# Wages and Family Time Allocation*

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**Abstract**

This paper examines how married people's time allocation responds to wages and the gender wage gap. In the US, real wages have grown steadily for married men, but even more for married women, narrowing the gender wage gap by as much as 25% over the last three decades. At the same time, women's labor supply has increased and, while couples spend less time on household work, men's relative burden has increased. I develop a collective life-cycle model for individuals in a household (spouses) who differ in preferences and bargaining power but share a common budget constraint; the model features lack of commitment. Individuals decide collectively about market work, household work, and leisure. Individual wages and the gender wage gap affect the family budget as well as intra-family bargaining power. I estimate gender-specific preferences and the parameters of intra-family bargaining power using data on married and divorced individuals from the PSID. The results suggest that the narrowing gender wage gap improved women's bargaining power in the family resulting in a shift of household work from women to men. The effect of women's improved bargaining power on their market work was small. If the gender wage gap was eliminated altogether, female full-time market work would increase by up to 32% in the childbearing years; moreover total time into household work would decrease by as much as 21% with the time allocation between spouses becoming relatively more equal.

**Keywords**: Life-cycle collective model, lack of commitment, wages, gender wage gap, equal pay
**JEL classification**: D12, D13, J22

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# 1 Introduction

How do wages that married people earn affect their use of time? What does the narrowing gender wage gap imply for the bargaining power spouses have in their households? And how does their bargaining power affect their time use? How would gender wage equality impact married people's time use? To address these questions, I develop a rich collective life-cycle model of family time allocation, consumption, and savings. Decision makers in the household (the spouses) choose jointly how to allocate their time across market work, work in the household (home production), and leisure in the presence of uncertainty in their wages and fertility.[1,2] The model features lack of commitment to lifetime marriage meaning that the spouses do not commit to staying together for life. Specifically, changes in wages or fertility can induce shifts in the bargaining power that one or another spouse has in the family decision process. Such shifts reflect better or worse options that a spouse may have outside the household (for example in case of divorce) as a result of the changing wages or fertility. I estimate the model using data from the PSID. I exploit cross-sectional variation in wages and fertility as well as the sharp decline in the gender wage gap (favoring women) that occurred after 1980. Focusing on one cohort, I find that the narrowing gender wage gap improved women's intra-family bargaining power over time. Such change in intra-family bargaining power is not consistent with full commitment between spouses. The effects of this improvement revolve mainly around spousal time into home production reducing women's household work and increasing men's. In a series of counterfactual experiments, I allow the wage gap between men and women to disappear; then the rate of female full-time market work increases strongly by up to 32% even during the childbearing years and women enter the labor market when they previously did not participate. Moreover, the allocation of time into home production becomes more equal between spouses but the total household time input decreases by as much as 21%.

Since 1980 the gender wage gap in the US, as measured by the ratio of male to female hourly wages, has fallen sharply by as much as 25%.[3] This decline has occurred systematically over most of the last three and a half decades even if one accounts for cohort effects, spousal education, fertility and other factors. It is the result of growth in male and female real wages, with the latter outperforming the former. At the same time, the proportion of women working full-time in the market has increased from approximately 45% in 1980 to nearly 70% thirty years after. This increase conceals a switch away from part-time work and a parallel overall increase in labor market participation. On the other hand, men's hours of work and labor market participation did not change. Women nearly halved the time they devote to activities related to home production (from an average of 29 weekly hours in 1980 down to 17 in 2009) whereas men's similar time has remained relatively flat. Given these observations, this paper aims to investigate how wages and the gender wage gap affect married people's use of time. The paper takes a life-cycle approach relating wages to use of time over the life-cycle.

[1] I use the terms 'household' and 'family' interchangeably throughout this paper. The same applies to the terms 'decision makers', 'spouses', 'partners', or 'individuals'.

[2] The importance of distinguishing between leisure and non-market work is stressed in Becker (1965).

[3] This and the following numerical figures in this introduction are based on data from the PSID described at length in section 2.

Wages are likely to affect married people's behavior through a number of channels. First, a higher hourly wage may render work in the labor market more attractive, along both the extensive (participation) and the intensive (hours) margins. Second, keeping labor supply fixed, a higher wage implies higher income and, in turn, higher expenditure and/or savings. If purchased goods (expenditures) are the material inputs to home production, higher expenditures may reduce or increase the time inputs to home production depending on the nature of complementarities between material and time inputs. Third, changes in relative wages within a family may alter the task specialization spouses engage in; for example, a spouse with a relatively higher wage may engage fully in the labor market whereas the other in home production. Fourth, changes in relative wages may make a spouse's outside option, often divorce, more or less attractive. To deter a person from leaving the family, their partner may consent to increase that person's weight (bargaining power) in the family decision process which, in turn, is likely to affect a number of time use and other household outcomes. These channels are all interrelated reinforcing or mitigating each other making it harder to analyze the relationship between wages and married people's use of time.[4]

The model allows for all the aforementioned channels. Two spouses are characterized by their own, possibly different, preferences over private leisure (in the spirit of Chiappori, 1988, 1992) and a public consumption good (in the spirit of Blundell et al., 2005).[5] The public good is produced inside the household with inputs raw materials purchased in the market (public expenditures) and time devoted to home production by each individual. The spouses are separately endowed with a fixed amount of time which they allocate jointly across work in the labor market, work in the household, and leisure. An hour of work in the labor market is compensated by a gender-specific stochastic wage which individuals take as exogenously given; earnings are used to purchase raw materials in the market or save for the future.

The partners choose public expenditures/savings and their use of time to maximize the (expected, discounted, and inter-temporally separable) weighted sum of their respective utility functions over their lifetime. The weights are given by the bargaining powers they hold in the household decision process; these are not constant across states of the world or over time due to lack of commitment in the spirit of Mazzocco (2007) and Lise and Yamada (2014). Lack of commitment restricts choices by a set of marriage participation constraints, one per partner and time period, which ensure spouses receive at least as much utility from inside their joint household as they can possibly get from their outside option that I take to be divorce. In this model the value of one's outside option depends on potential wages, reflecting the value of one's skills in the labor market, and on family composition regarding the presence or age of children. Wages and family composition are assumed exogenous and subject to uncertainty.

[4]Another potential effect of wages and the gender wage gap is on the selection of individuals into marriage and, in general, on marital patterns. This paper abstracts from this feature taking marriage as given. To some extent, Chiappori et al. (2015) address this question developing an equilibrium model of education, marriage, and labor supply. Expected returns in the labor market affect education and marital choices people make early on in their life-cycles; however, the paper shuts down many of the aforementioned channels through which wages (returns) affect choices, such as shifts in intra-family bargaining powers due to lack of commitment.

[5]The model treats the family as a *group* of individuals who act collectively under common constraints and, therefore, respects the fundamental principle of methodological individualism as in the early studies of Manser and Brown (1980) and McElroy and Horney (1981).

Using cross-sectional and inter-temporal variation in wages (and cross-sectional variation in fertility) I identify time-use preferences for married men and women as well as how intra-family bargaining powers change with the gender wage gap. A major difficulty arises because wages affect the budget set *and* bargaining powers simultaneously. I distinguish between the two channels because I fix the bargaining powers at the start of the life-cycle using reduced-form information on divorcees in the PSID. Specifically, I predict married spouses' lifetime earnings in a hypothetical scenario of divorce and I use the predictions to form an estimate of intra-family bargaining powers at the start of the life-cycle; these predictions serve as reduced-form approximations to the value of being divorced.

I estimate the model by the method of simulated moments using data from the PSID after 1980. Focusing on one cohort, the model fits the data well along all the dimensions of interest, namely life-cycle patterns of time use for married men and women. I find that, especially for families with young children, women's disutility from full-time market work is greater than the disutility from part-time work, which, in turn, is greater than work in the household. Consumption and leisure are complement goods for the majority of women; however for approximately 1/4 of them they are substitutes. Finally, men suffer greater disutility from work in the household than women do if the two supply the same amount of household hours.

The narrowing of the gender wage gap improves women's intra-family bargaining power over time; this result is not consistent with full commitment inside the household. The consequences of this improvement are mainly concentrated around spousal work in the household (but not labor supply). *Without* changes in bargaining power in response to a 10% narrower gender wage gap, women's household work would be higher by up to 6.48% whereas men's would be lower by up to 6.95% (bargaining effects of relative wages).

In addition, changing wages induce standard income and substitution effects. These are spread across labor supply and household work. Prohibiting the gender wage gap from closing down by 10% would lower the rate of female full-time work by up to 5.39% and more women would work part-time or stay out of the market. Moreover, women's household work would be higher by as much as 13.06% whereas that of men would be largely unaffected. A narrower gender wage gap induces women to work more in the market and less in the household. These numbers quantify exclusively the income and substitution effects leaving the bargaining effects aside.

Finally I assess a counterfactual scenario; through a series of experiments I eliminate the gender wage gap and I investigate the implications that equal pay between men and women has for their use of time. This is a realistic counterfactual that policy and business leaders around the world have pledged to implement. If women are given on average their husbands' wage, female labor market participation increases strongly throughout the life-cycle. The most striking effects occur in the childbearing years when the rate of female full-time market work increases to approximately 75% compared to 57% in the benchmark model (this change corresponds to an increase in the rate of full-time market work by approximately 32%). Only 1/8 of this increase comes from women switching from part- to full-time work; the rest comes from women entering the labor market when they previously did not participate.

Equal pay renders the allocation of spousal time into household work more equal between spouses but it also decreases the total time into home production by as much as 7 hours per week during the childbearing years (a decrease of 21% compared to the model benchmark). These counterfactual changes together have strong implications for family savings and expenditure, including expenditure on children. However, the timing of establishing equal pay in the life-cycle matters for the severity of the effects especially in the childbearing years. Perhaps not unexpectedly, the largest effects are seen when equal pay is established early on in the partners' lives.

**Relation to the literature** This paper builds on two strands of literature. On one side is the literature on models of household decision making with Chiappori (1988)'s and Apps and Rees (1988)'s collective concept being the most prominent representation. As I illustrate below, there has been a number of recent papers that extend the collective concept to the dynamics case.[6] On the other side is the literature that from a unitary standpoint studies the evolution of male or female labor supply over the life-cycle possibly alongside a number of other outcomes such as consumption or retirement.

The papers in the first strand of literature that this article is mostly related to are Lise and Yamada (2014) and Knowles (2013). Lise and Yamada (2014) use a general dynamic collective model of the household with which the model in my article shares common features. They study how intra-family bargaining power varies across as well as within households when wage shocks hit. They estimate the model at the steady state using the first-order conditions and a unique panel dataset from Japan with information on expenditure shares of each spouse. They find that relative wages affect intra-family allocations in the cross-section and wage shocks induce changes in those allocations during marriage. Unlike Lise and Yamada (2014), I allow an explicit role for wages and the gender wage gap over the entire life-cycle. I solve for the life-cycle behaviour of spouses (work inside the household, extensive- and intensive-margin labor supply) and, as such, my paper is directly comparable to papers in the aforementioned second strand of literature on unitary life-cycle labor supply.

Knowles (2013) asks how important bargaining is for labor supply in response to the narrowing gender wage gap. He develops a stylized two-period model in which intra-family bargaining power depends on a marriage market equilibrium. He abstracts from dynamic features such as savings, fertility etc. He finds small effects of bargaining on sex-specific labor supply without distinguishing between changes across cohorts versus within cohorts. My paper uses a richer household model with explicit roles for dynamics over the life-cycle, intensive and extensive labor supply, and a general bargaining not tied down to a specific equilibrium concept.

Fernández and Wong (2014) use a life-cycle collective model to study the increase in female labor supply in the second half of the 20$^{\text{th}}$ century. However, they disregard men's time use, abstract from home production, and impose full commitment between spouses. Voena (2015) explores how divorce and property division laws impact married people's intertemporal choices

[6] Early empirical implementations of the *static* collective model include Browning et al. (1994) and Fortin and Lacroix (1997).

using relevant reforms in the 1970s and 1980s. She specifies a life-cycle collective model for female market participation without home production; in her model changing wages do not affect spouses' outside options. Her findings support lack of intra-household commitment as in Mazzocco (2007), one of the first implementations of a dynamic collective model.[7]

There are several papers in the second strand of literature that this article relates to. French (2005) studies the labor supply and retirement behavior of men using a life-cycle model with wage and health uncertainty. He focuses particularly on the behavioral effects of social security benefits. Attanasio et al. (2008) study the increase in American women's labor force participation after the 1970s using a life-cycle model of labor supply, savings, and human capital. They focus primarily on the role played by changes in the gender wage gap and the care cost of children. Eckstein and Lifshitz (2011) also study women's employment and labor force participation rates, paying particular attention to the differential patterns that married and single have experienced. Blundell et al. (2013) study the implications that welfare programs have in the short (labor supply) and the long run (human capital accumulation) using a life-cycle model of female labor supply, education, human capital, and savings. Finally, in an earlier paper Francesconi (2002) estimates a dynamic model of female labor supply allowing for endogenous fertility decisions but not savings.[8]

The papers in this literature, with their various specifications and assumptions, have three features in common: they focus on male *or* female labor supply, they abstract from home production, and they ignore intra-family allocation issues. By contrast, my paper reserves an explicit role for all these features. However, I abstract from endogenous human capital (that several of those papers model explicitly) for reasons that are discussed in section 3.2.

In relation to the literature, my paper is the first one to (i) study female labor supply, on the intensive and extensive margins, using a collective life-cycle model with lack of commitment, home production, and household-level (public) spending; (ii) investigate the relation between the gender wage gap and intra-family bargaining power, (iii) assess the implications of equal pay between men and women through eliminating counterfactually the gender wage gap.

The paper is arranged as follows. Section 2 describes the data and the empirical facts that motivate this research. Section 3 develops the model of household decision making. Section 4 discusses technical aspects of the model and section 5 discusses identification and estimation. Section 6 presents the results. Section 7 discusses the implications of the model for behavior and section 8 describes the policy experiment. Section 9 concludes.

[7] Additionally, Gemici (2011) uses a dynamic collective model with Nash bargaining to study household migration decisions. Mazzocco et al. (2014) investigate the interconnectedness of labor supply, savings, and marital decisions using PSID data between 1984-1996 and a dynamic collective model. They abstract from changes in the gender wage gap during that period. A recent review of this literature, including static and dynamic collective models, is provided by Browning et al. (2014) and Chiappori and Mazzocco (2014). Finally, Chiappori and Meghir (2014) argue from a theoretical viewpoint why intra-household allocation of resources should not be ignored and Lise and Seitz (2011) provide solid empirical evidence.

[8] Important earlier papers in this strand of literature also include Eckstein and Wolpin (1989), who model women's labor force participation and fertility choices when current participation affects future earnings, and van der Klaauw (1996), who models women's labor force participation jointly with their marital choices.

# 2 An Empirical Overview

This section overviews the data used in this research, lays out the time-use facts this study aims to explain, and discusses the evolution of the gender wage gap over time. Section 2.1 presents the data and some baseline summary statistics, section 2.2 illustrates the time-use facts, and section 2.3 is devoted to the gender wage gap.

## 2.1 Data

This paper uses data from the Panel Study of Income Dynamics (PSID). This provides rich income and employment data for households and their members since 1968 as well as limited information on times devoted to home production.

The PSID[9] started in 1968 tracking a -then- nationally representative sample of households; repeated annually until 1997 the survey collected detailed information on incomes, market work, food consumption, and demographics of adult household members and their linear descendants should they split off and establish their own households. Over time the scope of the PSID widened allowing the collection of even richer information such as the amounts of time devoted to work in the household (from late 1970's onwards). After 1997 the survey becomes biennial but also includes information on a variety of household expenditures and wealth. I make no use of the expenditure or wealth information as this spans a relatively recent period of time only.

I select men and women aged 25 to 65 from the core sample ('Survey Research Center') between years 1980 and 2009. I impose the aforementioned age restriction because the model developed in this paper does not deal with early-life (education) or late-life (retirement) decisions. I split this into two distinct and non-overlapping samples: (i) a major sample of households of continuously married men and women throughout the years they are observed, and (ii) a minor sample of singles of both genders. I use the former for the main part of my analysis and I describe it in more detail below. I postpone a discussion of the latter sample until section 5.3.

In the major sample I follow households headed by a married opposite-sex couple.[10] The focus of the paper is a life-cycle model and I follow currently one cohort of households only. I define this cohort as those households whose male spouse is born between years 1943 and 1955. The average age of the male spouse is 30 in 1980 and 59 in 2009. A narrower definition of a cohort would be desirable but this is not possible without running into small sample sizes. Given that the age difference between spouses in approximately two thirds of households in this cohort does not exceed $\pm 3$ years, I do not explicitly condition on similar years of birth for the female spouse. I remove inflation from all monetary values[11] and, to account partly for measurement error, I drop households for which earnings of a *working* spouse fall below 1% or above 99% of the (gender- and time-specific) distribution. Finally, I require that households are stable in

[9] Detailed information on the PSID, as well as access to all the data, is available at psidonline.isr.umich.edu.
[10] I also consider couples that are permanently cohabiting (a tiny proportion in the data).
[11] I express all monetary amounts in 2010 dollars. To deflate I use the All-Urban-Consumers CPI available by the BLS at www.bls.gov/cpi.

that they do not experience compositional changes in the head couple. The resulting dataset is an unbalanced panel of 1279 households observed over at least two consecutive years. More than 55% of households are observed for at least 10 years and more than 30% for at least 20. Some key descriptive statistics are presented in table 1; appendix A provides further details.

Table 1: Main sample descriptive statistics

| | | |
|---|---|---|
| Prop. of stable households | 0.81 | |
| *Among stable households:* | | |
| | Men | Women |
| % some college | 0.63 | 0.55 |
| % working | 0.94 | 0.80 |
| Annual earnings | 65846 | 31352 |
| Annual work hours | 2255 | 1610 |
| Hourly wage rate | 28.86 | 18.73 |
| Num. of kids | 1.25 | |
| Observations* | 15917 | |

*Notes:* 'some college' is defined as any education above the 12th grade. '% working' is defined as the proportion of those working in a given year. Earnings and working hours are presented for those working. Hourly wages are for those working using the central 96% of the relevant distribution. All monetary amounts are expressed in 2010 dollars and all descriptive statistics for stable households are calculated across all stable household-year observations. *Refers to the number of household-year observations of stable households only.

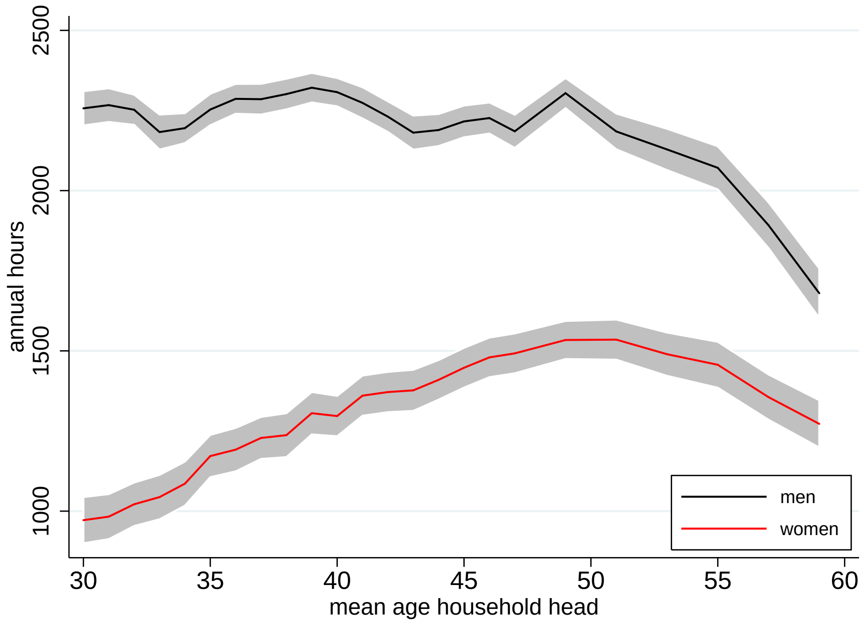
I concentrate on continuously married couples due to the strategy I follow regarding identification of the household structure presented in section 3. The main caveat is whether excluding couples that are unstable (i.e. who do not remain continuously married but separate or divorce) can bias my results. I discuss the direction of this potential bias in the results section 6.

### 2.2 Facts to Explain

In this section I illustrate the main facts about married men's and women's life-cycle time use over 1980-2009. Specifically I focus on the time they spend working in the labor market and inside the household.

Figure 1 plots average annual hours of market work for workers and non-workers. Three features stand out. First, women work much less in the market than men. Second, over the first two thirds of their life-cycle, men's labor supply is flat at approximately 2,250 hours annually; women's labor supply on the other hand increases steadily from less than 1,000 hours annually to a peak of 1,550 hours in 2000. Third, both men and women decrease their hours of market work in the last third of their life-cycle, possibly due to retirement.

Figure 1: Average annual hours worked in the market

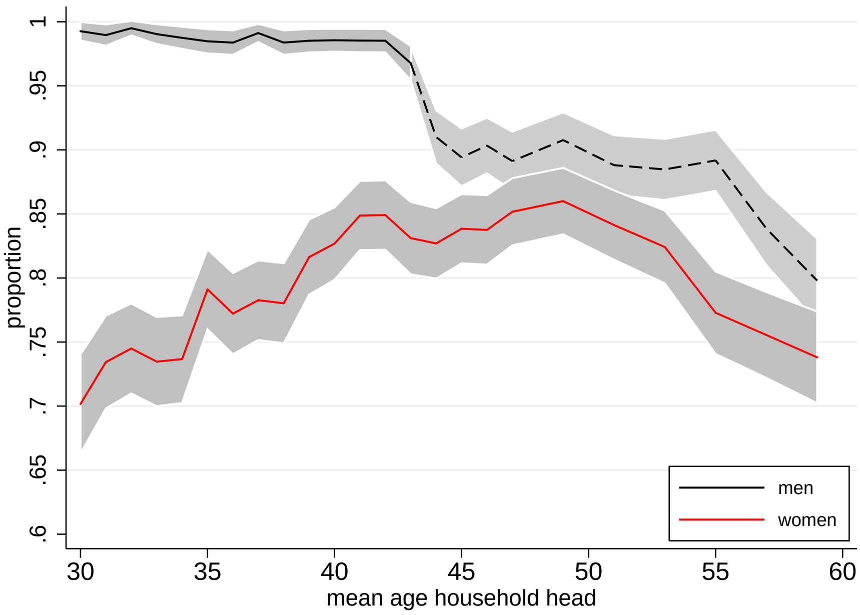



*Notes*: This figure plots average annual hours of market work for workers and non-workers. A 95% confidence interval appears in gray shade.

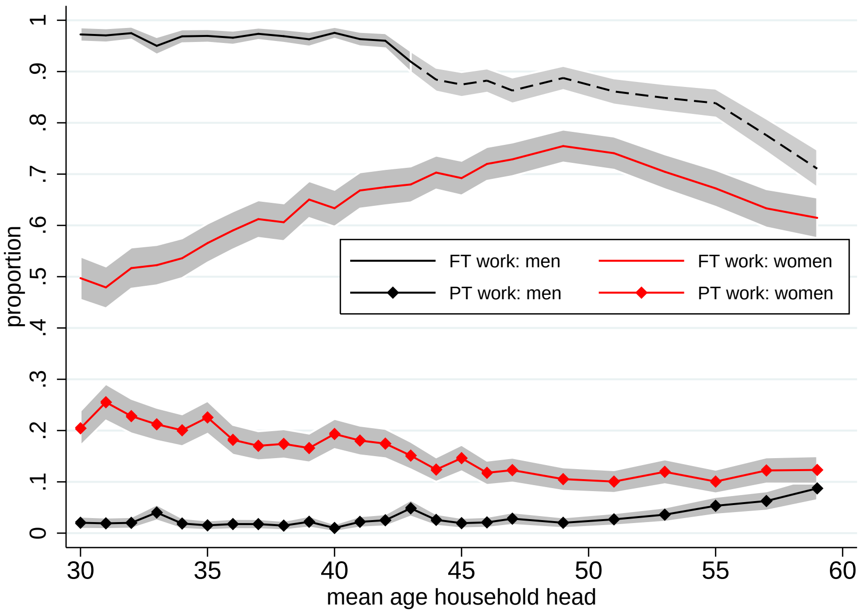
To understand these trends better, figure 2a plots the proportion of people who participate in the labor market over the life-cycle. A person is classified as participating if he/she works at least 10 hours and earns at least \$10 in any given year. For women the picture is clear. There is a big increase in labor market participation over the first two thirds of their life-cycle and a subsequent decrease in the last one third. These trends, occurring along the extensive margin of female labor supply, are responsible for the steady increase in women's working hours in figure 1. For men things are different. A nearly full participation in the first years is followed by a sudden downwards jump around mean age 43. Participation then flattens out again (at around 90% now) until it starts declining in the last few years.

A careful look at the data flags up an inconsistency in the measure of male earnings that occurs in 1993 and affects men in the main sample at mean age 43 onwards. The definition of earnings changes slightly after 1993 and the available measure excludes some previously included earnings components such as the labor part of business income (see appendix A for further information). This seems to be the reason behind the downwards jump in male employment at mean age 43. Indeed, until 1993 around 10 men in the sample report 0 earnings every year and the majority of them also reports 0 working hours. After 1993, however, the number of men reporting 0 earnings jumps to around 70 every year with around 20% of them also reporting 0 hours. Among those reporting 0 earnings after 1993, mean annual working hours are around 1,800, *i.e.* sufficiently close to the unconditional mean of figure 1. I conclude that men's employment jump at mean age 43 (corresponding to year 1993) is the result of a data design flaw and it does not reflect a true incident in the economy.

Figure 2: Employment trends: market participation, full-time and part-time work




(a) Labor market participation



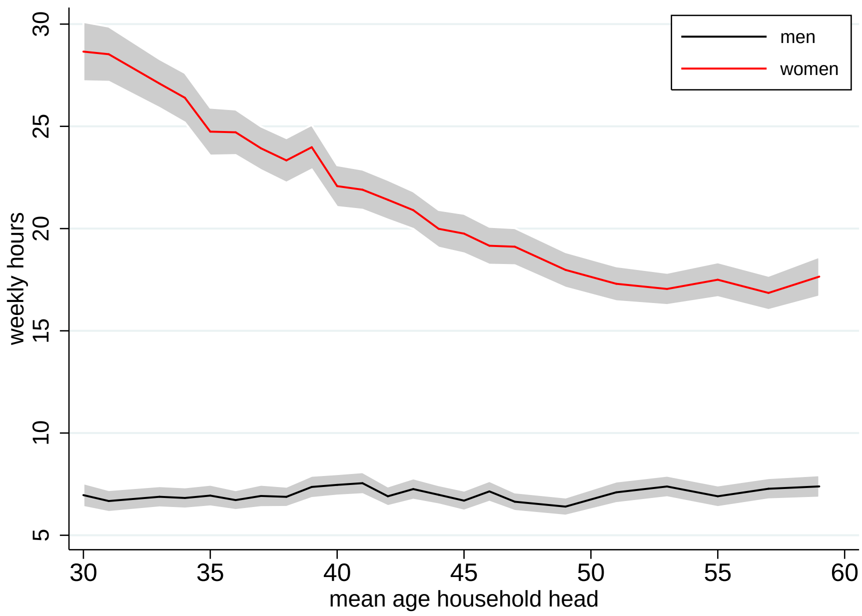

(b) Full-time against part-time work

*Notes*: This figure plots the proportion of people who participate in the labor market, as well as the proportions of people working full- or part-time. A 95% confidence interval appears in gray shade. Data for men after mean age 43 suffer from a data design flaw (see main text and appendix A for details).

Figure 2b delves deeper into the employment trends and plots the proportions of people working full- or part-time in the labor market. A person is classified as working full-time (part-time) if he/she participates in the market and works more than 1,000 (up to 1,000) hours annually. The figure paints an opposite picture for married men versus women: men work full-time for most of their life-cycle (with the same caveat about the employment measure around mean age 43) and they only start reducing slowly their full-time work in the last third of the life-cycle. Even then, a noticeable proportion seems to revert to part-time work rather than quit the market totally. Women, on the other hand, increase their full-time work by more than the overall increase in their participation, partly because they move gradually away from part-time work. Hence, the increase in female working hours in figure 1 is a combination of a strong increase in the extensive margin of labor supply (figure 2a) and a smaller increase in the intensive margin (figure 2b).

Turning to work inside the household (time devoted to home production), figure 3 plots *weekly* hours of household work for married men and women including those who report 0 such hours. The data refer to any work in and around the household, such as cooking or cleaning, and exclude time spent with children. Two features stand out. First, men supply much fewer hours than women. Second, women's hours drop a lot over the first two thirds of their life-cycle and they level off in the last one third. Men's hours, on the other hand, remain flat around 7 weekly hours throughout the life-cycle.

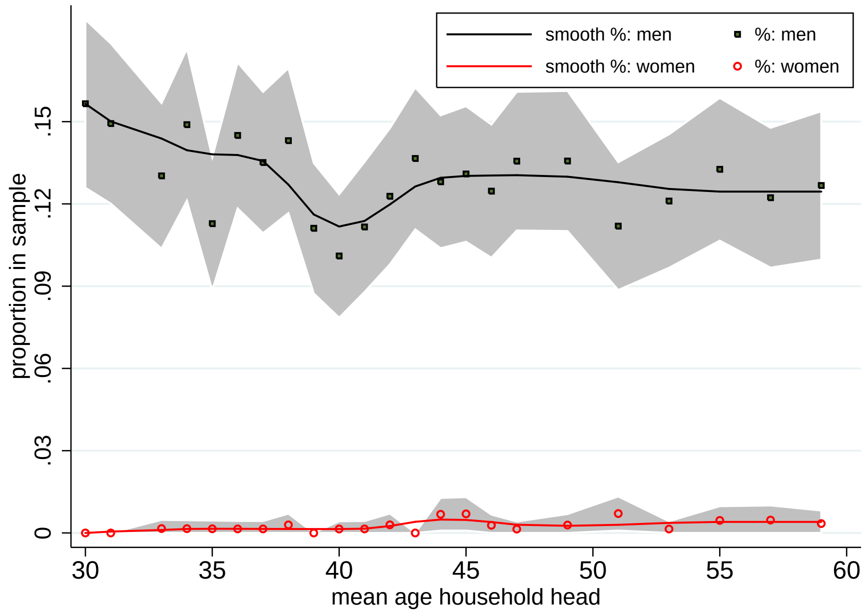
Figure 3: Average weekly hours worked in the household




*Notes*: This figure plots average weekly hours of household work for household workers and non-workers. A 95% confidence interval appears in gray shade.

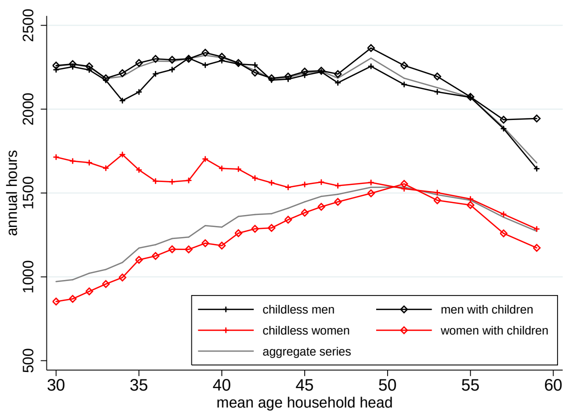
To investigate these patterns further, figure 4 plots the proportion of people over time who report supplying 0 weekly hours to home production. To improve legibility, I plot the actual proportions (squares and circles) as well as separate smoothing curves that pass through the scatters. Around 13% of men do not participate in household chores whereas for women the proportion is effectively 0. As there are no obvious trends over the life-cycle, one can conclude that women's big drop in household work in figure 3 is the result of a decrease in the intensive rather than the extensive margin of housework.

Figure 4: Non-participation in the household sector

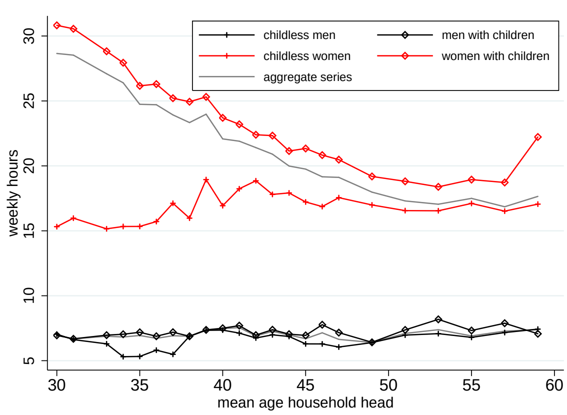



*Notes*: This figure plots the proportion of people who report supplying 0 weekly hours in the household sector. A 95% confidence interval around the original (non-smoothed) proportions appears in gray shade.

Figure 5: Annual hours worked in the market and weekly hours worked in the household by parental status




(a) Hours in the market




(b) Hours in the household

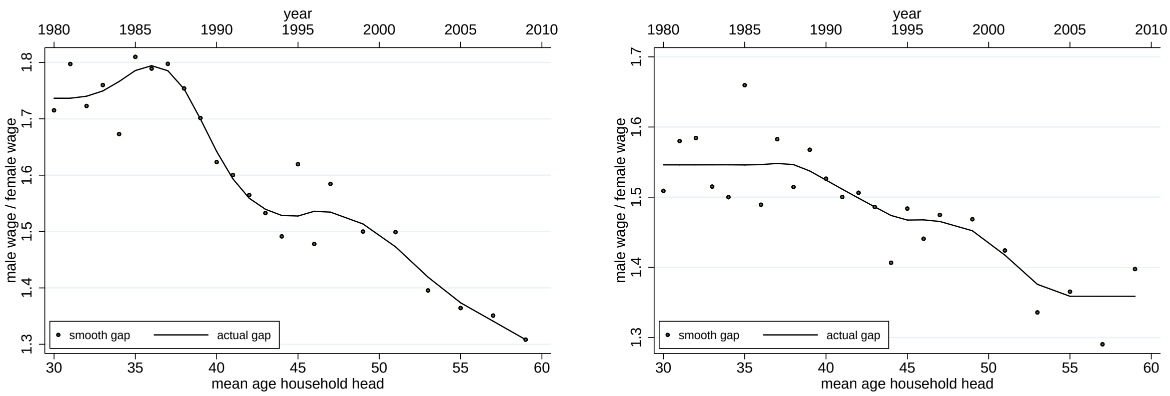
*Notes*: This figure plots average annual hours of market work for market workers and non-workers as well as average weekly hours of household work for household workers and non-workers. Confidence intervals have been suppressed to ease legibility of the graphs.

As one would expect, the above time-use trends vary across different groups of the population. The presence of kids in the household is likely to be one of the most important factors impacting on their parents' time use over the life-cycle. Indeed figure 5 redraws the initial market and household hours graphs splitting the sample by the parental status of the household (parents versus non-parents). Two facts emerge. First, men's use of time is not affected by the presence of children. Second, women's time use is affected severely by the presence of children with childless women experiencing trends very similar to men (albeit at different magnitudes). These facts are true for work in the market and the household sector.

## 2.3 The Gender Wage Gap

For the same cohort of married people, I calculate the raw gender wage gap in two alternative ways: (a) as the ratio of median male wages over median female wages; (b) as the median ratio of spousal (male/female) wages inside the family. Figure 6 plots these measures of the gender wage gap against mean age and calendar time; note that calendar time coincides with mean age given that the paper currently focuses on one cohort only. I plot the actual estimates of the gender gap (circles), as well as separate smoothing curves that pass through the scatters.

Figure 6: Unconditional gender wage gaps




(a) Economy-wide gender wage gap

(b) Within-household gender wage gap

*Notes*: This figure plots alternative definitions of the gender wage gap over the life-cycle. Only the central 96% of the wage distribution by gender and year is used.

The gender wage gap narrowed down steadily in favor of women throughout their life-cycle: in the start of the 1980s the 'median' man commands an hourly wage rate around 1.7-1.8 times higher than that of the 'median' woman; in 2009 the gender gap is around 1.3 or 25% lower. Within the family, the median ratio of spousal wages was approximately 1.55 in 1980 and 1.35 in 2009 or 13% lower. For completeness, figure A.1 in the appendix reports the levels of wages (medians and means) by gender. The narrowing of the gender gap is not specific to the main cohort of focus only. An earlier cohort[12] also experiences a relative improvement in women's wages, at least in the second half of their life-cycle, even though the gap between genders has been everywhere wider than in the main cohort. The wage gap for the earlier cohort is not plotted in the graph.

The narrowing of the gender wage gap is robust to a number of richer specifications that can be used alternatively to study it. Figure 7, panel (a), plots the evolution of the gender (log) wage gap after controlling for spousal education and number of kids, and after correcting women's wages for selection into the labor market. In this graph I define the gender wage gap as

$$GWG_t = \text{median}(\widetilde{w}_{1it}) - \text{median}(\widetilde{w}_{2it})$$

where $\widetilde{w}_{jit}$ is the (log) hourly wage of married people of gender $j$ ($j = 1$ for men, $j = 2$ for women) after removing the observable characteristics and correcting for women's participation selection.[13] Figure 7, panel (b), plots the gender (log) wage gap *within* the family after controlling for spousal education and number of kids, and after correcting it for women's selection into the labor market. In this graph I define the gender wage gap as

$$GWG_t = \text{median}(\widetilde{\Delta w_{it}})$$

where $\widetilde{\Delta w_{it}}$ is the within-household gap in (log) hourly wages after removing the observable characteristics and correcting for women's participation selection. Appendix A ('wage equations and participation selection') provides the details of these computations, including the correction for women's selection into the labor market.

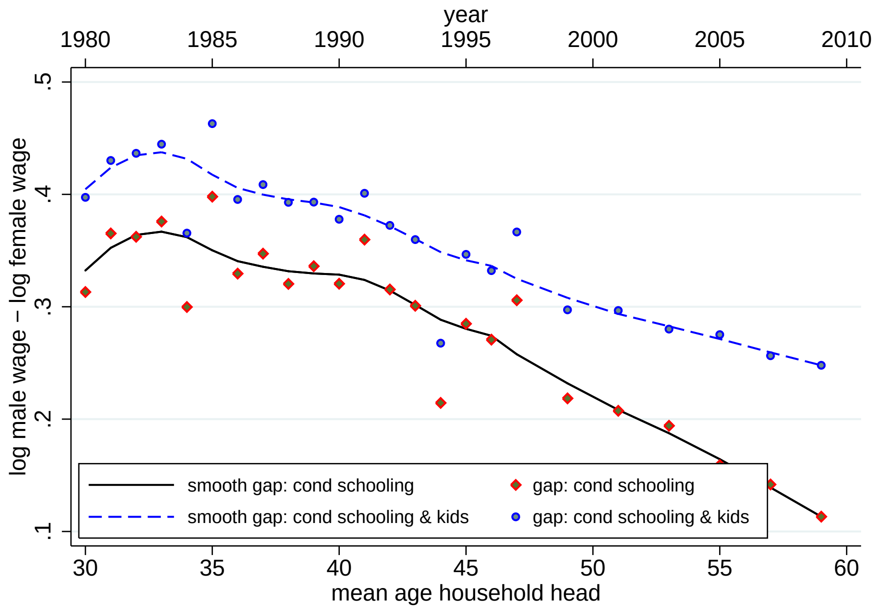
Across all figures the picture that emerges points to an improvement of the economic status of women relative to that of men (at least as reflected upon their wages). That improvement is robust to a number of factors that could potentially affect the gender wage gap, such as women's education, labor market participation, or the number of their kids.

In a series of papers, Blau and Kahn (1997, 2006) investigate the reasons behind the narrowing of the gender wage gap in the 1980s and 1990s (the years most of my data also come from). Using similar PSID data, they provide evidence of sex-biased institutional and technical change contributing to a faster growth in women's wages relative to men's. Such factors include improvements in the relative treatment of women in the labor market (possibly in response to the federal government's anti-discrimination policies in the 1970s) or demand-driven increased rents in industries where women had a comparative advantage (for example, in services). In the light of this evidence, the present paper aims to investigate the way and the extent to which an exogenous narrowing of the gender wage gap affects household time allocation choices.

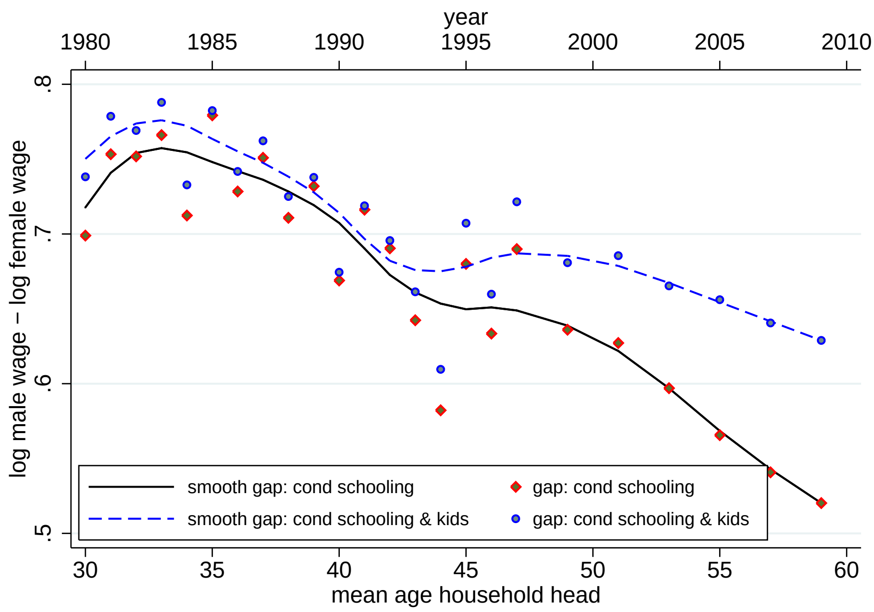
[12] The earlier cohort referred to in the text consists of stable households whose male head is born between 1933 and 1945; his mean age is 30 in year 1970. The same exactly selection criteria apply to this cohort as to the main one. This earlier cohort requires the use of earlier PSID data starting in 1970.

[13] I do not correct male wages for selection into the labor market due to their very high, almost full, participation rate throughout the period covered by this study (see figure 2a).

Figure 7: Conditional gender wage gaps




(a) Economy-wide gender wage gaps




(b) Within-household gender wage gaps

*Notes*: This figure plots the evolution of the gender wage gap over time in a number of different specifications. In graph (a), the gender wage gap is defined as $\text{median}(\widetilde{w}_{1it}) - \text{median}(\widetilde{w}_{2it})$ where $\widetilde{w}_{jit}$ is the (log) hourly wage of married people of gender $j$ ($j = 1$ for men, $j = 2$ for women) conditional on observable characteristics and after correcting wages for women's participation selection. In graph (b), the gender wage gap is defined as $\text{median}(\widetilde{\Delta w_{it}})$ where $\widetilde{\Delta w_{it}}$ is the within-household gap in (log) hourly wages conditional on observable characteristics and after correcting for women's participation selection. Only the central 96% of the wage distribution by gender and year is used. For details see appendix A ('wage equations and participation selection').

# 3 A Life-Cycle Collective Model without Commitment

This section develops the life-cycle collective model of family time allocation, public consumption, and savings that also features lack of commitment to lifetime marriage. Two spouses are characterized by their own, possibly different, preferences; each of them is fit to work in the labor market and their skills can earn them an hourly wage that is subject to productivity shocks. I allow for life-cycle changes in children-related family composition and I emphasize the constraints that lack of commitment imposes on household behavior.

The life-cycle consists of two distinct periods: the working period and the retirement period. In section 3.1 I summarize the key features of the model during the working period. The details are given in section 3.2, where I lay out the model's building blocks including its recursive formulation and some aspects of the solution, and in section 3.3, where I detail the model's specification. Section 3.4 describes the retirement period exclusively.

## 3.1 Illustration of Key Features

Two decision making spouses, $j = \{1, 2\}$, consume a public (non-rival) good and allocate their time to leisure, market work, and home production. There may be children in the household but children are not decision makers.[14] Although I use the terms 'partners' or 'spouses' frequently to refer to the two decision making individuals, the model applies equally to other modern forms of cohabitation. Spouse $j$ has preferences $U_j$ given by

$$U_j\big(Q, l_j; \mathbf{z}_j\big).$$

Here $Q$ is the public consumption good and $l_j$ is $j$'s private leisure. $\mathbf{z}_j$ is a vector of observable taste shifters affecting $j$'s preferences; possible taste shifters are $j$'s education or the number and age of his/her children. An extension to preferences over private consumption goods too is considered in appendix B.

The public good $Q$ is produced domestically by a household production function given by

$$f\big(K, \tau_1, \tau_2; \mathbf{Z}\big)$$

with inputs raw expenditures $K$ and time $\tau_j$ devoted to home production by each partner. The public good comprises items such as food at home or a clean house. In the former case $K$ can be viewed as the amounts paid in grocery shopping whereas $\tau_j$ as the time each partner spends cooking. Here $\mathbf{Z}$ is a vector of production shifters for which the obvious candidates are again the number and age of children in the household.

The partners stay together as members of the same household from period $t = 0$ (age 30) until the deterministic end of their working ($T$; age 60) and retirement lives ($T^R$; age 70). For

[14] See Dauphin et al. (2011) and Dunbar et al. (2013) for static collective models where children act as decision makers.

simplicity I assume that both individuals are of the same age and post the schooling periods of their lives. I do not model marriage/cohabitation decisions; instead the focus of the paper is on the partners' lives and choices after they have formed a household (i.e. conditional on marriage/cohabitation). However, the model does account for initial conditions that arise from assortative patterns in the marriage market (see the wage process in section 3.3).

The spouses do not commit ex ante to one another for life. In each period that they stay together, they do so because each of them satisfies, among other things, their participation constraints in the household. Such constraints take the form of lower bounds that the utility each partner enjoys from inside the household must respect in each time period. The participation constraints essentially ensure that both partners enjoy at least as much utility from inside their household as they could possibly enjoy from their best outside option, which I take to be divorce.[15] The outside options (the lower bounds) are not constant over time or across different states of the world; this changing nature of theirs imposes limits to commitment and risk sharing between spouses and affects household behavior. In this paper, I make the outside options depend on the wages spouses can command in the labor market and reflect in this way the possibility that higher paid individuals may be able to attract better outside options.[16]

During the working period of life, I model annual choices over public consumption/savings and time across leisure, market work, and work in the household. Market work generates income to fund raw expenditures in the market or save for the future and work in the household contributes to the home production of the public consumption good. Publicness of consumption is an important element in the model as it permits economies of scale and complementarities between partners' preferences regardless the specific functional forms that will represent them.

The value of each individual's time in the labor market is captured by the hourly wage they can earn. Inside the model individuals cannot affect their wage and the model abstracts from human capital accumulation and similar features. The wage is treated as the exogenous (gender-specific) price of one's skills in the labor market which individuals take as given in each period.[17] Wages can affect the trade-off among the different activities one can engage in and, therefore, the extent to which one or another individual specializes in market versus household work. Moreover, and as already said, wages affect the spouses' outside options.

Finally, family composition regarding children is an important determinant of individual choices during the working period of life. To capture the impact of children on behavior I model an exogenous stochastic 'fertility' process which reproduces the dynamics observed in the data over the life-cycle. Individuals make choices conditional on their household's composition rather than choosing 'fertility' explicitly (something that would complicate the model considerably).[18]

[15] Consistent with most of the literature (Chiappori et al., 2002; Knowles, 2013; Voena, 2015) I choose divorce to be the spouses' best outside option. Other papers within the household economics literature, however, consider non-cooperative cohabitation as the applicable outside option (see, for example, Lechene and Preston, 2011).

[16] By contrast, I assume that savings during marriage do not affect spouses' outside options. This simplification ensures the model's tractability and permits identification of the household structure.

[17] The wage may be a function of prior educational choices but these are outside the control of individuals in the time frame of this model. See Blundell et al. (2013) or Chiappori et al. (2015) for a treatment of schooling choices in the context of a dynamic unitary or collective model respectively.

[18] Francesconi (2002) and Keane and Wolpin (2010) are examples of studies that endogenize fertility in a

### 3.2 Model

Given the points made above, the household in the working period of life can be seen as solving

$$\max_{\{Q_t, A_{t+1}, l_{jt}, \tau_{jt}\}_{t=0, j=\{1,2\}}^{t=T}} \mathbb{E}_0 \sum_{t=0}^{T} \beta^t U_1\big(Q_t, l_{1t}; \mathbf{z}_{1t}\big) \tag{1}$$

subject to the following constraints

$$\mathbb{E}_0 \sum_{t=0}^{T} \beta^t U_2\big(Q_t, l_{2t}; \mathbf{z}_{2t}\big) \geq \mathcal{U}_2\big(\mathbf{x}_1, \mathbf{x}_2\big) \tag{2}$$

$$A_t + \sum_{j=1}^{2} w_{jt} h_{jt} = K_t + CC_t\big(h_{2t}, N_t\big) + \frac{A_{t+1}}{1+r} \qquad A_{t+1} \geq \underline{A}_{t+1} \tag{3}$$

$$U_1\big(Q_t, l_{1t}; \mathbf{z}_{1t}\big) \geq \bar{U}_1(w_{1t}, \mathbf{d}_{1t}; \mathbf{z}_{1t}) \tag{4}$$

$$U_2\big(Q_t, l_{2t}; \mathbf{z}_{2t}\big) \geq \bar{U}_2(w_{2t}, \mathbf{d}_{2t}; \mathbf{z}_{2t}) \tag{5}$$

$$Q_t = f\big(K_t, \tau_{1t}, \tau_{2t}; \mathbf{Z}_t\big) \tag{6}$$

$$l_{jt} + h_{jt} + \tau_{jt} = \mathcal{T} \qquad j = \{1, 2\}. \tag{7}$$

Constraints (3)-(7) must be satisfied in every period $t$. Expression (1) involves the maximization of the first individual's time-0-expected discounted lifetime utility; discounting is assumed to be geometric and $\beta$ is the discount factor. Expression (2) is a promise keeping constraint, essentially an agreement set out at $t = 0$ that individual 2's expected discounted lifetime utility will not fall below a minimum level $\mathcal{U}_2$ (more on this to follow). Equation (3) is the sequential budget constraint linking available resources to expenditure and savings in each period, (4)-(5) are the participation constraints for each individual, (6) is the household production function, and (7) is the time budget per individual for a total time endowment $\mathcal{T}$. Much of the notation has already been introduced; the remaining notation is as follows: (i) in the budget constraint $A_t$ is household common assets, $w_{jt}$ is spouse $j$'s hourly wage at $t$, $h_{jt}$ is his/her hours of market work, $CC_t\big(h_{2t}, N_t\big)$ is child care costs that families with young children may have to meet ($N_t$ summarizes the family composition; more on this to follow), $r$ is the deterministic and known market interest rate, and $\underline{A}$ is a borrowing limit; (ii) in the participation constraints $\bar{U}_j(\cdot)$ is the utility that individual $j$ can get from his/her outside option at $t$. The above program is written *as if* household member 1 makes all the choices in the household which obviously goes against the collective spirit. Decentralization is feasible but requires a combination of Lindahl (personal) and shadow prices for $Q$ because this is a good that is both public and produced domestically (see Chiappori and Meghir, 2014).

In writing the outside options I have assumed that only exogenous variables enter $\bar{U}_j$, mainly the wage, the observable taste shifters $\mathbf{z}_{jt}$, and a vector of distribution factors $\mathbf{d}_{jt}$. By distribution factors I refer to any exogenous variables that affect choices through shifting partners' outside options but not their preferences or the budget set.[19] Allowing the outside option to depend

unitary context.

[19] Chiappori et al. (2002) and Voena (2015) provide some examples of distribution factors such as laws governing

on individual choices while married would lead to inefficient allocations of time and would jeopardize the model's tractability. To see why, suppose $\bar{U}_j$ is an increasing function of one's market work (say, through the dependence of wages on some form of human capital). In this case the individual supplies labor for two reasons: first, labor generates income which can be used to buy current and future goods; second, labor improves one's outside option boosting his/her bargaining power in the household. As a result labor is over-supplied in this family beyond what is Pareto optimal and both partners can be better off if they agree to supply less. For a detailed illustration of this point see section 6.2.3 in Browning et al. (2014).

The assumption that only exogenous variables enter $\bar{U}_j$ serves also another purpose, that of simplifying the representation of the model (1)-(7). Consider representing the problem by its Lagrangian formulation. Let $\nu_1$ be the Lagrange multiplier on expected lifetime utility (1) and $\nu_2$ on (2); also let $\widetilde{\nu}_{1t}$ be the Lagrange multiplier on participation constraint (4) and $\widetilde{\nu}_{2t}$ on (5). Then the above problem is equivalent to

$$\max_{\{Q_t,A_{t+1},l_{jt},\tau_{jt}\}_{t=0,j=\{1,2\}}^{t=T}} \mathbb{E}_0 \sum_{t=0}^{T} \beta^t \Big[ \big(\nu_1 + \frac{\widetilde{\nu}_{1t}}{\beta^t}\big) U_1\big(Q_t, l_{1t}; \mathbf{z}_{1t}\big) + \big(\nu_2 + \frac{\widetilde{\nu}_{2t}}{\beta^t}\big) U_2\big(Q_t, l_{2t}; \mathbf{z}_{2t}\big) \Big]$$

or, written more compactly, to

$$\max_{\{Q_t,A_{t+1},l_{jt},\tau_{jt}\}_{t=0,j=\{1,2\}}^{t=T}} \mathbb{E}_0 \sum_{t=0}^{T} \beta^t \Big[ \mu_{1t} U_1\big(Q_t, l_{1t}; \mathbf{z}_{1t}\big) + \mu_{2t} U_2\big(Q_t, l_{2t}; \mathbf{z}_{2t}\big) \Big] \tag{1'}$$

subject to constraints (3), (6) and (7) only (for the details of this transformation see section 3.1 in Chiappori and Mazzocco, 2014). Essentially $\mu_{jt} = \nu_j + \frac{\widetilde{\nu}_{jt}}{\beta^t}$ is individual $j$'s bargaining/decision power in the household at time $t$ or, equivalently, the weight his/her preferences carry in the household decision process at that time. Moreover, if one imposes the normalization $\mu_{1t}+\mu_{2t} = 1$ then $\mu_{jt}$ can also be viewed as the Pareto weight a social planner attaches to member $j$'s preferences at $t$.

What determines the weights $\mu_{jt}$ is given by the nature of the constraints that their underlying elements serve as Lagrange multipliers to. $\nu_j$ is the weight attached to individual $j$'s expected *lifetime* utility at the beginning of time, hence the lack of a time subscript. This may be a function of the individual's predetermined characteristics, some economy-wide attributes, as well as beginning-of-time expectations about possible changes in these characteristics/attributes in the future. I denote such variables by a vector $\mathbf{x}_j$; candidate variables may include spousal education or occupation. Essentially, individuals' education or occupation at $t = 0$ may determine $\mathcal{U}_2$ in (5) and, as a consequence, the initial relative weights $\nu_1$ and $\nu_2$ attached to their expected lifetime utilities. $\widetilde{\nu}_{jt}$ is the multiplier on $j$'s participation constraint in period $t$. Whatever affects the outside option $\bar{U}_j$ at $t$ will affect $\widetilde{\nu}_{jt}$ too, therefore $\widetilde{\nu}_{jt} = \widetilde{\nu}_j(w_{jt}, \mathbf{d}_{jt}; \mathbf{z}_{jt})$. Pooling all the elements in $\mu_{jt}$ together and normalizing the weights to add up to 1 implies

$$\mu_{jt} = \mu_j(\mathbf{x}_1, \mathbf{x}_2, w_{1t}, w_{2t}, \mathbf{d}_{1t}, \mathbf{d}_{2t}, \mathbf{z}_{1t}, \mathbf{z}_{2t}).$$

divorce and property sharing or the sex ratio in the local marriage market. Also see Bourguignon et al. (2009).

The reason why *both* partners' wages, distribution factors and pre-determined attributes enter $\mu_{jt}$ is precisely the aforementioned normalization of the sum of the weights.

The Pareto weights $\mu_{1t}$ and $\mu_{2t}$ summarize the allocation of bargaining power in the household. The partners exert equal powers when $\mu_{1t} = \mu_{2t} = \frac{1}{2}$ whereas partner 1 is relatively more (less) powerful when $\mu_{1t} > \mu_{2t}$ ($\mu_{1t} < \mu_{2t}$). If the partners commit fully to never exploit their outside options, which is equivalent to removing the participation constraints, then $\widetilde{\nu}_{jt} = 0$ and $\mu_{jt} = \nu_j$ in each period (full commitment benchmark). If such commitment is impossible $j$'s participation constraint may bind whenever her outside option improves, for example, due to an increase in her wage. In this case $\widetilde{\nu}_{jt} > 0$ increasing her bargaining power by $\frac{\widetilde{\nu}_{jt}}{\beta^t}$ and decreasing her partner's power by the same amount (no commitment benchmark).

**Pareto efficiency** The participation constraints prohibit the spouses from reaching the first-best or *ex-ante* efficient allocation of their resources. The solution to the above problem is, however, *ex-post* efficient as the household still maximizes $\mathcal{U}(\mathcal{C}_t, \mathcal{S}_t)$ in each period. Ex-post efficiency implies that no alternative allocation of resources can take place once information at time $t$ is revealed without violating the prevailing participation constraints; for details see Chiappori and Mazzocco (2014) or section 6.2.2 in Browning et al. (2014).

Note that the model herein is unable to distinguish between lack of commitment and limited commitment, which both result in ex-post efficient allocations. The dependence of the Pareto weights on contemporaneous wages and distribution factors is, strictly speaking, consistent with the lack of commitment framework of Mazzocco (2007) because the spouses adjust intra-family bargaining power after *any* change affecting their outside options (for example, changes in their wages). By contrast, limited commitment, as developed for example in Ligon et al. (2002), requires that intra-family bargaining power shift only after a person's participation constraint binds. In this paper I model the former scenario (no commitment) and I test it against full commitment that is nested within it. Rejection of full commitment, however, may be due to lack of commitment being a reasonable representation of the data or, alternatively, due to lack of commitment serving as a reasonable approximation for limited commitment.

**Recursive formulation** Let $\mathcal{S}_t = \{\mathbf{z}_{1t}, \mathbf{z}_{2t}, \mathbf{Z}_t, \mathbf{x}_1, \mathbf{x}_2, w_{1t}, w_{2t}, \mathbf{d}_{1t}, \mathbf{d}_{2t}\}$ be the set of exogenous state variables at time $t$; current period assets $A_t$ is the endogenous state variable. Moreover, let $\mathcal{C}_t = \{K_t, l_{1t}, l_{2t}, \tau_{1t}, \tau_{2t}\}$ be the set of choice variables alongside next period's assets $A_{t+1}$ (a total of 6 variables). Finally, let $\mathcal{U}$ denote the weighted sum of the partners' intra-temporal utility functions given by

$$\mathcal{U}(\mathcal{C}_t, \mathcal{S}_t) = \sum_{j=1}^{2} \mu_j(\mathbf{x}_1, \mathbf{x}_2, w_{1t}, w_{2t}, \mathbf{d}_{1t}, \mathbf{d}_{2t}, \mathbf{z}_{1t}, \mathbf{z}_{2t}) U_j\big(f(K_t, \tau_{1t}, \tau_{2t}; \mathbf{Z}_t), l_{jt}; \mathbf{z}_{jt}\big)$$

Program (1') can be written recursively as

$$V_t(A_t, \mathcal{S}_t) = \max_{\mathcal{C}_t, A_{t+1}} \big\{\mathcal{U}(\mathcal{C}_t, \mathcal{S}_t) + \beta \mathbb{E}_{\mathcal{S}_{t+1}|\mathcal{S}_t} V_{t+1}(A_{t+1}, \mathcal{S}_{t+1})\big\}$$

subject to constraints (3) and (7). $V_t$ is the value function of the married household at $t$; $\mathbb{E}_{\mathcal{S}_{t+1}|\mathcal{S}_t}$

denotes expectations over the exogenous state space at $t+1$ conditional on its realization at $t$.

I do not write the value function for if the spouses divorce because I do not explicitly solve for the value of divorce numerically. Instead I approximate the gender-specific value of divorce using a reduced-form approach and I impose the approximate values to the married people's problem through fixing the Pareto weight in the first few years of the family life-cycle (these points are illustrated in section 5.3). This shortcut facilitates the computations in this paper (by the burden of solving the divorced man's and divorced woman's life-cycle problems) but it comes with the cost of restricting the estimation sample to stable households only (as discussed in section 2.1). I discuss the implications of this restriction in section 6.

### 3.3 Parametrization

In each period of their life in the household, which I take to be one year, the partners maximize expected lifetime utility (1') taking as given their individual characteristics and their economic circumstances. Their individual characteristics are described by their education ($educ_1$, $educ_2$) and the woman's utility costs of work ($\theta_2$);[20] their economic circumstances are described by calendar time/age ($t$), their common accumulated assets ($A$), the presence of kids in the household and the age of the youngest among them ($N$), and the spouses' idiosyncratic productivity in the labor market ($v_1$, $v_2$).

**Time allocations** I assume time can take on discrete values across three activities: market work, work in the household sector (home production), and leisure. On a daily basis the time put into these activities by each spouse must add up to 24 hours net of 8 hours that people need for sleep and personal care (Biddle and Hamermesh, 1990). Table 2 summarizes the discrete values market- and household work can take. Market work can take on three values (for 'no work', 'part time', and 'full time') whereas work in the household four values (for 'low', 'low middle', 'high middle', 'maximum'). The specific numerical values attached to these cases are not arbitrary; instead they correspond to the values most frequently reported in the PSID and the distribution implied by table 2 serves as a discrete approximation of the empirical distribution of time use observed in the data.

For computational reasons, not all choices of market- and household work are applicable to both men and women. I restrict men's household work to 'low' or 'low middle' (consistent with men in the PSID supplying very few hours to home production); I also restrict women's household work to 'high middle' or 'maximum' (again consistent with female household work time after 1980). Finally, I restrict men's market work to 'full time' only as there are very few men in the PSID sample not working full-time.[21] These restrictions imply that men's daily leisure is restricted between 6.4 and 7.6 hours whereas women's daily leisure between 2 and 13.

[20] The model is written with education $educ_j$ of either spouse as a state variable. However, in the current version of the paper education is suppressed in the estimation and results are reported without differentiating by education.

[21] Part-time work for men does increase slightly towards the end of the life-cycle (figure 2b). However, I shut down men's market work choice for reasons pertaining to the feasibility of the computations herein.

Table 2: Time into market- and household work

| Activity | Intensity | Abbrev. | Daily hours |
|---|---|---|---|
| *Hours per day* | | | *24* |
| *Sleep & personal care* | | | *8* |
| *Remaining productive hours* | | | *16* |
| | no work | $NW$ | 0 |
| *Market* | part time | $PT$ | 4 |
| | full time | $FT$ | 8 |
| | low | $L$ | 0.4 |
| *Domestic* | low middle | $LM$ | 1.6 |
| | high middle | $HM$ | 3 |
| | maximum | $MAX$ | 6 |

**Preferences and home production** I parameterize preferences $U_j$ of spouse $j$ by the non-separable function

$$U_j\big(Q_t, l_{jt}; \mathbf{z}_{jt}\big) = \frac{1}{1-\gamma}\big(Q_t/s(N_t)\big)^{1-\gamma} \times \exp\big(g_j(l_{jt}; \mathbf{z}_{jt})\big) \tag{8}$$

where $\gamma > 1$ is the common coefficient of relative risk aversion and $s(N_t)$ is an equivalence scale that depends on the presence and age of the youngest child $N_t$.[22] Function $g_j(\cdot)$ reflects how the marginal utility of consumption changes with leisure (and thus with market- and household work) and depends on $N_t$ and $j$'s education $educ_j$. I specify

$$g_j(l_{jt}; \mathbf{z}_{jt}) = \begin{cases} g_1(l_{1t}; \mathbf{z}_{1t}) & = \sum_n \kappa_1^n \times \mathbf{1}[N_t = n] + \sum_e \kappa_1^e \times \mathbf{1}[educ_1 = e] & \text{if } j = 1 \\ g_2(l_{2t}; \mathbf{z}_{2t}, \theta_2) & = \sum_n \kappa_2^n \times \mathbf{1}[N_t = n] + \sum_e \kappa_2^e \times \mathbf{1}[educ_2 = e] + \theta_2 & \text{if } j = 2 \end{cases}$$

The sum $\sum_n$ is over the different values $\{n\}$ of the age of the youngest child (if any) and the sum $\sum_e$ is over the different levels $\{e\}$ of $j$'s education. For all possible values $\{n\}$, $\{\mathbf{1}[N_t = n]\}_n$ constitutes a set of mutually exclusive dummies, each one of which is activated whenever $N_t = n$. Similarly, for all possible values $\{e\}$, $\{\mathbf{1}[educ_j = e]\}_e$ constitutes a set of mutually exclusive dummies, each one of which is activated whenever $educ_j = e$. The parameters $\kappa_j^n$ and $\kappa_j^e$ depend on the amount of leisure individual $j$ enjoys and thus on the amount of market- and household work he/she supplies.[23] Finally, $\theta_2$ is a permanent individual-specific random cost of

[22] The role of this equivalence scale is to account for the different needs that families with children of different ages have. It is not a means of comparison between a multi-member family and singles. I specify $s(N_t) = 1$ if the family has no children, $s(N_t) = 1.17$ if the youngest child is at most 5 years old, $s(N_t) = 1.23$ if it is between 5 and 10 years, and $s(N_t) = 1.32$ if it is between 10 and 18. These numbers come from the McClements equivalence scale after normalizing the scale to 1 in the case of a childless 2-adult-member family.

[23] For a given age $n$ of the family's youngest child I specify for males ($j = 1$):

$$\kappa_1^n(l_{1t}) = \kappa_{1,0}^n + \kappa_{1,1}^n \mathbf{1}[\tau_{1t} = LM]$$

work that depends on the amount of work the female spouse puts into the market and household sectors.[24] In practice, $\theta_2$ is drawn from a two point discrete distribution whose support and probability mass both depend on the amount of work in the labor market (full-time or part-time) and the household sector (maximum hours), and they are estimated inside the model. From this specification it follows that there are two relevant preference shifters affecting $U_j$, these are $\mathbf{z}_{jt} = (N_t, educ_j)'$.

I parameterize the household production function $f$ by the constant returns to scale specification

$$f\big(K_t, \tau_{1t}, \tau_{2t}; \mathbf{Z}_t\big) = K_t^{\phi}\big(\pi_1 \tau_{1t}^{\varphi} + \pi_2 \tau_{2t}^{\varphi}\big)^{\frac{1-\phi}{\varphi}} \tag{9}$$

with the additional restriction that $\pi_1 + \pi_2 = 1$. In the current specification the vector of production shifters $\mathbf{Z}_t$ is left empty.

**Budget constraint** The budget constraint is given by the assets evolution equation (3). The borrowing limit $\underline{A}$ is set at 10% of the family's minimum discounted lifetime income including pension income (more on pension income in section 3.4). This is not a generous borrowing limit as lifetime earnings are hindered by the possibility that the female spouse works part-time in the market or not at all. Hourly wages $w_{jt}$ and child care costs $CC_t\big(h_{2t}, N_t\big)$ are described in detail below.

**Wages** Each household member is fit to work in the market and is offered an hourly wage that evolves according to the following permanent/transitory process

$$\begin{aligned} \ln w_{jt} &= \overline{W}_{jt} + v_{jt} + \xi_{jt} \\ v_{jt} &= v_{jt-1} + \zeta_{jt}. \end{aligned} \tag{10}$$

This process has been shown to fit the PSID data well (Blundell et al., 2012). The hourly wage is assumed exogenous and the individuals are viewed as price-takers in the labor market. The process is education specific but those subscripts are removed to simplify the notation. $\overline{W}_{jt}$ is the mean of $j$'s log wage at $t$ which is common across people of the same gender $j$ and education.

The sum $v_{jt} + \xi_{jt}$ represents the stochastic idiosyncratic productivity which consists of a permanent and a transitory component, $v_{jt}$ and $\xi_{jt}$ respectively. The permanent component is the only economically relevant component and follows a unit root subject to a permanent shock $\zeta_{jt}$. I allow this shock to be correlated across family members; specifically I assume $\zeta_{1t}$ and $\zeta_{2t}$ are

and for females ($j = 2$):

$$\kappa_2^n(l_{2t}) = \kappa_{2,0}^n + \kappa_{2,1}^n \mathbf{1}[h_{2t} = FT] + \kappa_{2,2}^n \mathbf{1}[h_{2t} = PT] + \kappa_{2,3}^n \mathbf{1}[\tau_{2t} = MAX].$$

I specify $\kappa_j^e(l_{jt})$ similarly. I normalize $\kappa_{j,0}^n = 0$, $\forall j, n$, and $\kappa_{j,0}^e = 0$, $\forall j, e$; these are the dummies that correspond to $j$ supplying the fewest possible hours in the labor market and/or the household sector. As a result, a positive $g_j$ implies that work lowers the utility of consumption (given that $1 - \gamma < 0$) and that consumption and leisure are complement goods.

[24] I do not model random costs of work for men because these cannot be identified when men effectively have a binary time use choice only, $\tau_{1t} = LM$ or $\tau_{1t} = L$.

jointly normally distributed according to

$$\begin{pmatrix} \zeta_{1t} \\ \zeta_{2t} \end{pmatrix} \sim N\left( \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2_{\zeta_1,t} & \sigma_{\zeta_1\zeta_2,t} \\ \sigma_{\zeta_1\zeta_2,t} & \sigma^2_{\zeta_2,t} \end{bmatrix} \right).$$

This process is estimated directly from the data and details are provided in section 5.1. The beginning-of-life permanent components, $v_{1t=0}$ and $v_{2t=0}$, are also correlated to reflect initial conditions that arise from the marriage market (for example, assortative patterns in marriage); this correlation is also estimated directly in the data.

The transitory shock is viewed as measurement error and does not affect choices; a similar approach is taken by French (2005) using PSID data or Blundell et al. (2013). It follows that the gender wage gap in period $t$ within a particular family is given by $\exp(\overline{W}_{1t}+v_{1t})/\exp(\overline{W}_{2t}+v_{2t})$ whereas the economy-wide gender gap is given by $\mathbb{E}_t \exp(\overline{W}_{1t}+v_{1t})/\mathbb{E}_t \exp(\overline{W}_{2t}+v_{2t})$.

**Pareto weight** Let $m_t = \{\mathbf{x}_1, \mathbf{x}_2, w_{1t}, w_{2t}, \mathbf{d}_{1t}, \mathbf{d}_{2t}, \mathbf{z}_{1t}, \mathbf{z}_{2t}\}$ be the set of variables that enter the Pareto weight. As this must be bounded in the unit interval, I employ the logistic function to represent it. Let partner 1's Pareto weight be given by

$$\mu_{1t} = \frac{\exp\big(\eta(m_t)\big)}{1+\exp\big(\eta(m_t)\big)} \tag{11}$$

whereas partner 2's weight by $\mu_{2t} = 1 - \mu_{1t}$. For $\eta(m_t)$ I specify

$$\eta(m_t) = \eta^{(0)} + \sum_n \eta^{(n)} \times \frac{w_{1t}}{w_{2t}} \times \mathbf{1}[N_t = n].$$

Although not explicitly shown to economize on the notation, $\eta^{(n)}$ is a function of spouses' education; I specify $\eta^{(n)} = \sum_e \sum_{e'} \eta^{n,e,e'} \mathbf{1}[educ_1 = e, educ_2 = e']$ where the sum is over a set of mutually exclusive education dummies. $\eta^{(n)}$ reflects how intra-family bargaining power changes with the gender wage gap *within* a particular family and it varies with family composition and spousal education. If education $educ_j$ affects the initial allocation of bargaining power in the household (as well as its subsequent changes), it follows that $\mathbf{x}_j = \{educ_j\}$ and there is partial overlap between $\mathbf{x}_j$ and $\mathbf{z}_{jt}$. In this specification $\mathbf{d}_{1t}$ and $\mathbf{d}_{2t}$ are left empty.

**Stochastic fertility** The arrival of children is stochastic and exogenously set to reproduce patterns in the PSID over the life-cycle. Children can affect individual choices in the family through: (i) their needs (they require more of the public good in the form of an equivalence scale $s(N_t)$), (ii) their direct impact on their parents' time-use preferences $\kappa_2^{(n)}$, (iii) their direct impact on the budget constraint (children require child care if they are young and both parents work away from home), and (iv) their effect on the allocation of decision power between parents through $\eta^{(n)}$. To avoid increasing the state space beyond what is computationally feasible, I assume that only the age of the youngest child (if any) matters for family members' choices, not the number of children in the household. The idea is that the family will always have to cater for the needs and costs of the youngest child regardless the age or number of older ones.

I assume there are 4 possible family composition (fertility) states in year $t$, summarized by the state variable $N_t$. State $N_t = 1$ corresponds to a family with no children under 18 years, $N_t = 2$ indicates a family whose youngest child is between $(0, 5)$ years old, $N_t = 3$ indicates a family whose youngest child is between $[5, 10)$ years old, and $N_t = 4$ is when the youngest child is between $[10, 18]$ years. At age 18 any child leaves the household with certainty. The marginal distribution of children, estimated in the PSID, depends on age and parental education.

The transition between fertility states depends on age, parental education, as well as the fertility state one period before. For a childless family at age $t$ the probability that they have a child at age $t + 1$ is given by

$$\text{Prob}_{t+1}(N_{t+1} = 2 \mid N_t = 1, educ_1, educ_2).$$

I restrict the transition matrix to allow smooth transitions only: a family with $N_t = 1$ (no children) may next year have $N_{t+1} = 1$ again or progress to $N_{t+1} = 2$ (a child at the youngest age bracket), but not $N_{t+1} = 3$. Downwards transitions are not allowed with the exception of the arrival of a new child when an older one already exists (in this case I reinstate $N$ to 2) or the departure of an older child from the household. These restrictions accord well with the patterns seen in the data.

**Child care costs** The function $CC_t\big(h_{2t}, N_t\big) = cc_t\big(h_{2t}, N_t\big) \times \text{Prob}_t(costs > 0 \mid N_t)$ describes child care costs a family must meet as a function of the fertility state it operates in and the hours the mother is away from home due to market work (recall that the father always works full-time). The function depends on time to reflect changing prices of child care over the life-cycle as well as on the probability the family actually faces positive child care costs conditional on the age of their child. I assume that pre-school children need child care for so long as the mother is away from home working. If instead she is present in the household for some time, then child care costs are 0 for that time. Young school-age children require some child care only following the schooldays as education is publicly provided whereas older school-age children do not require child care. To account for the fact that some families may have informal child care arrangements in place (such as a grandparent looking after a child) I multiply the costs function $cc_t\big(h_{2t}, N_t\big)$ by the probability that the family faces positive such costs. I allow the probability to depend on time $t$ and the fertility state $N_t$ the family operates in and I estimate it directly in the PSID data.[25]

Given that the mother can work either 'full time' (FT) or 'part time' (PT) hours, the costs function $cc_t\big(h_{2t}, N_t\big)$ can be summarized by

$$cc_t\big(h_{2t}, N_t\big) = \begin{cases} FT \times cchrate_t & \text{if} \quad N_t = 2 \text{ and } h_{2t} = FT \\ PT \times cchrate_t & \text{if} \quad \begin{cases} N_t = 2 \text{ and } h_{2t} = PT \\ N_t = 3 \text{ and } h_{2t} = FT \end{cases} \\ 0 & \quad\;\; \text{in all other cases.} \end{cases}$$

[25] In principle I can estimate this probability inside the model (with the expense of increasing the state space by one more variable). As this is not a crucial point in this paper I prefer to save in computational time and input the empirical probabilities directly from the data.

The hourly price of child care is $cchrate_t$ and varies with time. Section 5.1 provides details on the estimation of $cchrate_t$ and the probability of positive child care costs.

### 3.4 Retirement

Retirement starts at time $T+1$ and ends at time $T^R$ for both spouses. During this period the individuals make no time allocation decisions: they are out of the labor force retired and do not engage in home production (thus their 'productive' time is entirely spent on leisure). They face no uncertainty regarding wages and productivity (as they earn no wages) or fertility (their children, if any, have grown up and left the household). They receive a pension income which, along with their savings (if any), they use to purchase market goods or save further. In the absence of wages their outside options remain fixed throughout the retirement period and intra-household bargaining power is constant at its value in the last period of working life.[26]

Retirement in this model serves as a stylized state towards the end of the partners' lifetime. It is not used or needed to infer behavior during the working period of life (which is the focus of this paper). In the absence of retirement, however, individuals would probably need to accumulate fewer assets during the working period of life and, possibly, work less. In that case, the model would generate full- or part-time employment profiles less easily without pushing the disutility of work towards zero (in the context of the parametrization in (8)).

Adopting a compact formulation equivalent to expression (1'), the household during retirement can be seen as solving

$$\max_{\{Q_t, A_{t+1}\}_{t=T+1}^{t=T^R}} \sum_{t=T+1}^{T^R} \beta^t \Big[\mu_{1T} U_1\big(Q_t, l_{1t}; \mathbf{z}_{1t}\big) + \mu_{2T} U_2\big(Q_t, l_{2t}; \mathbf{z}_{2t}\big)\Big] \tag{$1^{\mathrm{R}}$}$$

subject to

$$A_t + \sum_{j=1}^{2} I_{jt} = Q_t + \frac{A_{t+1}}{1+r} \qquad A_{t+1} \geq \underline{A}_{t+1} \tag{12}$$

$$l_{jt} = \mathcal{T} \qquad j = \{1, 2\}. \tag{13}$$

Most of the notation and parametrization has been introduced previously. Preferences $U_j$ are given by (8) and the Pareto weight $\mu_{jT}$ by (11); notice that the vector of observable taste shifters is now $\mathbf{z}_{jt} = (N_t = 1, educ_j)'$ as there is no fertility. The budget constraint is slightly different from (3) in that earnings are replaced by pension income $I_{jt}$, the public good $Q$ directly enters the constraint (as there is no household production), and there are no child care costs. For each individual, pension income is set to a deterministic 75% of their average full-time earnings at the *start* of their working life. This figure only serves as an approximation to the actual pension income one would expect to receive; it is not stochastic, it is history independent (it ignores

[26] Allowing the outside options to depend on distribution factors implies that reallocations of bargaining power are in principle possible during retirement too. However, in practice I am making no use of distribution factors and thus I fix the retirees' intra-family bargaining power to its last value prior to retirement.

whether one has worked full-time throughout their lifetime or not at all), and it is not adjusted for wage growth that has occurred over time.[27]

**Recursive formulation** Let $\mathcal{S}_t^R = \{\mathbf{z}_{1t}, \mathbf{z}_{2t}, \mathbf{x}_1, \mathbf{x}_2, w_{1T}, w_{2T}, \mathbf{d}_{1T}, \mathbf{d}_{2T}\}$ be the set of exogenous state variables at time $t$ of the retirement stage; current period assets $A_t$ is the endogenous state variable.[28] $Q_t$ and $A_{t+1}$ are the choice variables. Program ($1^{\mathrm{R}}$) can be written recursively as

$$V_t^R(A_t, \mathcal{S}_t^R) = \max_{Q_t, A_{t+1}} \Big\{ \sum_{j=1}^{2} \mu_j\big(\mathbf{x}_1, \mathbf{x}_2, w_{1T}, w_{2T}, \mathbf{d}_{1T}, \mathbf{d}_{2T}, \mathbf{z}_{1T}, \mathbf{z}_{2T}\big) U_j\big(Q_t, l_{jt}; \mathbf{z}_{jt}\big) + \beta V_{t+1}^R(A_{t+1}, \mathcal{S}_{t+1}^R) \Big\}$$

subject to the budget constraint (12) and the time budget (13). This is essentially a modified 'cake-eating' problem: in each period the partners maximize a fixed household welfare function deciding without uncertainty upon current-period expenditure and savings.[29]

**Transition from working to retirement period** At time $T$, the last period of working life, the household's problem can be written recursively as

$$V_T(A_T, \mathcal{S}_T) = \max_{\mathcal{C}_T, A_{T+1}} \big\{ \mathcal{U}(\mathcal{C}_T, \mathcal{S}_T) + \beta V_{T+1}^R(A_{T+1}, \mathcal{S}_{T+1}^R) \big\}$$

subject to the constraints of the working period.

## 4 Model Solution and Simulation

In this section I describe the steps I take to solve and simulate the model developed in section 3. This is a finite horizon life-cycle model which requires computation of the solution as a function of the entire state space, including time, as described at the start of section 3.3. A time period is taken to be 1 year.[30]

I solve the model starting at the end of the retirement period of life, assuming that households exhaust their assets and die without debts, and I move recursively backwards until the beginning of the working period. The solution in the retirement period is straightforward: this part of the model is a 'cake-eating' problem without uncertainty that involves the continuous choice of allocating contemporaneous assets and retirement income between public consumption and future assets. The solution in the working period is more involved: it entails a mixture of discrete (time allocation) and continuous (consumption/assets) choices under uncertainty which I describe in more detail below.

[27] In the absence of time-use choices during retirement (or, more generally, strictly private goods), the retirees' Pareto weights play in reality no role and their problem collapses to a unitary "cake-eating" problem.

[28] The variables $\mathbf{x}_1$, $\mathbf{x}_2$, $w_{1T}$, $w_{2T}$, $\mathbf{d}_{1T}$, and $\mathbf{d}_{2T}$ enter the retirement state space through their effect on the Pareto weight in the last period of working life. These are included here for theoretical completeness as, in reality, the retirees' problem is invariant to the Pareto weight; see footnote 27.

[29] Fernández and Wong (2014) also model a 'cake-eating' and non-stochastic retirement period.

[30] In the current version of the paper I focus on one cohort only (those born between 1943 and 1955) and time coincides with the age of the male spouse. Specifically, the age of the male spouse is 30 at the start of working life in the model; in the data I match that to people aged 25-37 in 1980. The age of the male is 60 at the end of working life; in the data I match that to people who are 55-65 years old in 2009.

I discretize the domain of all continuous state variables to reduce the dimensionality of the problem: these are assets $A$ (applies to both the working and retirement periods of life) and idiosyncratic productivity $v_1$ and $v_2$ (apply to the working period of life only). I use a grid of 12 points in $A$, the domain of which depends on time/age, and a grid of 8 points in each of $v_1$ and $v_2$. In generating the grids in $v_1$ and $v_2$, I assume the spouses expect the gender wage gap between them to remain flat (mean stationary) over their life-cycle. This fundamental assumption will enable the identification of the household structure and I discuss it further in section 5.2. I use information on the variance of each spouse's log wage net of the variance of the economically-irrelevant transitory shock, the mean of the male's log wage, and the gender wage gap at the start of the life-cycle. I trim the support of wages 3.25 standard deviations above and below their applicable means; the grid points are then the mid-points of the equiprobable adjacent intervals covering the applicable support.

The support of the discrete state variables is fully accounted for in the solution. Spouses' education $educ_1$ and $educ_2$ and calendar time/age $t$ are the discrete states in both working and retirement periods of life. Women's unobserved costs of work $\theta_2$ and the presence of children and the age of the youngest among them $N$ are additional discrete state variables in the working period only.

At any given point of the state space, the solution in the working stage of life proceeds in two steps. In the first step I calculate the optimal consumption/future assets allocation conditional on every possible combination of the spouses' discrete time use choices in the market and household sectors; these choices were summarized in table 2 of section 3.3. The second step involves the calculation of the value of the household objective across all possible combinations of time use (given the corresponding optimal consumption/future assets allocation from the first step) and the selection of that time use that is associated with the highest value. The solution in the retirement stage of life only involves the unconditional calculation of the optimal consumption/future assets allocation as there are no discrete time use choices in that stage.

The calculation of the optimal consumption/future assets allocation in the first step above requires knowledge of the expected value of the stream of weighted sums of the spouses' utilities from the following period onwards. This expected future value is a function of today's information, the realization of the state in the following period, and future assets (a choice variable today). Expectations are taken with respect to three stochastic components in the future period; these are future family composition (presence and age of youngest child) and the spouses' future labor market productivity. The transition matrices for the random components, *i.e.* the probabilities of moving from one point in today's grid to another grid point tomorrow, are estimated directly from the data given the parametric assumptions of section 3.3. Note that there is no separate grid for the Pareto weight (like, for exampe, in Mazzocco et al., 2014) as this is a mechanical transformation of the gender wage gap through (11).

Once the expected future values are calculated, the conditionally optimal allocation in the first step is obtained by maximizing the weighted sum of the spouses' utilities today and the discounted expected future value. The maximization proceeds in a 'table look-up' fashion where

I evaluate the objective in proximate points on the applicable domain of all the relevant choice variables (consumption, future assets). I select the point that produces the maximum value and, using the immediately adjacent points, I generate a new finer grid that is concentrated therein. I reevaluate the objective function and I proceed likewise until I reach the optimal with an acceptable tolerance. This approach guarantees a global maximum if the conditional (on current time use) objective function is concave. Although the discrete time use choices in the future can -in principle- induce kinks in the expected future value, I overcome this thanks to sufficient uncertainty about the future state (uncertainty about family composition and labor market productivity).[31] Finally, I use linear interpolations to evaluate the expected future value function outside the asset grid points for which it is explicitly generated.

I simulate 10 replications of the life-cycle choices of 1279 households observed in the data (a total of 12790 simulations). The simulations are based on initial conditions for spouses' education and family composition (fertility) as observed in the data. I draw initial (log) wages for men and women assuming they are normally distributed around their beginning-of-life means. I replicate the empirical covariance between the two netting out the covariance of the measurement error (transitory shock). I produce random draws for the entire profile of permanent shocks and I use (10) to generate the life-cycle profiles of wages in such a way so as to replicate the empirical profiles of wages and the gender wage gap. I trim the draws of such shocks 2.1 times above and below their annual means so as to ensure that the support of simulated wages falls within the support of wages used in the solution of the model. I also draw profiles of fertility shocks given the initial conditions and the fertility transitions estimated from the data. I use the model's policy functions to infer the optimal choices associated with the profiles of wages and fertility. This involves the interpolation of the policy functions outside the grid points that are explicitly constructed for. I interpolate linearly over the asset dimension only after selecting the slice of the policy functions that is closer to the simulated wage and fertility at a given time/age. I start the simulations assuming households hold 0 initial assets.

The above solution and simulation routines are written in Julia.[32] With currently one education level only active for either spouse, they run in approximately 40 seconds in total on a 12-core Intel Xeon E5-2630 at a 2.3GHz clock speed.

## 5 Identification and Estimation

In this section I describe the steps I take to estimate the structural model presented in section 3. I follow a two-step procedure. In the first step I estimate the external blocks of the model, namely the wage process for each spouse, the fertility process, and the child care costs. I also estimate the intra-household bargaining power (*i.e.* the Pareto weight) during the first few years of the life-cycle. This is a reduced-form estimation whose role and necessity are further explained below. In the second step I estimate the parameters of the structural model using

[31] I check concavity of the conditional (on time use) objective function by verifying that the second derivative of the expected future value function is globally non-positive with respect to assets.

[32] Julia is a new high-performance programming language; documentation is available at http://julialang.org.

the method of simulated moments and utilizing results from the first step.

Section 5.1 discusses identification and estimation of the external blocks of the model; section 5.2 discusses identification and estimation of the model's structural parameters. This part requires information on the initial intra-household bargaining power, something which I discuss in section 5.3.

### 5.1 External Processes

**Wages** To construct the wage grids used in the solution of the model, I require for each gender the mean of (log) wage over the life-cycle as well as the wage variance net of the variation in measurement error (transitory shock). To integrate out future uncertainty, I require the transition rule for wages, *i.e.* the probability of moving from one point on the wage grid to another, which, in turn, requires knowledge of the covariance matrix of permanent shocks over the life-cycle. To obtain simulated wage profiles, I also need the covariance matrix of spouses' transitory shocks in the first period (used for initial conditions).

The mean and the variance of wages are calculated directly in the data. Results are omitted for brevity but a graphical illustration of the mean appears in figure A.1 in the appendix. Results regarding the transition matrix for wages are also omitted (but available upon request).

Given the parametrization of the wage process in (10) the second moments of shocks can be readily identified from various second moments of spouses' contemporaneous, lagged, and lead wages. Meghir and Pistaferri (2004) and previous studies show that $\mathbb{E}[\Delta \ln w_{jt}(\Delta \ln w_{jt-1} + \Delta \ln w_{jt} + \Delta \ln w_{jt+1})]$ identifies the variance of individual $j$'s permanent shock at $t$ and $\mathbb{E}[\Delta \ln w_{jt} \Delta \ln w_{jt+1}]$ identifies (minus) the variance of $j$'s transitory shock. In the first case the sum of consecutive wage growths removes the transitory elements and the remaining covariation between this and contemporaneous growth is due to the permanent shock. In the second case the covariation between immediately consecutive wage growths picks up the mean-reverting transitory shock. Similar moments between spouses identify the covariance between shocks.

To obtain estimates of the second moments of shocks I run a minimum distance estimation matching the empirical covariance matrix of (log) wages over the life-cycle to its theoretical counterpart. I use equal weights across all moments (identity matrix). Appendix C reports the estimation details and a full table of estimates. To reduce the effect of wage measurement error during the structural estimation, I input into the structural model a 5-point two-sided moving average of the covariance matrix of shocks instead of the original point-estimates; figure C.1 in the appendix provides a graphical illustration of the moving average of the variances of men's and women's permanent shocks.

After estimating the wage process, I draw 12790 random profiles for men's and women's wages. Figure 8 plots the mean of the simulated wages over time against the empirical ones. This simulation naturally performs well although there are some small discrepancies due to the use of the smoothed second moments of shocks rather than the actual ones.

Figure 8: Simulated against actual wages (means)

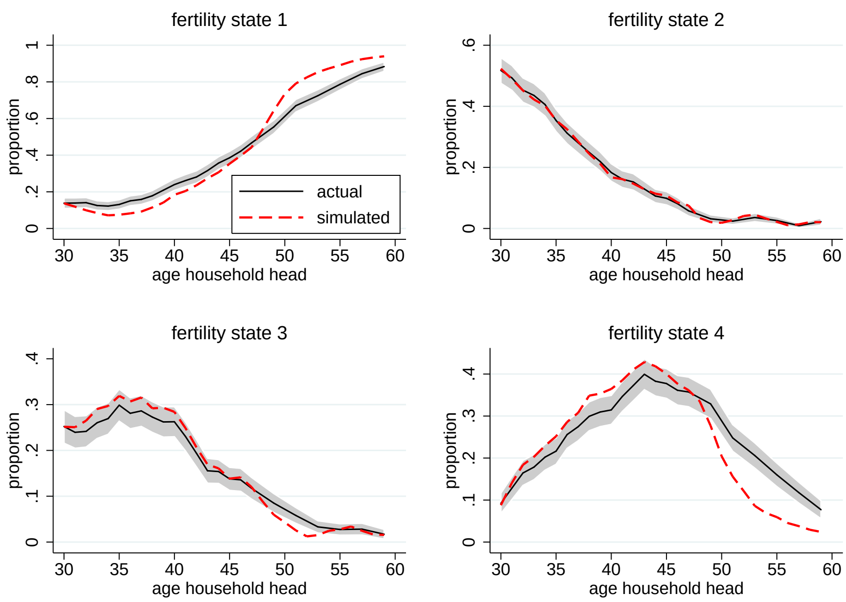

*Notes*: This figure plots the mean of simulated against actual wages over the life-cycle. Simulated wages are based on wage process (10). A 95% confidence interval around the data means appears in gray shade.

**Fertility** To integrate out future uncertainty while solving the model I require the transition rule for fertility, *i.e.* the probability that a family moves from one fertility state to another. These probabilities are obtained directly from the PSID data. I count the number of families reporting a given fertility status at time $t$ conditional on their fertility status at $t-1$. The is done separately by age $t$ of the life-cycle; the calculation only involves families that are observed in consecutive years and, therefore, uses a subset of the major PSID sample only.

To simulate the model I also require the categorical distribution of fertility at the beginning of the life-cycle. This is taken directly from the data. With this in hand and using the aforementioned transition rule I draw 12790 random fertility profiles for families over their life-cycle. I use those as an input to the estimation of the structural model. Figure 9 plots the proportion of families in each fertility state in the actual and the simulated data over the life-cycle. Again, this simulation performs quite well.

**Child care costs** The hourly rate of child care in function $CC_t(h_{2t}, N_t)$ is $cchrate_t$ and varies with *calendar* time. It is hard to find direct evidence on this. The PSID reports child care expenditure by households but any meaningful analysis of this measure would be incomplete for several reasons. First, child care expenditure does not necessarily convey information about the price of child care; as an example, child care expenditure may increase for a given household expenditure due to increased demand (say, parents work longer hours, mothers switch from part to full time work etc.) but the hourly price may well have stayed constant. Second, as already said, only a fraction of households report positive such costs due to, possibly, one parent being available at home or some other informal child care arrangements. It is not clear how these households compare to the general population and standard selectivity issues arise.

Figure 9: Proportion of families in various fertility states




*Notes*: This figure plots the proportion of families in each fertility state in the actual and the simulated data over the life-cycle. A 95% confidence interval around the data means appears in gray shade.

To get around these problems, I exploit the fact that child care is a labor intensive industry and I assume that its sole cost is the hourly wage child care workers are paid. A study that provides a systematic analysis of the wages of such workers is Blau (1992). Based on Current Population Survey data between 1976 and 1986, the study finds that child care workers are paid approximately 50% of the mean wage of all other female workers in that period.[33] This number is somehow confirmed by Whitebook et al. (1993) who argue that "child care teaching staff in 1992, as in 1988, continue to earn less than half as much as comparably educated women".

Given that the PSID data I use for estimation cover the years 1980-2009, I adopt the above percentage and I fix *cchrate* in year 1981, the mid-year between 1976 and 1986, at \$6.59 (expressed in 2010 dollars).[34] A question remains regarding *cchrate* prior to and after 1981. There is lack of consistent 'hard' evidence on the compensation of child care workers in the longer period. Blau (1992) finds a significant negative trend for wages in one child care sector (with trends in other sectors being insignificant); Whitebook et al. (1993, page 7) report that a growing segment of the child care workforce has seen a decline in their real wages between 1988

[33] Blau (1992) selects a nationally representative sample of around 4,000 child care givers (all of whom are women) and divides them in 3 broad child care sectors (private household care, non-household care, teachers). Table 3 therein reports the average hourly wage in each of the three sectors alongside the average hourly wage of a random sample of other female workers. Based on these numbers I calculate the weighted average child care wage across all sectors and divide it by the average wage of other female workers to obtain a ratio of $0.496 \approx 0.5$.

[34] $cchrate_{1981} = \$6.59$ is 50% of the average female wage in the PSID between 1976 and 1986.

and 1992. O'Neill and O'Connell (2001) report that real wages of child care have been flat or slightly decreasing over the 1977-1997 period. In light of this 'soft' evidence I calibrate *cchrate* at a constant \$6.59 (expressed in 2010 dollars) throughout the 1980-2009 period (this period coincides with the life-cycle of the cohort the paper focuses on). Whenever this rate is below the real federal minimum wage, I update *cchrate* to reflect this.[35] Essentially this pattern implies that the hourly wage of child care workers decreases relative to that of the general population (of both men and women) reflecting -what seems to be- a consensus that child care has steadily become less expensive in the last 3 decades.

Finally, I calculate the probability of a family facing positive child care costs by counting the number of families of a given fertility status that report non-zero such costs (the PSID collects information on child care expenditure after 1988). This is done separately by *calendar* time $t$. In years when child care expenditures are missing I use the probabilities estimated in the closest period when data are available. Table C.2 in the appendix reports the estimated probabilities as well as the calibrated hourly price of child care over time.

### 5.2 Structural Parameters

The model is estimated by the method of simulated moments conditional on pre-estimated processes for wages, fertility, child care costs, and a pre-estimated intra-family bargaining power (the Pareto weight) in the first few years of the family's life-cycle. The estimation of this is presented in section 5.3 after I discuss its role and necessity in the present section.

There is a number of parameters in the model that are fixed based on estimates available in the literature; these are summarized in table 3.

Table 3: Fixed parameters

| Parameter | Value | Reference |
|---|---|---|
| $r$ | 0.01 | Attanasio et al. (2008) |
| $\beta$ | 0.98 | Attanasio et al. (2008) |
| $\gamma$ | 1.5 | Attanasio et al. (2008) |
| $\phi$ | 0.8 | Lise and Yamada (2014) |
| $\pi$ | 0.5 | Lise and Yamada (2014) |
| $\varphi$ | 0.5 | Lise and Yamada (2014) |

The interest rate $r$ is set at 1% annually which is very close to the interest rate in Attanasio et al. (2008) and Blundell et al. (2013). The discount factor $\beta$ is set at 0.98 (exactly like in

[35] I update the hourly child care rate upwards to reflect a binding federal minimum wage in the following years: 1980-1987, 1992-1993, 1996-1999, and 2008-2009 (average upwards adjustment of \$0.69 and maximum upwards adjustment of \$2.27; all amounts are in \$2010). Historical data for the federal minimum wage rate is available by the US Department of Labor at www.dol.gov/whd/minwage/chart.htm.

the aforementioned papers) implying that families are slightly impatient as the corresponding discount rate is higher than the interest rate. The coefficient of relative risk aversion $\gamma$ is set at 1.5 as for example in Attanasio et al. (2008). In principle $\gamma$ can be estimated combining consumption data (from the Consumer Expenditure Survey for example). Finally I calibrate 3 parameters pertaining to the household production function: the output elasticity of public expenditures $\phi$ is set at 0.8, the share of men's housework time $\pi$ at 0.5, and the technology parameter $\varphi$ at 0.5. These numbers are consistent with estimates from Lise and Yamada (2014) of the household production function in a collective setting. The production parameters cannot be identified in the current setup because the output of household production is not observed and there are no observable factors that operate solely as production shifters.[36]

There is a total of 26 remaining parameters: 4 pertaining to male time use preferences ($\kappa_1^{(n)}$), 18 pertaining to female time use preferences including unobserved types ($\kappa_2^{(n)}$, $\theta_2$), and 4 parameters entering the Pareto weight function multiplying the gender wage gap ($\eta^{(n)}$). The estimation proceeds as follows. Given a set of parameter values I solve the life-cycle problem and simulate 12790 households (the solution and simulation details were discussed in section 4). I compute a number of time-use-related moments over the life-cycle using the simulated dataset (and I do exactly the same using the actual data). Finally, I calculate a distance metric between the simulated and actual moments and I repeat the process until the metric is minimized. Formally, the estimated parameters $\hat{\mathbf{\Theta}}$ solve the minimization problem

$$\hat{\mathbf{\Theta}} = \arg\min_{\mathbf{\Theta}} (\widetilde{\mathbf{M}}_n - \mathbf{M}_s(\mathbf{\Theta}))' \mathbf{V}_n (\widetilde{\mathbf{M}}_n - \mathbf{M}_s(\mathbf{\Theta}))$$

where $\widetilde{\mathbf{M}}_n$ is a $k \times 1$ vector of moments over $n$ observations from the real data, $\mathbf{M}_s(\mathbf{\Theta})$ is a similar vector of moments over $s$ simulations from the artificial data, and $\mathbf{V}_n$ is the inverse of the diagonal of the variance-covariance matrix of the data moments.[37] For the optimization I use `NLopt` (Johnson) and a number of algorithms therein;[38] I compute asymptotic standard errors according to Gourieroux et al. (1993) and Adda and Cooper (2003). In total I fit $k = 72$ moments; these are probabilities of married men and women engaging in various uses of their time. Specifically I fit the average rate of:

- 'low middle' household work for men,
- 'full time' market work *and* 'maximum' household work for women,
- 'full time' market work *and* 'high middle' household work for women,

[36] In a recent study by Cherchye et al. (2012) the household production parameters are identified through variation in exclusive production shifters (number and age of children) that leave individual preferences unchanged. By contrast, in this paper the age of the number and age of children affect individual tastes and the Pareto weight. Lise and Yamada (2014) identify the home production parameters parametrically using the marginal rates of substitution between leisure, household work and private consumption (all of which they observe in their data). Such marginal rates of substitution cannot be used in the current setup as time use is a discrete variable.

[37] I use the inverse diagonal of the variance-covariance matrix of the data moments in the light of evidence about the small-sample biases that arise in minimum distance estimations when using the optimal weighting matrix; see Altonji and Segal (1996).

[38] I use a combination of a local and a global derivative-free algorithm. The local is the `Subplex` algorithm implemented by Rowan (1990); the global is a fast controlled random search algorithm described in Kaelo and Ali (2006).

- 'part time' market work *and* 'maximum' household work for women,
- 'part time' market work *and* 'high middle' household work for women,
- no market work *and* 'maximum' household work for women.

These moments are calculated separately by family composition (fertility) and over 3 different stages of the working stage of the life-cycle (beginning - first 10 years, middle - subsequent 10 years, end - last 10 years).

Identification works as follows. Consider fixing intra-household bargaining power in the *first few years* of the family's life-cycle. Women's full-time (part-time) employment rates in the same few years identify individual preferences over full-time (part-time) market work ($k_2^{(n)}$, $\theta_2$). Moreover, men's and women's rates of household work, again in the same years, identify individual preferences over time into home production ($k_1^{(n)}$, $k_2^{(n)}$, $\theta_2$). These preferences may differ by family composition and variation in the above rates across fertility states precisely identifies such differences.

Given preferences and the initial intra-household bargaining power, I use the model to generate life-cycle profiles of time allocations for men and women. Then, I allow intra-family bargaining power to shift in *subsequent* years of the life-cycle in response to changes in the gender wage gap, so as to minimize the wedge between the model-generated and the empirical profiles of time allocations. This identifies $\eta^{(n)}$. The following two identifying assumptions are needed: (1) preferences conditional on family composition do not change with time; (2) changes in the gender wage gap over time are unexpected (i.e. entirely treated as shocks). This implies that individuals do not foresee the narrowing of the gender wage gap; the extent to which they do foresee it, their choices should reflect that right from the beginning of their life-cycle and subsequent changes in the gender gap should not induce further behavioral responses.

A question remains about how I fix intra-household bargaining power in the first few years of the family's life-cycle. This I discuss extensively in the following section. As a brief illustration here, I proxy decision power of a spouse by comparing his/her lifetime earnings to those of her/his partner if the spouses deviate to their outside option (divorce). I project each spouse's lifetime earnings should they get divorce given their observable characteristics and using information on divorcees from the PSID.[39] I construct the ratio of male lifetime earnings over the sum of male and female lifetime earnings in the hypothetical scenario of divorce and I treat this as the bargaining power of the male spouse in the household. I calculate the average ratio across households and I use it as the Pareto weight $\mu_1$ in the first 10 years of the family life-cycle in the model. Conditionally on it, I identify preferences and subsequent changes in bargaining power as described above.[40]

[39]The current paper is not the first one to use information on divrocees/singles in order to obtain identification in the context of the collective model. Among other papers, Browning et al. (2013) use singles to identify a version of equivalence scales and intra-household bargaining power.

[40]Identification of the parameters of the structural model obtains if the Pareto weight is fixed, alternatively, in *any* arbitrary year(s) in the family's life-cycle, not necessarily the first 10 ones.

## 5.3 Initial Pareto Weight

The projection of lifetime earnings if spouses get divorce requires information on the earnings of divorcees. I obtain this information from the minor PSID sample of singles whose discussion I postponed previously in data section 2.1. This sample consists of single men and women and mimics many of the selection criteria applied to the major PSID sample of married. Specifically, I restrict my attention to persons aged 25 to 65 from the core 'Survey Research Center' sample between years 1980 and 2009 irrespective of their cohort. I select individuals who report being divorced, who work in the labor market (as I require information on their earnings), and whose earnings do not fall below 1% or above 99% of the (gender- and time-specific) distribution.[41] The resulting dataset consists of 4561 divorced male-year and 7614 divorced female-year observations. Some key descriptive statistics are presented in table 4 and appendix A discusses this sample at a greater length. A few differences are apparent between married (table 1) and divorced individuals: the latter are on average less likely to have been to college, divorced men work and earn less than their married counterparts and divorced women earn roughly the same but work more than their married counterparts. A stark contrast is the number of kids each group has with those continuously married having on average more kids.

Table 4: Divorcees' descriptive statistics

| | Men | Women |
|---|---|---|
| % some college | 0.50 | 0.48 |
| Annual earnings | 49759 | 31762 |
| Annual work hours | 2133 | 1826 |
| Num. of kids | 0.26 | 0.94 |
| Observations* | 4561 | 7614 |

*Notes:* 'some college' is defined as any education above the $12^{\text{th}}$ grade. Annual earnings are expressed in 2010 dollars. *Observations refer to the number of person-year observations.

My first goal is to form an estimate of the expected flow of lifetime earnings (expected human wealth) of married men and women in the major PSID sample should they get divorce. Specifically, for each married individual and each time period I want to calculate

$$\text{Human Wealth if Divorced}_{jt} = E_t(Y^d_{jt}) + \frac{E_t(Y^d_{jt+1})}{1+\rho} + \frac{E_t(Y^d_{jt+2})}{(1+\rho)^2} + \ldots$$

where $Y^d_{jt}$ is $j$'s earnings as divorcee at time $t$. The main difficulty is to estimate expected future earnings and for that I make use of the minor PSID sample of divorcees. Following Blundell et al. (2012) and Blundell et al. (2015) on the estimation of expected lifetime earnings, I pool earnings of divorcees for all years and ages. I do so separately by gender. I regress their earnings

[41] This sample includes those separated alongside those formally divorced.

$Y$ on two types of individual attributes: attributes that are fixed over time (race and education) and attributes that change with time in a deterministic way (a quadratic polynomial in age and its interactions with race and education). Specifically I regress

$$Y_{kt} = \boldsymbol{\chi}_k' \mathbf{a}_k + \boldsymbol{\psi}_{kt}' \mathbf{b}_k + \epsilon_{kt}, \qquad k = \{1, 2\} \tag{14}$$

where $\boldsymbol{\chi}_k$ points to the first set of attributes and $\boldsymbol{\psi}_{kt}$ to the second; subscript $_k$ points to the gender of the divorcee. $\mathbf{a}_k$ and $\mathbf{b}_k$ are linear regression parameters to be estimated. To obtain a time-$t$ estimate of future earnings at $t+s$ should *married* individual $j$ get divorce, I use estimates from (14) along with information known at $t$ about the concerned person $j$. Specifically I construct $\widehat{Y}_{jt+s} = \boldsymbol{\chi}_j' \widehat{\mathbf{a}}_j + \boldsymbol{\psi}_{jt+s}' \widehat{\mathbf{b}}_j$, $j = \{1, 2\}$, and I use it in place of $E_t(Y_{jt+s}^d)$. To generate the sequence of expected future earnings I assume that individuals work until age 65 and that $(1+\rho)^{-1} = \beta$.

My final goal is to generate a proxy for intra-family bargaining power at $t$. The spouses' projected human wealth serves as an estimate of the value of their outside option in the event of a divorce (and the outside options determine, in turn, bargaining power within the household). I employ a simple form to represent the mapping from the approximate value of the outside option into bargaining power. Specifically, intra-family bargaining power of the *male* spouse at time $t$ ($\mu_{1t}$) is given by

$$\text{Human Wealth if Divorced}_{1t} / \big(\text{Human Wealth if Divorced}_{1t} + \text{Human Wealth if Divorced}_{2t}\big)$$

where subscript $_1$ points to the male spouse and subscript $_2$ to the female. This mapping has a few desirable properties such as it is bounded in the unit interval, it is increasing in the value of the man's human wealth and decreasing in the value of the women's human wealth.[42]

Before presenting the results, a discussion is warranted of the assumptions needed to make these projections work. The story develops intuitively as follows. At any given time, the spouses observe perfectly how divorced people of various ages and characteristics fare in life and form expectations about how they *would* fare, *should* they get divorce themselves. In other words, the spouses have perfect knowledge of equation (14) at any time $t$ and they use it to form expectations about themselves, assuming that the distribution of errors $\epsilon_{kt}$ is the same among married and divorced persons of the same gender.

The results from regressions (14) appear in table C.3 in the appendix. These results use information (earnings, individual attributes) on divorcees of all ages in calendar years 1980-1989. These years coincide with the first 10 years of the married people's life-cycle, given the restriction of my estimation sample to one cohort only. Table 5 reports basic descriptive statistics for the derived intra-family bargaining power of married males in the major PSID sample in years 1980 to 1989; figure 10 is a graphical representation of its cross-sectional distribution.

[42]The way intra-family bargaining power is constructed favors mechanically the youngest spouse in the household (as for such spouse the sequence of earnings forming human wealth as divorcee would be longer). This can be a problem especially when the age difference between spouses is large. To remove this undesirable feature I replace human wealth as divorcee by an equivalent annual annuity; specifically I divide Human Wealth if Divorced$_{jt}$ by $\rho^{-1} \times (1 - (1+\rho)^{-T_j})$ where $\rho$ is the discount rate and $T_j$ is the remaining years of individual $j$ until age 65.

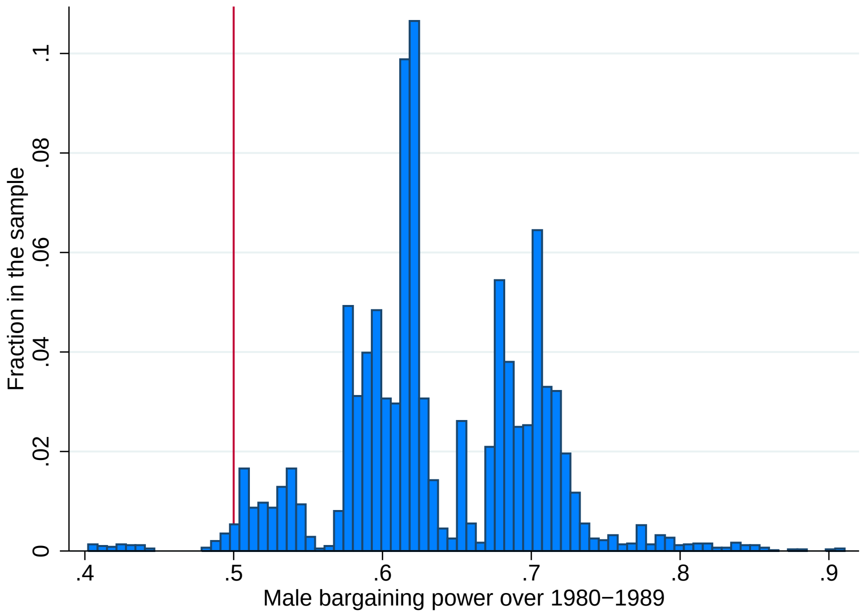
Table 5: Derived intra-family bargaining power of men

| | mean | median | std.dev. | minimum | maximum | N |
|---|---|---|---|---|---|---|
| Male decision power | 0.6358 | 0.6208 | 0.0673 | 0.4022 | 0.9106 | 5970 |

*Notes:* This table reports descriptive statistics for the derived intra-family bargaining power of married men in the major PSID sample in years 1980 to 1989. 'N' refers to the number of family-year observations.

Men hold on average 63.58% of intra-family bargaining power in years 1980-1989; the median is slightly lower at 62.08%.[43] They can extract approximately as much as 91% of the power but there are also households in which women are relatively stronger (*i.e.* for which men's bargaining power is less than 50%). Appendix table C.4 reports how the derived intra-family bargaining power correlates with each spouse's education, race, and age.

Figure 10: Histogram of derived intra-family bargaining power of men




*Notes*: This figure is a graphical representation of the distribution of the derived intra-family bargaining power of married men in the major PSID sample in years 1980 to 1989. A reference line is plotted at 0.5 (equal bargaining powers between spouses).

In light of this evidence, I fix men's intra-family bargaining power in the first 10 years of the life-cycle at 0.6208 (the median value from table 5). Following the rationale deployed in the end of section 5.2 I can then identify men's and women's time-use preferences as well as subsequent changes in intra-family bargaining power in response to changes in the gender wage gap. A

[43] Voena (2015) estimates the male Pareto weight at 0.7 but she uses earlier years of the PSID.

caveat is worth noting here. The estimated structural parameters are conditional on the initial bargaining power in the family. It remains an open question how sensitive they are to a different value of this parameter. Even if a different value was chosen however, the sign of the parameters in the Pareto weight function should remain unchanged. And this is still important as this sign is indicative of the direction of the effect the narrowing gender wage gap has on bargaining power within the family.

# 6 Results

This section presents the estimates of the parameters of the structural model and displays its overall fit. Table 6 reports the estimates for the parameters of time-use preferences, namely the determinants of the $g_j(\cdot)$ functions in (8). Panel A reports women's labor supply parameters and panel B reports men's and women's household work parameters.

Table 6: Estimates of the parameters of time use preferences

| | | **A. Market work: Women** | | | |
|---|---|---|---|---|---|
| | | (I) full-time work women | | (II) part-time work women | |
| | | value | st.error | value | st.error |
| (1) | No children | 0.174 | (0.0023) | 0.143 | (0.0024) |
| (2) | Youngest child: up to 5 | 0.262 | (0.0025) | 0.185 | (0.0024) |
| (3) | Youngest child: 5-10 | 0.227 | (0.0029) | 0.183 | (0.0015) |
| (4) | Youngest child: 10+ | 0.222 | (0.0024) | 0.158 | (0.0015) |
| *Unobserved types:* | | | | | |
| (5) | Type I: utility cost of work | 0.131 | (0.0023) | 0.020 | (0.0022) |
| (6) | Type II: utility cost of work | -0.321 | (0.0099) | -0.023 | (0.0023) |
| | | **B. Household work: Men and Women** | | | |
| | | (I) men | | (II) women | |
| | | value | st.error | value | st.error |
| (1) | No children | 0.0600 | (0.0004) | 0.109 | (0.0004) |
| (2) | Youngest child: up to 5 | 0.0613 | (0.0000) | 0.106 | (0.0004) |
| (3) | Youngest child: 5-10 | 0.0608 | (0.0001) | 0.097 | (0.0004) |
| (4) | Youngest child: 10+ | 0.0620 | (0.0007) | 0.104 | (0.0003) |
| *Unobserved types:* | | | | | |
| (5) | Type I: utility cost of work | | | 0.012 | (0.0008) |
| (6) | Type II: utility cost of work | | | -0.004 | (0.0003) |

*Notes:* This table reports estimates of the parameters of time use preferences. Asymptotic standard errors are reported in parentheses.

Reading through table 6 note that *within* a type of time use, for example within 'full-time work women' in panel A(I), the parameters corresponding to different fertility types (rows 1-4) are mutually exclusive inside $g_j(\cdot)$. Notice also that the parameters *across* types of female market work in panel A do not increment but they too are mutually exclusive. Finally, note that positive and larger values of these parameters imply that work, in the market or the household in panel B, induces greater disutility as utility in (8) is negative due to $\gamma$ being set to 1.5. In this case leisure can be seen as a complement good of consumption.

The parameters of female full-time market work (panel A(I), rows 1-4) turn out positive and with a good spread across fertility regimes. Women with very young kids (up to age 5) suffer the greatest disutility from work whereas childless women the least. This evidence is in line with Blundell et al. (2013) who use a similar preference specification for UK women. The parameters of female part-time market work (panel A(II), rows 1-4) are everywhere lower than those of full-time work implying that the former causes less disutility than the latter. Again, women with young kids (up to age 10) suffer the greatest disutility from part-time work compared to their counterparts with older or no children. Interestingly, whether childless women work full- or part-time in the market makes little difference in terms of the disutility these two types of market work induce.

Rows (5) and (6) report the estimates for women's unobserved random costs of work $\theta_2$ as they materialize in the case of market work. Recall that $\theta_2$ is drawn from a two-point discrete distribution separately for each type of market work (full-time, part-time) and note that these costs *increment* to the time-use parameters in rows 1-4. Row (5) refers to the 'low type' of market work (*i.e.* the type who dislikes work the most) and row (6) refers to the 'high type' (*i.e.* the type who favors work). The probability attached to each type is such that the average of $\theta_2$ per type of market work is zero over the population. Taken together with rows 1-4 in panel A(I), these estimates suggest that for approximately 25% of women in the sample function $g_2(\cdot)$ is negative rendering consumption and leisure substitutes. These may be highly educated women for whom the costs of *not* working are significantly higher than the utility benefits and who are, therefore, highly attached to the labor market.

The parameters of male and female time into home production (panel B, rows 1-4) also turn out positive. For women these estimates are everywhere lower than the parameters of part-time market work implying that 'maximum' household work is relatively more attractive to them despite the higher amount of hours it entails (see table 2 and text thereafter). Comparing men's and women's household work parameters it seems at first that men's disutility from this type of work is less than women's (given the lower estimates for men's household work parameters). However, the amount of time each gender actually devotes to household work is very different. Women in the model devote more than 3 times as much time as men and this is likely to be driving the big wedge between their preferences.

Rows (5) and (6) in panel B report the estimates for women's unobserved random costs of work $\theta_2$ as they materialize in the case of work in the household. $\theta_2$ also increments to the time-use parameters in rows 1-4, panel B(II). There are no unobserved costs for men's household work because these cannot be identified when men have one binary time-use choice only. The results suggest that there is not much heterogeneity in women's household work preferences; indeed shutting down such heterogeneity does not affect the model fit or the other estimates too much.

Table 7 reports the estimates for the parameters of intra-household bargaining power, namely the parameters $\eta^{(n)}$ in the Pareto weight function (11). Note again that, as these are parameters corresponding to different fertility types (rows 1-4), they are mutually exclusive in (11). Positive and larger values of these parameters imply that a narrower gender wage gap in a given year reduces the argument of the logistic function in (11), lowers men's bargaining power in the household, and increases women's by an equal amount.

Table 7: Estimates of the parameters of intra-household bargaining power

| | | parameter $\eta^{(n)}$ | |
|---|---|---|---|
| | | value | st.error |
| (1) | No children | 0.0490 | (0.0033) |
| (2) | Youngest child: up to 5 | -0.0171 | (0.0069) |
| (3) | Youngest child: 5-10 | 0.1143 | (0.0187) |
| (4) | Youngest child: 10+ | -0.0538 | (0.0046) |

*Notes:* This table reports estimates of the parameters of intra-household bargaining power. Asymptotic standard errors are reported in parentheses.

The magnitudes of these parameters are small implying that the overall effect of relative wages on intra-family bargaining power is modest.[44] Delaying a discussion of the implications of intra-family bargaining for married people's time use until section 7, these estimates suggest that shifts in intra-family bargaining power do occur over the lifetime but to a small extent. Partly responsible for the small magnitudes is the restriction of the sample to stable households (*i.e.* those that do not actually experience divorce).[45] Stable households are those for whom re-allocation should take place less frequently as opposed to the entire population, pushing the bargaining effects of relative wages (or of any other factor affecting powers) to zero. Another reason behind the small magnitudes is that the "aggregate" moments of time use that I target *separately* for men and women may not convey adequate information to uncover shifts in intra-family power. Possibly, targeting moments of joint time use in the household (for example, the proportion of men supplying 'low middle' hours to household production when their wives work full-time in the market etc.) would be more appropriate in the present context.

[44] Using the estimates in table 7 I calculate that the modal woman in the data (modal in terms of fertility) sees her Pareto weight improve gradually by up to 1.3% between 1980 and 2009. For this calculation I use the parametrization of the Pareto weight in (11) and I assume wages in the household change intertemporally according to the gender wage gap in figure 6. Note that the magnitude of this improvement, unlike its direction, is not of practical interest as it is subject to the initial Pareto weight at the start of the life-cycle as well as the specific cardinal preferences employed herein.

[45] The restriction of the estimation sample to stable households is not uncommon in the literature of dynamic household decision making. Lise and Yamada (2014) also select a sample of families that do not experience divorce. This restriction is unavoidable in their paper as they estimate a dynamic collective model at the steady state using the first order conditions. In my paper this restriction is not unavoidable thanks to the use of a dynamic programming solution method and in future research I plan to relax it.

The overall model fit is good. Table 8 reports selected moments of time use in the data alongside their counterparts from the model simulations. These moments are aggregates of the full set of fertility- and life-cycle period- specific moments that are targeted in the estimation. The full set of targeted moments in the data, alongside their model counterparts, appears in tables D.1-D.2 in the appendix.

Table 8: Proportions in sample by type of time use - aggregates of targeted moments

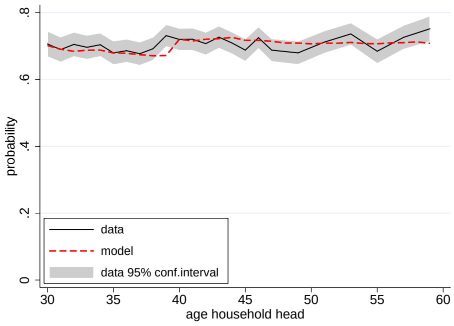
| | Data | Model |
|---|---|---|
| **A. Men** | | |
| low middle household work | 0.705 | 0.703 |
| low household work | 0.295 | 0.297 |
| **B. Women** | | |
| *FT market work and* | | |
| maximum household work | 0.295 | 0.318 |
| high middle household work | 0.352 | 0.370 |
| *PT market work and* | | |
| maximum household work | 0.121 | 0.098 |
| high middle household work | 0.039 | 0.037 |
| *No market work and* | | |
| maximum household work | 0.165 | 0.148 |
| high middle household work | 0.029 | 0.029 |

*Notes:* This table reports the proportion of individuals in the actual and simulated samples across different combinations of time-use. The definitions of 'maximum', 'high middle', 'low middle', and 'low' housework refer to different amounts of time put into household work; see table 2 for details.

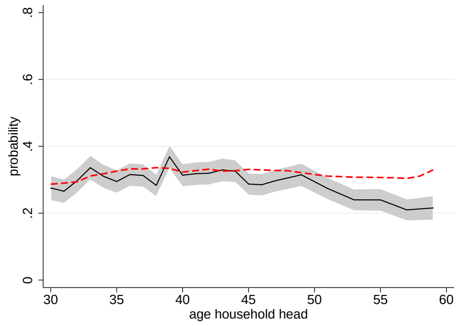
Figure 11 illustrates the life-cycle model fit across types of time use for men and women (aggregated over different fertility types). The most noticeable discrepancy between data and model occurs for women who work full-time in the market and also supply 'maximum' hours to the household sector (figure 11b). This is because the model overestimates the proportion of women who work full-time in the market during the last few years of their working life. This discrepancy is mirrored for women who do not work in the market but supply 'maximum' hours to the household (figure 11f). There is currently no mechanism in the model inducing early retirement, such as a compulsory receipt of social security benefits that crowds out labor earnings (French, 2005), and allowing for such a mechanism is likely to rectify this.

Finally, I check a big number of non-targeted dynamic moments of time-use as a means of over-identification. These are transition probabilities, namely probabilities that an individual engages in a given time-use activity conditional on what they or their partner did one or two period in the past. These appear in figure D.1 in appendix D.

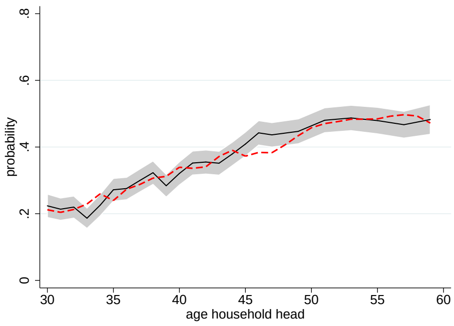
Figure 11: Model fit



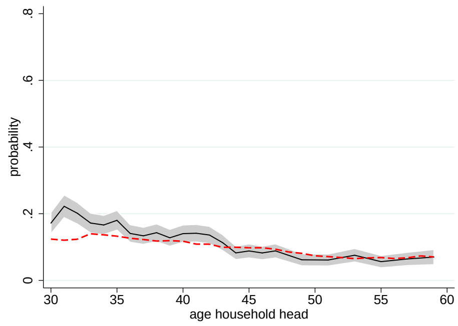

(a) Men: 'low middle' household work



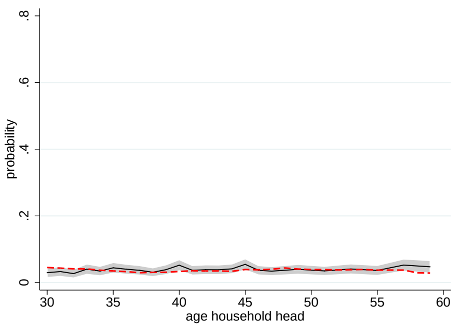

(b) Women: full-time market work & 'max' household work



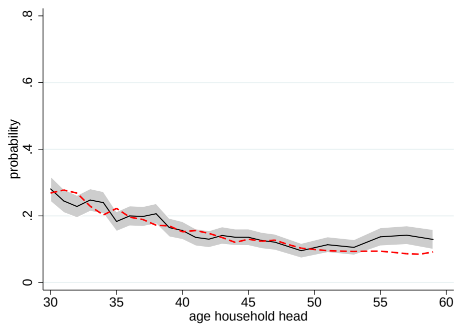

(c) Women: full-time market work & 'high middle' household work




(d) Women: part-time market work & 'max' household work




(e) Women: part-time market work & 'high middle' household work




(f) Women: no market work & 'max' household work

*Notes*: This figure plots the model fit across types of time use for men and women aggregated over different fertility types. A 95% confidence interval around the data means appears in gray shade. The definitions of 'maximum', 'high middle', and 'low middle' refer to different amounts of time put into household work; see table 2 for details.

# 7 Implications of Model for Behavior

This section discusses the implications of a narrowing gender wage gap for married people's time allocations. It does so by illustrating the various (income, substitution, bargaining) effects the gender wage gap induces on their behavior.

Changes in the gender wage gap (and therefore changes in spousal wages) induce a number of effects on family behavior:

1. A higher female wage is likely to render female labor supply relatively more attractive (especially so for women with young children for whom child care costs may have previously been prohibitive). This is the standard sum of own income and substitution effects operating on labor supply with the latter outperforming the former. A higher male wage may render female labor supply less attractive due to a standard income or added worker effect (Lundberg, 1985).
2. Conditional on labor supply, increased family wages imply higher public expenditure which, depending on the household production technology, may crowd out or boost spousal work inside the household. Whether this effect is symmetric across spouses or not depends on the nature of complementarity between $\tau_1$ and $\tau_2$ in the production function.[46]
3. Additionally, changes in relative wages inside the household can alter the task specialization the spouses engage in. For example, a spouse with a higher wage may engage fully in the labor market and her spouse may increase his involvement in home production.
4. Finally, changes in relative wages can alter spouses' valuation of the outside options, shift intra-family bargaining powers, and induce bargaining effects across all choices made by the individuals.

In the data, the average within-family gender wage gap, which is what I feed into the model through the budget constraint (3) and the parametrization of intra-family bargaining power (11), narrows down approximately by approximately 10% over the family lifetime (illustrated in graph 6b). This pattern for the within-family gender wage gap induces effects that can be categorized in two broad groups: income and substitution effects on family time allocations (corresponding to points 1-3 on the above list) and bargaining effects (corresponding to point 4 above).

My aim is to separate and quantify the two types of effects. I proceed as follows. Using the preference estimates from section 6 and the observed wage and fertility dynamics over the family life-cycle, I simulate 12790 random households *prohibiting* changes in intra-family bargaining power in response to the gender wage gap. I compare the resulting life-cycle family time allocations to the original ones (the original model fit); any difference between the two identifies the bargaining effects of the narrowing gender wage gap.

Subsequently, I simulate a new set of 12790 random households assuming men's and women's wages grow *similarly* over the entire family life-cycle and, therefore, relative wages remain unchanged throughout.[47] I compare the resulting life-cycle family time allocations to the orig-

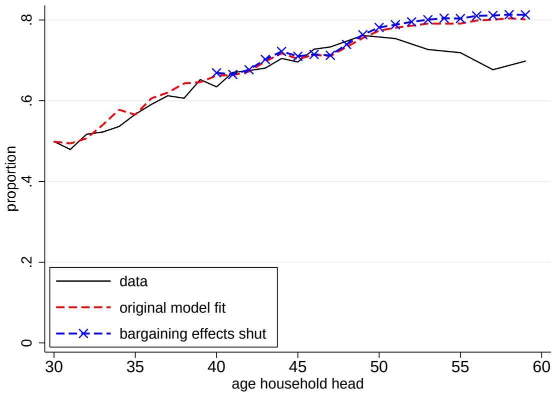
[46] An inspection of the production function (9) yields $\frac{d\tau_{jt}}{dK_t} < 0$ and $\frac{d\tau_{2t}}{d\tau_{1t}} < 0$ for $\phi \in (0, 1)$ and $\pi_j > 0$. Hence the inputs to household production are all substitutes.

[47] Specifically I assume that women's wages grow according to men's, relatively slower, wage growth. The within-family gender wage gap remains on average constant at its beginning of life level.

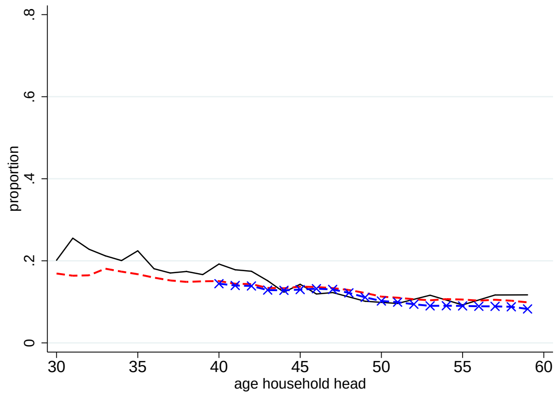
inal ones (the original model fit); the difference between the two identifies the sum of income/substitution *and* bargaining effects of the narrowing gender wage gap. Netting out the bargaining effects (identified above) isolates the income and substitution effects.

The results of the first application suggest that wages induce small bargaining effects on women's labor supply but sizeable effects on men's and women's household work. Figure 12 depicts life-cycle profiles of family time allocations when intra-family bargaining power is not allowed to respond to the gender wage gap (blue dashed lines through the X's). It superimposes them over the original model-generated profiles (red dashed lines). Table 9 quantifies the differences: it reports average changes in rates of family time-use when bargaining effects are shut, and it does so over various age bands in the life-cycle. The original model's baseline rates (in %) appear in square brackets on the side.

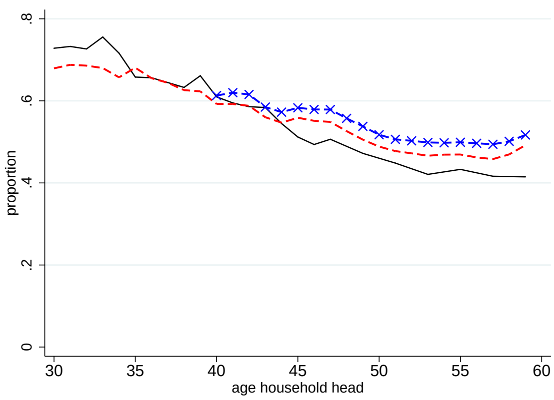
Figure 12: Bargaining effects of the narrowing gender wage gap



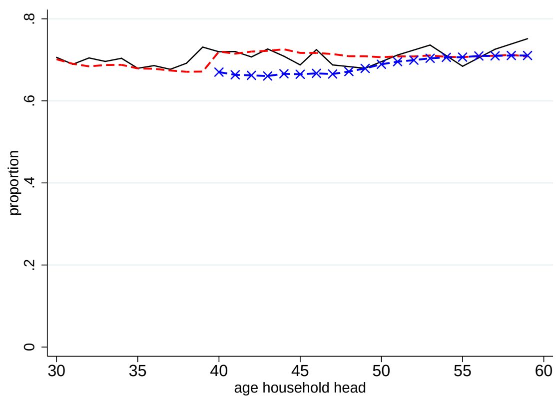

(a) Women: full-time market work




(b) Women: part-time market work




(c) Women: 'maximum' household work




(d) Men: 'low middle' household work

*Notes*: This figure plots life-cycle profiles of family time allocations when intra-family bargaining power is not allowed to respond to the gender wage gap (bargaining effects shut; blue dashed line through the X's). The solid line depicts the original data and the red dashed line depicts the original model fit when bargaining effects are allowed. The definitions of 'maximum' or 'low middle' refer to different amounts of time put into household work; see table 2 for details.

Table 9: Average changes in rates of time-use when bargaining effects are shut: by age band

| | (1) women full time work | | (2) women part time work | | (3) women 'max' home work | | (4) men 'low middle' home work | |
|---|---|---|---|---|---|---|---|---|
| ages 40-49 | +0.46 | [70.3%] | -0.58 | [13.6%] | +2.72 | [55.7%] | -4.98 | [71.7%] |
| ages 50-59 | +1.03 | [79.2%] | -1.40 | [10.5%] | +3.06 | [47.2%] | -0.47 | [70.9%] |

*Notes:* The table reports average changes in rates of family time-use when bargaining effects are shut. The original model's baseline rates (in %) appear in square brackets on the side. There are no changes in the first 10 years of the life-cycle because intra-family bargaining power in the original model is anyway kept constant in those years (section 5.3). The definitions of 'maximum' or 'low middle' refer to different amounts of time put into household work; see table 2 for details.

Prohibiting changes in intra-family bargaining power implies that women's Pareto weight is not allowed to improve alongside the narrowing gender wage gap. This induces up to 3.06% more women into working 'maximum' hours in the household and up to 4.98% fewer men into supplying 'low middle'. When compared to the baseline rates in the original model, the first figure corresponds to an increase in women's rate by 6.48% and a decrease in men's by 6.95%.[48] Up to 1.03% more women are also induced into full-time market work.

The idea behind these numbers is the following: the relatively more powerful spouse can afford to work less in the market and the household, and thus enjoy more leisure. The case above is essentially the opposite story: prohibiting changes in intra-family bargaining power keeps women's power down and results in women working more in both sectors.

The results of the second application suggest that keeping the average within-family gender wage gap constant at its beginning-of-life level has, through its income/substiotution effects, important implications for women's labor supply and household work but not for men's household work. Figure 13 presents life-cycle profiles of family time allocations when men's and women's wages are made to grow according to men's observed wage growth over time and, as a result, the average within-family gender wage gap remains unchanged (orange lines through the triangles). Table 10 reports average changes in rates of family time-use when the gender wage gap remains constant at its beginning-of-life level. The table reports exclusively the income/substitution effects of (maintaining) the gender wage gap, *i.e.* after accounting for the bargaining effects of table 9. Model baseline rates (in %), after factoring in the bargaining effects, appear in square brackets on the side.[49]

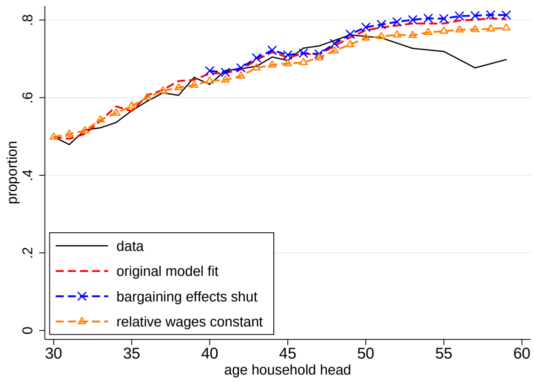
The results in this case suggest that up to 3.39% fewer women work full-time in the market. Only some of them work part-time and the majority does not participate in the market at all.

[48] The drop in men's rate of 'low middle' household hours is mitigated as time goes by possibly due to women supplying more housework or the family affording higher public expenditures.

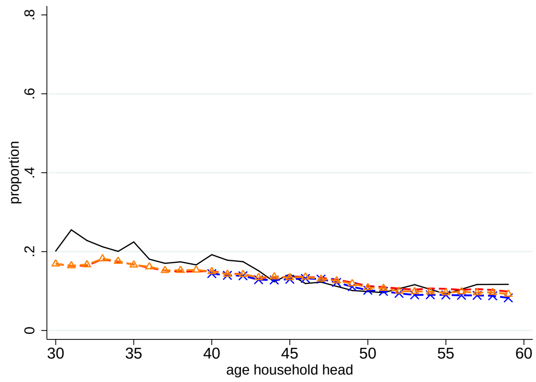
[49] The figures presented inside the square brackets are the model's original baseline rates adding the bargaining effects of table 9. When the gender wage gap narrows down, it induces the aforementioned income/substitution and bargaining effects. Removing the narrowing of the gender gap, as this application suggests, removes both types of effects. Table 10 reports exclusively the former as the latter are already reported in table 9.

'Maximum' household work attracts up to 3.55% more women whereas men's housework is less responsive: up to 0.52% fewer men supply 'low-middle' housework hours.

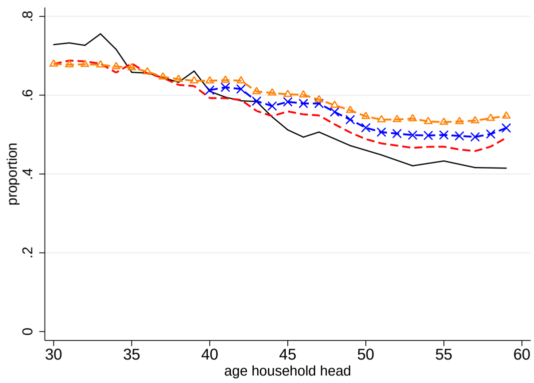
Figure 13: Prohibiting changes in the gender wage gap



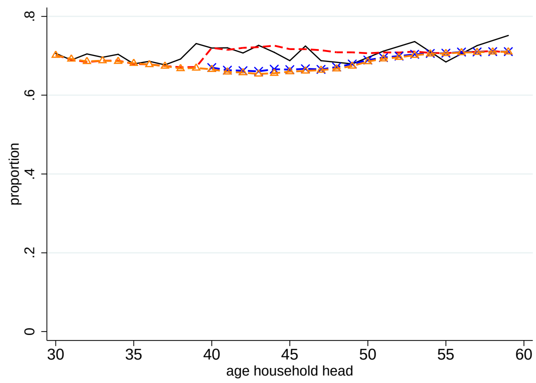

(a) Women: full-time market work




(b) Women: part-time market work




(c) Women: 'maximum' household work




(d) Men: 'low middle' household work

*Notes*: This figure depicts life-cycle profiles of family time allocations when men's and women's wages grow according to men's observed wage growth over time and the average within-family gender wage gap remains unchanged (orange lines through the triangles). The solid line depicts the original data and the red dashed line depicts the original model fit. The blue dashed line through the `X`'s depicts life-cycle profiles when the gender wage gap narrows down but intra-family bargaining power is not allowed to respond to it. The definitions of 'maximum' or 'low middle' refer to different amounts of time put into household work; see table 2 for details.

Overall, prohibiting the gender wage gap from narrowing does not alter the overall shape of the life-cycle profiles of family time allocations. The 10% closing of the within-family gender wage gap appears important for women's household work as it accounts for approximately 1/2 of its decline over the life-cycle. It is not as important for female labor supply. Women's rate of full-time work is a few percents (up to 3.5%) lower when the gap remains constant but the profile retains its steep incline over the life-cycle. This suggests that the fertility dynamics and child care costs spouses face over their lifetime are jointly more important for female labor supply than the narrowing gender wage gap. Finally, the narrowing gap is important for men's household work, at least in the middle years of life, primarily through its bargaining effects.

Table 10: Average changes in rates of time-use when the gender wage gap remains constant: by age band; income/substitution effects only

| | (1) women full time work | | (2) women part time work | | (3) women 'max' home work | | (4) men 'low middle' home work | |
|---|---|---|---|---|---|---|---|---|
| ages 30-39 | -0.19 | [57.0%] | +0.16 | [16.3%] | +0.19 | [66.2%] | -0.03 | [68.3%] |
| ages 40-49 | -2.30 | [70.8%] | +0.48 | [13.0%] | +2.13 | [58.4%] | -0.52 | [66.7%] |
| ages 50-59 | -3.39 | [80.2%] | +0.78 | [9.2%] | +3.55 | [50.3%] | -0.17 | [70.4%] |

*Notes:* The table reports average changes in rates of family time-use when the average within-family gender wage gap remains constant at its beginning-of-life level. The table reports exclusively the income/substitution effects of (maintaining) the gender wage gap, i.e. after accounting for the bargaining effects of table 9. The figures presented inside the square brackets are the model's original baseline rates adding the bargaining effects of table 9. When the gender wage gap narrows down, it induces income/substitution and bargaining effects. Removing the narrowing of the gender gap, as this application suggests, removes both effects. This table reports exclusively the income/substitution effects after accounting for the bargaining effects reported in table 9. The definitions of 'maximum' or 'low middle' refer to different amounts of time put into household work; see table 2.

## 8 Equal Pay between Genders

In this section I investigate the implications that establishing equal pay between married men and women has for their use of time. This is a realistic counterfactual that policy and business leaders have pledged to implement.

In the United States the gender wage gap has been criticized on grounds of discrimination against women. During a weekly radio address on April 12, 2014, President Obama called the lack of equal pay between men and women in the same profession and with the same education "an embarrassment".[50] In the same month, President Obama took executive action requiring federal contractors to publish data on their employees' pay by race and gender whereas earlier, in February 2010, he announced the establishment of a National Equal Pay Enforcement Task. He has also signed into bill the related Paycheck Fairness Act.[51]

Using the life-cycle collective model of section 3 and the parameter estimates in section 6, I investigate the implications of equal pay through three counterfactual experiments. The experiments have a similar 'flavor' in that across all three of them I shift the mean of the distribution of female wages towards the mean of men's wage distribution, leaving the latter unchanged; the timing that this shift occurs in married people's lifetime differs across experiments.[52]

[50] The full speech of President Obama is available at www.whitehouse.gov/blog/2014/04/12/weekly-address-ensuring-equal-pay-equal-work.

[51] Detailed information is available at www.whitehouse.gov/issues/equal-pay. Other countries too have followed, or led, the campaign for gender wage equality. For example, Prime Minister Cameron in the UK declared on July 14, 2015 his intention to "end the gender pay gap in a generation" (www.gov.uk/government/news/prime-minister-my-one-nation-government-will-close-the-gender-pay-gap).

[52] So far I have estimated the model with one only schooling level active for each spouse. In a more detailed estimation across multiple schooling levels, the counterfactual experiments would involve equalizing the *mapping* from education to wages between the two genders.

In the first counterfactual, I make women earn on average the same wage as men over their entire life-cycle. Specifically, I shift women's mean wage up so that $\overline{W}_{2t} = \overline{W}_{1t}$ at all times (where $\overline{W}_{1t}$ is the mean of men's wages at $t$). In the second counterfactual, men and women start off their working lives with gender-specific wages at the observed start-of-life levels; subsequently, female wages grow rapidly and catch up with men's during the *last* 1/3 of their life-cycle (*i.e.* in year 21 out of 30). Once they catch up, men's and women's wages grow in parallel. Finally, the third experiment is a repetition of the second one but now women catch up with men just after the *first* 1/3 of the life-cycle (*i.e.* in year 11 out of 30; after that spouses earn the same on average wages until the end of their working lives). Across all counterfactuals spouses are faced with the observed fertility dynamics and child care costs as well as with the actual gender-specific variance in their wages. Table 11 summarizes the details of the three counterfactual experiments.

Table 11: Equal pay counterfactuals

| | When do women catch up with men? | Bargaining effects allowed? |
|---|---|---|
| #1 | equal average wages throughout life-cycle | no; gender wage gap constant |
| #2 | in year 21 of 30 | yes |
| #3 | in year 11 of 30 | yes |

Equal pay between genders has important implications for men's and women's time allocation. The results across all experiments are illustrated numerically in table 12 and visually in figure 14. Figure 14 plots life-cycle profiles of time-use; across all graphs therein the black solid lines depict the real data whereas the red dashed lines depict the original model fit. Counterfactual #1 is depicted by the blue lines through the crosses, counterfactual #2 by the orange lines through the triangles, and counterfactual #3 by the purple lines through the hollow circles.

In a nutshell, equal pay induces women's entry in the labor market even during the child bearing years. It increases full-time market work rate by as much as 32% in certain years and it decreases part-time work by smaller amounts. It affects spousal time into home production, lowering women's rate of 'maximum' hours by 22.1% and increasing men's by a small 3.2% in certain years.

The most sizeable changes in married people's time use are seen in counterfactual #1 where men's and women's wages are on average equal throughout the life-cycle. Equal pay makes women 18.36 percentage points -or by 32% relative to the baseline- more likely to be in full-time market work at ages 30-39. Compared to a model baseline rate of full-time work at 57% in those ages,[53] equal pay implies that up to 75.36% of women would work full-time. The

[53]The 'model baseline rates' refer to the proportions observed in the originally simulated data after fitting the model to the PSID.

effect is even more striking if one looks at specific early ages: at 30, for example, equal pay renders women 21.3 percentage points more likely to work full-time. Equal pay makes women of ages 30-39 up to 2.28 percentage points *less* likely to work part-time; therefore the big increase in full-time work comes from women entering the labor market when they previously did not participate. Interestingly, equal pay induces women to enter the market and work full-time even though they would generally be in their child bearing years. Their higher earnings more than cover the increased costs of child care and also allow an increase in family public expenditures.

Table 12: Average counterfactual changes in rates of time-use: by age band

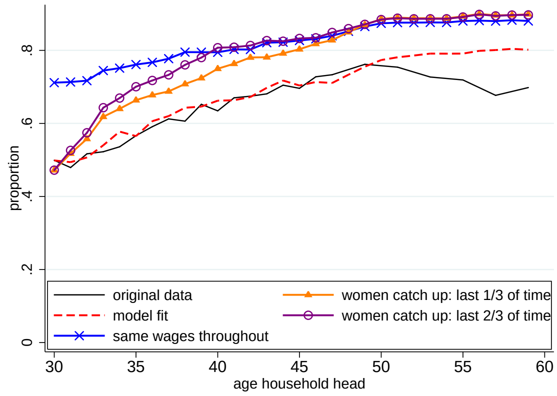
| | (1) women full time work | | (2) women part time work | | (3) women 'max' home work | | (4) men 'low middle' home work | |
|---|---|---|---|---|---|---|---|---|
| *Experiment 1: equal average wages throughout life-cycle* | | | | | | | | |
| ages 30-39 | +18.36 | [57.0%] | -2.28 | [16.3%] | -14.55 | [66.2%] | +2.18 | [68.2%] |
| ages 40-49 | +12.29 | [70.3%] | -3.00 | [13.6%] | -7.27 | [55.7%] | -1.99 | [71.7%] |
| ages 50-59 | +8.64 | [79.2%] | -3.71 | [10.5%] | -3.63 | [47.2%] | +0.03 | [70.9%] |
| *Experiment 2: women catch up with men in year* 21 | | | | | | | | |
| ages 30-39 | +5.69 | [57.0%] | +0.48 | [16.3%] | -3.08 | [66.2%] | +1.16 | [68.2%] |
| ages 40-49 | +10.06 | [70.3%] | -2.46 | [13.6%] | -6.72 | [55.7%] | +0.46 | [71.7%] |
| ages 50-59 | +10.04 | [79.2%] | -4.06 | [10.5%] | -7.09 | [47.2%] | -0.13 | [70.9%] |
| *Experiment 3: women catch up with men in year* 11 | | | | | | | | |
| ages 30-39 | +8.79 | [57.0%] | -0.52 | [16.3%] | -6.03 | [66.2%] | +1.47 | [68.2%] |
| ages 40-49 | +12.98 | [70.3%] | -3.69 | [13.6%] | -9.04 | [55.7%] | +0.34 | [71.7%] |
| ages 50-59 | +9.91 | [79.2%] | -4.03 | [10.5%] | -5.51 | [47.2%] | -1.71 | [70.9%] |

*Notes:* The table reports average changes in rates of time-use when the gender wage gap is eliminated counterfactually across three experiments. Baseline proportions from the fitted model appear in square brackets. The definitions of 'max' or 'low middle' refer to different amounts of time put into household work; see table 2.

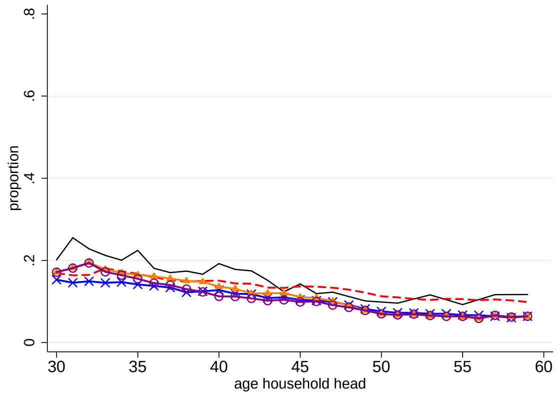
The proportion of women of ages 30-39 supplying 'maximum' hours to household production drops 14.55 percentage points (from a baseline of 66.2% to 51.7%), whereas the proportion of men supplying 'low middle' increases 2.18 points (from a baseline of 68.2% to 70.4%). The first figure corresponds to a 22% drop in women's 'maximum' household work rate, whereas the second to a mere 3.2% increase in men's 'low middle' rate. Less time is now devoted jointly to household work possibly because the household substitutes time with higher public expenditures into home production. The decline in women's household work rate during the child bearing years is equivalent to up to 7 hours of such work less per week (see figure 14e).[54]

[54] An additional calibration is carried out in order to translate *rates* of household work into work *hours* because the level of household hours is not targeted in the structural estimation. The details of this calibration are omitted for brevity but are available upon request.

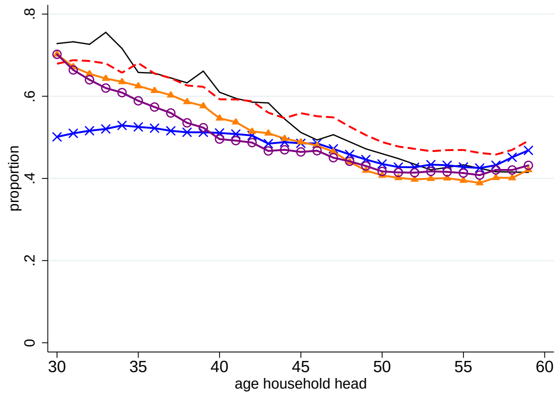
Figure 14: Counterfactual life-cycle profiles of time use



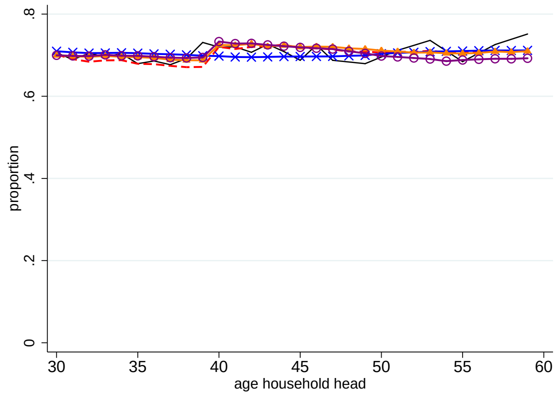

(a) Women: full-time market work



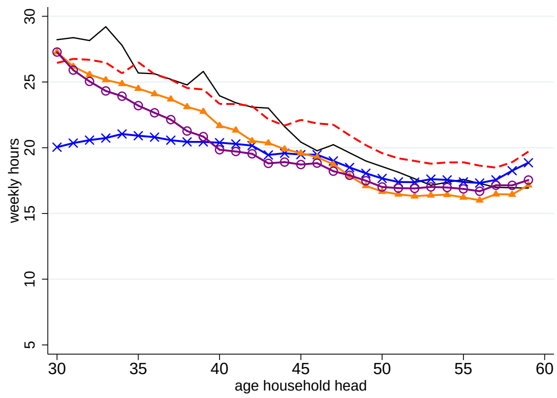

(b) Women: part-time market work



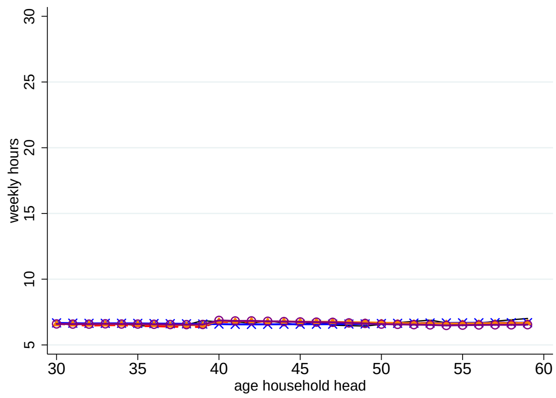

(c) Women: 'maximum' household work




(d) Men: 'low middle' household work




(e) Women: household hours




(f) Men: household hours

*Notes*: This figure illustrates the life-cycle profiles of family time use when the gender wage gap is eliminated counterfactually. The real data appear in the black solid line and the original model fit appears in the red dashed line; experiment #1 is depicted by the blue lines through the crosses, experiment #2 by the orange lines through the triangles, and experiment #3 by the purple lines through the hollow circles.

The effects of equal pay remain big in later periods of the life-cycle, albeit less profound. The reason is that the gender wage gap in the real data anyway narrows down as time goes by, so the effects of equal pay become inevitably less noticeable in later periods. Nevertheless, equal pay still implies an average increase of 12.29 (8.64) percentage points in women's rate of full-time market work at ages 40-49 (50-59). The drop in part-time work is again much smaller. The proportion of women supplying 'maximum' household work drops on average 7.27 (3.63) percentage points at ages 40-49 (50-59) whereas the proportion of men supplying 'low middle', perhaps surprisingly, drops too approximately 2 points at 40-49 and remains unchanged afterwards.

Counterfactual #1 generates a higher and flatter female life-cycle profile of full-time market work compared to the data. If men and women can earn on average the same wages, the model predicts that more than 75% of women would work full-time right from the beginning of their life-cycle; that would increase to more than 82% in the middle years as women become less restricted by young children and to approximately 88% in the later years. With equal pay women's full-time market work rate tends to mimic men's toward the end of the life-cycle. The life-cycle profile of part-time work is lower and also flatter compared to the data, as also is the profile of women supplying 'maximum' hours to the household. Men are the least responsive to the elimination of the gender wage gap; the life-cycle profile of men supplying 'low middle' hours tends to be lower in the middle years but the changes are a fraction of those of women.

Counterfactuals #2 and #3 induce eventually similar effects on married people's allocation of time like counterfactual #1: higher female full-time market work, lower female part-time market work and household work, higher male household work. There are little differences between all three experiments in the last 10 years of the life-cycle (when for all three average wages are equal between spouses), but there are some noticeable differences in the earlier years.

Counterfactual #2 generates a steeper profile of female full-time market work over the first 20 years of the life-cycle. As women's wages gradually catch up with men's, the proportion of women in full-time work increases from 62.7% at ages 30-39 to 80.4% at 40-49 and reaches eventually 89.2% at 50-59. These numbers imply an overall 5.7 to 10.1 percentage points increase compared to the baseline model rates. Experiment #3 generates the steepest full-time work profile predicting a jump from 65.8% at ages 30-39 to 83.3% at 40-49 as women's wages catch up quickly in the first 10 years of the life-cycle. These numbers imply an overall 8.8 to 13 percentage points increase in female full-time work rate compared to the original model simulations. During the first 20 years the rate of full-time work in experiment #3 is everywhere higher than in experiment #2.

Counterfactual #2 generates a downward profile in part-time market work similar to what we see in the data: the proportion of part-time work decreases from 16.8% at ages 30-39 to 11.1% at 40-49 and 6.4% in the late years. These numbers correspond to a drop of up to 4.1 percentage points compared to the original model simulations. Counterfactual #3 generates the steepest downwards profile in part-time work: the proportion decreases from 15.8% at ages 30-39 to 9.9% at 40-49 and 6.5% in the late years. During the first 20 years the rate of part-time work in experiment #3 is everywhere lower than in experiment #2.

Regarding women's household work, experiment #3 generates the steepest downward profile in the early years from a proportion of 60.2% at ages 30-39 to 46.7% at 40-49 and 41.7% afterwards. Counterfactual #2 generates a slightly less steep profile over the first 20 years (actually quite similar to what we see in the data) and the proportion of women supplying 'maximum' hours is almost everywhere higher than in experiment #3. Finally, the proportion of men supplying 'low middle' hours is usually higher in both experiments than it is in the original model simulations (and with little differences between them).

Overall, equal pay has important implications for married people's time allocation with the most striking changes concentrated around women's entry in the labor market and full-time market work in the child bearing years. The effects during the child bearing years are greatly mitigated when equal pay is established later on in their lives. A higher proportion of women working full-time and a higher hourly wage result in additional income for their households, a boost to their savings, and a more equal allocation of household work between men and women. The time mothers spend with children is not modeled in this paper and it remains an open question how equal pay would impact on that important dimension (Del Boca et al., 2014, in a unitray context, model parental time spent with children).

## 9 Conclusions

Over at least the last three decades married women in the United States have seen their wages grow faster than their husbands' wages and the gap between them narrow down dramatically. This paper is concerned with how the closing of the gender wage gap affects the family allocation of time across market work, work in the household, and leisure. I developed a life-cycle collective model of public consumption, savings and time allocation for spouses who differ in preferences but share a common budget constraint. In the model, the wages spouses can earn affect choices in the household through (i) the intertemporal budget constraint and (ii) their intra-family bargaining power. The latter is so because wages shift the utility spouses can enjoy outside their household in the event of divorce. To estimate the model I used cross-sectional variation in wages and family fertility as well as the narrowing of the gender wage gap since 1980 which I treat entirely as shock. I used data on married as well as divorced individuals.

The empirical life-cycle profiles of family time use are reproduced closely. To achieve that, the model assigns women a higher on average intra-family bargaining power as the gender wage gap narrows down in their favor. The improvement in women's power over time affects primarily spousal time into home production. Without such improvement women's rate of top household work would be higher by up to 6.48% whereas men's lower by up to 6.95%. Besides their bargaining effects, changes in relative wages within the household induce also income and substitution effects on female labor supply and spousal household work.

I used the model to assess the implications that equal pay between genders has for family time allocations. If women are given their husband's wage, women's rate of full-time work increases dramatically throughout the life-cycle. The increase is more striking in the early child bearing years when the model predicts that 75.36% of women would work full time compared with 57% in the data. This is primarily due to women entering the labor market when they previously did not participate. Equal pay makes the allocation of time into home production more equal between spouses but it also decreases the overall amount of time invested therein.

This study is subject to a number of limitations. Wages are assumed exogenous and the model abstracts from human capital; in the present framework this would lead to inefficiencies within the household and jeopardize identification of the married household structure. Divorce exists in the model as a threat point but the *choice* to divorce is not modeled per se. Instead of solving for the full dynamic problem of divorcees, I estimate the expected lifetime value of being divorced using reduced-form techniques and I impose that value to the married people's problem. This shortcut facilitates the solution to the latter problem but comes with the cost of restricting the applicable estimation sample to stable households only. Solving for the full problem of divorcees is desirable because it should improve identification of the changes in intra-family bargaining power and allow the characterization of divorce. In the same lines, household formation is taken as given and the narrowing gender wage gap does not affect the patterns of marital formation. Parental time with children is not modeled due to lack of consistent data over time although this is certainly an important component of parents' time use (Knowles, 2013). The paper does not model changes in the price of household appliances as in Greenwood et al. (2005), although it does model the price of child care. Finally, the paper revolves around one cohort investigating the implications of a narrowing gender wage gap *over the life-cycle*; an extension to multiple cohorts would enable to investigate how the gender gap ultimately affects time allocations *over time*. These issues certainly deserve attention and the present implementation is only one step towards a full understanding of how wages affect time use.

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# A Data: Sample Selection and Variables

The paper uses information from the Panel Study of Income Dynamics (PSID). I select men and women aged 25 to 65 from the core sample ('Survey Research Center') between years 1980 and 2009. I split this into two distinct and non-overlapping samples: (i) a major sample of households of continuously married men and women throughout the years they're observed, and (ii) a minor sample of singles of both genders. Below I describe the two samples in detail.

**Major PSID sample** I follow households headed by a married or permanently cohabiting opposite-sex couple. I require that these households are stable in that they do not experience any compositional changes in the head couple such as divorce or remarriage. Compositional changes regarding kids are permitted. Currently I follow one cohort of households only. I define this cohort as those households whose male spouse (male head of the household in the PSID) is born between years 1943 and 1955 (implying he is between 25 and 37 years old in 1980). Given that the age difference between him and his spouse in approximately two thirds of households in this cohort does not exceed $\pm 3$ years, I do not explicitly condition on similar years of birth for the female spouse. I drop a few households for which information on their state of residence is ambiguous (these may be households that reside outside the US for part of the survey year). I also drop households with one or more spouses being farmers (hard to trust their earnings), disabled or students (because their time allocation choices may be constrained by their circumstances), or households for which labor earnings of a *working* spouse fall below 1% or above 99% of the (gender- and time-specific) distribution. The resulting dataset is an unbalanced panel of 1279 households observed over at least two consecutive years. More than 55% of households are observed for at least 10 years and more than 30% for at least 20.

*Hourly wages* are calculated as annual labor earnings over annual hours of work for those working. To account partly for measurement error in wages I only use the central 96% of the wage distribution for each gender after excluding those who work less than 10 hours per year. Figure A.1 in this appendix plots median and mean wages by gender. *Annual labor earnings* are self-reported gross earnings from all jobs and include salaries, bonuses, overtime, tips etc. Around 1993 the definition of earnings changes slightly and the available measure excludes some previously included minor components of earnings (such as the labor part of business income).[55] I remove inflation from all monetary values using the All-Urban-Consumers CPI.

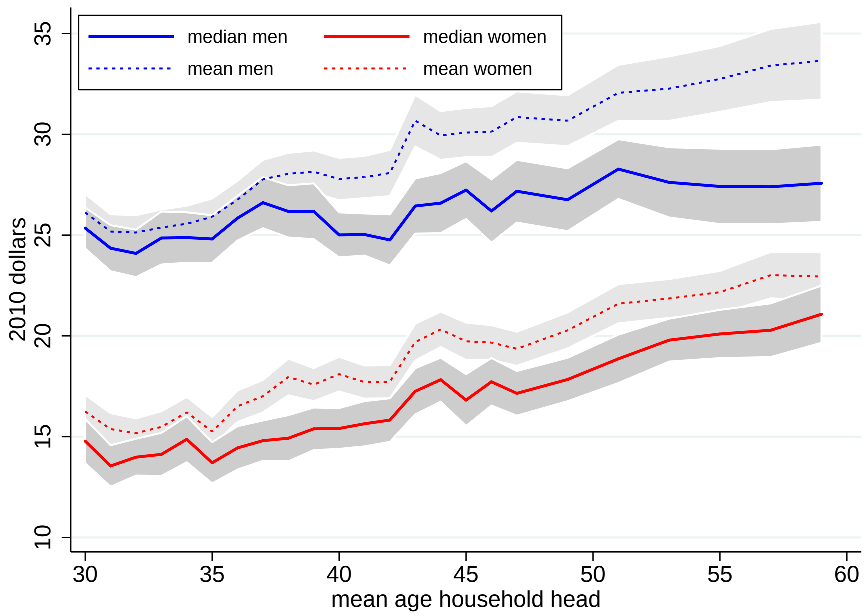
*Annual hours of work* are defined as total work hours across all jobs in a given year including overtime. I assume that hours reported at one point in the year are evenly allocated over the year. I discretise the amount of time women put into market work (see table 2) using a 3-point distribution: not working (0-10 annual hours modeled as 0 hours), working part-time (10-1000 annual hours modeled as 4 daily hours in a 5-day 50-week annual schedule), and working full time (more than 1000 annual hours modeled as 8 daily hours). There is sufficient bunching of hours in the data to justify the above discrete approximation.

[55] Despite this well known inconsistency the PSID treats men's earnings series as consistent over time. For female earnings two different series are provided (one prior to 1993 and one after). I combine the two into a single female series.

*Household work* is defined on a weekly basis as time spent on cooking, cleaning, and "doing other work around the household". I discretise the amount of time put into household work using a separate 2-point distribution for each gender: for men, 'low' hours (up to 2 hours weekly modeled as 0.4 hours/day in a 5-day week) or 'low middle' hours (more than 2 hours weekly modeled as 1.6 daily hours); for women 'high middle' hours (up to 15 hours weekly modeled as 3 daily hours in a 5-day week) or 'maximum' hours (more than 15 modeled as 6 daily hours). Again, there is sufficient bunching of household hours in the data to justify these discrete approximations.

Finally, *age of the youngest child* is classified in four groups to reflect the way stochastic fertility is modeled in section 3.3: an age 0 in the data indicates the absence of a child younger than 18 years old (modeled as $N_t = 1$), ages $1-4$ indicate a child less than 5 years ($N_t = 2$), ages $5-9$ indicate a child at least 5 but less than 10 years old ($N_t = 3$), and ages $10-17$ indicate older children up to 18 years old ($N_t = 4$).

Figure A.1: Evolution of wages over the life-cycle: median and mean




*Notes*: This figure plots median and mean hourly wages by gender for married people over their life-cycle. One cohort only is depicted; mean age on the horizontal axis coincides with calendar time (1980-2009). Only the central 96% of the wage distribution by gender and mean age (year) is used. A 95% confidence interval appears in gray shade.

**Minor PSID sample** This sample consists of single men and women and mimics many of the selection criteria applied to the major PSID sample above. Specifically, I select individuals who report having been divorced or separated, work in the labor market (as I require information on their earnings), and whose earnings do not fall below 1% or above 99% of the (gender- and time-specific) distribution. I drop a few individuals for which information on their state of residence is ambiguous (these may reside outside the US for part of the survey year), farmers (hard to trust their earnings), or those with missing information on their education (required for the projections of earnings). The resulting dataset consists of 4561 divorced male-year and 7614 divorced female-year observations. I define and deflate *annual labor earnings* like above.

**Wage equations and participation selection**

Follows Heckman (1979). To Be Written.

## B Model: Public and Private Consumption

This appendix extends the model in section 3 to allow spouses to consume public *as well as private* consumption goods. In this case, individual $j$ has preferences $\widetilde{U}_j$ given by

$$\widetilde{U}_j(Q, q_j, l_j; \mathbf{z}_j)$$

where $q_j$ is the private (rival) consumption good. The rest of the notation remains like in the main text. One can think of the private good as, say, own clothing and the public good as food at home or children's expenditure.

The household problem during the working period of life is given by (1)-(7) after replacing individual preferences with $\widetilde{U}_j$ and the budget constraint (3) with

$$A_t + \sum_{j=1}^{2} w_{jt} h_{jt} = K_t + p_t \sum_{j=1}^{2} q_{jt} + CC_t\big(h_{2t}, N_t\big) + \frac{A_{t+1}}{1+r}.$$

Here $p_t$ is the relative price of the private good at $t$ after normalizing the price of the public good to 1 in every period. The set of state variables is unaffected but the set of choice variables $\mathcal{C}_t$ is augmented to include $q_{1t}$ and $q_{2t}$.

Preferences can be parameterized by

$$\widetilde{U}_j\big(Q_t, q_{jt}, l_{jt}; \mathbf{z}_{jt}\big) = \frac{1}{1-\gamma}\left(\alpha_j\big(Q_t/s(N_t)\big)^{1-\gamma} + (1-\alpha_j)q_{jt}^{1-\gamma}\right) \times \exp\big(g_j(l_{jt}; \mathbf{z}_{jt})\big)$$

which is a straightforward extension of (8). The leisure sub-utility $g_j(\cdot)$ remains unchanged. Here $\alpha_j$ serves as the utility share of public consumption which may depend on observables such as the presence or age of the youngest child in the family $N_t$.

The extension to private consumption does not alter the fundamentals of the problem: the problem still is a typical mixture of discrete (time-use) and continuous choices (public and private consumption, savings). The solution algorithm is not complicated significantly: for each optimal public consumption-savings bundle, and conditional on a time-use choice, the marginal rates of substitution between the private consumption goods *and* between public-private consumption deliver the optimal quantities for $q_1$ and $q_2$. The separability between public and private consumption facilitates the solution. However, the solution is slowed down as one now has to search for the best $Q$ and (with the use of the marginal rates of substitution) for the optimal $q_1$ and $q_2$ given some future assets and then repeat this along a grid of future assets (*i.e.* two-dimensional instead of one-dimensional 'table look-up').

For identification of $\alpha_j$ one needs information on private goods *for each spouse* as well as public consumption goods. The Consumer Expenditure Survey in the US provides information on clothing expenditure by gender. However this tends to be a tiny proportion of total household expenditure and it is unclear which other goods reported therein can serve as private.

# C Estimation: Exogenous Blocks

**Wages** To obtain estimates of the second moments of shocks I run a Minimum Distance estimation matching the empirical covariance matrix of log wages over time to its theoretical counterpart. I illustrate the main points of this estimation referring to time $t$ as calendar time but recall that calendar time coincides with mean age of the household head given my focus on one cohort only. From the major PSID sample I collate the vector $\widetilde{\mathbf{W}} = (\widetilde{\mathbf{W}}_{1980}, \widetilde{\mathbf{W}}_{1981}, \dots, \widetilde{\mathbf{W}}_{2009})'$ where

$$\widetilde{\mathbf{W}}_t = \begin{pmatrix} \mathbb{E}[(\Delta \ln w_{1t})^2] \\ \mathbb{E}[\Delta \ln w_{1t} \Delta \ln w_{1t+1}] \\ \mathbb{E}[(\Delta \ln w_{2t})^2] \\ \mathbb{E}[\Delta \ln w_{2t} \Delta \ln w_{2t+1}] \\ \mathbb{E}[\Delta \ln w_{1t} \Delta \ln w_{2t}] \\ \mathbb{E}[\Delta \ln w_{1t} \Delta \ln w_{2t+1}] \\ \mathbb{E}[\Delta \ln w_{2t} \Delta \ln w_{1t+1}] \end{pmatrix}, \quad t \in [1980, 2009]$$

Due to the transitory shock being a mean-reverting component, I ignore any auto-covariances of order higher than 1. In the PSID data these are insignificantly different from 0 anyway. In the construction of $\widetilde{\mathbf{W}}$ I make use of wage data prior to 1980 and post 2009.

The theoretical counterpart is $\mathbf{W}(\boldsymbol{\vartheta})$ and is a function of the second moments of permanent and transitory shocks (parameter $\boldsymbol{\vartheta}$). An estimate of $\boldsymbol{\vartheta}$ is given by

$$\hat{\boldsymbol{\vartheta}} = \arg\min_{\boldsymbol{\vartheta}} (\widetilde{\mathbf{W}} - \mathbf{W}(\boldsymbol{\vartheta}))' I (\widetilde{\mathbf{W}} - \mathbf{W}(\boldsymbol{\vartheta}))$$

where $I$ is the identity matrix. The estimates of $\boldsymbol{\vartheta}$ appear in table C.1 alongside their standard errors; to calculate those I adopt the block bootstrap with 500 replications. Finally, provisions are made in the estimation routine to deal with PSID's switch from annual to biennial frequency after 1997.

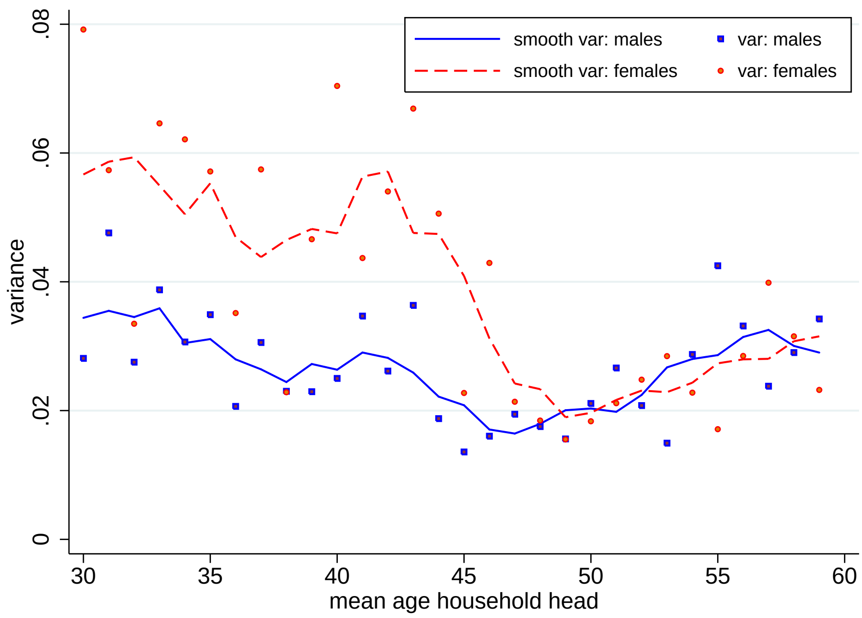
The point-estimates in table C.1 are not used directly as inputs into the structural model of section 3. To reduce the effect of measurement error, I replace these estimates with 5-point two-sided moving averages (suitably adapted to deal with corners); a similar approach is taken by French (2005). The original point-estimates of the variances of men's and women's permanent shocks, as well as the refined ones, appear graphically in figure C.1 in this appendix.

**Child care costs** Regarding child care costs, I calibrate *cchrate* at a constant \$6.59 (expressed in 2010 dollars) throughout the 1980-2009 period; see section 5.1 in the main text for details. Whenever this rate is below the real federal minimum wage, I update *cchrate* to reflect this. Essentially the hourly wage of child care workers in the model decreases relative to that of the general population (of both men and women) reflecting -what seems to be- a consensus that child care has steadily become less expensive in the last 3 decades. Finally, I calculate the probability of a family facing positive child care costs by counting the number of families of a given fertility status that report non-zero such costs (the PSID collects information on child care expenditure after 1988). This is done separately by calendar year. In years when child care expenditure is missing from the PSID I use the probabilities estimated in the closest period when data are available.

Table C.2 in this appendix reports the imposed hourly rate of child care over time as well as the estimated probabilities of positive child care costs for the relevant fertility states $N_t = 2$ (youngest child younger than 5 years) and $N_t = 3$ (youngest child between 5 and 10 years). Households in fertility states $N_t = 1$ and $N_t = 4$ are modeled to not require formal child care. This is confirmed by the data (but not reported in table C.2). For the even years after 1997 (when the PSID did not collect data) I use the mid-point of probabilities in the adjacent years.

**Initial Pareto weight** To project lifetime earnings if spouses get divorce, I first pool earnings of divorcees for all years and ages; I do so separately by gender. The data come from the minor PSID sample described above. I regress earnings on race, education, a quadratic polynomial in age and their interactions. This is regression (14) in the main text and the results appear in table C.3 in this appendix. These results use information on divorcees solely between years 1980-1989 because I require a proxy for intra-family bargaining power in the first 10 years of the family's life-cycle only (see last paragraph of section 5.2). Using the estimates from (14) I project lifetime earnings for each married spouse should they get divorce and I use these projections to form a proxy for intra-family bargaining power (see section 5.3 in the main text for details). Table C.4 below reports how the derived intra-family bargaining power *of married men* correlates with a number of characteristics of each partner.

Figure C.1: Actual and smoothed variance of permanent shocks




*Notes*: This figure plots the estimates of the variance of the permanent shock of each spouse (scatter points) as well as 5-point two-sided moving averages that pass through the scatters. To estimate the variances the central 96% of the wage distribution by gender and year is used only.

Table C.1: Second moments of male and female wage shocks

| Year | Mean age head | I. Permanent shocks | | | II. Transitory shocks | | |
|---|---|---|---|---|---|---|---|
| | | Men | Women | Covari-ance | Men | Women | Covari-ance |
| 1980 | 30 | 0.0281 | 0.0792 | 0.0081 | 0.0214 | 0.0546 | 0.0039 |
| | | (0.0080) | (0.0226) | (0.0080) | (0.0058) | (0.0164) | (0.0052) |
| 1981 | 31 | 0.0476 | 0.0573 | -0.0009 | 0.0253 | 0.0710 | 0.0060 |
| | | (0.0107) | (0.0200) | (0.0079) | (0.0055) | (0.0211) | (0.0051) |
| 1982 | 32 | 0.0275 | 0.0335 | 0.0097 | 0.0226 | 0.0697 | 0.0037 |
| | | (0.0079) | (0.0211) | (0.0073) | (0.0046) | (0.0228) | (0.0063) |
| 1983 | 33 | 0.0388 | 0.0646 | 0.0093 | 0.0176 | 0.0602 | -0.0019 |
| | | (0.0071) | (0.0194) | (0.0075) | (0.0045) | (0.0155) | (0.0047) |
| 1984 | 34 | 0.0307 | 0.0621 | 0.0062 | 0.0254 | 0.0380 | -0.0010 |
| | | (0.0070) | (0.0146) | (0.0064) | (0.0052) | (0.0127) | (0.0049) |
| 1985 | 35 | 0.0349 | 0.0571 | 0.0121 | 0.0239 | 0.0725 | -0.0045 |
| | | (0.0062) | (0.0169) | (0.0081) | (0.0051) | (0.0161) | (0.0049) |
| 1986 | 36 | 0.0207 | 0.0351 | 0.0102 | 0.0305 | 0.0737 | -0.0032 |
| | | (0.0061) | (0.0146) | (0.0057) | (0.0059) | (0.0155) | (0.0051) |
| 1987 | 37 | 0.0306 | 0.0575 | 0.0172 | 0.0253 | 0.0789 | -0.0017 |
| | | (0.0065) | (0.0249) | (0.0059) | (0.0048) | (0.0251) | (0.0038) |
| 1988 | 38 | 0.0230 | 0.0229 | 0.0108 | 0.0290 | 0.0638 | -0.0053 |
| | | (0.0062) | (0.0153) | (0.0060) | (0.0057) | (0.0123) | (0.0045) |
| 1989 | 39 | 0.0229 | 0.0466 | 0.0099 | 0.0337 | 0.0199 | 0.0027 |
| | | (0.0060) | (0.0122) | (0.0050) | (0.0073) | (0.0071) | (0.0044) |
| 1990 | 40 | 0.0250 | 0.0704 | 0.0043 | 0.0178 | 0.0408 | 0.0055 |
| | | (0.0064) | (0.0177) | (0.0058) | (0.0049) | (0.0089) | (0.0041) |
| 1991 | 41 | 0.0347 | 0.0437 | 0.0084 | 0.0259 | 0.0466 | -0.0010 |
| | | (0.0059) | (0.0116) | (0.0064) | (0.0060) | (0.0092) | (0.0039) |
| 1992 | 42 | 0.0261 | 0.0540 | 0.0165 | 0.0469 | 0.0343 | -0.0118 |
| | | (0.0097) | (0.0147) | (0.0070) | (0.0101) | (0.0097) | (0.0053) |
| 1993 | 43 | 0.0363 | 0.0669 | 0.0243 | 0.0673 | 0.0566 | -0.0032 |
| | | (0.0123) | (0.0143) | (0.0072) | (0.0116) | (0.0123) | (0.0059) |
| 1994 | 44 | 0.0188 | 0.0506 | 0.0173 | 0.0595 | 0.0885 | 0.0035 |
| | | (0.0085) | (0.0175) | (0.0069) | (0.0125) | (0.0165) | (0.0055) |
| 1995 | 45 | 0.0136 | 0.0227 | 0.0071 | 0.0337 | 0.0514 | 0.0011 |
| | | (0.0077) | (0.0135) | (0.0063) | (0.0057) | (0.0099) | (0.0044) |
| 1996 | 46 | 0.0160 | 0.0429 | 0.0128 | 0.0106 | 0.0589 | -0.0017 |
| | | (0.0055) | (0.0128) | (0.0071) | (0.0032) | (0.0139) | (0.0058) |
| 1997 | 47 | 0.0194 | 0.0214 | -0.0004 | 0.0413 | 0.0628 | 0.0083 |
| | | (0.0059) | (0.0069) | (0.0040) | (0.0101) | (0.0118) | (0.0051) |
| 1999 | 49 | 0.0156 | 0.0155 | 0.0024 | 0.0436 | 0.0494 | -0.0048 |
| | | (0.0046) | (0.0061) | (0.0028) | (0.0090) | (0.0092) | (0.0042) |
| 2001 | 51 | 0.0266 | 0.0212 | 0.0057 | 0.0522 | 0.0359 | 0.0112 |
| | | (0.0083) | (0.0062) | (0.0033) | (0.0102) | (0.0065) | (0.0063) |
| 2003 | 53 | 0.0149 | 0.0285 | 0.0034 | 0.0571 | 0.0415 | -0.0049 |
| | | (0.0052) | (0.0087) | (0.0036) | (0.0126) | (0.0091) | (0.0059) |
| 2005 | 55 | 0.0425 | 0.0171 | 0.0019 | 0.0621 | 0.0411 | -0.0003 |
| | | (0.0103) | (0.0045) | (0.0042) | (0.0155) | (0.0067) | (0.0051) |
| 2007 | 57 | 0.0238 | 0.0399 | 0.0032 | 0.0430 | 0.0390 | 0.0054 |
| | | (0.0075) | (0.0078) | (0.0038) | (0.0129) | (0.0105) | (0.0059) |
| 2009 | 59 | 0.0342 | 0.0232 | 0.0008 | 0.0431 | 0.0304 | -0.0004 |
| | | (0.0091) | (0.0069) | (0.0053) | (0.0098) | (0.0123) | (0.0102) |

*Notes:* The table presents minimum distance estimates of the variances of permanent and transitory shocks over time, as well as their covariances between spouses. Block I refers to permanent shocks; block II refers to transitory shocks. Within a block the first column is the male variance of the shock, the second column is the female variance, and the third column is the covariance between the two. Block bootstrap standard errors from 500 replications are reported in parentheses.

Table C.2: Child care costs: price and probabilities

| Year | Hourly rate (in $2010) | Probability child care expenditure > 0: Fertility state $N_t = 2$ | Fertility state $N_t = 3$ |
|---|---|---|---|
| 1980 | 8.71 | 59.07% | 40.32% |
| 1981 | 8.20 | 59.07% | 40.32% |
| 1982 | 8.04 | 59.07% | 40.32% |
| 1983 | 7.57 | 59.07% | 40.32% |
| 1984 | 7.33 | 59.07% | 40.32% |
| 1985 | 7.03 | 59.07% | 40.32% |
| 1986 | 6.79 | 59.07% | 40.32% |
| 1987 | 6.67 | 59.07% | 40.32% |
| 1988 | 6.59 | 59.07% | 40.32% |
| 1989 | 6.59 | 56.47% | 45.56% |
| 1990 | 6.59 | 60.34% | 43.17% |
| 1991 | 6.59 | 57.66% | 42.11% |
| 1992 | 6.80 | 60.93% | 42.97% |
| 1993 | 6.61 | 51.30% | 41.74% |
| 1994 | 6.59 | 55.85% | 48.70% |
| 1995 | 6.59 | 59.69% | 47.13% |
| 1996 | 6.59 | 59.13% | 47.89% |
| 1997 | 6.60 | 58.58% | 45.39% |
| 1998 | 7.00 | 56.05% | 45.25% |
| 1999 | 6.89 | 53.52% | 45.10% |
| 2000 | 6.74 | 52.28% | 43.34% |
| 2001 | 6.59 | 51.04% | 41.58% |
| 2002 | 6.59 | 49.99% | 43.01% |
| 2003 | 6.59 | 48.95% | 44.44% |
| 2004 | 6.59 | 49.25% | 41.44% |
| 2005 | 6.59 | 49.56% | 38.43% |
| 2006 | 6.59 | 50.19% | 40.07% |
| 2007 | 6.59 | 50.82% | 41.70% |
| 2008 | 6.59 | 50.64% | 40.14% |
| 2009 | 6.63 | 50.45% | 38.58% |

*Notes:* This table presents the hourly rate of child care in 2010 dollars (column 2) alongside the probability of a family reporting positive child care expenditure by fertility state (columns 3 and 4). Only the relevant fertility states are reported here. In years when child care expenditure is missing from the PSID (prior to 1988) I use the probabilities estimated in the closest period when data are available. In the even years after 1997 when the PSID did not collect data I use the mid-point of probabilities in the adjacent years.

Table C.3: Earnings regressions: male and female divorcees

| | **Dependent variable: Annual Earnings** | | | |
|---|---|---|---|---|
| | I. Male divorcees | | II. Female divorcees | |
| *Regressors:* | Coeff. | p-value | Coeff. | p-value |
| Age | 4269.56 | [0.005] | 807.36 | [0.292] |
| $Age^2$ | -50.71 | [0.006] | -8.44 | [0.330] |
| Race (black) | 45811.67 | [0.717] | -25464.03 | [0.123] |
| Race (other) | 287579.56 | [0.018] | 19119.09 | [0.667] |
| Educ. (high school) | 24278.46 | [0.557] | -30085.92 | [0.103] |
| Educ. (some college) | 54787.30 | [0.240] | -43205.38 | [0.029] |
| Educ. (college) | 80539.48 | [0.124] | 42461.88 | [0.130] |
| Educ. (post-college) | -13021.28 | [0.826] | -88158.37 | [0.005] |
| Race (black) × Age | -3309.25 | [0.657] | 874.94 | [0.282] |
| Race (other) × Age | -17150.95 | [0.006] | -1014.91 | [0.658] |
| Race (black) × $Age^2$ | 41.97 | [0.698] | -5.98 | [0.533] |
| Race (other) × $Age^2$ | 245.77 | [0.001] | 9.80 | [0.729] |
| Educ. (high school) × Age | -718.35 | [0.727] | 1939.59 | [0.028] |
| Educ. (some college) × Age | -2747.19 | [0.254] | 2654.67 | [0.006] |
| Educ. (college) × Age | -3009.72 | [0.235] | -1759.51 | [0.193] |
| Educ. (post-college) × Age | 1491.24 | [0.622] | 5652.83 | [0.000] |
| Educ. (high school) × $Age^2$ | 9.57 | [0.695] | -22.70 | [0.023] |
| Educ. (some college) × $Age^2$ | 47.91 | [0.110] | -29.94 | [0.007] |
| Educ. (college) × $Age^2$ | 40.81 | [0.164] | 27.26 | [0.082] |
| Educ. (post-college) × $Age^2$ | -13.05 | [0.727] | -66.13 | [0.000] |
| Cons. | -50450.89 | [0.096] | 1033.31 | [0.949] |
| R-Square | 0.201 | | 0.204 | |
| Regression p value | 0.000 | | 0.000 | |
| Obs. | 1201 | | 1915 | |

*Notes:* This table presents estimates and p-values from OLS linear regressions of divorcees' earnings on a set of individual characteristics. These include: a quadratic polynomial in age, race and education dummies, and their interactions with the age polynomial. Race takes on three values for: 'white' (omitted), 'black', and 'other'. Education takes on five values for 'less than high school' (omitted), 'high school', 'some (less than) college', 'college', and 'post college'. The regressions are carried out separately by gender using years 1980-1989 of the minor PSID sample described in Appendix A. The number of observations reflects the number of male/female divorcees-year observations.

Table C.4: Married men's initial intra-family bargaining power: correlations with spousal attributes

| | **Dependent variable: men's bargaining power** | |
|---|---|---|
| *Regressors:* | Coeff. | p-value |
| Educ. Male (high school) | 0.080 | [0.000] |
| Educ. Male (some college) | 0.179 | [0.000] |
| Educ. Male (college) | 0.168 | [0.000] |
| Educ. Male (post-college) | 0.144 | [0.000] |
| Educ. Female (high school) | -0.082 | [0.000] |
| Educ. Female (some college) | -0.110 | [0.000] |
| Educ. Female (college) | -0.176 | [0.000] |
| Educ. Female (post-college) | -0.187 | [0.000] |
| Race Male (black) | -0.031 | [0.000] |
| Race Male (other) | 0.143 | [0.000] |
| Race Female (black) | -0.053 | [0.000] |
| Race Female (other) | 0.055 | [0.000] |
| Age Male | 0.006 | [0.000] |
| Age Male$^2$ | -0.000 | [0.000] |
| Age Female | -0.007 | [0.000] |
| Age Female$^2$ | 0.000 | [0.000] |
| Cons. | 0.622 | [0.000] |
| Obs. | 5970 | |

*Notes:* This table presents estimates and p-values of the correlations (linear regressions) between the derived intra-family bargaining power *of married men* and a number of characteristics of each spouse. For each spouse these include: a quadratic polynomial in age, race dummies, and education dummies. Race of either spouse takes on three values for: 'white' (omitted), 'black', and 'other'. Education of either spouse takes on five values for 'less than high school' (omitted), 'high school', 'some (less than) college', 'college', and 'post college'. The number of observations reflects the number of married household-year observations in 1980-1989.

# D Estimation: Model Fit

The following two tables present the full set of targeted moments used in the structural estimation (see section 5.2 in main text for details). The tables report the values of the moments in the data as well as their counterparts from the model. Finally, figure D.1 reports the values of 64 non-targeted dynamic moments of time-use in the data and the simulations. These are all possible transition probabilities, namely the probabilities that an individual engages in a given time-use activity conditional on what they or their partner did one or two periods in the past.

Table D.1: Targeted time-use rates: men

| | fertility state 1 | | fertility state 2 | |
|---|---|---|---|---|
| | Data | Model | Data | Model |
| *Mean age head: 30-39* | | | | |
| Low middle household work | 0.732 | 0.704 | 0.734 | 0.713 |
| *Mean age head: 40-49* | | | | |
| Low middle household work | 0.680 | 0.681 | 0.784 | 0.749 |
| *Mean age head: 50-59* | | | | |
| Low middle household work | 0.705 | 0.705 | 0.679 | 0.737 |
| | **fertility state 3** | | **fertility state 4** | |
| | Data | Model | Data | Model |
| *Mean age head: 30-39* | | | | |
| Low middle household work | 0.686 | 0.716 | 0.620 | 0.585 |
| *Mean age head: 40-49* | | | | |
| Low middle household work | 0.742 | 0.694 | 0.693 | 0.752 |
| *Mean age head: 50-59* | | | | |
| Low middle household work | 0.673 | 0.728 | 0.786 | 0.738 |

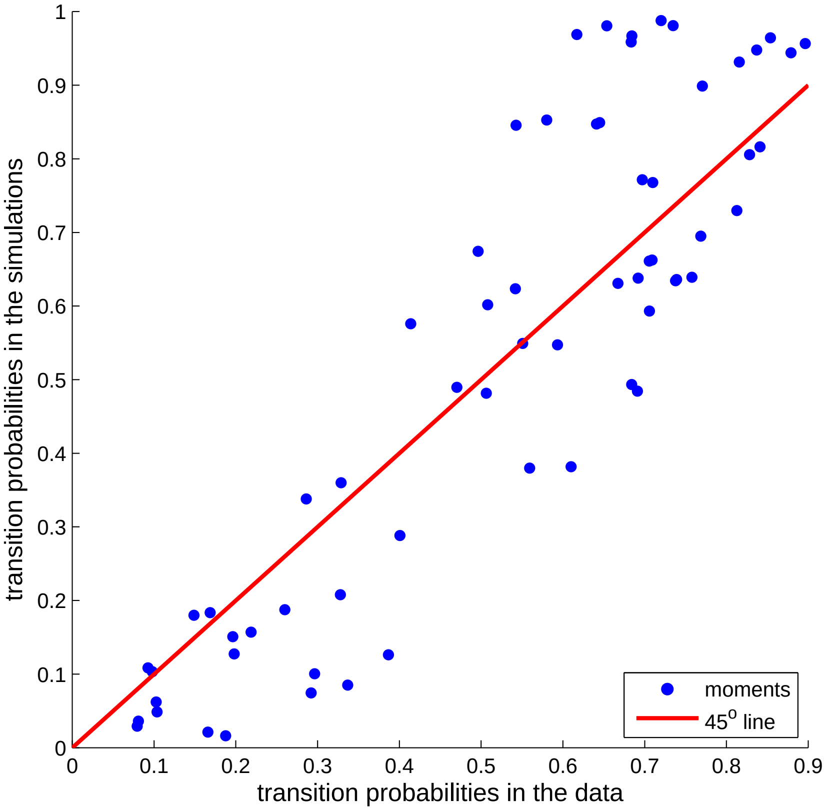
*Notes:* This table reports the values of men's targeted moments (time-use rates) in the data and the model simulations. For the definition of 'low middle' household work refer to table 2 in the main text.

Table D.2: Targeted time-use rates: women

| | fertility state 1 | | fertility state 2 | | fertility state 3 | | fertility state 4 | |
|---|---|---|---|---|---|---|---|---|
| | Data | Model | Data | Model | Data | Model | Data | Model |
| *Mean age head: 30-39* | | | | | | | | |
| FT market work & max household work | 0.282 | 0.333 | 0.236 | 0.302 | 0.341 | 0.309 | 0.400 | 0.339 |
| FT market work & high middle household work | 0.537 | 0.434 | 0.154 | 0.164 | 0.209 | 0.258 | 0.283 | 0.311 |
| PT market work & max household work | 0.063 | 0.079 | 0.217 | 0.090 | 0.184 | 0.180 | 0.124 | 0.138 |
| PT market work & high middle household work | 0.035 | 0.029 | 0.037 | 0.034 | 0.034 | 0.033 | 0.036 | 0.047 |
| No market work & max household work | 0.060 | 0.096 | 0.328 | 0.312 | 0.214 | 0.219 | 0.144 | 0.129 |
| *Mean age head: 40-49* | | | | | | | | |
| FT market work & max household work | 0.296 | 0.312 | 0.271 | 0.308 | 0.283 | 0.319 | 0.345 | 0.350 |
| FT market work & high middle household work | 0.468 | 0.479 | 0.229 | 0.249 | 0.295 | 0.293 | 0.394 | 0.348 |
| PT market work & max household work | 0.050 | 0.062 | 0.195 | 0.095 | 0.165 | 0.181 | 0.103 | 0.100 |
| PT market work & high middle household work | 0.037 | 0.044 | 0.042 | 0.035 | 0.069 | 0.021 | 0.034 | 0.039 |
| No market work & max household work | 0.120 | 0.097 | 0.225 | 0.239 | 0.156 | 0.186 | 0.106 | 0.110 |
| *Mean age head: 50-59* | | | | | | | | |
| FT market work & max household work | 0.213 | 0.303 | 0.256 | 0.320 | 0.218 | 0.348 | 0.280 | 0.376 |
| FT market work & high middle household work | 0.460 | 0.505 | 0.385 | 0.259 | 0.300 | 0.299 | 0.448 | 0.354 |
| PT market work & max household work | 0.064 | 0.063 | 0.038 | 0.115 | 0.109 | 0.159 | 0.085 | 0.092 |
| PT market work & high middle household work | 0.047 | 0.037 | 0.077 | 0.037 | 0.009 | 0.017 | 0.037 | 0.034 |
| No market work & max household work | 0.144 | 0.086 | 0.205 | 0.213 | 0.227 | 0.177 | 0.122 | 0.095 |

*Notes:* This table reports the values of women's targeted moments (time-use rates) in the data and the model simulations. For the definitions of 'maximum' and 'high middle' household work refer to table 2 in the main text.

Figure D.1: Non-targeted dynamic moments of time-use




*Notes*: This figure plots 64 non-targeted dynamic moments of time use in the data (horizontal axis) against their model counterparts (vertical axis). These moments are transition probabilities, namely the probabilities $\text{Prob}\big[\text{spouse}_j \text{ time-use}_t \mid \text{spouse}_k \text{ time-use}_{t-s}\big]$ that an individual of gender $j$ engages in a given time-use activity conditional on what they ($j = \{1, 2\}$) or their partner ($k = \{1, 2\}$) did $s = 1$ or $s = 2$ periods in the past.