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Market Work, Housework and Childcare: A Time Use Approach *

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Abstract

Raising children takes considerable time, particularly for women. Yet, the role of childcare time has received scant attention in the macroeconomics literature. We develop a life-cycle model in which the time dimension of childcare plays a central role. An important contribution of the paper is estimation of the parameters of a childcare production function using data on primary and secondary childcare time as reported in the American Time Use Survey (2003–2015). The model does a better job matching the observed life-cycle patterns of womens' time use than a model without childcare. Our counterfactual experiments show that the increase in the relative wage of women since the 1960s is an important factor in the increase in womens' work time; changes in fertility associated with the baby boom play a smaller role, and changes in the price of durables are found to have a negligible effect. We consider the effects of cheaper daycare. Not surprisingly, this experiment leads to greater use of daycare and more time allocated to market work. A knock-on effect of cheaper daycare is a substantial decline in primary childcare time.

JEL: D13, E24, J13

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1 Introduction

An important message in Becker's (1965) seminal paper is that in order to understand the full impact of policies on the economy, we should also examine their effects on non-market activities. Important, recent papers studying the allocation of womens' time include Greenwood, Seshadri and Yorukoglu (2005), Attanasio, Low and Sánchez-Marcos (2008) and Jones, McGrattan and Manuelli (2015). However, most studies on womens' labor market decisions ignore the role of childcare, and those that do typically treat childcare as exclusively a monetary cost. The implications of childcare has received little, if any, attention in the literature exploring the allocation of womens' time in a life-cycle setting. Yet childcare requirements constitute a substantial constraint on how women with children allocate their time. This inattention seems surprising since most of the increase in female participation is from married women. Further, 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."

This paper develops a life-cycle model in which the time requirements of childcare are treated seriously. Since women often bear the brunt of childcare, the focus is on women – men are an exogenous source of income for the household. The data used to discipline our choices and to evaluate the model are from the American Time Use Survey (ATUS) which is available since 2003. The ATUS data distinguishes between two types of childcare time. The first is *primary childcare time* which corresponds to time during which the primary activity of the survey respondent is taking care of a child. Included among such activities is bathing, feeding and reading to children. The second type of childcare time is *secondary childcare time* during which another activity, like housework or leisure, is the primary activity, but the respondent is nonetheless caring for a child. In order to focus on the role of the childcare constraint on the allocation of time, we take the childcare requirement as exogenous. In the model, this constraint can be satisfied through the choice of primary childcare time, secondary childcare time, and daycare. One contribution of this paper is the estimation of the parameters of the childcare production function, including the elasticity of substitution between primary and secondary childcare time using data from the American Time Use Surveys between 2003 and 2015.

As shown in Section 5, childcare requirements differ markedly depending on both the number of children, and their age. So as to develop a reasonably parsimonious model, the length of a period is set to six years. Since older children can, to a large extent, take care of themselves, our focus, is on children under the age of twelve. Consequently, for the purposes of the childcare constraint, what matters is the number of children under the age of six, and the number of children six to eleven years of age. Since women in their 40s have very few children, there are four model periods during which a women can bear children (age groups 18-23, 24-29, 30-35 and 36-41). We categorize the number of children (in each of the two child age groups) as being: zero, one, or two or more. As a result, there are 81 ($= 3^4$ where the 3 refers to the number of children that a woman can bear in each of her 4 model periods during which she is fertile) 'types' of women, depending on their fertility pattern. Women face no uncertainty over the timing of children: at the start of her life-cycle, each woman knows how many children she will bear, and at what ages she will bear them.

In the data, there are two chief sources of secondary childcare time: leisure and housework time. As is typical, households directly value leisure. Housework time is incorporated into the model by modeling home production as in Benhabib, Rogerson and Wright (1991) and Greenwood and Hercowitz (1991). More specifically, home produced goods require both housework time and durables.

Finally, the model features a hump-shaped profile for wages, the particulars of which are borrowed from Gomme, Rogerson, Rupert and Wright (2005), and womens' wages are, on average, a fraction of mens' wages. Market wages are important since they help determine the opportunity cost of both primary childcare time, as well as that of housework time.

The model is evaluated on its ability to replicate the allocation of time between working in the market, housework, primary childcare, and leisure. While some of the model's parameters are calibrated to closely match the *average* allocation of time to these activities, the allocation of time over the life-cycle is not targeted and so constitutes an important test of the model. The model captures the way that time spent on primary childcare varies with a woman's age. In particular, primary childcare time is high when women have many children – up to their mid-30s – after which primary childcare time drops off. The model also does well in mimicking the life-cycle pattern of leisure and housework time. While not a tight fit, the model nonetheless captures the general life-cycle pattern on womens' market time.The model overstates womens' market time for women over the age of 65, likely due to omitting modeling retirement decisions in the model.

What is the role of childcare in this model? To answer this question, we look at the behavior of women in the model who never have children. In the model, the chief difference between these women and the averages reported across all women lies in the behavior of market time. The model predicts that women who never bear children have a profile for market time that is strictly declining with age, a pattern which simply does not match up with the hump-shaped profile observed in the ATUS data for all women. This observation shows that the role of childcare in the model is to cause a substitution of time out of market work into time activities to satisfy the childcare requirement – chiefly, primary childcare time. Childcare can also mute the effects of certain changes or policies. Secondary childcare, for example, can decrease the impact of an increase in wages.[1] The latter would decrease leisure and time spent doing secondary childcare, which needs to be substituted by costly daycare which in turn decreases the benefits of higher wages.

To investigate the driving forces in the model, we run several counterfactuals: lower relative wages for women, a higher price of durables, and higher fertility. To ground these counterfactuals in reality, we look back roughly 50 years to the 1960s. At that time, women earned about 60% of what men earned, compared to 80% in the early 2000s. Not surprisingly, our model predicts that lowering womens' wages leads them to allocate less time to the market, and more time to housework, primary childcare, and leisure. This result is in accord with Jones *et al.* (2015). As described below, in the 2000s, the relative price of durables is normalized to one; in the 1960s, this relative price is roughly 2.8. Greenwood *et al.* (2005) find that when durables are more expensive, households use fewer of them, substituting into housework time at the expense of market time. In contrast, our model finds virtually no effect of the price of durables on womens' market time – despite our use of an elasticity of substitution between durables and housework time that makes this substitution relatively easy. Finally, higher fertility, as in the 1960s, increases childcare requirements. However, this change has little effect on market time, housework time or leisure. Instead, the chief effect of increased fertility is to increase both primary childcare time and the use of daycare. Evidently, women find it efficacious to maintain the amount of time allocated to market activity and purchase market daycare inputs.

In the public policy sphere, there has been some concern over the lower allocation of time to the market by younger women relative to men. One way to potentially boost the market time of younger women is to subsidize daycare. This public policy issue is addressed in the model by lowering the price of daycare. In response to a 25% decline in the price of daycare, the model predicts more than a three-fold increase in the use of daycare. This experiment also raises the time spent by young women on market activity. One potential downside to this policy: the model predicts sharply lower primary childcare time. This last prediction is troubling in light of the documented importance of primary childcare time in child development. The recent empirical literature shows ambiguous effects of the expansion of subsidized child care. Baker, Gruber and Milligan (2008), for example, find that the expansion of universal subsidized child care in Québec increased aggressiveness and decreased

[1] 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.

social and motor skills of children.

The remainder of the paper is organized as follows. The related literature is discussed in Section 2. In Section 3 we examine data from the American Time Use Survey; in Section 4, we describe the model; in Section 5 we discuss the calibration of the model. Solving the model is difficult owing to the number of potentially non-binding constraints; see Section 6. In Section 7 we examine the results of the simulations. Section 8 concludes.

2 Related Literature

As previously mentioned, we are not the first to look at the time allocations of women. Broadly speaking, there have been two approaches. The first looks 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.* (2015) use a home production model more similar to ours. Since 1950, they find that most of the increase 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 do not find large effects associated with the declining price of durables.

The second approach combines rising wages of women with childcare (thus ignoring the durable goods revolution) and analyzes the latter part of the 20th century; see, for example, Attanasio *et al.* (2008). They too use a life-cycle model with exogenous fertility to examine the role of childcare on market work. An important difference relative to our work is that they consider the pecuniary cost of childcare while we look at the time dimension. Attanasio *et al.* find that a combination of higher wages and lower daycare costs can explain the changes in womens' market time since 1950. In our model, the increase in wages accounts for the rise in womens' market time while lower daycare costs as in Attanasio *et al.* (2008) produce an implausibly large decline in primary childcare; see Section 7.1. 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 (see Section 3). If, instead, maternal childcare is understood to include secondary childcare time, then our model provides a means to square Olivetti's results with the data. Prior to the 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.

Fernández (2013) and Fogli and Veldkamp (2011) provide alternative explanations for the changes in womens' allocation of time. Fernández finds that societal changes in the attitudes towards women have quantitatively important effects on womens' decisions to work. In Fogli and Veldkamp a woman's decision to work or not is affected by whether women nearby were working or not when she was a child. They find results consistent with observed geographic patterns.

Like us, Knowles (2013) examines the intra-household allocation of market time using the ATUS to assess the ability of the model to reproduce time spent on market work, leisure and home production. The home good is produced using time-inputs of the married couple. He finds that the increase in the relative wage of women over the second part of the century can explain all of the increase in married women's hours over the period but not the decline in marriage rates over the same period.[2] Knowles does not model childcare. Similar results are found by Fernández and Wong (2014) who develop a quantitative life-cycle model to examine the role of divorce and increased wages on married womens' labor force participation. They include childcare costs in the household budget constraint.

Gelber and Mitchell (2012), examine the impact of income tax policies on the labor supply of single women and of men. They look at not only the impact of tax policies on market work, but also on non-market activities. They find that a reduction in income taxes has a large impact on market work for single women, significantly reduces their time spent doing housework, and has no change in time spent with children. Guner, Kaygusuz and Ventura (2012) examine the effects of tax changes on married couples with children. They find a larger effect for couples with children than for couples without children. In their model, childcare is a market good; they do not consider the time implications of childcare. Recently, Bick (2012) develops a life-cycle model that distinguishes between paid and unpaid childcare. He finds that a lack of subsidized child care can decrease participation and fertility.

Domeij and Klein (2013) find that subsidies to daycares financed by distortionary taxation increase welfare by encouraging women with children to work. They assume that when a woman works an hour in the market, she must purchase an hour of daycare. In other words, in their model, daycare is perfectly substitutable for primary childcare time. Our estimated childcare production function point to less than perfect substitutability between primary childcare time and secondary inputs, including daycare.

[2]Like us, Knowles finds that the decline in the price of labor-saving technologies plays a minor role on time allocations.

3 Historical Facts: Female Labor Force, Housework and Childcare

This section uses data from 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.

Figure 1(a) 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 Time Use Survey (TUS) and the American Time Use Survey (ATUS) where we use an average of the years 2003–2015. Figure 1(a) suggests that on average, married women in their prime childbearing years allocated less time to market work in 1965 than in the early 2000s. In 1965, married women aged 24-29 spent 89.97 minutes a day in market work versus 163.08 minutes spent by married women aged 42-47. In the 2000s, these figures were 200.53 and 220.10 minutes (the figures for the 2000s are reported in Table 1).

Figure 1(b) shows changes in primary childcare over the life-cycle and across the two time-use surveys. The micro data do not reveal large changes in the amount of time spent on primary childcare between 1965 and the 2000s. However, women 36-42 years old devote almost 30 more minutes in primary childcare in the 2000s than in 1965, and overall for women 18-47 years old, primary childcare increases from 375 minutes a day to 440 minutes a day.

Figure 1(c) shows marked declines in housework between 1965 and the 2000s. For women aged 24-29, housework fell from 283.63 minutes a day in 1965 to 132.38 minutes in the 2000s. The decline was similar for other age groups. On average, married women were spending 276.79 minutes a day in housework in 1965 versus 161.74 in the 2000s. While housework declined sharply after 1965, in principle, the supervision of a child required the same number of hours.[3] 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 the information we have from the earlier time use surveys cannot be compared to the information collected in the more recent ATUS.

The ATUS also collects 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.[4] In addition, if the respondent reports providing

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

[4] 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.

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

Age	Observations	Personal Care	Leisure	Market Work	Housework	Housework (broad)
18-23	681	598.94	257.42	150.54	127.22	151.19
24-29	3522	577.46	220.99	200.53	132.38	154.52
30-35	6615	558.96	204.51	199.16	144.40	168.78
36-41	7286	551.48	205.86	210.58	159.02	184.36
42-47	6494	553.63	226.51	220.10	166.29	193.11
48-53	5130	551.85	244.46	241.57	158.94	184.24
54-59	4201	555.80	262.18	212.77	164.42	190.06
60-65	3323	561.85	313.05	130.54	175.84	201.44
66-71	2320	577.56	357.73	54.26	190.12	214.18
72-78	1683	582.33	386.26	15.32	205.10	229.88
18-78	41255	561.01	252.97	185.06	161.74	186.80
Age	**Observations**	**Primary Childcare**	**Secondary Childcare (total)**	**Secondary Childcare (with housework)**	**Secondary Childcare (with broad housework)**	**Secondary Childcare (with leisure)**
18-23	681	84.98	304.58	77.85	89.66	122.56
24-29	3522	98.63	290.82	80.17	91.22	98.69
30-35	6615	116.41	331.77	96.38	109.43	101.39
36-41	7286	91.90	298.81	87.77	98.13	91.91
42-47	6494	48.46	171.47	49.07	54.61	55.88
48-53	5130	16.03	53.11	16.00	17.61	17.05
54-59	4201	5.19	17.11	5.35	5.97	5.24
60-65	3323	3.21	9.20	2.55	2.71	3.46
66-71	2320	1.29	5.33	1.28	1.40	2.49
72-78	1683	0.45	2.42	0.49	0.54	1.19
18-78	41255	48.74	152.64	43.83	49.32	49.04

both primary and secondary childcare, the time is attributed to primary care only. In the earlier time use surveys, when respondents reported that they were engaged in secondary childcare, they were then asked "what else were you doing?" As a result, respondants may have under-reported passive supervision of children making it difficult to directly compare secondary childcare time from the earlier time use surveys with the more recent ATUS. The ATUS reports much higher estimates of secondary childcare than previous time use surveys, suggesting that the question asked across the various time use surveys captured different notions of secondary childcare, with less passive child supervision captured in the earlier surveys.[5] For these reasons our figures report secondary childcare only for the ATUS while primary childcare is reported for both the ATUS and the 1965 TUS. For both primary and secondary childcare,[6] we use only information about the respondent's own child/children and/or their spouse's child/children.

Table 1 reports for the 2000s how many minutes per day married women spent on personal care, leisure, market work, housework, primary and secondary childcare.[7] It shows shows that married women spend three times more time on secondary childcare than doing primary childcare.

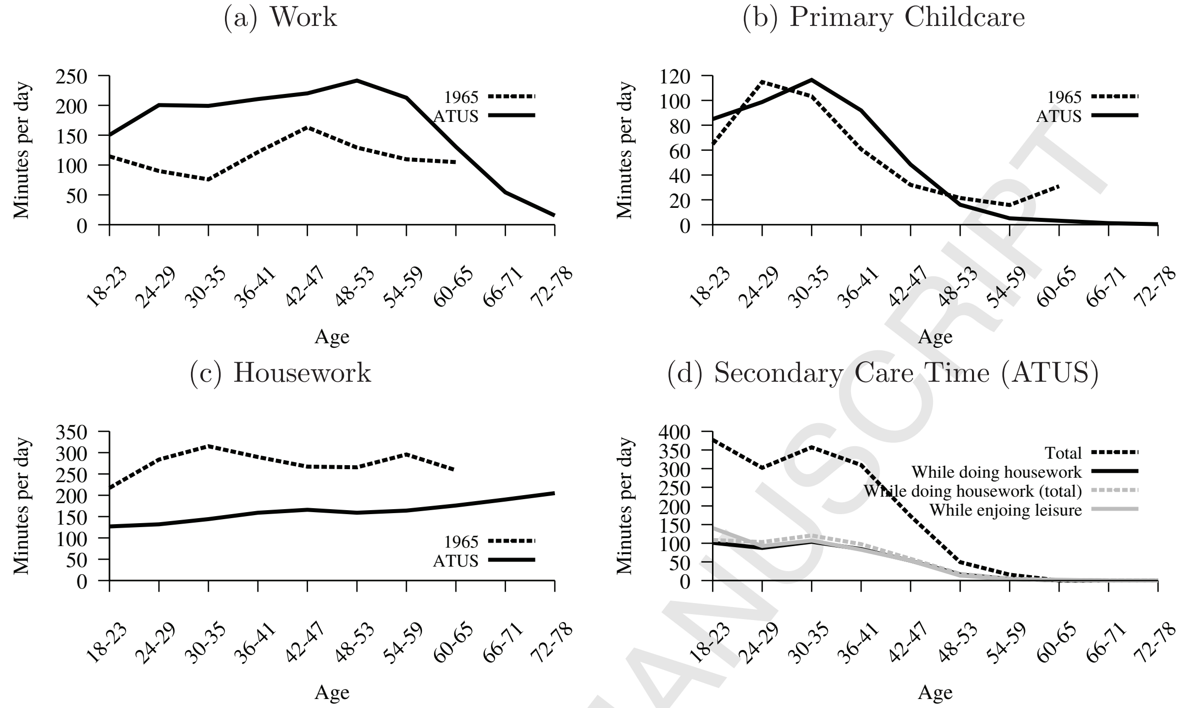
Figure 1(c) plots the total time married women spent on household chores while Figure 1(d) disaggregates, for the 2000s, secondary childcare time into its chief components (secondary childcare time while doing housework, and while enjoying leisure). Two measures of housework are used: one includes standard activities (code 02), while "broad 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 impor-

[5] Allard, Bianchi, Stewart and Wright (2007) describe the different measures of secondary childcare used in the surveys. They 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.

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

[7] The ATUS codes for personal care are: tutier1code=01; for leisure: tutier1code==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 1: Married Females: Allocation of Time (Time Use Surveys)



Note: ATUS is an average of the years 2003-2015.

tance of the link between housework and childcare.

Figure 1(d) 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.

To recap, the evidence shows that there has been an increase in time allocated to primary childcare over the second half of the twentieth century. High quality data on secondary childcare time is only available since 2003 (ATUS); this data shows that roughly a third of secondary childcare time occurs when women are performing household tasks, and a third when they are enjoying leisure. Figure 1 reveal a marked increase in market work and a decrease in housework by married women since the 1960s. The implications of these uses of time on the life-cycle pattern of womens' time allocations are explored below.

4 Economic Environment

4.1 Households

The economy is populated by overlapping generations of households. As discussed in the Introduction, households differ with respect to their fertility patterns. There is no uncertainty with regards to fertility: a household knows how many children it will have, and when. The index j is used to distinguish between households of different fertility patterns; for a given fertility pattern, households are otherwise identical.

Households are 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 other studies of womens' time allocation (see Section 2), women earn a fraction of what men earn. A household of type j 'formed' at date t has preferences summarized by

$$\sum_{i=0}^{T-1} \beta^i U(c_{mj}^i, c_{hj}^i, \ell_j^i) \tag{1}$$

where T is the 'lifetime' of the household, c denotes consumption, ℓ leisure, i superscripts refer to the *age* of the household, m subscripts pertain to *market* variables, and h subscripts indicate *home work* activities. Thus, c_{mj}^i is market consumption of household type j at age 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_{hj}^i, are produced by combining durables, d^i, with time, n_h^i:

$$c_{hj}^i = H(d_j^i, n_{hj}^i) \tag{4}$$

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 production function and constraint:

$$G(n^i_{pj}, n^i_{hj}, \ell^i_j, s^i_j) \geq y^i_j \tag{6}$$

where y^i_j is the childcare that a household of type j must provide when it is aged i. As mentioned at the start of this section, household type, j, indexes different fertility patterns. As discussed below, different fertility patterns will imply different patterns of childcare requirements. The childcare production function exhibits a constant elasticity of substitution between *primary* childcare time (n_p), *secondary* inputs (the sum of secondary childcare time, n_s, and purchased daycare services, s, which are assumed to be perfect substitutes):

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

Secondary childcare is a fraction of leisure time, ℓ, and housework time, n_h:

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

Notice that while Eq. (8) specifies that secondary childcare time is a fixed fraction of leisure and housework time, there is a sense that this assumption is not overly restrictive. In particular, the childcare production function, Eq. (6), is written as a weak inequality. As a result, the household could choose a sufficiently high level of leisure and housework time that more childcare is produced than is strictly necessary given the number of children in the household. In fact, it is this sort of consideration that makes solving the model more challenging than it would be otherwise. Childcare is a constraint in that a household of type j, aged i *must* provide total childcare services of at least y^i_j; 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_{pj}, or a secondary input (a combination of secondary childcare time, n^i_{sj}, and daycare, s^i_j). Consequently, when there are children in the household, home work time, n^i_{hj}, produces two distinct goods: home consumption goods, c^i_{hj}, and childcare, y^i_j.

The household's budget constraint is

$$c^i_{mj} + qd^i_j + ps^i_j + a^{i+1}_j = \overline{n}w^i + \phi n^i_{mj} w^i + ra^i_j \tag{9}$$

where d^i_j represents purchases of durables by a household of type j at age i, a^i_j denotes this household's beginning-of-period market assets, $\overline{n}$ is the (fixed) amount of time that the husband works, w^i is the real wage (assumed to be age-dependent), ϕ is the efficiency of the wife relative to the husband, r is the gross return on capital, q is the price of durables and

p is the price of daycare. It is assumed that the price of daycare is a fraction ρ of the wife's wage: $p = \rho\phi w$.

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

$$n^i_{mj} + n^i_{hj} + n^i_{pj} + \ell^i_j = \tilde{T} \tag{10}$$

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:

$$0 \leq n^i_{mj} \leq \overline{n}, \quad n^i_{hj} \geq 0, \quad n^i_{pj} \geq 0, \quad \ell^i_j \geq 0, \quad s^i_j \geq 0. \tag{11}$$

The household faces the following boundary conditions:

$$a^0_t = 0, \quad a^{T+1}_t \geq 0 \tag{12}$$

That is, the household starts with no real assets, and it ends with non-negative holdings of real assets.

The problem of the household is to maximize Eq. (1) subject to Eqs. (4), (6) and (9)–(12), taking as given prices.

4.2 Firms

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

$$\max_{\{K,N\}} K^\alpha N^{1-\alpha} - \tilde{r}K - wN$$

where K is capital, N the labor input, $\tilde{r}$ the real rental rate of capital, and w the real wage. The relationship between $\tilde{r}$, above, and r in the household's problem is:

$$r = \tilde{r} + 1 - \delta.$$

4.3 Market Clearing Conditions

Capital market clearing is given by

$$K = \sum_j \sum_{i=0}^{T-1} f_j a^i_j.$$

where f_j is the fraction of type j households. The right-hand side adds up, over fertility patterns and age, the market assets of all households.

Let e^i denote the 'efficiency' in market production of an individual of age i. Then, labor market clearing is

$$N = \sum_j f_j \left[\sum_{i=0}^{T-1} e^i \left(\overline{n} + \phi n_{mj}^i \right) \right].$$

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

Finally, goods market clearing is written

$$\sum_j f_j \left[\sum_{i=0}^{T-1} \left(c_{mj}^i + q d_j^i + p s_j^i \right) \right] + \delta K = K^\alpha N^{1-\alpha}$$

5 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. This choice is motivated by the observation that children tend to start school at age 6, and that their childcare requirement may change upon entering school. 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, the depreciation rate of market capital. The depreciation rate is consistent with results reported in Gomme and Rupert (2007). The price of durables, q is normalized to 1. Time spent working by men, $\overline{n}$, is 320 minutes per day (based on 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. The market efficiency profiles, $\{e^i\}$, are taken from Gomme *et al.* (2005).

Perhaps the most problematic parameters are those characterizing the childcare production function. To understand how these parameters are set, consider the problem when there is only one level of childcare, regardless of the number or ages of the children. Assuming that the constraint Eq. (6) holds with equality and focusing on women who use no daycare services, the estimating equation is

$$y = \left[\nu n_{p\hat{\imath}}^{\varphi} + (1-\nu) n_{s\hat{\imath}}^{\varphi} \right]^{1/\varphi} + \epsilon_{\hat{\imath}}$$

where $\hat{\imath}$ indexes households and $\epsilon_{\hat{\imath}}$ is an error term. Since the level of childcare is, by assumption, constant, this amounts to fitting the parameters of the childcare production

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	Depreciation rate of market capital (annual)	0.07
Utility		
ω	Weight on leisure in utility function	0.3010
β	Discount factor (annual)	0.9756
Consumption aggregator		
ψ	Weight on market consumption	0.6138
ξ	CES parameter	0.429
Home production		
η	Weight on durables	0.5522
ζ	CES parameter	0.35
q	Price of durables	1
Childcare		
ν	Weight on primary childcare time	0.5492
φ	CES parameter	0.6041
θ_ℓ		0.6
θ_h		0.8
ρ	cost of childcare as a fraction of wages	0.635

function to a given isoquant (the same level of childcare, but different combinations of primary and secondary childcare) which allows us to determine y, the level of childcare. To turn the equation into a more conventional formulation, rewrite it as

$$0_N = y - \left[\nu n_{p\hat{\imath}}^{\varphi} + (1-\nu) n_{s\hat{\imath}}^{\varphi}\right]^{1/\varphi} + \epsilon_{\hat{\imath}}.$$

where N is the number of observations.[8]

Of course, it is likely that childcare requirements will differ depending on the number of children of different ages. Let $\hat{\jmath}$ be a counter for the number of children less than 6 years of age (with a top code of 2 children), and $\hat{\jmath}'$ be a counter for the number of children aged 6-11. Under the assumption that the share and curvature parameters are the same across households, the task is to estimate a collection of $y_{\hat{\jmath}\hat{\jmath}'}$s along with ν and φ via

$$0_N = \sum_{\hat{\jmath}=0,1,2} \sum_{\hat{\jmath}'=0,1,2} I_{\hat{\jmath}\hat{\jmath}'} \left\{ y_{\hat{\jmath}\hat{\jmath}'} - \left[\nu n_{p\hat{\imath}}^{\varphi} + (1-\nu) n_{s\hat{\imath}}^{\varphi}\right]^{1/\varphi} \right\} + \epsilon_{\hat{\imath}}$$

where $I_{\hat{\jmath}\hat{\jmath}'}$ is an indicator function equal to 1 when a household has $\hat{\jmath}$ children under the age of 6 and $\hat{\jmath}'$ children aged 6-11. Implicitly, households with no children under the age of 12 are discarded. Now, the task is to estimate a family of isoquants where the level of childcare required varies by the age and number of children. In fact, our identifying assumption for the $y_{\hat{\jmath}\hat{\jmath}'}$s is that all households with $\hat{\jmath}$ children under the age of 6 and $\hat{\jmath}'$ children aged 6-11 must provide the *same* level of childcare.

Recall that in developing this estimating equation, it was assumed that the household purchases no daycare. This is because the ATUS does not report the use of daycare. Consequently, for the purposes of estimation, the sample is further restricted to women who do not work and so are unlikely to actually use daycare.[9]

The parameters are estimated in R via maximum likelihood; the resulting 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.[10]

Feeding these estimates into the model is, at this point, fairly straightforward. Since the

[8] We are grateful to Angelo Melino for pointing out this estimation strategy.

[9] In principle, we should be using primary and secondary childcare 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.

[10] We have, in addition, allowed the parameters ν and φ to differ with the number and age of children. The resulting set of parameter estimates are quite close to those estimated restricting these parameters to be the same across households.

Table 3: Childcare Production Function Estimates

Parameter	Estimate	Standard Error
y_{01}	176.72578	2.36865
y_{02}	196.20960	2.55648
y_{10}	245.12563	1.87904
y_{11}	239.67693	2.34848
y_{12}	249.89332	3.39079
y_{20}	268.38311	2.28837
y_{21}	273.40611	3.90951
y_{22}	274.47051	6.14538
ν	0.54919	0.00464
φ	0.60410	0.01824

number of children of a particular age is either 0, 1 or 2+, and since women can bear children only in the first four periods of their life-cycle, it follows that there are 81 ($= 3^4$) fertility patterns. As discussed earlier, it is assumed that a household knows upon its formation how many children it will have, and at what age. The childcare requirement in the model, y_j^i, simply needs to be looked up in Table 3.

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 do they vary with the age or number of children. The fractions are taken to roughly match observations from the ATUS data and are as reported in Table 2. The *weighted average* childcare requirement is reported in Figure 2(f). The average requirement initially rises, reflecting both the greater fertility of women 24-29 relative to those 18-23, and the fact that women 18-23 have no older children. The childcare requirement after age 35 falls quickly due to the lower birth rates among older women.

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 is set to -0.75 which implies that $\xi = 0.429$ – the same value estimated by McGrattan *et al.* (1997) and used by Jones *et al.* (2015). This elasticity implies that market and home goods are less substitutable than implied by a Cobb-Douglas aggregator.

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; ρ, the cost of daycare as a fraction of a woman's wage; 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 ATUS, married women aged 18-65 worked, on average, 195.7 minutes per day.

2. From the ATUS, on average, married women aged 18-78 performed 161.7 minutes of housework.

3. From the ATUS, married women aged 18-47 report spending an average of 88.1 minutes on primary childcare.

4. The durables share of output is 10%.

5. An annual real interest rate of 4%.

5.1 Population Shares

In the model, there are 81 household types that differ by completed fertility pattern (the number of children born in each household age group). What weights should be attached to these types? Vital statistics data provides information on the age of a woman and birth order (that is, for a woman of a particular age, the fraction having their first, second, etc. child). This data is insufficient to construct the required completed fertility patterns.

Census data is more promising since it reports the number of children in each household. Completed fertility can be inferred by looking at women aged, say, 42 and counting up the number of children aged 0-5, 6-11, 12-17 and 18-23. However, older children may have moved out of the household, leading to under-counting of children aged 18-23 (and so the number of children born to the woman when she was 18-23). Fortunately, the 1990 (and earlier) Census also reports the total number of children borne by a woman, and this information can be used to better infer the number of older children.

We used the Census data to obtain general fertility patterns. Consider a woman aged 18-23 who has one child (under 6); we need to know the likelihood of various combinations of subsequent child births. It is more likely that her next child is born when she is in the 24-29 age group than the 36-41 group. This is the information obtained from the Census data. For such a woman (who has one child when she is 18-23), there are 27 such combinations; thus, there are 81 combinations when one considers that an 18-23 year old can have 0, 1 or 2+ children.

So that the shares of women with young children are consistent with the ATUS data, the shares obtained from Census are adjusted to match the observed shares in the ATUS. Consequently, there is no single set of weights that is used to construct the model's counterparts to the ATUS time allocations. This procedure takes as given the ATUS data (including the demographic weights) and adjust the model's output so that the demographics of the model better match the fertility patterns observed in the ATUS data.

6 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 be slack, 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.[11] In a sense, including these Euler equations amounts to blending a straight maximization of lifetime utility with solving Euler 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.

7 Results of the Simulations

In this section we examine how well the model performs with regards to the life-cycle profiles for the allocation of time as reported in the ATUS.

7.1 Life-cycle Patterns

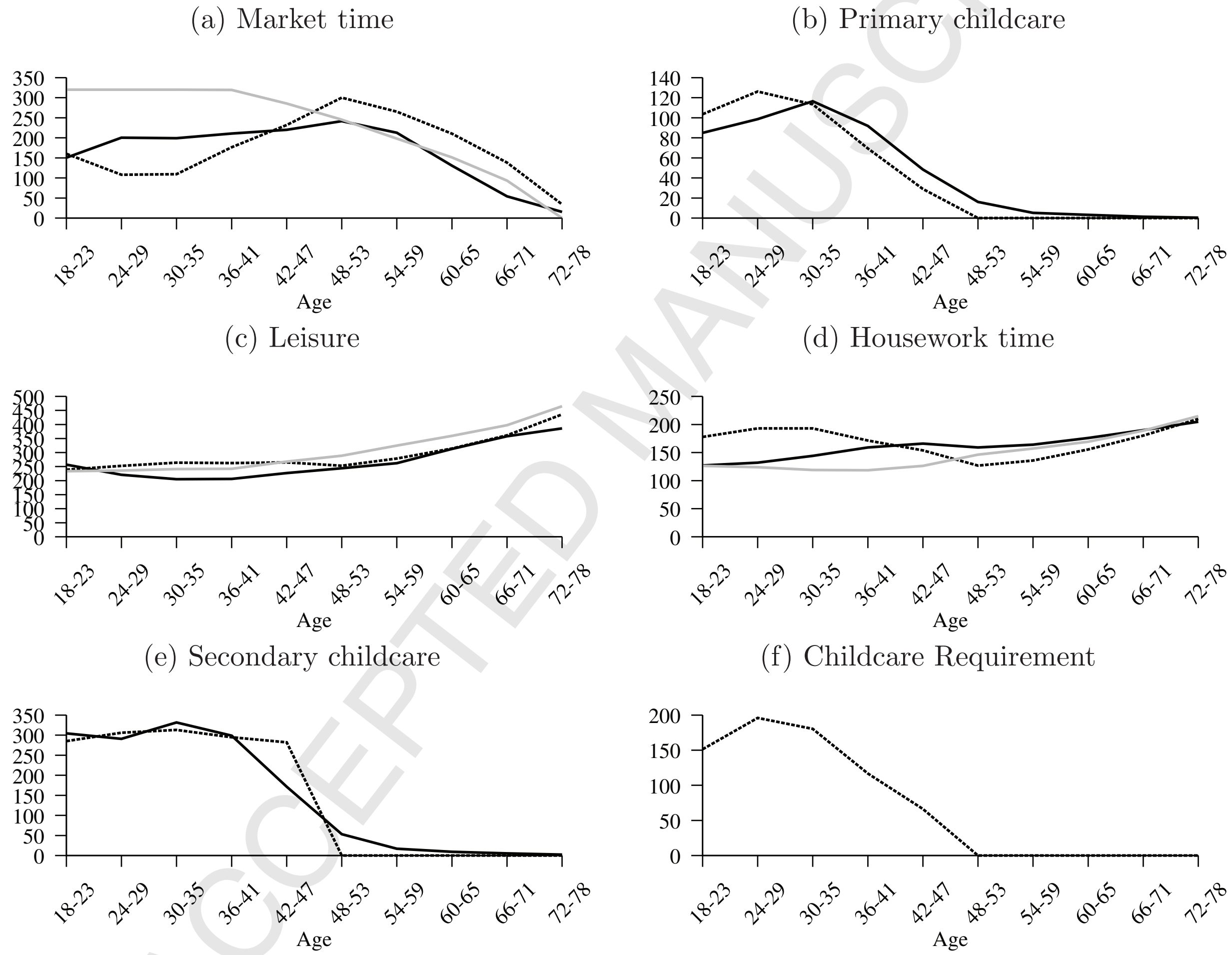
Time allocations for the model and ATUS are reported in Figure 2. Recall that by construction, the model matches *average* market, housework and primary childcare time – but not necessarily the life-cycle patterns. That said, the childcare requirement reported in Figure 2(f) certainly influences the life-cycle pattern of primary childcare time, although model households are free to choose the mix of primary versus secondary childcare time (or daycare) used to satisfy this childcare requirement. The model captures the general pattern of market time over the life-cycle. Specifically, the data displays a hump-shaped pattern, peaking around age 50. The model predicts a similar, albeit exaggerated, pattern. The model's under-prediction for market time of women aged 24-35 may be due to overstating the cost of daycare for which there is simply very little information available. For example, Cardia and Ng (2003), using the 1992 release of the Health and Retirement Survey, find that 42.5% of households with at least one child and grandchild spent more than 100 hours per year caring

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

for grandchildren. Presumably, these women receive this family help with childcare at low or zero cost.

In the data, women 18-23 spend more time on education than other age groups. Including education in the model would likely lead to a clearer hump-shaped pattern for market time. Attanasio *et al.* (2008) exclude this age group in their analysis, perhaps reflecting its problematic nature. The model over-predicts market time for women over the age of 65; incorporating retirement would, no doubt, help the model on this dimension.

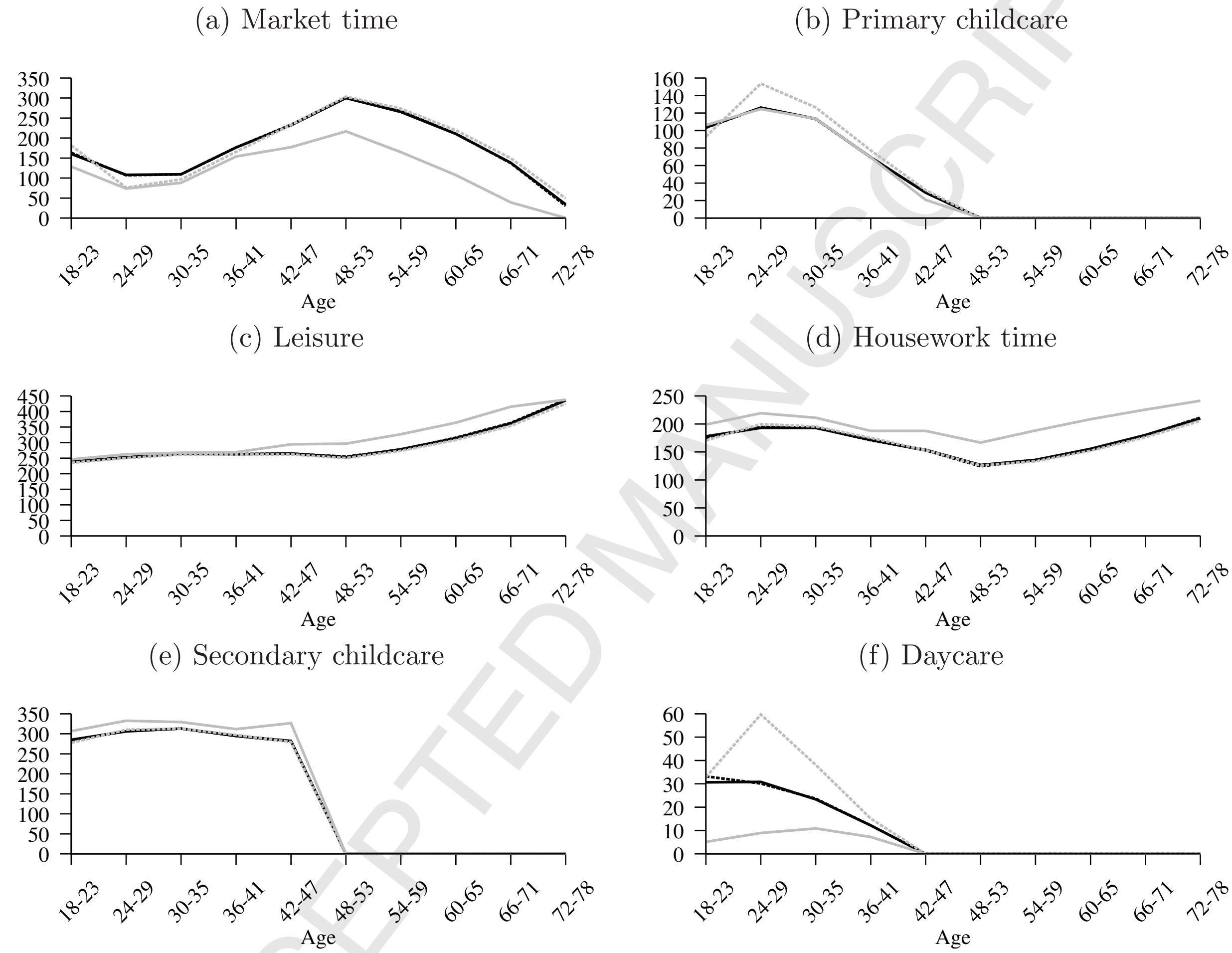
Figure 2: Model versus ATUS (2003-2015)



Note: Solid black lines: ATUS data; dotted black lines: benchmark model; solid gray lines: women with no children.

To assess the role of childcare in the model, Figure 2 also reports life-cycle profiles for the group of women in the model who never have children. Whereas the ATUS exhibits a hump-shaped pattern for market time, the model predicts that women who never have children have a life-cycle pattern that declines monotonically with age. This result shows that the role of childcare in our model is to reduce time allocated to market work for younger women – those who bear children. As these women bear children, they must allocate time to their care. Looking across the time allocations, one can see that childcare works primarily by shifting time from market work to primary childcare time. Leisure and housework time are little affected by fertility, despite their importance in providing secondary childcare time.

Figure 3: Model Counter-Factuals



Note: Solid black lines: benchmark model; dotted black lines: 1965 price of durables; solid gray lines: 1965 relative wage; dotted gray lines: 1965 fertility.

To understand the driving forces in the model, Figure 3 presents results for a number of counter-factual experiments. To discipline the nature of these counter-factuals, look back roughly 50 years to conditions in the 1960s. Then, the relative price of durables was roughly 2.8 times higher than in the early 2000s; women earned about 60% of what men earned, compared to 80% today; and fertility was higher, reflecting the effects of the post-World War II baby boom.[12]

[12]While the benchmark model's calibration requires solving for general equilibrium, the counter-factual experiments are partial equilibrium.

A higher price of durables leads households to purchase fewer durables, as in Greenwood *et al.* (2005). Indeed, the durables share of output falls from 10% in the benchmark model to 2%. However, despite the fact that the elasticity of substitution in the home production function implies that durables are labor-saving devices, the fall in durables has no discernable effect on housework time. Consequently, there is virtually no change in the profiles for market time, primary childcare time or leisure.

Lowering the relative wage of women reduces their market time, in this case by 80 minutes per day (40%). Given lower market compensation, women substitute into housework and leisure. While there is very little change in primary childcare time, the increase in secondary childcare time leads to a collapse in the use of daycare; see Figure 3(f).

Finally, increasing fertility to its 1960s levels has little effect on leisure and housework. Instead, women respond by increasing primary childcare and their use of daycare. The largest effect is seen among those women aged 24-29 who accommodate the increase in fertility through a combination of working, on average, roughly 30 minutes less per day, and nearly doubling their use of daycare. These results suggest that women prefer to continue working, purchasing more daycare for their children.

Overall, these counterfactuals point to the complex interaction of economic forces within our model. Changes in housework time and leisure have knock-on effects operating through the fact that they are inputs to the production of childcare. In other words, one must look beyond the straightforward market-versus-home margins that are present in the works of Greenwood *et al.* (2005) or Jones *et al.* (2015). All three counterfactuals favor the home sector over the market sector, yet only one, the lower relative wage of women, leads to lower womens' market time.

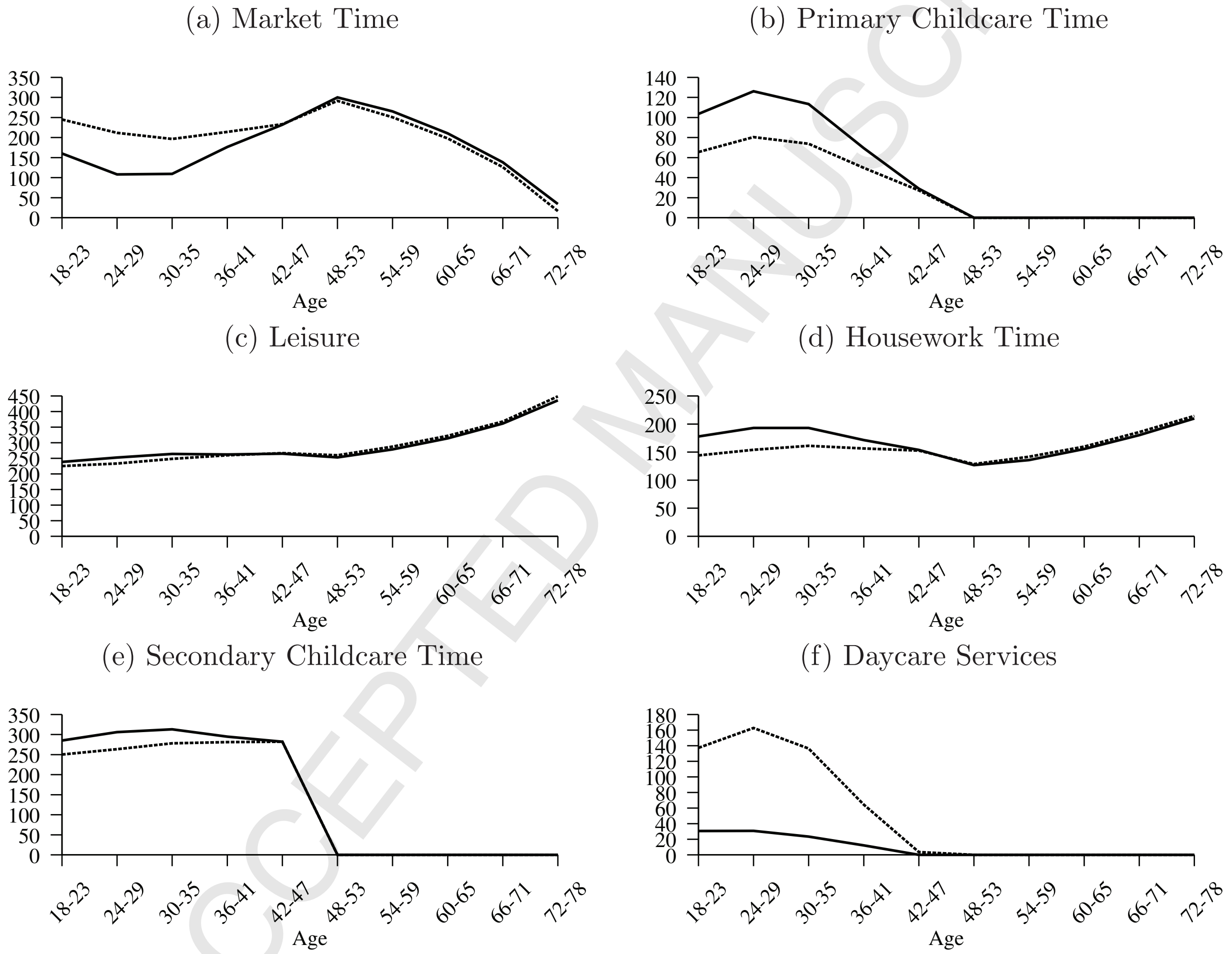
Overall, the model's predictions for the allocation of womens' time between market work, housework, leisure and children line up reasonably well with the ATUS.

Cheaper Daycare

What are the effects of cheaper daycare? This is an issue that has received some attention in public policy circles. Indeed, in 1997 the province of Québec in Canada implemented a policy of heavily subsidized daycare. Here, the experiment is to reduce the price of daycare by 25% – a substantial decline in its price, but far short of that enacted in Québec.

This policy leads to more than a three-fold increase in the use of daycare. While there is a relatively small decrease in secondary childcare time (meaning leisure and housework time), the chief effects on the allocation of time are a reallocation from primary childcare (a reduction of 29 minutes, or 33%, for women aged 18-47) to working in the market (36 minutes, or 18%).

Figure 4: Cheaper Daycare



Note: Solid black lines: benchmark model; dotted black lines: 25% lower daycare price.

The results of this cheaper daycare experiment cast some doubt on Attanasio *et al.*'s (2008) explanation for the observed increase in womens' market time. Specifically, they attribute the increase between the 1970s and 1990s to a combination of an increase in the relative wage of women and lower price of daycare; the increase in relative wages alone is insufficient. Yet, given our model's predictions for the response of primary childcare time to the price of daycare – a dimension overlooked by Attanasio *et al.* – along with the very small observed changes in womens' primary childcare time reported in Figure 1(b) suggests that Attanasio *et al.*'s cheaper daycare explanation for the increase in womens' market time comes at the cost of a counter-factual decline in their primary childcare time.

8 Conclusions

This paper constructed a life-cycle model of the allocation of womens' time that includes the time cost of childcare. While the calibration matched the average allocation of time to the market, housework and primary childcare, households within the model were free to determine the life-cycle patterns of their time allocations. The paper made a number of contributions. First was the estimation of the parameters of the childcare production function, including: the weight on primary versus secondary childcare; the share parameter on these inputs; and the actual childcare requirements by age and number of children.

Second, incorporating the time dimension of childcare was shown to improve the model's predictions for the life-cycle allocation of time. In particular, in the data, the age profile of womens' market time is hump-shaped; the benchmark model predicts a similar pattern. In contrast, women in the model who never have children exhibit a profile for market time that is monotonically declining with age.

Third, we showed that the increase in the relative wage of women between the 1960s and early 2000s has important effects of womens' market time, but not their primary childcare time. The prediction for market time supports similar results in Attanasio *et al.* (2008) and Jones *et al.* (2015). However, Attanasio *et al.* also find a large role for decreased daycare costs. Our price of daycare experiments cast doubt on this latter finding since it predicts a substantial decline in primary childcare time – a decline that is not observed in U.S. time use surveys.

Fourth, the model predicted that changes in fertility show up chiefly through time spent on primary childcare and purchased daycare services.

Finally, the decline in the relative price of durables between the 1960s and early 2000s was predicted to have virtually no impact on market and housework time, a result that stands in contrast to those in Greenwood *et al.* (2005).

The model's predictions for the impact of cheaper daycare show that models like this one can be used to analyze the effects of public policy interventions. An interesting extension of the model would incorporate the role of primary childcare time in early childhood development, and the analysis of the impacts of changes in public policy on childrens' well-being.

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References

Aguiar, Mark and Erik Hurst (2007). "Measuring Trends in Leisure: The Allocation of Time over Five Decades," *Quarterly Journal of Economics*, 122 (3): 969–1006.

Allard, Mary Dorinda, Suzanne Bianchi, Jay Stewart and Vanessa R. Wright (2007). "Comparing Childcare Measures in the ATUS and Earlier Time-diary Studies," *Monthly Labor Review*: 27–36.

Attanasio, Orazio, Hamish Low and Virginia Sánchez-Marcos (2008). "Explaining Changes in Female Labor Supply in a Life-Cycle Model," *American Economic Review*, 98 (4): 1517–52.

Baker, Michael, Jonathan Gruber and Kevin Milligan (2008). "Universal Child Care, Maternal Labor Supply, and Family Well-Being," *Journal of Political Economy*, 116 (4): 709–745, URL `https://ideas.repec.org/a/ucp/jpolec/v116y2008i4p709-745.html`.

Becker, Gary S. (1965). "A Theory of the Allocation of Time," *Economic Journal*, 75: 493–517.

Benhabib, Jess, Richard Rogerson and Randall Wright (1991). "Homework in Macroeconomics: Household Production and Aggregate Fluctuations," *The Journal of Political Economy*, 99 (6): 1166–1187.

Bick, Alexander (2012). "The Quantitative Role of Child Care for Female Labor Force Participation and Fertility," No. 31713, MPRA Paper.

Cardia, Emanuela and Serena Ng (2003). "Intergenerational Time Transfers and Childcare," *Review of Economic Dynamics*, 6 (2): 431–454.

Dinkelman, Taryn (2011). "The Effects of Rural Electrification on Employment: New Evidence from South Africa," *American Economic Review*, 101 (7): 3078–3108.

Domeij, David and Paul Klein (2013). "Should Day Care be Subsidized?" *The Review of Economic Studies*, 80 (283): 568–595.

Fernández, Raquel (2013). "Cultural Change as Learning: The Evolution of Female Labor Force Participation over a Century," *The American Economic Review*, 103 (1): 472–500.

Fernández, Raquel and Joyce C. Wong (2014). "Divorce Risk, Wages, and Working Wives: a Quantitative Life-Cycle Analysis of Female Labor Force Participation," *The Economic Journal*, 124 (576): 319–358.

Fogli, Alessandra and Laura Veldkamp (2011). "Nature or Nurture? Learning and the Geography of Female Labor Force Participation," *Econometrica*, 79 (4): 1103–1138.

Gelber, Alexander M. and Joshua W. Mitchell (2012). "Taxes and Time Allocation: Evidence from Single Women and Men," *The Review of Economic Studies*, 79 (3): 863–897.

Gomme, Paul, Richard Rogerson, Peter Rupert and Randall Wright (2005). "Home Production in a Life-cycle Model," in Mark Gertler and Kenneth Rogoff, eds., "NBER Macroeconomics Annual 2004," Cambridge, Mass. and London: MIT Press, pp. 415–461.

Gomme, Paul and Peter Rupert (2007). "Theory, Measurement, and Calibration of Macroeconomic Models," *Journal of Monetary Economics*, 54 (2): 460–497.

Greenwood, Jeremy and Zvi Hercowitz (1991). "The Allocation of Capital and Time over the Business Cycle," *The Journal of Political Economy*, 99 (6): 1188–1214.

Greenwood, Jeremy, Ananth Seshadri and Mehmet Yorukoglu (2005). "Engines of Liberation," *Review of Economic Studies*, 72 (1): 109–133.

Guner, Nezih, Remzi Kaygusuz and Gustavo Ventura (2012). "Taxation and Household Labour Supply," *The Review of Economic Studies*, 79 (3): 1113–1149.

Jones, Larry E., Ellen R. McGrattan and Rodolfo E. Manuelli (2015). "Why Are Married Women Working So Much?" *Journal of Demographic Economics*, 81 (1): 75–114.

Knowles, John A. (2013). "Why are Married Men Working So Much? An Aggregate Analysis of Intra-Household Bargaining and Labour Supply," *The Review of Economic Studies*, 80 (3): 1055–1085.

McGrattan, Ellen R., Richard Rogerson and Randall Wright (1997). "An Equilibrium Model of the Business Cycle with Household Production and Fiscal Policy," *International Economic Review*, 38 (2): 267–290.

Olivetti, Claudia (2006). "Changes in Women's Hours of Market Work: The Role of Returns to Experience," *Review of Economic Dynamics*, 9 (4): 557–587.

Rupert, Peter, Richard Rogerson and Randall Wright (1995). "Estimating Substitution Elasticities in Household Production Models," *Economic Theory*, 6 (1): 179–93.

Schittkowski, Klaus (1985/86). "NLPQL: A FORTRAN subroutine solving constrained nonlinear programming problems," *Annals of Operations Research*, 5: 485–500.