



# 1 Introduction

Home production has changed dramatically during the course of the 20th century: Labor saving technologies, from running water to modern appliances, have substantially reduced the time demands of home production. In 1890 in the United States only 24% of households had running water and only 8% had electricity; in 1950, these figures were 83% and 94%, respectively. By 1950, a majority of households also had indoor bathrooms and modern appliances such as stoves, electric irons, vacuum cleaners, refrigerators and washing machines.

In an influential paper [Greenwood, Seshadri and Yorukoglu \(2005\)](#) suggest that the household technology revolution played an important role in increasing female labor force participation rates during the 20th century. One important feature is, however, missing from their work: childcare requirements. These may have reduced the impact of the household revolution on women's decision to participate in the labor force. In 1900, 20.6% of women were part of the labor force versus 50% in 1980. The bulk of this increase was due to married women entering the labor force; their participation rate increased from 5.6% in 1900 to 51% in 1980. This differential increase in the participation rate of married women suggests that childcare constraints could have slowed the entrance of women in the labor market despite the adoption of important labor-saving new technologies. In this paper, we examine the effects of introducing childcare requirements on the household revolution. As in [Greenwood \*et al.\*](#), we take as given both the secular decline in the price of durable goods and the observed increases in female wages relative to male wages.

There are two types of childcare, primary and secondary. The first implies time spent exclusively with children, like teaching, reading, playing or taking them to the doctor. With secondary childcare, children are under parental supervision while the parent is doing other activities as primary activities such as the laundry, preparing dinner, shopping for groceries, or watching a movie. Childcare requirements are important: the American Time Use Survey of 2006 reports that married women between the age of 30 and 35 spend 110 minutes a day in primary childcare and 357 minutes in secondary childcare, of which 120 minutes while doing housework.

Childcare requirements are therefore a pertinent and important inclusion in a model of house-

hold production since a large part of childcare is secondary and done jointly with other activities, one of which is housework. Bryant (1996) estimated that total housework chores by married women occupied 7.35 hours a day in 1925 which implies that many women had little choice but to supervise their children while doing household chores. The decline in housework time may have changed the way mothers supervised their children by increasing primary childcare and/or secondary childcare done while enjoying leisure. If this is true, the direct impact of the household revolution on female market work may have been more limited than has been suggested by models that do not include childcare constraints.

To examine whether children reduced the impact of the household revolution on female labor market participation, we use a life-cycle model in which households live several periods. Consequently, we are able to address not only time series variation in female labor market participation, but also how these patterns differ by age, over time. We have two home goods. The first is the traditional home production good which is produced using two inputs, labor and durable labor-saving goods. The second home good is childcare and combines primary and secondary childcare time. In the model, secondary childcare can be done while doing housework or leisure activities. As in Greenwood *et al.* (2005), men work a fixed number of hours and only women do housework and look after children.

To anchor the model to the data, we use micro data files from the U.S. time use surveys from 1965, 1975, 1985 and 2006. The University of Michigan conducted time-use studies starting in 1965 at roughly 10-year intervals. The 1965 sample was drawn from a population of urban, mostly employed individuals. We use the 1965, 1975, and 1985 surveys. Since 2003, the American Time Use Surveys (ATUS) are sponsored by the Bureau of Labor Statistics and conducted by the U.S. Census Bureau. The ATUS is a large sample that is drawn from households that have just completed participation in the Current Population Survey. The time use surveys before and after 2003 are not fully comparable, particularly regarding secondary childcare. For this reason the simulations are anchored to the 2006 ATUS survey but comparisons of results regarding market work, housework and childcare, use all 4 surveys. Unfortunately, only one adult in each household

is selected to complete the survey. It is therefore impossible to assess the total time spent on household chores or primary and secondary childcare by the household and possible reallocations on time spent doing housework between a husband and a wife, as a consequence of the durable good revolution.

As already mentioned, the 2006 ATUS survey shows that secondary childcare is an important form of childcare. Married women between the ages of 30 and 35 spent 357 minutes a day in secondary childcare versus 110 minutes of primary childcare. Married men in the same age group also devoted a considerable amount of time doing secondary childcare: 201 minutes a day versus 51 minutes a day of primary childcare. Similar results are also found for other industrialized countries using different sources. 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](#)). In the U.S., a married woman with at least 1 child below the age of 6 spends 341 minutes a day in secondary care and 150 minutes in primary care; a married man, 220 and 60 minutes, respectively.

Our model is calibrated to reproduce observed time allocations between housework, market work and primary childcare in the early part of the 21st century and is used to examine the impact on the labor market participation of different cohorts of women of: (1) the decrease in the price of durables, (2) the rise in the relative wage of women, and (3) changes in fertility.

We also re-examine the microdata to obtain information for married women and married men on how much time they spent on primary and secondary childcare, housework and market work. Following World War II, a double peaked pattern arose in the life-cycle pattern of market time by women: the first peak is for women in their early 20s; the second peak, in their 40s. By the 1980s, there was a flattening of this double peak pattern, and by the 1990s, it had disappeared. Between 1965 and 2006, the evidence points to an overall increase in market work for married women, and a secular decline in the time they spend doing housework.

[Bryant \(1996\)](#) estimated that total housework chores by married women occupied 7.35 hours a day in 1925 and 6.31 in 1968, not a large decline. The U.S. time use survey data from 1965,

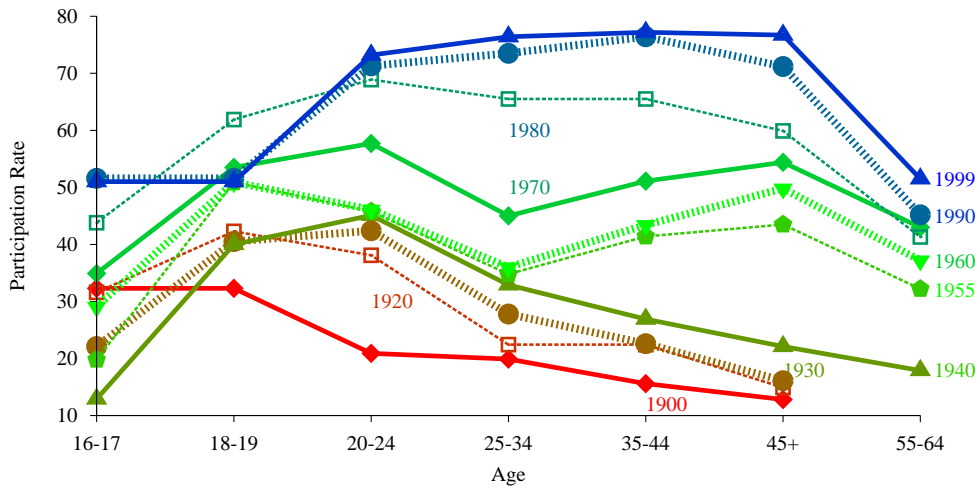
show that married women (averaged over all age groups) spent a little more than 5 hours a day on housework (including purchases of goods and services), slightly less than, but not too far from, [Bryant's](#) estimates. Our examination of the microdata from the 1975 time use survey shows that in 1975 married women also devoted about 5 hours a day in housework (including shopping time). By 2006, however, the U.S. time use survey suggest that married women were, overall, spending around three hours a day in housework, a substantial decrease since 1965.

The size of the decline in housework implied by the durable good revolution has been controversial. Many researchers studying time-use data have argued that the effect of the revolution was qualitative and compositional rather than time saving. [Vanek \(1973\)](#) argued that improvements to household technology did not translate into a substantial reduction in housework because households substituted away from paid help, and the standard for hygiene and cleanliness increased (see also [Ramey and Francis, 2005](#); [Mokyr, 2000](#)). Housework went from being hard physical labor to being lighter but time-consuming, with more time spent in activities such as shopping for different types of foods and products, and cooking better meals.

Nonetheless, changes in the nature of housework afforded women greater discretion over the amount of time spent on housework. This allocation of time clearly responded to changes in women's market opportunities and the age of their children: A study by Robinson and Converse (see [Vanek, 1973](#)) reported that in 1965-1966 employed and currently married women with no children devoted 23.4 hours a week to housework while non-employed married women with no children devoted 45.2 hours to housework. This observation suggests that an important part of housework could be reduced, and that the revolution introduced significant flexibility in time use choices. Women with children had a greater incentive to delay exit from the labor market, and to re-enter after their kids entered school. It also made it easier to raise children and work while raising kids.

This 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; in [Section 5](#) we examine the results of the simulations. [Section 8](#)

Figure 1: Female Labor Force by Age (1900-2000)



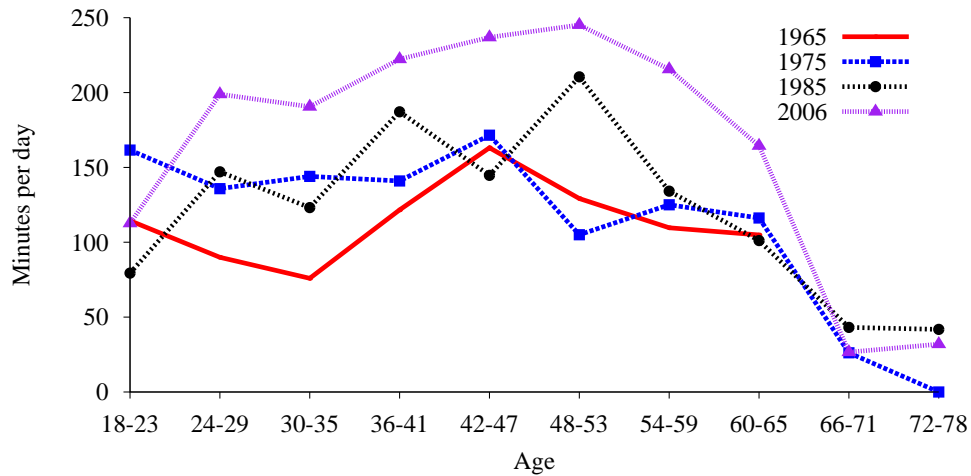
concludes.

## 2 Historical Facts: Female Labor Force, Housework and Child-care

In this section we use data from the U.S. census and from U.S. time use surveys between 1965 and 2006 to examine trends in female labor participation rates and in their use of time. We focus on married women (which we use as a shorthand to include not only married women but also women with a domestic partner) but also examine changes in the contribution of married men to childcare. These surveys allow us to examine the importance of the decline in housework, of the increase in market work, and of changes in the allocation of time for the purpose of childcare – between primary and secondary childcare, and between men and women – in the second half of the 20th century.

Figure 1 uses information from the U.S. census on female labor force participation rates by age group. It shows that before the Second World War female participation rates declined after women reached their mid twenties. In 1955 a significant portion of women started to reenter the labor force after their childbearing years. Up until 1970, we observe a double-peaked pattern in the life-

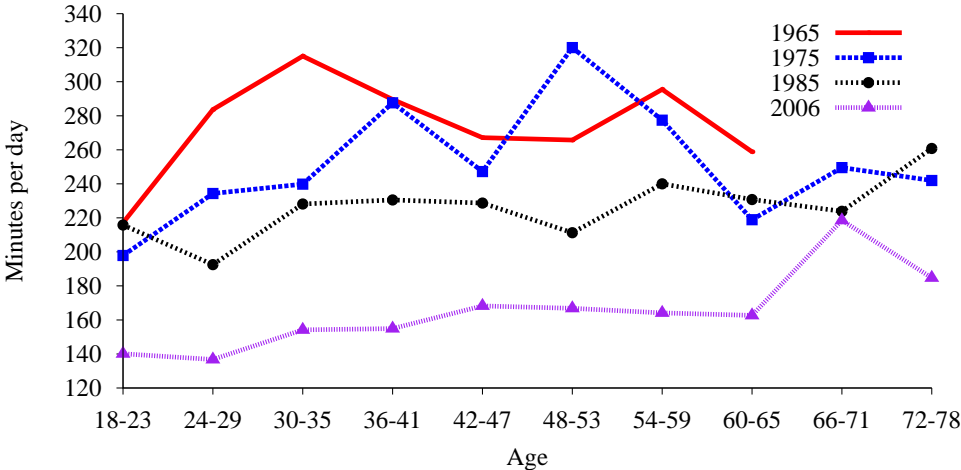
Figure 2: Married Females: Daily Minutes of Work (Time Use Surveys)



cycle pattern of labor force participation, with one peak in womens' early 20s and the other in their 40s. By 1980, the double-peaked pattern has flattened out, and has disappeared by 1990. Can the durable good revolution – perhaps interacting with changes in childcare requirements associated with the baby boom – explain women re-entering the labor market after raising children during the 1950s? Can further improvements in home production also explain the flattening of the double peaked pattern?

The Census data are on *participation rates* and may overstate the increase in the number *hours* spent on market work by treating equally part time and full time work. However, the disappearance of the double-peaked pattern in the second half of the twentieth century, even if less pronounced, is also visible in the U.S. time use surveys which reports the time women spend on market work. Figure 2 shows how many minutes per day married women spent on market work. 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). In 1965, having children impinged significantly on the amount of time that a women spent working in the market. This effect has diminished somewhat since then, but there is still a sizable negative influence on hours of market work by women with children. This can be seen by conditioning the

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



time married women spend on market work on whether they have or not have children. Using the 2006 ATUS survey we find that married women in the age bracket 24-35 with no children worked 285 minutes a day; married women with 1 child below 6 worked 194 minutes a day; and married women with 1 child below 6 and 1 child between 6 and 12, worked 104 minutes a day. Single women without children, in the same age bracket, worked 264 minutes a day. These observations suggest that while married and single women without children worked about the same number of minutes per day, children are still an important constraint with the respect to the time married women spend on market work. Even with the dramatic increases in the female labor force and the flattening of the double-peak pattern, in the late 20th century the presence of children is still associated with less time spent in the labor market. So, changes in fertility during the second half of the 20th century may have had an important role in explaining the flattening of the double-peaked pattern.

Interestingly, the ATUS 2006 survey shows that married men in the age group 24-35 work more the more children they have. Married men 24-35 years old without children work 343.7 minutes; those with one child below 6, 368.4 minutes; and those with one child below 6 and one between 6 and 12, work 411.8 minutes a day (these figures are based on calculations not reported in our paper).

How much did housework decline? Figure 3 shows marked declines in housework between 1965 and 2006. For women in the age group 24-29, housework fell from 283.63 minutes a day in 1965 to 136.73 minutes a day 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. In contrast, men increased time spent doing housework. For men in the age group 30-35, it went from 46.12 minutes in 1965 to 72.14 in 2006. Housework time increases for all age groups and overall it almost doubles, from 53.07 minutes a day in 1965 to 90.11 minutes a day in 2006. The figures do not include time spent purchasing goods. In 1965, married women spent 44.52 minutes a day purchasing goods versus 52.16 minutes in 2006 (see Table 1). These figures are 29.66 and 34.33, respectively, for married men. While both men and women have increased their shopping time, this increase is fairly modest.

While housework declined sharply, in principle, the supervision of a child required the same number of hours. The household revolution made it easier to raise kids, from cooking to doing the additional washes or even entertaining them, but it did not release the basic time constraint: children needed supervision and someone had to be around.<sup>1</sup> 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 for the second half of the century cannot be compared to the information collected in the more recent surveys. Since 2003 the ATUS collects information about times when a respondent had a household child under 13 in “his/her care”. The child may or may not be in the same room and the respondent is doing something else as a primary activity. The time individuals spend providing secondary childcare to household children is further restricted to the time between when the first household member under the age of 13 woke up and the last household child under 13 went to bed. It is also restricted to times when the respondent was awake. In addition, if the respondent reports providing both primary and secondary childcare, the time is attributed to primary care

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<sup>1</sup>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

only. In the earlier time use surveys, for secondary childcare the respondents were asked “what else were you doing?” which may also have lead respondents not to report passive supervising of children. The recent time use surveys (ATUS) give much higher estimates of secondary childcare than previous time use surveys thus suggesting that the question asked captured different notions of secondary childcare, with less passive child supervision captured in the earlier surveys. 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. The difference is again in 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 he/she is doing and capable of intervening if necessary. For primary childcare, however, the notion used in the different surveys provide very similar estimates. 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,<sup>2</sup> we use only information about household children. Household children can be the respondent’s own child/children and/or their spouse’s child/children.

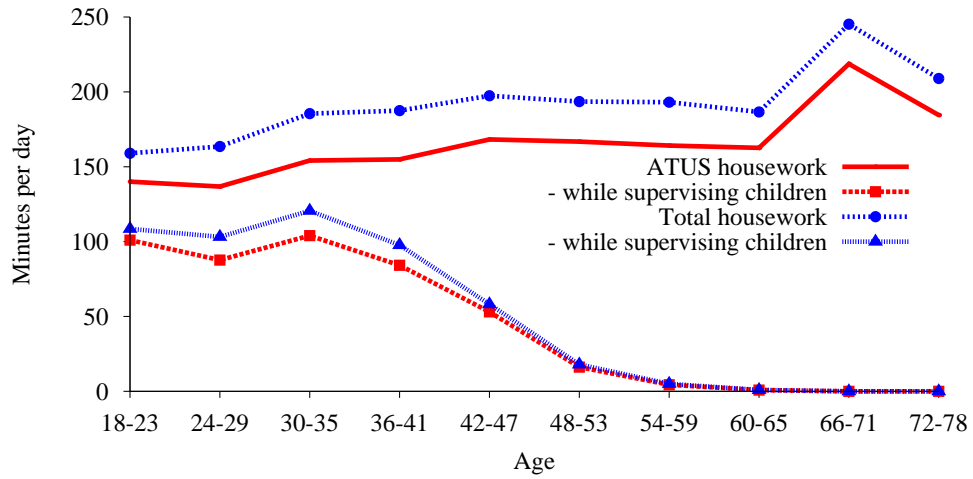
Figure 4 plots secondary childcare that takes place while doing household chores together with the total time married women and married men spend on household chores in 2006. Two measures of housework are used: one includes standard activities (code 02), while “total housework” also includes time spent purchasing groceries and other household goods and services, including time spent traveling to purchase these goods (see Table 1). Figure 4a reports data for married women, and Figure 4b for married men. The figures show that a considerable fraction of secondary childcare is done while mothers do household chores; this fraction is much more important than for

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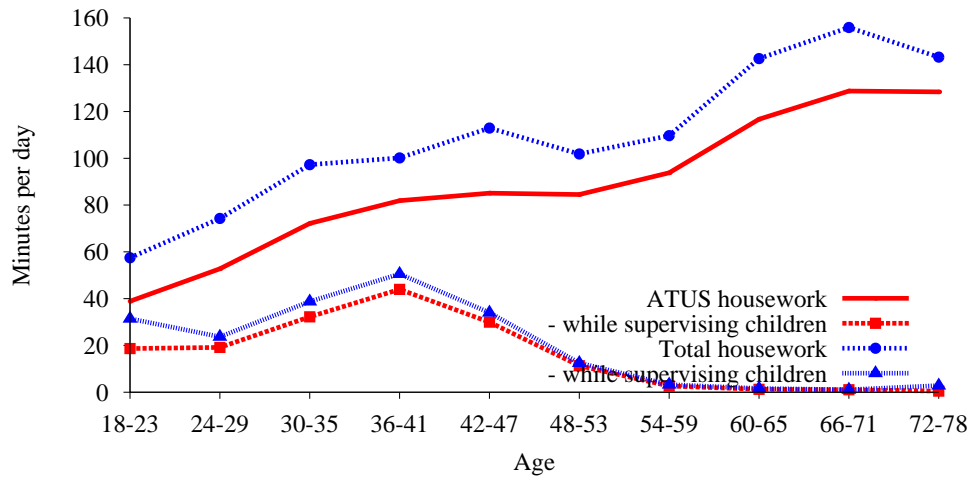
<sup>2</sup>For secondary childcare we use the information under the flag trthh.In

Figure 4: Housework and Housework While Supervising Children (2006 ATUS)

(a) Women



(b) Men



men. Another important feature, not exploited in this paper, is that married men do a considerable amount of housework. Married men in the age group 42-47 do about half as much housework as married women. This may mean that part of the decline in housework shown in Figure 3 may have been not just the result of the household revolution, but also of a within-family reallocation of time. These reallocations may be important for understanding the dramatic increase in female participation, but are not part of our analysis since, in our model, men do not contribute to either childcare or housework.

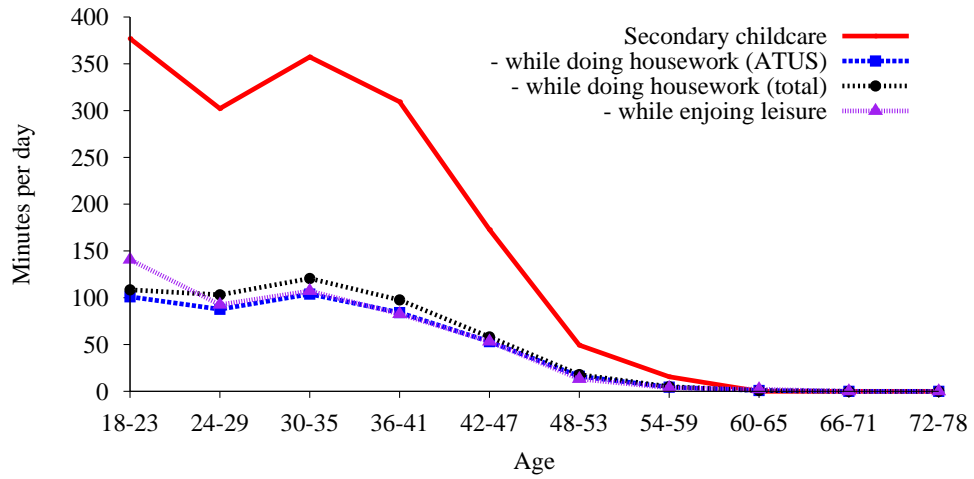
Figure 5a shows that secondary childcare while doing housework or while enjoying leisure are of similar magnitude, each about a third of total secondary childcare. The other third of secondary childcare was done when the primary activity was some other activity such as grooming, eating a meal, or studying. For example, in the 2006 ATUS survey a woman between the ages of 30 and 35 spent 39.84 minutes supervising the kids while eating a meal, and 26.88 minutes while the primary activity was traveling. These types of secondary childcare are not included in the calculation of secondary childcare requirements in our model and simulations. For married mothers between the ages of 30 and 35, of their 107.27 minutes spent supervising their children while enjoying leisure as a primary activity, 59.9 minutes a day went into watching TV. For married mothers between the age of 18 and 23, 93.4 minutes of their 140.7 minutes went into watching TV. While we have no evidence regarding secondary childcare during the first stages of the household revolution, we suspect that there has been a shift from secondary childcare while doing housework to secondary childcare while enjoying leisure (at least for women without domestic help).

Figure 5b show that men make large contributions to secondary childcare, particularly men in the age group 30-47. Unlike women, men tend to supervise children while enjoying leisure rather than while doing housework. For men watching TV was the most important leisure activity while supervising children. Men between the ages of 30 and 35, spent 59.90 minutes a day watching TV out of the 86.9 minutes that they spend doing secondary childcare while enjoying leisure.

Overall, while married women did most of the childcare, men also make considerable contributions. For example, while married women between the age of 30 and 35 spent 357.30 minutes

Figure 5: Secondary Care and Housework While Supervising Children (2006 ATUS)

(a) Women



(b) Men

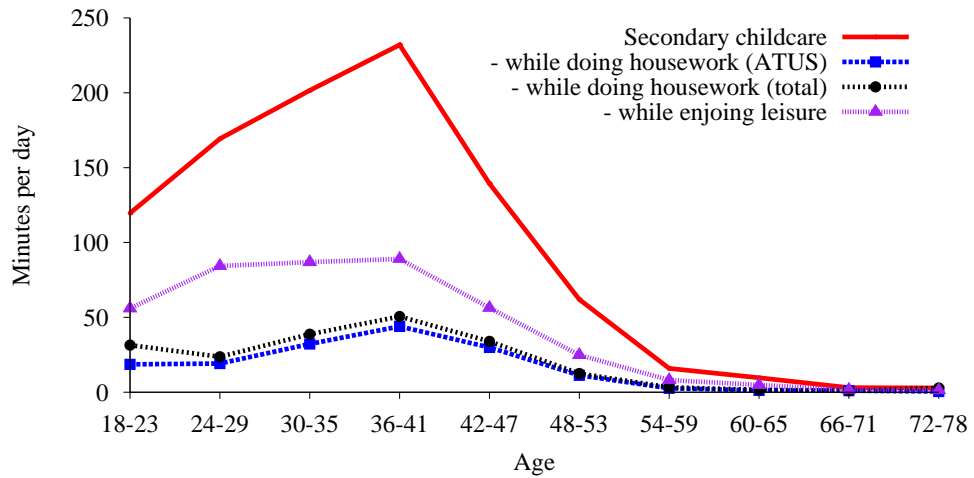


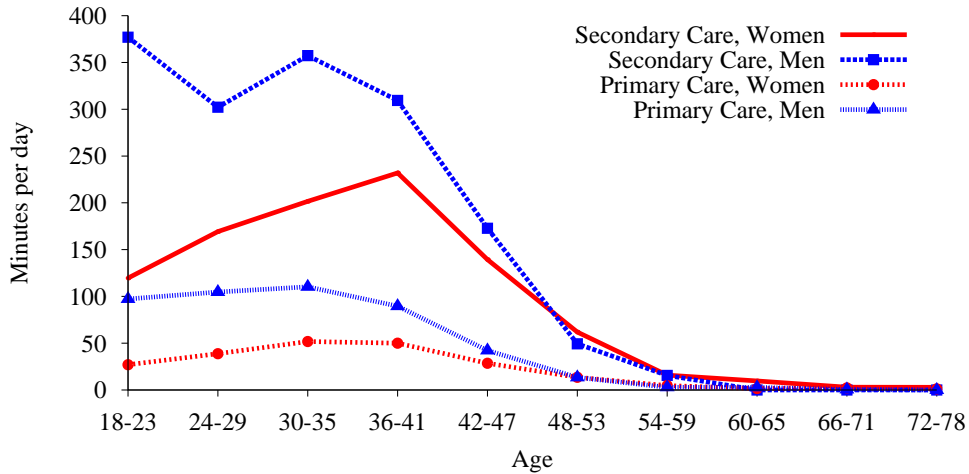
Table 1: From the 2006 ATUS

Age	Observations	Personal Care	Leisure	Market Work	Housework	Housework (Purchase of Goods)	Primary Childcare
<b>Married Men</b>							
18-23	19	490.92	227.94	432.79	38.99	28.78	27.00
24-29	186	520.98	227.74	424.17	53.06	34.94	38.78
30-35	400	529.32	248.58	355.56	72.14	37.25	51.77
36-41	563	525.42	222.21	396.81	81.95	31.45	50.04
42-47	532	535.68	257.97	334.95	85.08	42.41	28.60
48-53	385	506.24	255.48	394.72	84.54	30.02	13.57
54-59	303	518.83	307.56	333.20	93.79	25.14	4.62
60-65	212	542.60	347.86	210.73	116.73	38.00	1.53
66-71	165	575.37	418.84	62.94	128.71	45.69	2.19
72-78	174	575.05	441.20	56.18	128.40	26.57	1.24
Total	2939	531.35	287.08	313.27	90.11	34.33	23.78
<b>Married Women</b>							
18-23	71	620.75	243.51	112.64	140.09	64.04	97.30
24-29	321	571.50	218.52	198.88	136.73	48.87	104.72
30-35	605	552.74	215.41	190.54	154.17	54.62	110.20
36-41	644	545.59	196.85	222.27	154.92	58.95	89.53
42-47	579	551.23	214.77	236.88	168.23	51.63	42.27
48-53	407	551.13	251.52	245.13	166.80	52.03	13.41
54-59	320	568.04	248.10	215.52	164.13	56.79	2.86
60-65	224	556.86	309.43	164.39	162.67	44.32	2.75
66-71	163	579.61	356.40	26.60	218.56	49.23	0.52
72-78	113	577.36	403.07	31.92	184.73	36.14	0.00
Total	3447	559.94	248.08	191.75	163.09	52.18	49.15

Table 2: From the 2006 ATUS Primary and Secondary Childcare

Age	Observations	Primary Childcare	Secondary Childcare	Secondary Childcare (with house- work)	Secondary Childcare (with total housework)	Secondary Childcare (with leisure)
<b>Married Men</b>						
18-23	19	27.00	119.60	18.65	31.45	56.00
24-29	186	38.78	169.30	19.16	23.68	84.32
30-35	400	51.77	201.60	32.22	38.75	86.90
36-41	563	50.04	232.00	43.95	50.55	89.04
42-47	532	28.60	139.36	29.97	34.00	56.34
48-53	385	13.57	61.96	11.34	12.49	24.90
54-59	3039	4.62	15.92	2.67	3.25	8.13
60-65	212	1.53	9.68	1.26	1.62	4.87
66-71	165	2.19	3.04	1.06	1.06	1.64
72-78	174	1.24	2.84	0.48	2.84	1.37
Total	2939	34.33	23.78	101.72	18.65	12.69
<b>Married Women</b>						
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
Total	3447	163.09	52.18	49.15	139.53	32.14

Figure 6: Primary and Secondary Care Time (2006 ATUS)

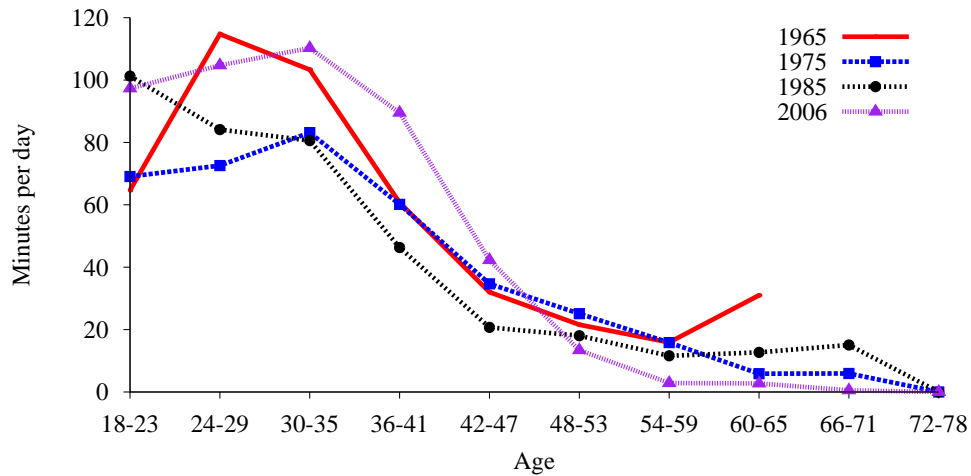


a day, on average, doing secondary childcare, married men, in the same age group, spent 201.6 minutes a day (see Table 1). Although we do not know the implications of these observations for the total childcare requirements of a child (recall that the time use surveys provide time us for the respondent, not for the entire household, or even for a husband-wife pair), this data suggests that there is the potential for considerable changes in the allocation of time within the couple; such reallocations may also have been the direct or indirect result of the household revolution. In terms of total childcare requirements, these data also seem to indicate that married women childcare requirements may be a lower bound estimate of the total childcare requirements of a child.

Figure 6 shows that secondary childcare is considerably larger than primary childcare. Men and women spend almost three times more time doing secondary childcare than doing primary childcare, and men are engaged in secondary childcare in a significant way while women remain the main provider of both primary and secondary childcare (see Table 1). For example, in 2006 married women 30 to 35 years old, spent 357.30 in secondary care a day and 110.20 minutes a day in primary care. For married men in the same age group, these figures are 201.6 and 51.77, respectively (see Table 2).

An important change in the composition of secondary childcare may have taken place over the decades, shifting secondary care while doing housework to secondary care while doing other

Figure 7: Married Females: Daily Minutes of Primary Childcare Time (Time Use Surveys)



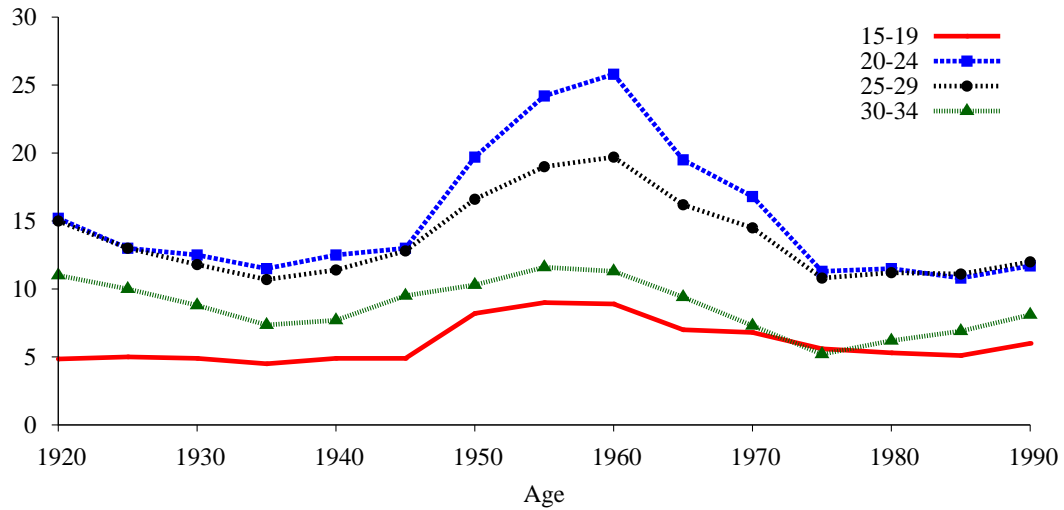
activities. This shift may have led to an increase in the contribution of men to childcare.

Figure 7 shows the evolution of primary childcare over the second half of the 20th century. The micro data do not indicate important changes in the amount of time spent in 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 women spend giving primary childcare to their children, about 40 minutes more in 2006 than in 1985 and 1975.

Overall this information suggests that the durable good revolution affected housework importantly, but provides only indirect evidence on how these changes affected childcare since we do not have comparable information for secondary childcare for the second half of the century, and no information for the first half of the century.

To recap, the evidence suggests that there have been small changes in primary childcare time, at least over the second half of the twentieth century. The evidence also tells us that secondary childcare time is much larger than primary childcare time, and that a large fraction of secondary childcare time is spent doing housework. Consequently, the proximate effect of the household revolution may have been through secondary childcare time, not primary childcare time. To the extent that childcare services are increasingly using secondary childcare time, men have been afforded the opportunity to become more actively involved in the care of their children and at the same time

Figure 8: Live Births per 100 Women



released time from women allowing them to increase their participation to the labor market.

Finally, Figure 8 illustrates the importance of fertility changes throughout the 20th century and particularly during the second half of the century. The sharp increase in fertility rates after World War II, and up until 1960, and their subsequent decline may reflect households' decisions to take advantage of the household revolution by postponing children, having fewer children and/or a shorter spacing between children, the net result of which is to allow married women to work more, on average, in the market. Although this interpretation implies that fertility decisions are endogenous and affected by the durable revolution, this paper will assume that fertility changes are exogenous. We will, however, examine whether these changes contribute to the flattening of the double-peaked pattern observed in the latter part of the 20th century.

### 3 Economic Environment

#### 3.1 Households

The economy is made of overlapping generations and a household comprises a married couple which splits its time among market work, housework, secondary care and primary childcare and leisure. We assume that men always work and that the household chooses how much women work.

As in [Greenwood \*et al.\*](#), we assume that women earn a fraction of what men earn. A household ‘formed’ at date  $t$  has preferences summarized by

$$\max \sum_{i=0}^{T-1} \beta^i U(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i) \quad (1)$$

where  $T$  is the ‘lifetime’ of the household,  $c$  denotes consumption,  $n$  hours of work,  $i$  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,  $h$  subscripts indicate *home work* activities, and  $c$  subscripts signify (*primary*) *childcare*. Thus,  $c_{mt}^i$  is market consumption of a household of cohort  $t$  at age  $i$  (which means this consumption is enjoyed at calendar date  $t+i$ ), and  $n_{ht}^i$  refers to home work hours at age  $i$  of a household of cohort  $t$ . The functional form for  $U$  is:

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

where  $\tilde{T}$  is the household’s time endowment (for women), and  $C(c_m, c_h)$  is a consumption aggregator:

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

Home goods,  $c_{ht}^i$ , are produced by combining durables,  $d_t^i$ , with time,  $n_{ht}^i$ :

$$c_{ht}^i = H(d_t^i, n_{ht}^i) \quad (4)$$

where

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

A key feature of the model is the childcare constraint:

$$c_{ct}^i = G(n_{ct}^i, n_{st}^i) \quad (6)$$

where

$$c_c = \begin{cases} n_c^v n_s^{1-v} & \text{if } \varphi = 0 \\ [v n_c^\varphi + (1-v) n_s^\varphi]^{1/\varphi} & \text{if } \varphi \in (-\infty, 0) \cup (0, 1) \end{cases} \quad (7)$$

where  $n_s$  is *secondary* childcare time which is some fraction of leisure time,  $\ell$ , and housework time,  $n_h$ :

$$n_s = \theta_\ell \ell + \theta_h n_h. \quad (8)$$

Childcare is a constraint in that a household of age  $i$  *must* provide total childcare services of  $c_c^i$ ; the household does not directly value the provision of these childcare services. These services, in turn, are produced either with primary childcare time,  $n_c^i$ , or with secondary childcare time,  $n_s^i$ . Consequently, when there are children in the household, home work time,  $n_h^i$ , produces two distinct goods: home consumption goods,  $c_h^i$ , and childcare,  $c_c^i$ .

The household's budget constraint is

$$c_{mt}^i + q_{t+i} x_t^i + a_t^{i+1} = \bar{n} w_{t+i} + \phi_t^i n_{mt}^i w_{t+i} + r_{t+i} a_t^i \quad (9)$$

where  $x_t^i$  represents investment in durables by a household of cohort  $t$  at age  $i$ ,  $a_t^i$  denotes this household's beginning-of-period market assets,  $\bar{n}$  is the (fixed) amount of time that the husband works,  $w_{t+i}$  is the real wage,  $\phi_t^i$  is the efficiency of the wife relative to the husband,  $r_{t+i}$  is the gross return on capital, and  $q_{t+i}$  is the price of durables.

The law of motion for durables is

$$d_t^i = (1 - \delta_d) d_t^{i-1} + x_t^i. \quad (10)$$

The household faces the following boundary conditions:

$$d_t^{-1} = 0, \quad a_t^0 = 0, \quad d_t^T \geq 0, \quad a_t^{T+1} \geq 0 \quad (11)$$

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)–(11), 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

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

On the right-hand side, we need to add 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

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

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

Finally, goods market clearing is written

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

Table 3: Parameter Values

<b>Time</b>		
	Length of a period (years)	6
	Number of periods of ‘life’	10
<b>Child-care</b>		
$\nu$	Weight on primary child-care time	0.6068
$\varphi$	CES parameter	0.6219
$\theta_\ell$		.6
$\theta_h$		.8
<b>Market production</b>		
$\alpha$	Capital’s share	0.3300
$\delta_k$	Depreciation rate of market capital (annual)	0.07
$\bar{\phi}_{1900}$	Average relative wage of women in 1900	0.4800
$\bar{\phi}_{2006}$	Average relative wage of women in 2006	0.6000
<b>Utility</b>		
$\omega$	Weight on leisure in utility function	0.6354
$\beta$	Discount factor (annual)	0.9821
<b>Consumption aggregator</b>		
$\psi$	Weight on market consumption	0.7450
$\xi$	CES parameter	-0.2000
<b>Home production</b>		
$\eta$	Weight on durables	0.4590
$\zeta$	CES parameter	0.3500
$\delta_d$	Depreciation rate of durables (annual)	0.2
$q_{1900}$	Initial price of durables, 1900	37,800
$g_q$	Change in price of durables	-8.3%

## 4 Calibration

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

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 6-18. So, 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.

Perhaps the most problematic parameters are those characterizing the childcare production function,  $\nu$  and  $\varphi$ . The *model* says that for household  $i$ , childcare is

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

Given parameter values for  $\nu$  and  $\varphi$ , and using time data for married women from the 2006 ATUS, the above equation can be used to generate an inferred value for  $c_c^i$ . In principle, we should be using primary care time and housework 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. We chose women because they account for the bulk of time spent with children. We ‘estimate’  $\nu$  and  $\varphi$  via

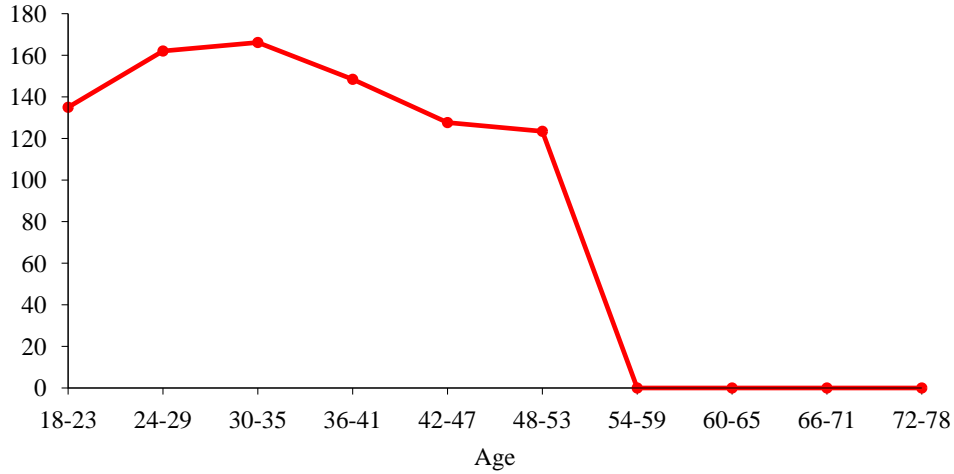
$$(\nu, \varphi) = \operatorname{argmin} \left\{ \operatorname{var} \left[ \frac{c_c^i}{\bar{c}_c} \right] \right\}$$

where  $\bar{c}_c$  is *average* childcare. If the model is correct, then  $c_c^i$  is constant across households, although households may choose different combinations of primary childcare and housework time to satisfy this constraint. Minimizing the variance of  $c_c^i$  simply recognizes that there is no combination of the parameters  $\nu$  and  $\varphi$  that manage to set  $c_c^i$  constant.

One complication that arises in our estimation procedure is that households differ with regards to the age and number of children. Presumably, a child under the age of 6 has a larger childcare requirement than an older child, and two children under the age of 6 require more childcare than a single child under 6. So, we divide the sample by: the number of children under 6, and the number of children aged 6-18. Average inferred childcare,  $\bar{c}_c$ , is computed for each group. The division by  $\bar{c}_c$  in the variance minimization above renders the childcare requirement unit free so that we can pool households during our estimation.

As reported in Table 3, both  $\nu$  and  $\varphi$  are found to have values of around 0.6. What is most important is that the CES parameter,  $\varphi$ , implies a fair deal of substitutability between primary childcare and housework (secondary childcare) time. In other words, households will find it relatively easy to substitute, say, primary childcare time for housework time in order to satisfy their childcare requirement.

Figure 9: Calibrated Childcare Requirement



A number of the model’s parameters are standard, and hopefully require little discussion. These parameters include:  $\alpha$ , capital’s share of income;  $\delta_k$ , the depreciation rate of market capital; and  $\delta_d$ , the depreciation rate of durables. As in [Greenwood \*et al.\* \(2005\)](#), we calibrate the model to a 1900 steady state and a 2006 steady state. We take the relative wage of women from their work:  $\bar{\phi}_{1900} = 0.48$  and  $\bar{\phi}_{2006} = 0.60$ . The initial price of durables,  $q_{1900}$  is chosen so that in 2006, the durables-output ratio is around 0.325 – a value that is consistent with the data; see [Gomme and Rupert \(2007\)](#). Also, the price of durables declines at the rate 8.3% per annum, as in [Greenwood \*et al.\*](#)

The CES parameters for home production,  $\zeta$ , and the consumption aggregator,  $\xi$ , require some discussion. For durables to be labor-saving requires that durables and housework time be fairly substitutable. Hence, we set  $\zeta = 0.35$  which implies more substitutability than Cobb-Douglas. This value for  $\zeta$  is in the range estimated by [McGrattan, Rogerson and Wright \(1997\)](#) and [Rupert, Rogerson and Wright \(1995\)](#). We set  $\xi = -0.2$  which means that market and home consumption are less substitutable than in the Cobb-Douglas case. As the price of durables falls, and the household acquires ever more durables, production of the home produced good increases. Making market and home goods complements helps to get an increase in market hours.

Regarding the childcare requirement, we assume that children are in the household for 5 model

periods (30 years), corresponding to ages 18 to 47 years in the data. This choice was motivated by the fact that, in the data, older households have few children in their households. We suspect that the relatively small amount of time allocated to primary childcare by older households is provided to grandchildren. The age-specific childcare requirements,  $c_c^i$ , are taken from our calculations from the 2006 ATUS. In particular, given estimates of the parameters  $\varphi$  and  $\nu$ , the childcare services produced by a household in the ATUS can be computed from Eq. (7). We take averages of  $c_c$  across households, grouping households by the number of children under 6, and the number of children aged 6-18. We then use fertility data to infer the per household number of children of various ages over the twentieth century, and use the age composition of the children in the ‘typical’ household to infer the required childcare services. The series for  $c_c^i$  is reported in Figure 9

The remaining parameters are:  $\omega$ , the weight on leisure in utility;  $\beta$ , the discount factor;  $\psi$ , the weight on market consumption in the consumption aggregator; and  $\eta$ , the weight on durables in the home production function. These parameters are chosen to match the following observations:

1. A 5% participation rate for married women in 1900, translated into minutes per day based on a 40 hour work week.
2. Average market work time of married women of 198.28 minutes per day.
3. An annual real interest rate of 4% in 1900.
4. Average housework time in 2006 of 192.02, as it is in the 2006 ATUS.

The first two observations are from [Greenwood \*et al.\* \(2005\)](#) while the real interest rate target is a conventional value.

## 5 Results of the Simulations

Two different sets of experiments are examined here; the first set assumes no children while the second includes children. Both experiments assume a 8.3% a year decline in the relative price of durables as in [Greenwood \*et al.\* \(2005\)](#) and an increase in the female-male earning gap that matches

U.S.data (see also [Greenwood \*et al.\* \(2005\)](#), and [Goldin \(1990\)](#)). When we include children we also impose childcare requirements for the observed fertility rates, which therefore includes the effects of fertility changes during the 20th century. Keep in mind that secondary childcare time in the model corresponds to some fraction of time spent doing housework, and some fraction of time spent enjoying leisure. In both cases, the durable good revolution increases consumption and households total assets (these results are not reported in the paper). Durable goods increase for all age groups, but more so for older households.

## 5.1 The Durable Good Revolution and Children

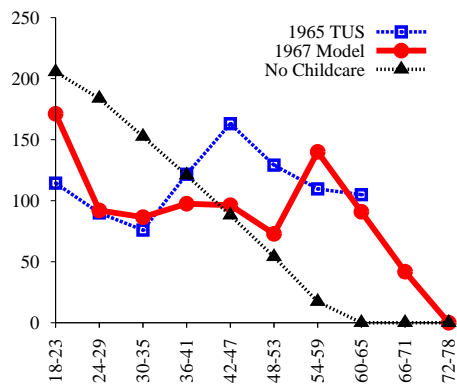
Figures 10 and 11 compares the 1965 to 2006 time use surveys with the baseline model (i.e., with childcare) as well as a version of the model without childcare (our version of [Greenwood \*et al.\* \(2005\)](#)).

The model without childcare does a fairly good job with regards to the life-cycle pattern of housework time but, clearly, cannot replicate the pattern of market hours. Market work is too high during the period in which women have high fertility rates. In addition, after an initial period of high market hours, this version of the model predicts a monotonic decline in market hours whereas the data displays either a flat (1965 and 1975) or hump-shaped pattern (2006). Overall, the life-cycle pattern predicted by the model that does not include childcare constraints has counterfactual implications for market time of women.

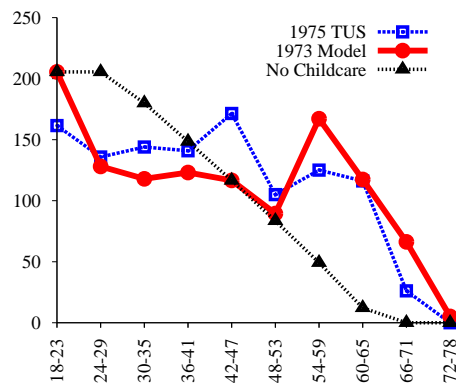
Figures 10 and 11 also report the base case of the model which includes childcare constraints. The model is solved dynamically with synthetic time use surveys constructed from the model data. The childcare constraints are based on the number of children each cohort actually has had. Thus the fact that the baby boom increased the time women had to spend on children is included in the childcare time constraint. The steady states for consumption, capital and female market hours (not reported) are similar to the case with no children. The only difference is that the presence of children lowers the steady state impact of the revolution on female market hours. We do not have data on primary childcare in 1900 but in 2006 primary childcare time from the model is consistent

Figure 10: Baseline model: 1965 and 1975

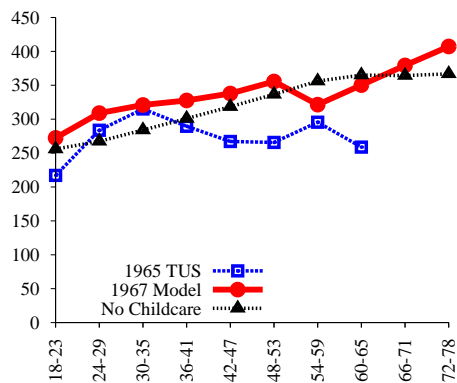
(a) Market Time



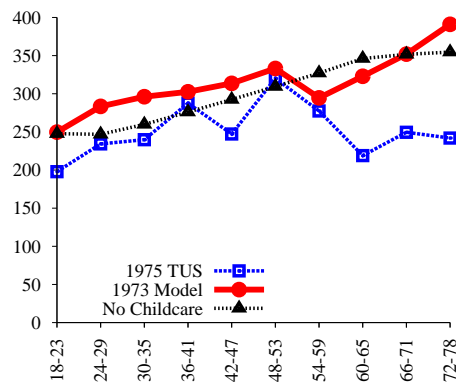
(b) Market Time



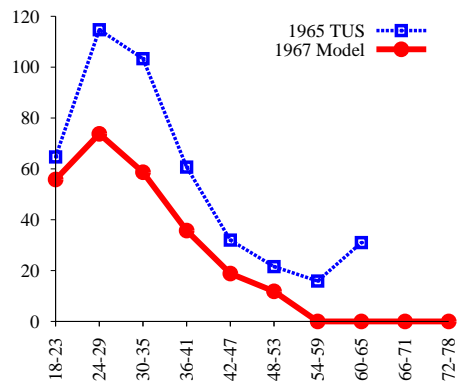
(c) Housework Time



(d) Housework Time



(e) Primary Childcare Time



(f) Primary Childcare Time

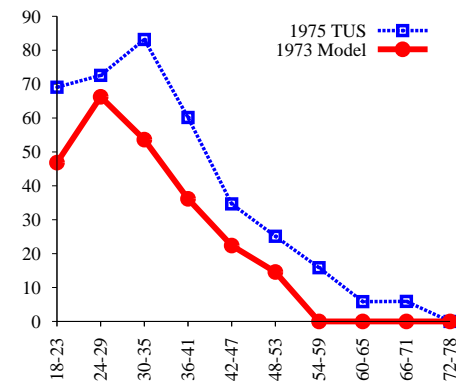
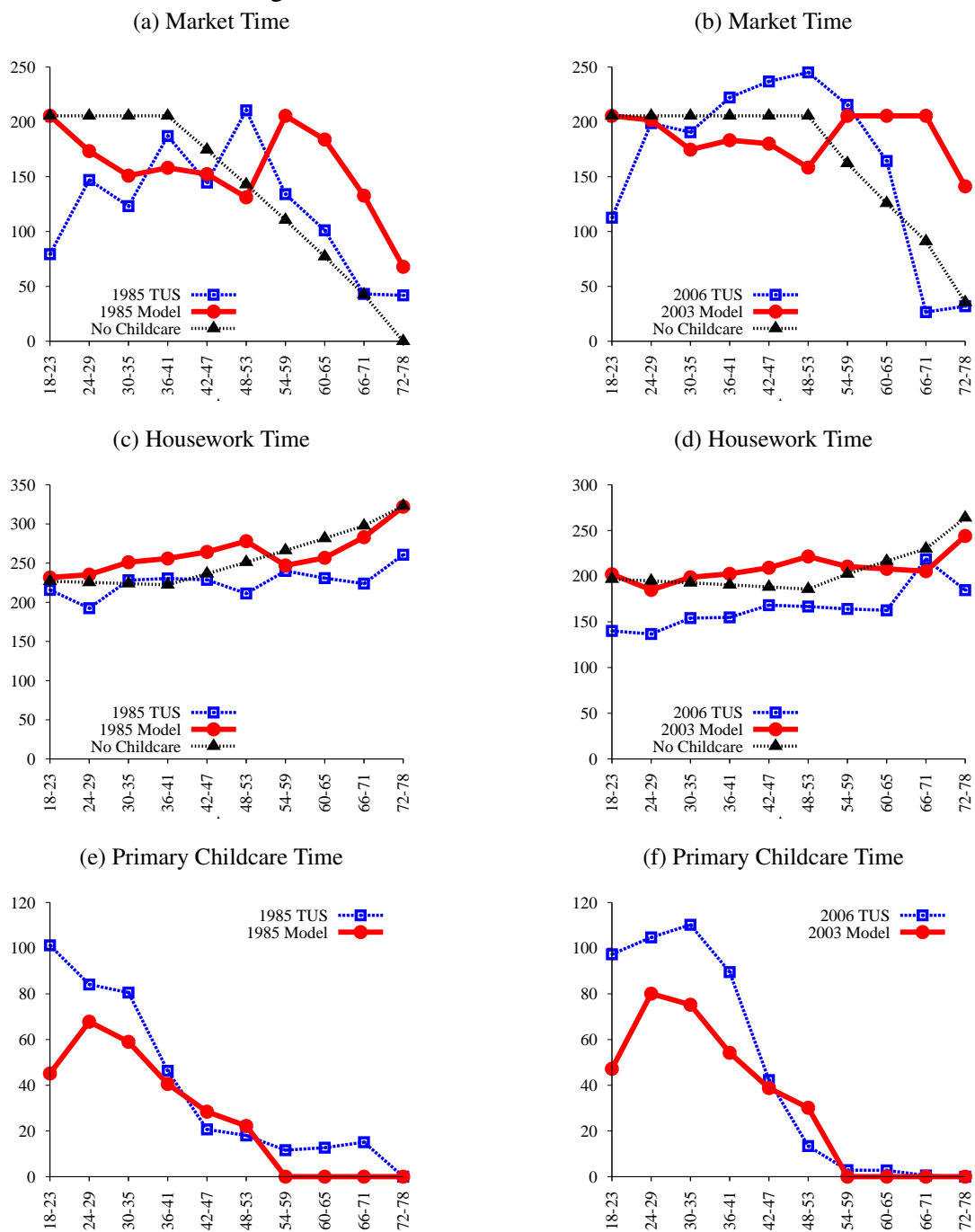


Figure 11: Baseline model: 1985 and 2006



with what observed in the time use data.

In response to the increase in productivity in the durable sector, households decrease their housework time which would also decrease secondary childcare time. To satisfy their childcare constraint, they increase primary childcare time. The childcare requirements estimated are exactly imposed for all periods, but the allocation of time between primary and secondary childcare and between types of secondary childcare (leisure or housework) responds to the optimal time allocation in response to the decline in the relative price of durables. The model underpredicts primary childcare and overpredicts secondary childcare. For the period 1965-1985 the comparison with the TUS survey data is not meaningful because, as mentioned earlier, the surveys do not use the same notion of secondary childcare as in the post-2003 surveys. The most important comparison is therefore with the 2006 survey. From Figure 11 it can be seen that the model does fairly well for the group of women age 18-35 but predicts too much secondary childcare for the older group of women. The model predicts quite well leisure except for older women.

Overall the model with childcare reproduces well housework in the 1965 to 1985 time use surveys. For 2006, the model predicts more housework than in the data and that may be due to the fact that housework requirements have decreased so much that the binding constraint is childcare and therefore housework is higher than required.

The most interesting results concern market hours. For 1965 to 1985, the model reproduces the double peaked pattern of female participation over the second half of the century, whereas the model without children does not. In addition, the model without childcare requirements produces too much market work, while the model with childcare requirements is much closer to the observed number of hours married women spent on market work. The simulations imply too much work for the very young and this is probably due to the fact that we did not include the time young women spend on education. It also underestimates market work for the 43-47 age group in 1965 and to a lesser extent in 1975 and 1985.

However, the model fails to reproduce the sharp increase in female participation of the late 20th century. In 2006, the ATUS survey shows a pattern where women overall only slightly decrease

their participation for the 24 to 29 age group while 30 and older women increase their participation to the labor market. In the model, participation rates decrease for all groups, except for an increase for women in the age group 46-54, thus still showing a double-peaked pattern. Overall therefore, the household revolution has difficulty in explaining the dramatic increase in female participation for young married women that is observed for the late 20th century.

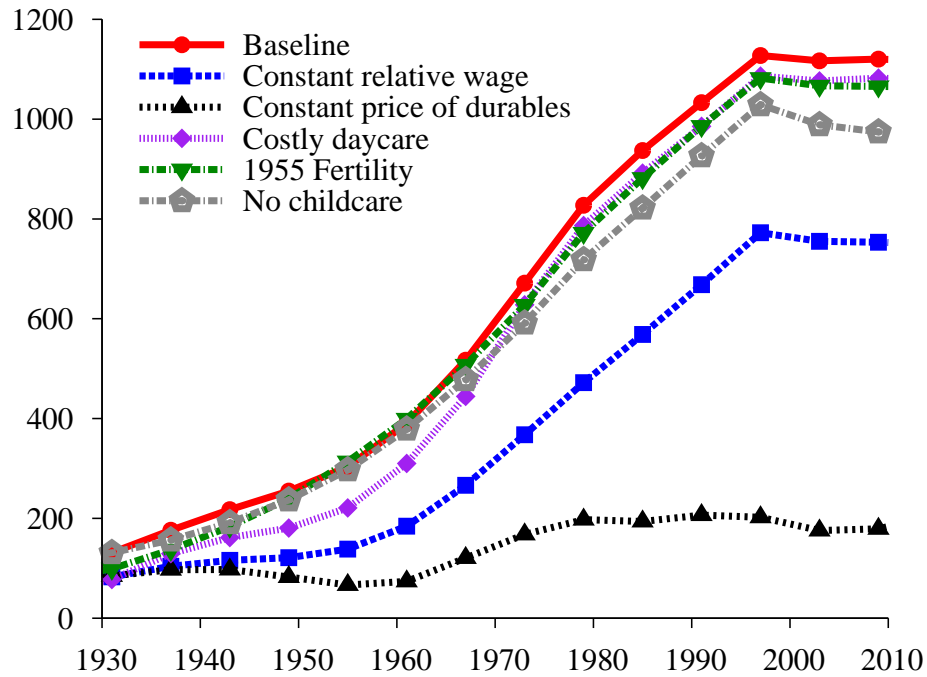
In the model we do not allow men to help women in home production or in childcare while the time survey data however show that men spend a considerable amount of time in secondary childcare. Introducing men into childcare production could help reduce the childcare constraint and allow women to work more than our model predicts, in the later part of the 20th century and early 21st century.

## **6 The Durable Good Revolution and Children: Century Long Changes**

Figure 13 examines the baseline experiment with childcare requirements but looks at the dynamics of female time allocation over a longer time frame: from 1937 to 2009. Compared to Figure 1, where female labor force participation rates are plotted for each cohort over the century, this figure looks different. This in part due to the fact that the figures are not strictly comparable: Figure 1 refers to participation rates and does not distinguish between part-time and full-time jobs while Figure 13 refers to minutes worked per day. Figure 1 therefore overstates female market work by attributing a full participation to the market to a woman who only works part-time.

The model shows a trend towards an increase in female participation for younger women, as it is observed in the data. As noted in the previous section, it fails to account for the strong increase in market work for younger women in the late part of the century. It also implies that women re-entered the labor market in the early part of the century and throughout the century while at the beginning of the century women exited the labor market early and did not re-enter; see Figure 1. Institutional factors (bars to married women working in certain types of jobs) and/or social norms

Figure 12: Model: Female Aggregate Market Work Time



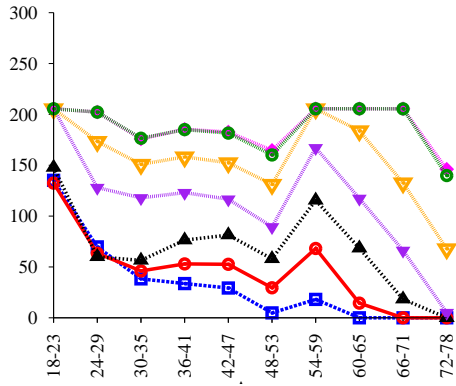
not included in the model, could explain this discrepancy.

As well, in the model women work too much when they are very young in the late part of the century. Inclusion of education would probably help reduce the difference since women invested more on their education in the later part of the century.

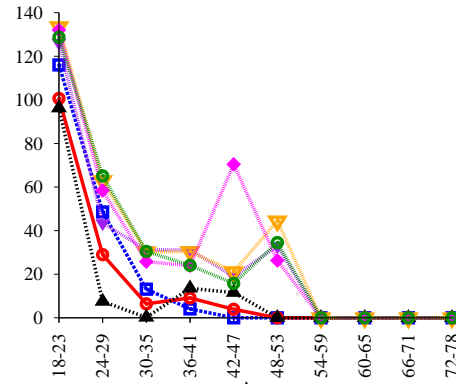
Overall, the model reproduces well important shifts in housework and market work. Without the household revolution (the right-hand side of Figure 13), increases in the female-male earning gap and fertility changes (both included in the base case and in the simulations with no household revolution) explain very little of the changes in market work that is observed for the 20th century.

Figure 13: A set of model-generated time use surveys at selected years covering the baby boom

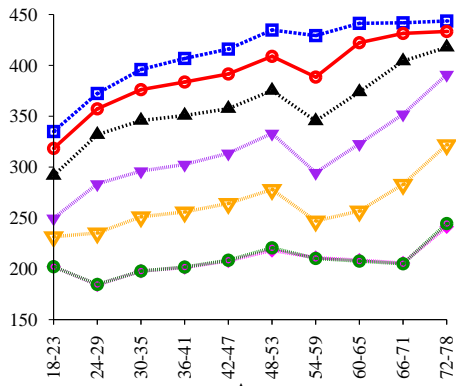
(a) Baseline: Market Time



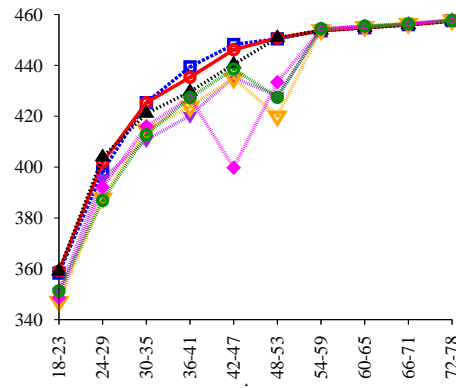
(b) No Durable Goods Revolution: Market Time



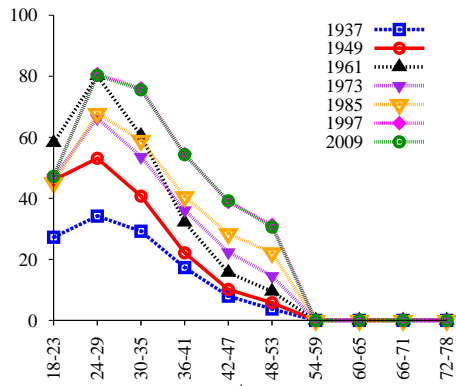
(c) Baseline: Housework Time



(d) No Durable Goods Revolution: Housework Time



(e) Baseline: Primary Childcare Time



(f) No Durable Goods Revolution: Primary Childcare Time

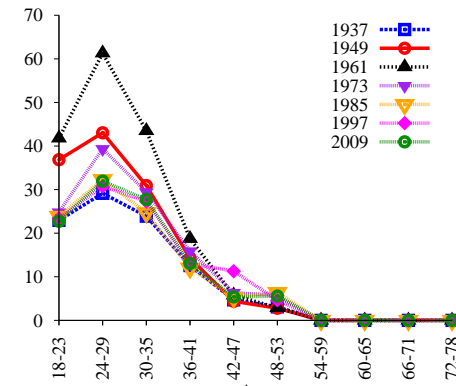
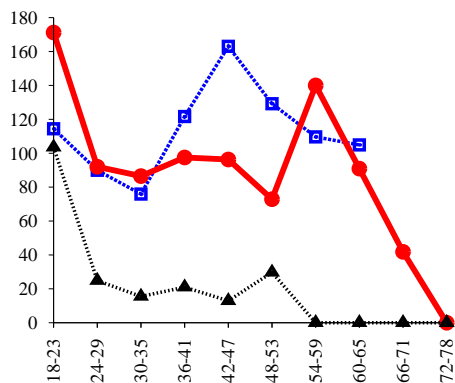
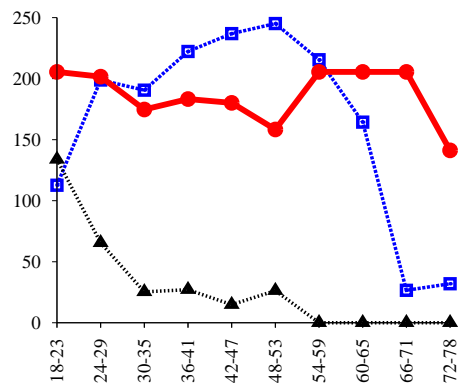


Figure 14: No Change in the Price of Durables

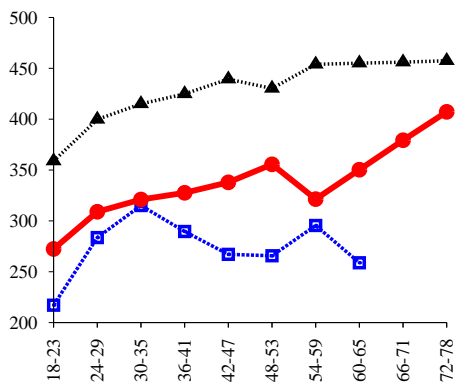
(a) Market Time



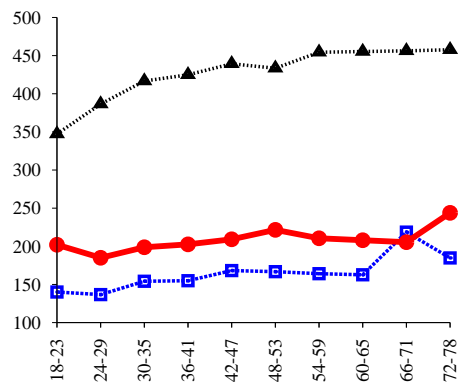
(b) Market Time



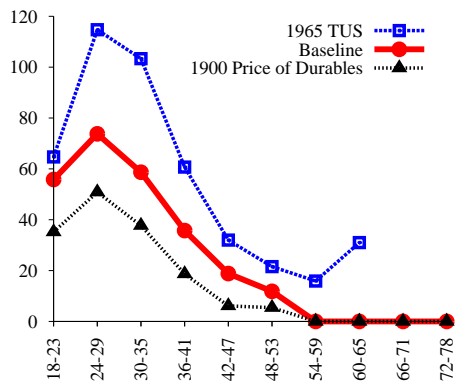
(c) Housework Time



(d) Housework Time



(e) Primary Childcare Time



(f) Primary Childcare Time

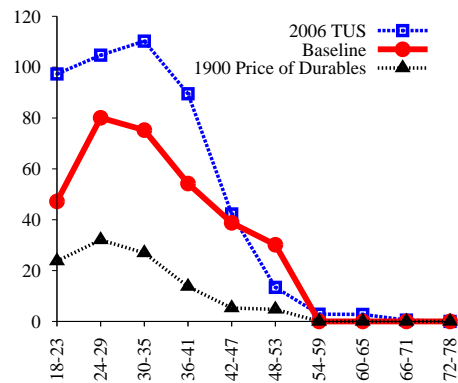


Figure 15: 1955 Fertility

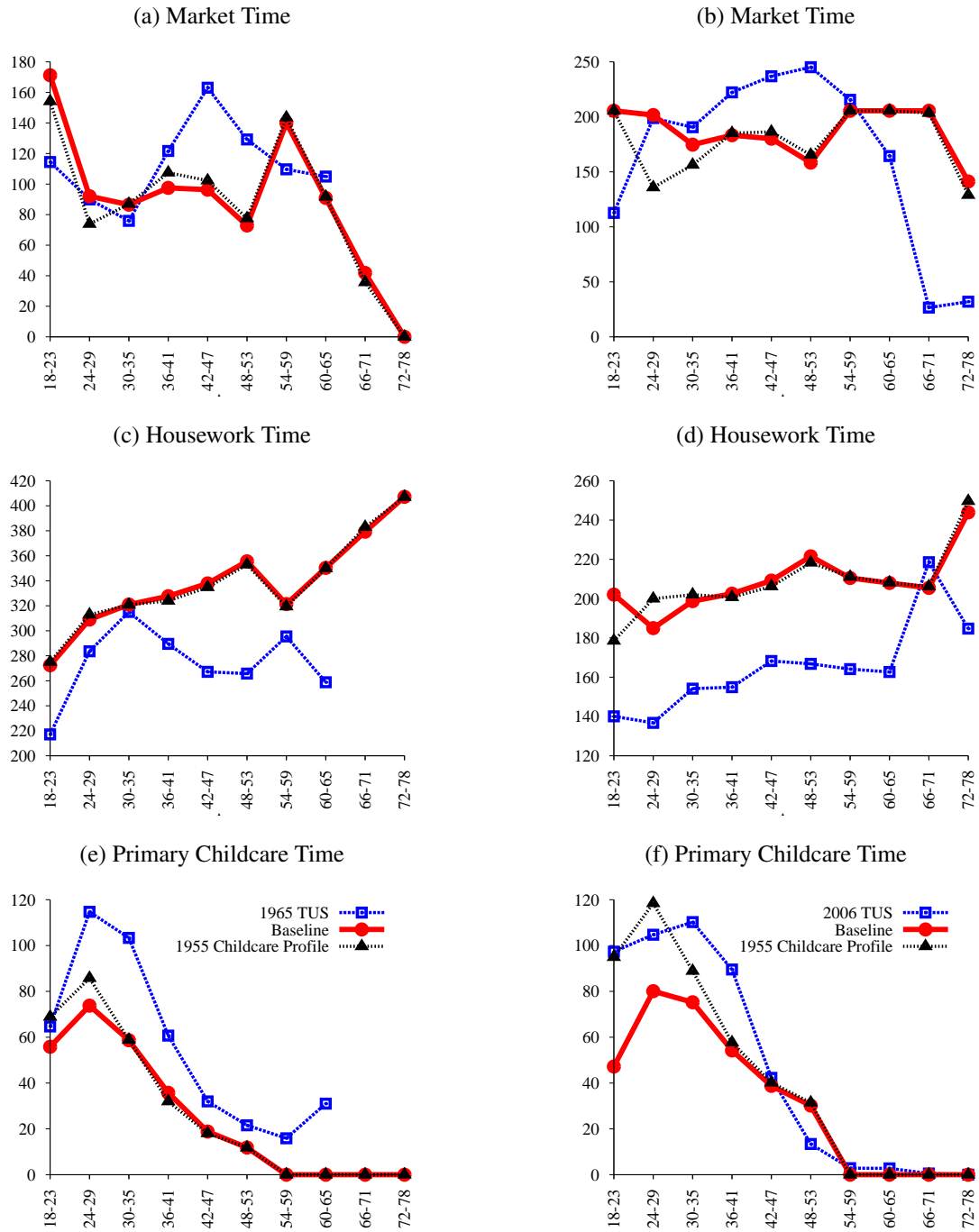
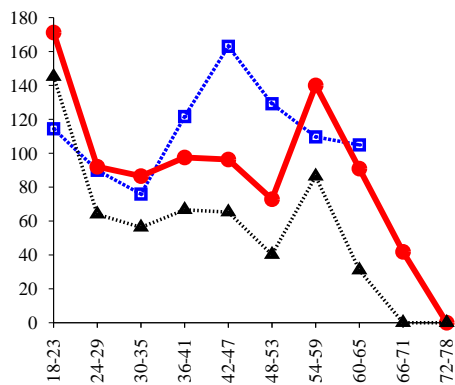
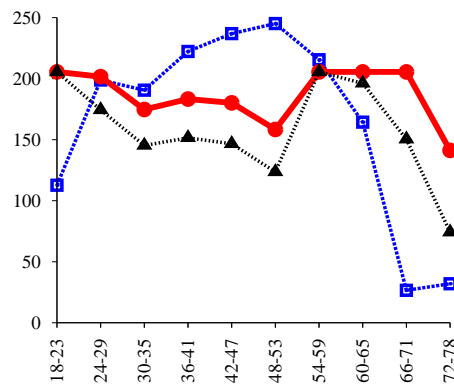


Figure 16: No Change in the Relative Wage of Women

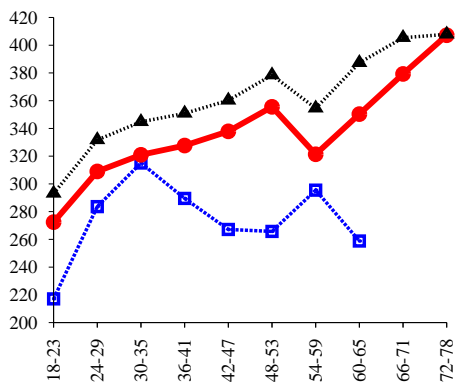
(a) Market Time



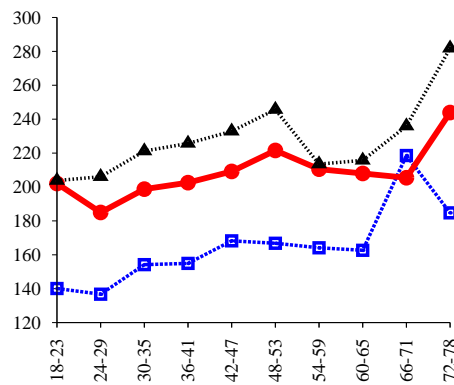
(b) Market Time



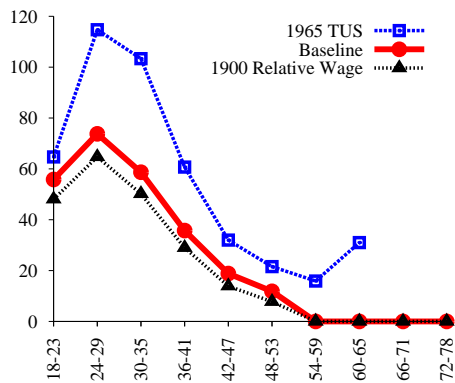
(c) Housework Time



(d) Housework Time



(e) Primary Childcare Time



(f) Primary Childcare Time

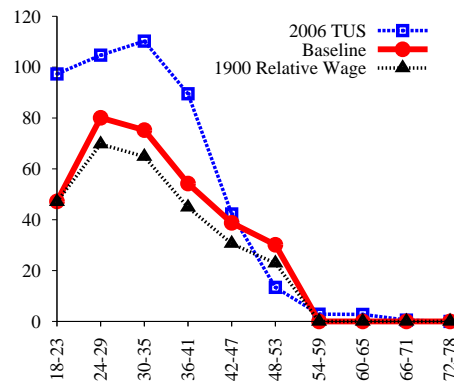
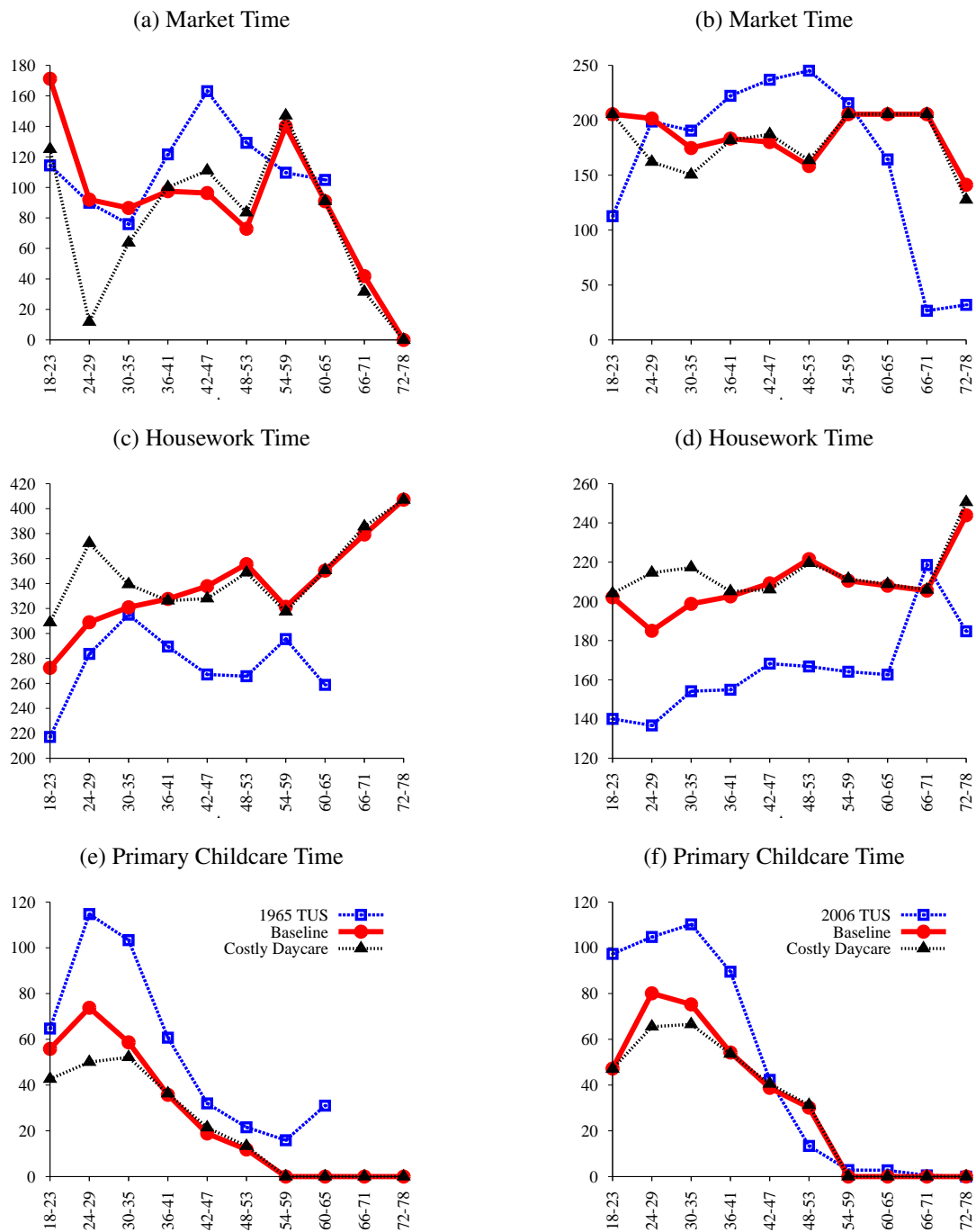


Figure 17: Costly Daycare



## 7 The Durable Good Revolution and Children: Some Experiments

We report the life-cycle profiles for market work, housework and primary childcare time assuming no change in the price of durables (Figure 14), keeping fertility at its 1955 level (Figure 15), no change in the relative wage of women (Figure 16) and costly daycare (Figure 17). Given broad similarities across the years for the U.S. time use surveys, We report the results for two years, 1965 and 2006, to conserve on space.

Figure 14 gauges the effects of the household revolution by maintaining the price of durables at its 1900 level. In both cases fertility and the relative wages change over the decades. It is clear that without the household revolution, the model produces far too little market work, too much housework and underpredicts primary childcare time.

Figure 15 fertility level constant at the 1955 level which corresponds to the peak impact of the baby boom on the childcare requirement. The only significant difference is for the 24 to 29 age group in 2006. Without the decrease in fertility for this age group, the model underpredict the baseline model and the ATUS data for female market work. Overall, this results suggest that changes in fertility cannot account for the important increase in female labor force observed throughout the century.

Figure 16 shows the effects, on the model, of changes in the relative wage of women by maintaining their relative wage at their 1900 level. Changes in fertility and the household revolution are as in the base case. As can be seen, the effects of the increase in the relative wage of women are important for 1965 but become less relevant in later decades.

While it is clear that without household revolution we cannot explain the important increases in female labor force participation rates, if there were no changes in fertility, women would be working much less than when we include fertility changes, particularly in 2006. This suggests that to capture the effects of the household technology it may be important to look at fertility decisions and that women may have reduced fertility in order to benefit from the household revolution and

enter the labor market.

Finally, in Figure 17, we assume that daycare is costly. To evaluate the cost of childcare we use as rough measure the relative wage of domestics to the average female wage using data from the 1950 Census. We model the costs of daycare as a labor income tax with the “tax” set equal to 33% times the number of children under the age of 6 (since children over that age are presumably in school and do not need daycare). The proximate effect of costly day care is on younger women since they are the ones who, in the data, have young children who would need daycare if their mother works in the market. This effect is most pronounced in 1965 than 2006 owing to the higher fertility in the 1960s relative to the 2000s.

## 8 Conclusions

This paper investigated the effects of childcare requirements on the household revolution. The results of the simulations show that the durable good revolution has had an important impact on female labor force even when childcare requirements are included. In addition, imposing childcare requirements helps reproduce market work differences across cohorts within each period and over time. The simulations also show that neither changes in female relative wages, nor changes in fertility can by themselves or together account for the important growth in female labor force in the 20th century.

While the household revolution can explain increasing participation rates for women 25-34 years old, it underpredict the extent of the increase for women in the older age group.

The analysis of the time use survey suggests that further work including men as producers of home goods (both housework and childcare) may be important and improve the understanding of the pronounced increase in female labor market participation observed for the late 20th century, early 21st century.

# Technical Appendix

## A Derivation of the Household's Euler Equations

The household's problem can be cast using the language of dynamic programming as

$$\begin{aligned}
 V(a_t^i, d_t^{i-1}; i) \equiv \max & \left\{ U [c_{mt}^i, H(d_t^i, n_{ht}^i), n_{mt}^i, n_{ht}^i, n_{ct}^i] + \beta V(a_t^{i+1}, d_t^i; i+1) \right. \\
 & + \lambda_{1t}^i [\bar{n}w_{t+i} + \phi_t^i n_{mt}^i w_{t+i} + r_{t+i} a_t^i + (1 - \delta_d) d_t^{i-1} q_{t+i} - c_{mt}^i - a_t^{i+1} - d_t^i q_{t+i}] \\
 & \left. + \lambda_{2t}^i [G(n_{ct}^i, n_{st}^i) - c_c^i] \right\} \quad (\text{A.1})
 \end{aligned}$$

First-order conditions:

$$c_{mt}^i : \quad U_1(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i) = \lambda_{1t}^i \quad (\text{A.2a})$$

$$\begin{aligned}
 n_{ht}^i : \quad & U_2(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i) H_2(d_t^i, n_{ht}^i) + U_4(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i) \\
 & + \lambda_{2t}^i G_2(n_{ct}^i, n_{st}^i) = 0 \quad (\text{A.2b})
 \end{aligned}$$

$$n_{mt}^i : \quad U_3(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i) + \lambda_{1t}^i \phi_t^i w_{t+i} = 0 \quad (\text{A.2c})$$

$$n_{ct}^i : \quad U_5(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i) + \lambda_{2t}^i G_1(n_{ct}^i, n_{st}^i) = 0 \quad (\text{A.2d})$$

$$a_t^{i+1} : \quad \beta V_1(a_t^{i+1}, d_t^i; i+1) = \lambda_{1t}^i \quad (\text{A.2e})$$

$$d_t^i : \quad U_2(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i) H_1(d_t^i, n_{ht}^i) + \beta V_2(a_t^{i+1}, d_t^i; i+1) = \lambda_{1t}^i q_{t+i} \quad (\text{A.2f})$$

Envelope theorem:

$$a_t^i : \quad V_1(a_t^i, d_t^{i-1}; i) = \lambda_{1t}^i r_{t+i} \quad (\text{A.2g})$$

$$d_t^{i-1} : \quad V_2(a_t^i, d_t^{i-1}; i) = \lambda_{1t}^i (1 - \delta_d) q_{t+i} \quad (\text{A.2h})$$

Eliminate partials of  $V$  and  $\lambda_{1t}^i$ :

$$U_3(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i) + \phi_t^i w_{t+i} U_1(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i) = 0 \quad (\text{A.3a})$$

$$U_1(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i) = \beta U_1(c_{mt}^{i+1}, c_{ht}^{i+1}, n_{mt}^{i+1}, n_{ht}^{i+1}, n_{ct}^{i+1}) r_{t+i+1} \quad (\text{A.3b})$$

$$\begin{aligned}
U_1(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i)q_{t+i} &= U_2(c_{mt}^i, c_{ht}^i, n_{mt}^i, n_{ht}^i, n_{ct}^i)H_1(d_t^i, n_{ht}^i) \\
&+ \beta(1 - \delta_d)U_1(c_{mt}^{i+1}, c_{ht}^{i+1}, n_{mt}^{i+1}, n_{ht}^{i+1}, n_{ct}^{i+1})q_{t+i+1}
\end{aligned}
\tag{A.3c}$$

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