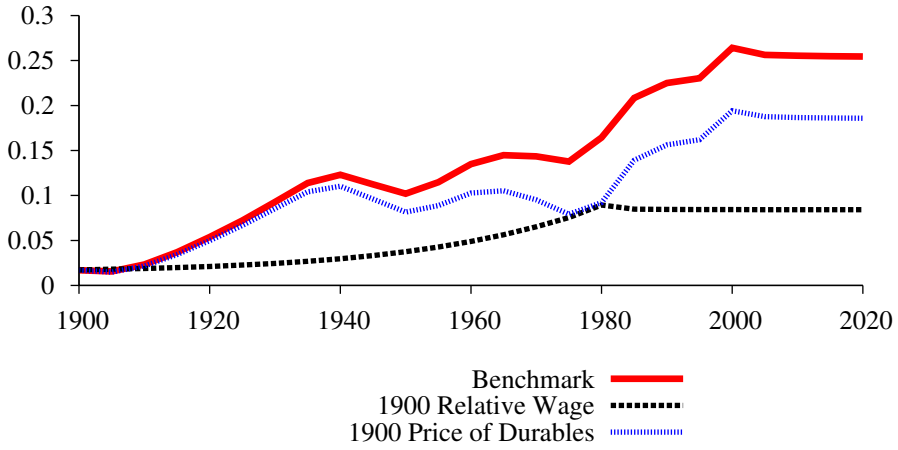
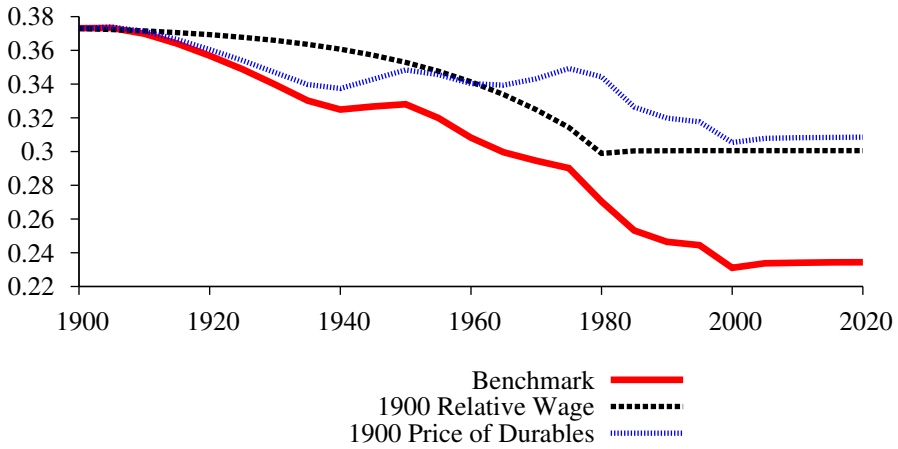


Figure 24: $\delta_d = 0.2$ (annual), 1900 and 1980 Market Time Targets

(a) Market Time



(b) Housework Time



(c) Expenditure Share on Durables

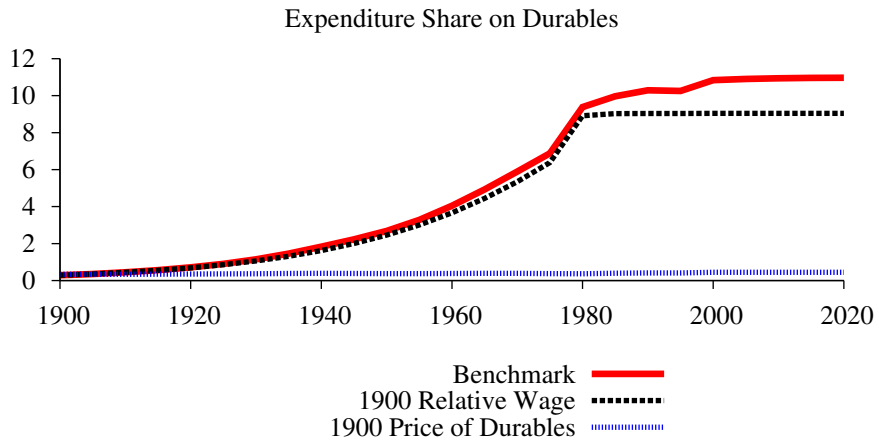
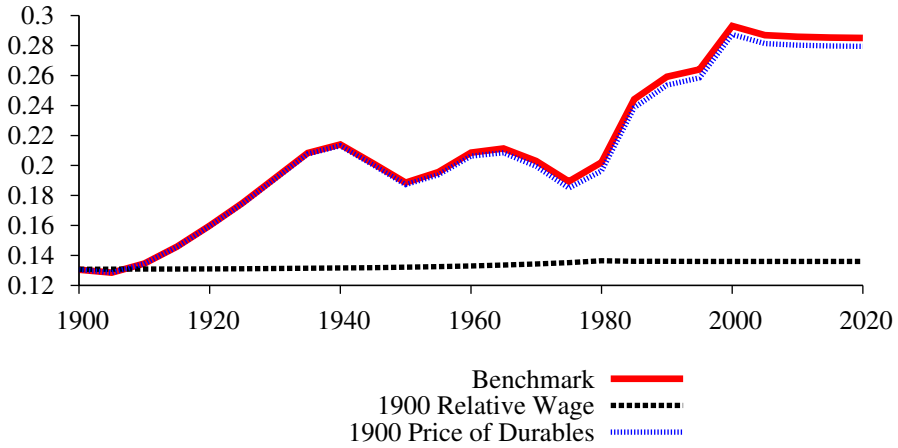
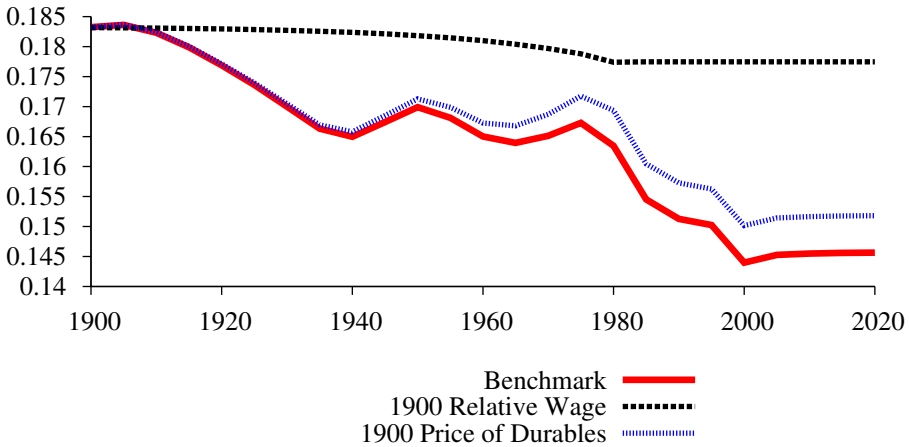


Figure 25: $\delta_d = 0.2$ (annual), 2005 ATUS Time Targets

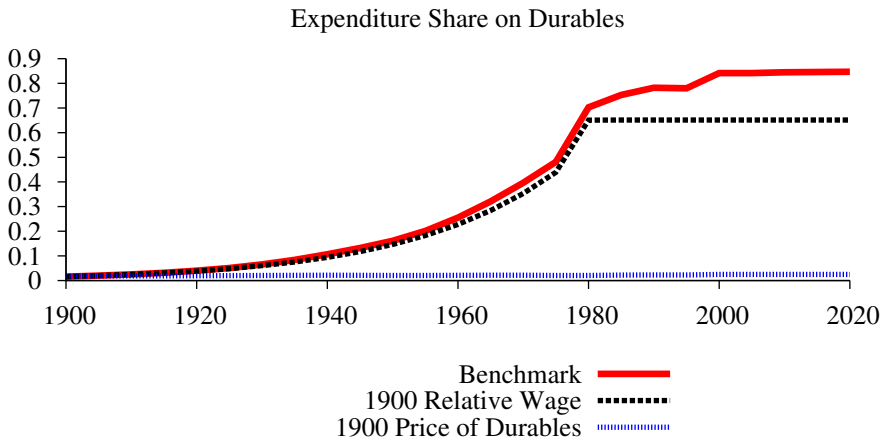
(a) Market Time



(b) Housework Time



(c) Expenditure Share on Durables



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