On the time allocation of married couples since 1960

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Abstract

In the last half a century, married females more than doubled their workforce participation and significantly reduced their time spent on home production. Using a model of family decision making with home production and individual earnings heterogeneity, we subject two prominent explanations for this aggregate change, namely, the evolution of the gender earnings gap and the cost of home appliances, to quantitative tests with respect to changes in participation for disaggregated groups of couples and trends in time spent in leisure and home production activities. We find that both forces are needed to understand the evolution of married female time allocation over time, although the falling cost of home appliances is a dominant explanation for the time allocation outside of workplace, while the gender earnings gap is the dominant explanation for the workforce participation decision.

1. Introduction

The main observation investigated in this paper is the dramatic increase in the proportion of two-earner households, from 33% to 76%, during the period 1959–1999 (Fig. 1). This change was due mainly to a large number of married females joining the workforce. In fact, married females’ labor force participation (LFP) increased by approximately 130%, while married males’ participation remained roughly constant. Interestingly, the average number of annual hours worked, conditional on working a positive number of hours, has remained roughly constant for males and only slightly increased for females. Hence, the overall trend in the labor supply of married couples was driven by the rise in the labor supply of married women, which transpired primarily at the extensive (participation) rather than the intensive (hours conditional on participation) margin.

Goldin (1990) and Costa (2000) provide a comprehensive documentation of historical trends in female labor supply and proposed explanations. Most commonly cited among the economic explanations of the rise in female labor supply are the home production revolution and factors that tend to close the gender wage gap. The former refers to the widespread...
diffusion of electrical appliances, such as washing machines, dishwashers and vacuum cleaners, often assumed to be a result of falling prices of home appliances. Jones et al. (2003) find that a small reduction in the gender wage differential, modeled as a discrimination tax on female income, can account for the entire observed increase in the labor supply of married females during the period 1950–2000, while the decline in prices of home appliances is much less quantitatively important. By contrast, Greenwood et al. (2005) focus on the period 1900–1990, finding the decline in the relative price level of home appliances to be the main driving force underlying the rise in female LFP.

The main objective of this paper is to extend the test of these competing explanations by studying their implications for the cross-sectional features of the rise in the LFP of married females and trends in the time allocation outside of workplace, which we document from the US census and time-use surveys. To highlight the main facts, we document that although female participation increased for all groups differentiated by husband’s real earnings, the increase was greater for females married to men in the upper range of the earnings distribution. Put differently, the strong negative correlation of female participation and the husband’s earnings in 1959 became much weaker by 1999.

With regard to the empirical trends in time spent in leisure and home production activities outside of work, we emphasize that both working and stay-home wives experienced gains in leisure time, with a greater increase enjoyed by stay-home wives. The average leisure time of married females, however, remained unchanged, as the composition of married females changed in favor of working wives who always enjoyed less leisure. Time spent in home production fell for working and non-working females, the change in the composition further contributing to the fall in the average time worked at home. The relative male-to-female leisure time declined among both, the male-earner and the two-earner couples, the larger decline experienced among the male-earner couples because stay-home wives enjoyed the strongest increase in leisure.

We construct a model of heterogenous couples, in which the potential market earnings of husbands and wives are jointly log-normally distributed. Spouses jointly decide on their time allocation between market work, home production, and leisure. Because the change in married female labor supply occurred predominantly at the extensive rather than intensive margin, we focus on the participation decision, assuming that the market hours of work are fixed, although at different levels for men and women, to allow for a better fit with the data. The home consumption good is produced by combining home appliances, purchased in the market, with perfectly substitutable male or female time.

We calibrate the parameters of the model to ensure a match with several important moments that we document using the 2000 US census data, such as the fraction of two-earner couples, several moments of the observed earnings distribution and hours worked conditional on participation. We then examine the impact of declining prices of home appliances and changes in the gender earnings gap, estimation of which is described in detail in Section 5, in the context of our model. Our model allows us to subject the factors under consideration to empirical tests, previously unexplored in this context. In particular, we investigate their implications for (1) changes in participation among groups of women disaggregated according to the husband’s earnings and (2) gender-specific leisure/home production trends among two-earner couples, one-earner couples, and on aggregate.

Our main findings are as follows. We find that both, the closing of the gender earnings gap and the modest decline in the cost of home appliances, were important factors behind the dramatic changes in the time allocation of married couples in the
last 50 years. However, the roles of these two explanations were pronounced differently. On one hand, the closing of the gender earnings gap accounts for much of the observed increase in the LFP of married females (70%) while being consistent with the cross-sectional pattern of female participation. However, despite its large effect on couples’ real income, it has a low quantitative impact on the time allocation outside of work among working and stay-home women. On the other hand, we find that the declining cost of home appliances explains a much smaller part of the rise in female participation (about 5%). However, despite of its modest fall, it appears to have been very important in generating diffusion of home appliances and through that greatly affecting the time allocation outside of work. In particular, it drove over 60% (and almost half) of gains in leisure and decline in home production time among working wives (and stay-home wives).

Interestingly, the fall in the cost of home appliances generated substantially greater leisure gains for stay-home wives than for working wives. This result is intuitive: as many of the one-earner male families are close to the case of full specialization of stay-home wives in home production, these women did not have to share gains in leisure time from the diffusion of home appliances with their spouses. When both explanations are considered together, the average leisure time of married females does not change, as gains in leisure among working and stay-home women are offset by the compositional change, exactly as it appears in the data.

It is important to emphasize that we employ a family decision making model that treats couples’ potential earnings and prices of home appliances as exogenously given. We do not inquire about the underlying reasons for their change. Thus, our results only speak to the direct effects of the earnings and appliance prices on households’ time allocation choices. To the extent that we study the aggregate and disaggregated responses of households to changes in their potential earnings, without inquiring into the underlying causes of these changes, our paper is close in spirit to Juhn and Murphy (1997). Our results are important because they suggest that in order to understand the dramatic rise in LFP of married women, it is essential to understand the determinants of the joint earnings distribution of husbands and wives, and in particular, those leading to the closing of the gender gap. These can potentially include the introduction of anti-discriminatory laws (Jones et al., 2003), factors affecting selection into marriage (Caucutt et al., 2002), changes in production technology, such as women-biased technical change (Galor and Weil, 1996), changes in returns to experience (Olivetti, 2006), and finally, factors affecting women’s decisions regarding gains in education and experience, e.g., diffusion of the contraceptive pill (Goldin and Katz, 2002), changes in cultural norms (Fernandez et al., 2004), reduction in the cost of child care (Attanasio et al., 2008), or improvement in home production technology. More work is needed to disentangle the effects of these various factors (e.g. Gayle and Golan, 2010; Mulligan and Rubinstein, 2008; Jones et al., 2003). Our work further suggests that a household-level decision making should be incorporated in these attempts. Future work should aim at understanding jointly heterogenous individuals’ decisions over the lifecycle with respect to schooling, marriage, fertility, labor force participation and the evolution of the observed gender earnings gap.

The rest of this paper is organized as follows. Section 2 describes the empirical trends in more detail. The model is presented in Section 3, and its calibration is described in Section 4. The estimation of the earnings distribution parameters is given in Section 5. The main quantitative findings are reported in Section 6. The sensitivity analysis is reported in Section 7. In Section 8, we conclude.

2. Empirical trends in the time allocation of married couples

We use the US census data on married couples. Since we do not model human capital accumulation, we consider only those individuals who are sufficiently old that they can be regarded as having completed their education, thus restricting our attention to couples with each of the spouses between the ages of 25 and 64. (See the appendix for more details on the sample.) All the couples in the sample can be identified as either two-earner couples, male-earner couples, female-earner couples, or no-earner couples. Since nearly the entire increase in the fraction of two-earner couples is due to the decline in the fraction of male-earner couples, we choose to focus on only these two types of couples, and eliminate female-earner and no-earner couples from the original sample. Note that in doing so, we ignore only a small fraction of the married population (6%). Note that in the remaining sample, two-earner couples are equivalent to couples with working females.

Note that the sample we are working with is different from samples used in labor studies. Labor studies usually aim to estimate the returns to observable or unobservable characteristics, the degree of gender discrimination, etc., and work with samples of white individuals (not married couples) that are employed full time and full year. These studies refer to the gender gap as the difference in gender-specific hourly wage not accounted for by differences in characteristics. By contrast, we aim to study how the household-level time allocation choice of all married couples of working age is affected by their potential earnings and prices of home appliances. Hence, what we refer to as the gender gap is the difference in annual potential earnings of men and women, the measure not purged of differences in gender characteristics, discrimination, or annual hours of work.

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4 Greenwood et al. (2005) provides a comprehensive summary of the home production revolution that took place in the US in the 20th century.
5 Their main focus is on documenting features of time allocation for disaggregated groups of couples. Qualitatively, the same features carry over to our dataset.
6 Note that the finding of this paper that the fall in appliance prices accounts for a very small part of the rise in female LFP, does not rule out its indirect effects. For example, a part of the effect of falling prices of home appliances could be manifested in the closing of the gender gap through its impact on education and experience gains.
The main observation we investigate is the increase in the fraction of two-earner couples, from 0.33 to 0.76 during the period 1959–1999 (Fig. 1). (Table A.8 in the appendix reports the descriptive statistics of the US census sample used here.) Notably, the increase in female LFP occurred across all groups of couples differentiated according to the husband’s earnings. Since all male labor earnings are observed in the sample, we were able to split the couples into groups, characterized by the husband’s real earnings. Specifically, we split the sample into ten groups, corresponding to the following arbitrarily chosen ranges of the husband’s labor earnings, measured in 1999 dollars: (0, 12,000], (12,000, 24,000], (24,000, 36,000], ..., (108,000, +).

Fig. 2 plots female participation as a function of the husband’s real earnings, revealing that female participation increased for all groups of couples, but the increase was greater for females with husbands in the upper range of the income distribution. Indeed, in 1959, less than 10% of females with husbands earning over 108,000 per year participated in the workforce, while in 1999, this number was over 60%. Thus, in some sense, female LFP became less tied to the husband’s earnings. Table 1 reports the percent change in female LFP between 1959 and 1999 for couples differentiated according to the husband’s earnings.

Fig. 3 highlights the rotation in the schedule of female LFP, by taking out the trend. Precisely, each value reported in Fig. 2 was divided by the average female participation in that year.

In order to document patterns in leisure, we use the dataset compiled from several time-use surveys by Aguiar and Hurst (2007). The only modification here is that we retain the variable, contained in the source files, that provides information regarding the spousal participation status. We use the same sample characteristics guidelines (e.g., age group, marital status, working husband, etc.) as we applied to the US census data.

Time-use surveys are not representative of the married population in the US. In fact, 27% and 48% of females declared that they work a positive number of hours in the 1965 and 2003 surveys, respectively, whereas the corresponding numbers inferred from the US census are 40% and 76%. Thus, we use time-use surveys to obtain gender-specific time allocation between home production and leisure activities for male-earner and two-earner couples, but we use the US census to obtain the composition of couples (fraction of two-earner couples) and the average gender-specific working hours of those who participate.

We use the same activity variables as defined by Aguiar and Hurst (2007). However, to be consistent with our conceptual framework, we compute leisure as a fraction of productive time not spent on market or home work. First, we compute weekly productive time for each respondent as $24 - 7 \times \text{time spent on sleeping, eating and personal care}$. Weekly leisure hours are defined as the productive time less the time spent working less the time spent on home production (including basic child care, own medical care and care for others).

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7 Labor earnings are defined as the sum of wage and business income, the latter representing labor income for the self-employed.
8 We use the Consumer Price Index to compute real incomes.
9 Percent change computations throughout the paper are based on a midpoint formula. This table essentially decomposes the aggregate change across subgroups of the married population.
10 The dataset is available at http://troi.cc.rochester.edu/~maguiar/timeuse_data/datapage.html.
11 For 2003, we use the information on the composition from the 2000 census (76% of married women working) and for 1965, we use the linear interpolation of the 1960 and the 1970 census composition (39.7% of married women working).
12 The workers’ time allocated to work appears somewhat higher in time-use surveys when compared to the US census, although it is also stationary over time. Since the US census sample is representative and we use it to estimate the earnings distribution later, we chose to take working hours from it as well.
13 With the Stata variable names defined by Aguiar and Hurst (2007), our measure of leisure hours is $24 - 7 \times \text{work} = \text{home production + child care basic + own medical care + care others}$.
The main time allocation trends are as follows. (1) Working wives and stay-home wives both experienced an increase in leisure time (7% and 15% increase), with stay-home wives benefiting the most. (2) Despite the first fact, the average leisure time of married females remained approximately unchanged, due to the compositional change, as more women joined the labor force, and working women have always enjoyed less leisure. (3) Time spent in home production fell for working and non-working females, the change in the composition further contributing to the fall in the average time worked at home, as working females always worked less at home (4) The relative male-to-female leisure time declined among both male-earner and two-earner couples (25% and 20% decreases), the larger decline experienced among the male-earner couples because stay-home wives enjoyed the strongest increase in leisure.

3. Model

There is a continuum of measure 1 of heterogeneous households. Each household consists of two people, a male and a female. Individuals are heterogeneous with respect to their earning ability. In particular, couple \(i\)'s potential earnings are drawn from a bivariate log-normal distribution, \(\left( w^m_i, w^f_i \right) \sim LN(m, S)\), where \(m\) and \(S\) refer to the mean vector and covariance

<table>
<thead>
<tr>
<th>Husband's earnings</th>
<th>[0,12]</th>
<th>(12,24]</th>
<th>[24,..]</th>
<th>(36,..]</th>
<th>(48,..]</th>
<th>(60,..]</th>
<th>(72,..]</th>
<th>(84,..]</th>
<th>(96,..]</th>
<th>(108,+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>%(\Delta) in female LFP</td>
<td>52.7</td>
<td>56.4</td>
<td>75.7</td>
<td>96.7</td>
<td>116.9</td>
<td>124.9</td>
<td>134.9</td>
<td>137.6</td>
<td>140.9</td>
<td>150.3</td>
</tr>
</tbody>
</table>

**Fig. 3.** Female work participation rate relative to the average female participation rate in that year, as a function of the husband's real earnings. Each line corresponds to a particular year.

<table>
<thead>
<tr>
<th>Two-earner couples</th>
<th>Female LFP 1959</th>
<th>Female LFP 1969</th>
<th>Female LFP 1979</th>
<th>Female LFP 1989</th>
<th>Female LFP 1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home production</td>
<td>0.267</td>
<td>0.235</td>
<td>0.469</td>
<td>0.386</td>
<td>0.389</td>
</tr>
<tr>
<td>Leisure</td>
<td>0.393</td>
<td>0.425</td>
<td>0.531</td>
<td>0.614</td>
<td>0.476</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Male-earner couples</th>
<th>Male LFP 1965</th>
<th>Male LFP 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home production</td>
<td>0.060</td>
<td>0.120</td>
</tr>
<tr>
<td>Leisure</td>
<td>0.500</td>
<td>0.441</td>
</tr>
<tr>
<td>Leisure_m/Lesisure_f</td>
<td>1.274</td>
<td>1.038</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average for all couples</th>
<th>Female LFP 1965</th>
<th>Female LFP 1979</th>
<th>Female LFP 1989</th>
<th>Female LFP 1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home production</td>
<td>0.053</td>
<td>0.104</td>
<td>0.056</td>
<td>0.115</td>
</tr>
<tr>
<td>Leisure</td>
<td>0.456</td>
<td>0.50</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>Leisure_m/Lesisure_f</td>
<td>0.742</td>
<td>1.060</td>
<td>0.946</td>
<td></td>
</tr>
</tbody>
</table>

Table 1
Percent change from 1959 to 1999 in female LFP by the interval of the husband's earnings (in thousands of 2000 dollars).
matrix of the log-normal distribution. This distribution reflects both observable (e.g., education, age, experience, number of young children) and non-observable (e.g., innate ability, ambition, leadership skills) characteristics of married individuals, as well as the state of production technology, market conditions and factors affecting selection into marriage.

All agents are endowed with 1 unit of productive time, which is allocated between market work \((l^1)\), home work \((l^2)\), and leisure \((1 - l^1 - l^2)\). Agents have identical preferences over consumption of the market good \((c^1)\), consumption of the home good \((c^2)\) and leisure, represented by \(u(c^1,c^2,1 - l^1 - l^2) = x \log(c^1) + \log(c^2) + (1 - 2x) \log(1 - l^1 - l^2)\). Motivated by the discussion in Section 2, we assume that all men participate in market production. Furthermore, market hours are indivisible; i.e., the male works \(l_m\), while the female chooses her market worktime from the set \(\{0, \frac{l^2}{2}\}\). Market hours differ for working men and working women to allow for a better mapping of observables into the model. Throughout the paper, individual variables are subscripted by the individual’s gender.

The household chooses to be either a two-earner household \((2E)\) or a male-earner household \((1M)\). Formally, given the potential household earnings space into two regions: \(2E\) and \(1M\). We define the decision rule threshold \(V_m(w_m)\). After substituting for the optimal consumption of the market and home good, we simplify the following.

The bargaining problem within households is solved efficiently, each household’s problem can be written as a social planning problem, with \(\lambda\) denoting the relative weight of the male’s utility. This weight represents the relative bargaining power of the husband. We assume it to be constant across households and over time. (We return to this assumption later when discussing the results.) Depending on the maximum value associated with each time allocation choice, a household chooses to be either a two-earner household \((2E)\) or a male-earner household \((1M)\). Formally, given the potential earnings draw \((w_m, w_f)\), a couple chooses max\(\{V_{2E}(w_m, w_f), V_{1M}(w_m, w_f)\}\), where

\[
V_{2E}(w_m, w_f) = \max_{\lambda c_m^1, \lambda c_f^1, \lambda c_m^2, \lambda c_f^2} \lambda \left[ x(\log(c_m^1) + \log(c_f^1)) + (1 - 2x) \log(1 - l_m^2 - l_m^2) \right] + (1 - \lambda) \left[ x(\log(c_f^1) + \log(c_f^2)) + (1 - 2x) \log(1 - l_f^1 - l_f^2) \right]
\]

s.t. \(c_m^1 + c_f^1 + qk \leq w_m + w_f\), \(c_m^2 + c_f^2 \leq F(k, l_m^2 + l_m^2)\), \(0 \leq l_f^2 \leq 1 - l_f^2\), \(j \in \{m, f\}\),

and \(V_{1M}(w_m, w_f)\) is identical to \(V_{2E}(w_m, w_f)\) with \(w_f = l_f^2 = 0\). Note from (1) that female and male time inputs are perfect substitutes in home production.

Households split the market and home goods so that fraction \(\lambda\) is consumed by the male and fraction \((1 - \lambda)\) is consumed by the female. In the \(2E\) case, for example, \(c_m^1 = \lambda(w_m + w_f - qk)\) and \(c_f^1 = (1 - \lambda)(w_m + w_f - qk)\). Similarly, \(c_m^2 = \lambda F(k, l_m^2 + l_m^2)\) and \(c_f^2 = (1 - \lambda)F(k, l_f^2 + l_f^2)\). After substituting for the optimal consumption of the market and home goods, we simplify the maximum value functions associated with each of the two time allocation choices as follows:

\[
V_{2E}(w_m, w_f) = \max_{k, l_m^2, l_f^2} \lambda x \log(w_m + w_f - qk) + x \log\left(\frac{F(k, l_m^2 + l_f^2)}{k}\right) + (1 - \lambda) \left[ x(\log(1 - l_m^2 - l_m^2) + (1 - \lambda) \log(1 - l_f^1 - l_f^2)) \right] + k \log(w_m + w_f)/q,
\]

\(0 \leq l_f^2 \leq 1 - l_f^2, j \in \{m, f\}\).

Then, \(V_{1M}(w_m, w_f)\) is the special case of the above \(V_{2E}(w_m, w_f)\) with \(w_f = l_f^2 = 0\). The constant \(\kappa = 2x(\lambda \log \lambda + (1 - \lambda) \log(1 - \lambda))\) is irrelevant for the household’s optimization problem.

The model implies a partition of the earnings space into two regions: \(2E\) and \(1M\). We define the decision rule threshold separating the two regions as a function \(r(w_m)\) that solves

\[
V_{1M}(w_m, 0) = V_{2E}(w_m, r(w_m)). \tag{3}
\]

The solution can be found only numerically. Fig. 4 illustrates the mechanism of the model pertaining to the aggregate labor force participation. Any given point in the earnings space represents a possible realization, \((w_m, w_f)\). The contour plots of the bivariate log-normal density indicate how the couples are distributed over the space. Couples with potential earnings realizations above (below) the threshold choose to be \(2E\) (\(1M\)) households. In other words, the wife chooses to participate in market production if and only if her potential earnings are large enough relative to those of her husband; and \(r(w_m)\) essentially represents the reservation earnings of a female whose husband earns \(w_m\). Female reservation earnings increase in her husband’s earnings. Intuitively, a female’s decision to work must justify the implied loss of leisure. As we increase her husband’s earnings, the marginal utility from consumption declines, so it takes a larger income for her to justify the loss of leisure associated with market participation.

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14 There is a one-to-one mapping between \(m_S\) and the mean vector and covariance matrix of the underlying normal distribution \(\mu = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix}\) and \(\Sigma = \begin{bmatrix} \sigma_{11} & \rho \sigma_1 \\ \rho \sigma_1 & \sigma_{22} \end{bmatrix}\). It is given by \(\mu_2 = \log(\frac{\mu_2}{\mu_1 + \mu_2})\) and \(\rho = \log(\frac{\mu_2}{\mu_1 + \mu_2})\). \(\sigma^2_1 = \log(1 + \rho^2)\) and \(\sigma^2_2 = \log(1 + \rho^2)\).

15 Alternatively, one could model the bargaining game explicitly as, for example, in Knowles (2008), or one could model the relative weight as an explicit function of certain important factors, for example, relative earnings (Browning and Gortz, 2007).

16 See Bar and Leukhina (2010) for details. Derivations of sufficient equilibrium conditions are included.
Note that the parameters of the earnings distribution determine where the couples are located in the earnings space, while the rest of the parameters \( \Omega = \{ \lambda, \alpha, \beta, \theta, \rho, q \} \) determine the shape and location of the decision rule threshold. With a general CES home production function, the decision rule threshold is non-linear. In the appendix (Proposition 1), we show that there are two special cases of the model that deliver a linear decision rule threshold: one is the case with a Cobb-Douglas home production function and one is the case with no home production.

What is important to understand is that both, a shift in the mass of the earnings distribution towards the 2E region (for a fixed decision rule) and a downward shift of the decision rule (for a fixed distribution) cause an increase in the proportion of two-earner couples. As we will see next, the closing of the gender earnings gap transpired primarily through the growth of female earnings, as male incomes stagnated in the 70s and 80s. This change tends to shift the earnings distribution upward, thereby pushing females to work. A decline in \( q \), the relative price of home appliances, can be interpreted as a capital-augmenting technological progress in home production (See Proposition 2 in the appendix). Hence, as long as time and home appliances are substitutes in the home production function, the decline in \( q \) will shift the decision rule threshold down, thereby increasing the fraction of working females.

4. Calibration

For computational accuracy, it is convenient to work with the logs of the earnings rather than the earnings themselves. Let \( X = \log(w_m) \) and \( Y = \log(w_f) \), so that \((X,Y) \sim N(\mu, \Sigma)\).

Because the selection bias problem is least severe in the latest census (as only 24% of women in the 2000 census sample do not work), we choose to calibrate the model to 1999. Assuming 5000 h of annual productive time, the fixed work hours (conditional on working), \( l_{1m} \) and \( l_{1f} \), are set to 0.44 and 0.34 respectively, to match the data counterparts.

We borrow parameters of the home production function, \( \theta = 0.206 \) and \( \rho = 0.189 \), from the estimation given in McGrattan et al. (1997), thus maintaining the assumption of substitutibility of the two inputs and maintaining the possibility that the falling prices of home appliances drove females to work. Substitutibility is the only reasonable assumption in this case. In fact, Aguiar and Hurst (2007) use the substitutability of inputs to classify an activity as home production.

The interior solution to home work in the 2E case must satisfy

\[ \frac{\lambda_1 - \theta}{\gamma_1 - \theta} = \frac{1}{2}. \]

We set \( \lambda = 0.5 \) to match the relative leisure of men and women among 2E couples (\( \approx 1 \) from Table 2). With equal utility weights, purchases of market consumption and home good production are divided evenly between the spouses. Note that a woman’s time available for leisure and home production is greater than that of her spouse (for both working and non-working females), so at the point of producing no home good, his marginal utility from leisure is greater, and hence it is optimal to use the wife’s time in home production, until their leisure equalizes. It may very well be the case that many of the 1M couples are in the case of complete specialization, with the optimal amount of home good produced entirely with the female’s time input.

The remaining parameters are the relative weights on consumption goods, parameters of the earnings distribution and the relative price of home appliances, \( \Theta = \{ \lambda, \mu_x, \mu_y, \gamma, \sigma_x, \sigma_y, q \} \).

We calibrate \( \Theta \) to match several 1999 data moments, summarized in Table 3. The last moment helps us capture the cross-sectional feature of participation, namely, that in 1999, female participation was not closely tied to the husband’s earnings.

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Fig. 4. This figure illustrates the mechanism of the model pertaining to the aggregate work participation. Any given point in the earnings space represents a possible earnings realization, \((w_m, w_f)\). The contour plots of the bivariate log-normal density indicate how the couples are distributed over the space. Couples with potential earnings realizations above (below) the threshold choose to be 2E (1M) households.
Table 3
Summary of moments used for calibration, 1999.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2379</td>
<td>Proportion of 1M couples</td>
</tr>
<tr>
<td>0.614</td>
<td>Average fraction of time spent in leisure activities among stay-home wives</td>
</tr>
<tr>
<td>0.425</td>
<td>Average fraction of time spent in leisure activities among working wives</td>
</tr>
<tr>
<td>10.537</td>
<td>Mean of log of male earnings</td>
</tr>
<tr>
<td>0.7543</td>
<td>Variance of log of male earnings</td>
</tr>
<tr>
<td>9.802</td>
<td>Mean of log of the working (observed) female earnings</td>
</tr>
<tr>
<td>1.126</td>
<td>Variance of log of the working (observed) female earnings</td>
</tr>
<tr>
<td>0.2285</td>
<td>Proportion of 1M couples among couples with log(wm) below the mean</td>
</tr>
</tbody>
</table>

Table 4
Summary of calibrated parameters.

<table>
<thead>
<tr>
<th>Value</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\lambda = 0.5, \xi = 0.33)</td>
<td>Preferences</td>
</tr>
<tr>
<td>(l_0 = 0.44, \delta = 0.34)</td>
<td>Market hours</td>
</tr>
<tr>
<td>(\delta = 0.206, \rho = 0.189, q = 0.99)</td>
<td>Home production</td>
</tr>
<tr>
<td>(\mu_1 = 10.374, \mu_0 = 9.5586, \sigma_0 = 0.86894, \sigma_1 = 1.2346, \sigma_{xx} = 0.66739)</td>
<td>Earnings distribution</td>
</tr>
</tbody>
</table>

Denoting these data moments by \(M\) and the corresponding moments implied by the model by \(M(\Theta)\), we solve \(\min_{\Theta} \sum_{i=1}^{8} (X_i-M(\Theta))^2\). Bar and Leukhina (2010) present derivations of \(M(\Theta)\) and discuss the numerical integration methods adopted in its computation.\(^{17}\) Table 4 summarizes the calibrated parameters.

5. Estimation of the earnings distribution parameters

In order to examine households’ responses to changes in the gender earnings gap over the period 1959–1999, we must first estimate changes in the parameters of the joint earnings distribution over this period. We do this in two steps. First, we predict the female earnings for non-working females by using the estimated year-specific censored regression model in conjunction with the participation (censoring) rule implied by our model. Second, once the potential earnings dataset is completed with predicted earnings for non-working females, we infer \(\{m, s\}_{t=1959,1969, \ldots}\) from their sample counterparts.

In general, a censored regression model allows the dependent variable to be censored and for the censoring value to vary from observation to observation. In our case, female earnings are censored, but our model implies a censoring value, or reservation earnings \(r(w_m)\), defined in (3), for a female with the spousal income of \(w_m\). We recast this decision rule in the log-earnings space and denote it by \(R(X_i, \Omega)\), where \(X_i\) is the male log-earnings and where we choose to explicitly emphasize its dependence on the model parameters \(\Omega = \{x, \alpha, \lambda, \delta, \beta, \rho, q\}\). Formally, the censored regression we employ to predict the missing earnings is given by

\[
Y_i = \begin{cases} 
Y_i & \text{if } Y_i \geq R(X_i, \Omega) \\
\beta_i x_i + u_i & \text{otherwise}
\end{cases}
\]

(4)

where \(Y_i\) denotes the observed log of the earnings of married female \(i\), and \(Y_i^*\) denotes the log of the potential earnings of married female \(i\), which is postulated to depend on her personal attributes \(x_i\), such as years of education, experience, race (see the appendix). A female’s potential earnings are observed \((Y_i\) equals \(Y_i^*)\), whenever her potential log-earnings exceed her reservation log-earnings \(R(X_i, \Omega)\). The derivation of the log-likelihood function is given in the appendix. We apply this censored regression model to each census year separately, and adjust \(q\) (which affects the reservation earnings through \(\Omega\)) to reflect the fall in the relative price of home appliances over time, discussed later and reported in Table 6, while keeping the rest of the parameters fixed at their calibrated values.\(^{18}\)

Why do we use this procedure for predicting the missing earnings? On one hand, our model speaks to the optimal family time allocation across different activities, conditional on their earnings potential. On the other hand, the census dataset

\(^{17}\) The difficulty arises when computing the moments in the model, because the limit of the integration, i.e., a point on the decision rule threshold, must be found for every point at which we evaluate the integrand. This threshold must be computed numerically by equating the value functions of the 2E and 1M problems, which may have corner solutions.

\(^{18}\) If \(q\) were fixed at its calibrated value, our main result, that the closing of the gender earnings gap was the main driving force behind the rise in the female LFP, would be reinforced. To understand this, consider estimating potential earnings for non-working females in 1959. In case of the low level of \(q\) implied by the 1999 calibration, the participation rule would have a relatively small slope, resulting in lower values of predicted missing earnings, and hence a slightly larger estimated gender earnings gap in 1959. Similarly, considering gains in female bargaining power over time (a fall in \(\beta\)) would result in a lower decision rule threshold in 1959, lower predictions for missing earnings and a larger closing of the gender earnings gap.
includes personal characteristics that contain useful information about individual earnings potential. The procedure we employ allows us to combine the time allocation decision rule from our model together with the earnings regression (4), which allows to extract relevant information from the individuals’ observed characteristics. Our procedure is similar to applying a standard Heckman (1979) selection model, except that the selection rule is taken from our model. In Section 7 on sensitivity, we explain how our results are affected if the Heckman (1979) selection model is applied instead.

As discussed above, we use predictions of the estimated year-specific censored regression model to fill out the missing Y’s. We then convert log earnings into annual earnings and record \( \{m_t, S_t\}_{t=1959,1969, \ldots} \) for the completed year-specific earnings datasets. We summarize our findings in Table 5, where instead of reporting \( S_t \), we report the more intuitive measures of the distribution shape, i.e. coefficients of variation of male and female earnings, and correlation between them. In fact, recall that the covariance matrix of any bivariate distribution, \( S = \begin{bmatrix} s_1 & s_{12} \\ s_{12} & s_2 \end{bmatrix} \), can be uniquely represented as

\[
S = \begin{bmatrix} (m_1 CV_1)^2 & \rho (m_1 CV_1)(m_2 CV_2) \\ \rho (m_1 CV_1)(m_2 CV_2) & (m_2 CV_2)^2 \end{bmatrix}.
\]

where \( CV_1 \equiv s_1/m_1 \) and \( CV_2 \equiv s_2/m_2 \) are coefficients of variation (a measure of inequality within gender i) and \( \rho = s_{12}/(s_1 s_2) \) is the correlation coefficient (a reflection of the degree of assortativeness of matching, or factors that make spousal potential earnings similar post-marriage). It should be pointed out that because the selection bias is relatively small in 1999 and we use the selection rule predicted by the model, the obtained parameters of the earnings distribution for 1999 are in close accordance with the calibrated parameters for the earnings distribution reported in Table 4.

We find that the gender earnings gap, corrected for the selection bias, narrowed monotonically \( (m_2/m_1 \text{ increased by } 143\% \text{ over the } 40 \text{ years}) \), in contrast to the pattern in the observed gender earnings gap, which remained roughly unchanged until 1980. To a large extent, the closing of the gap is due to females’ gains in observable characteristics. Finally, we find that within-gender inequality increased for men and slightly decreased for women. Also, note that the estimated correlation of husbands’ and wives’ earnings increased over time, although remaining at a very low value even today. Caution should be applied when directly comparing our estimates to those derived in studies of wage distributions. First, we consider all married individuals of working age and regard a person to be a worker if he/she works a positive number of hours, while most related studies consider full-time full-year working-age employees. Second, while other studies consider either hourly wages or annual labor earnings of full-time full-year individuals, we consider annual earnings without controlling for gender differences in hours worked, or any other characteristic. In fact, women work much less on average in our sample. These two facts are responsible for the large size in our measure of the gender earnings gap.

6. Quantitative results

Our goal is to examine the separate impact of the closing of the gender earnings gap and the fall in the cost of home appliances on female LFP and couples’ time allocation between leisure and home production activities.

6.1. Description of the gender earnings gap experiment (GG experiment)

To assess the quantitative impact of the closing gender earnings gap on aggregate and group-specific participation of married couples and their time allocation between leisure and home production, we now use our model (calibrated to 1999) to answer the following conceptual question: what time allocation choices would married couples make in 1999 (i.e., under the labor market conditions, within-gender inequality, assortativeness of matching, and bargaining within households as they existed in 1999) if faced with the gender earnings gap of 1989, 1979, \ldots, 1959? The counterfactual experiment needed to answer this question thus involves introducing the change in the gender earnings gap in accordance with our estimates from Table 5, while keeping other aspects of the earnings distribution at their 1999 level, and all model parameters – at their calibrated levels.

Hence, we need to compute the experimental distribution parameters \( \{m_t^{GG}, S_t^{GG}\}_{t=1959,1969, \ldots} \). We set the experimental mean vector to the one we estimated, i.e. \( \{m_t^{GG}\}_{t=1959,1969, \ldots} := \{m_t\}_{t=1959,1969, \ldots} \). However, in order to keep the correlation and coefficients of variation fixed at the 1999 level (thus isolating the effect of the mean vector alone), we compute

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Year, t</th>
<th>1959</th>
<th>1969</th>
<th>1979</th>
<th>1989</th>
<th>1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m_1 )</td>
<td></td>
<td>36712</td>
<td>47597</td>
<td>47382</td>
<td>48078</td>
<td>52888</td>
</tr>
<tr>
<td>( m_2 )</td>
<td></td>
<td>6779</td>
<td>11434</td>
<td>13702</td>
<td>18958</td>
<td>23739</td>
</tr>
<tr>
<td>( CV_1 = s_1/m_1 )</td>
<td></td>
<td>0.781</td>
<td>0.744</td>
<td>0.769</td>
<td>0.849</td>
<td>1.035</td>
</tr>
<tr>
<td>( CV_2 = s_2/m_2 )</td>
<td></td>
<td>1.212</td>
<td>0.997</td>
<td>0.977</td>
<td>0.956</td>
<td>1.075</td>
</tr>
<tr>
<td>( \rho = s_{12}/(s_1 s_2) )</td>
<td></td>
<td>0.004</td>
<td>0.042</td>
<td>0.052</td>
<td>0.143</td>
<td>0.159</td>
</tr>
<tr>
<td>( GG = m_2/m_1 )</td>
<td></td>
<td>0.185</td>
<td>0.240</td>
<td>0.289</td>
<td>0.394</td>
<td>0.449</td>
</tr>
</tbody>
</table>
We can observe that the relative price of durable consumption to non-durable consumption indeed experienced a much more dramatic fall in the first half of the 20th century. In fact, by 1960, refrigerators, electricity, gas, telephone and water, did not change over the time period under consideration. The change in a more narrow category, halved in the period under consideration, while the relative price of housing operation, a category including electricity, running water and central heating were widely adopted across the US households. So the home production since 1960 had to involve the continued diffusion of washers/dryers, vacuums and microwaves. We emphasize that we could not explore the first experiment, the shape and location of the decision rules move in accordance with the relevant change in while keeping the earnings distribution and all other model parameters at their calibrated levels. Operationally, as we conduct this experiment, the shape and location of the decision rules move in accordance with the relevant change in smaller changes in the data. According to these, the relative price of durable consumption to non-durable consumption halved in the period under consideration, while the relative price of housing operation, a category including electricity, gas, telephone and water, did not change over the time period under consideration. The change in a more narrow category, titled “kitchen and other household appliances” (item 30), was most dramatic. Table 6 reports the price index of this category relative to the price index of personal consumption expenditures. This series is normalized to 1 in 1999. We set the distribution of couples in the earnings space remains fixed at its 1999 level.

It is instructive to relate our experiment to the change considered in Jones et al. (2003) and Greenwood et al. (2005). Jones et al. (2003) ask whether a small exogenous change in the relative female-to-male wages (due to anti-discriminatory law) through its direct effect and its indirect effect on human capital accumulation, can account for the observed trends in participation and the observed gender wage gap. In other words, the series they use is not observable and not comparable to our definition of the gender earnings gap. The gender gap time series used in the analysis of Greenwood et al. (2005) is directly taken from Goldin (1990), and it reflects the relative observed earnings of full-time full-year workers. Correcting for the selection bias, as we show, results in a greater closing of the gender gap.

### 6.2. Description of the home appliances cost experiment (HA experiment)

Similar to the gender earnings experiment, in order to assess the quantitative impact of the fall in prices of home appliances, we use our calibrated model to answer the following conceptual question: what time allocation choices would married couples make in 1999 if faced with the prices of home appliances of 1989, 1979, ..., 1959? The counterfactual experiment needed to answer this question thus involves introducing into the model the price change, estimated below, while keeping the earnings distribution and all other model parameters at their calibrated levels. Operationally, as we conduct this experiment, the shape and location of the decision rules move in accordance with the relevant change in q, while the distribution of couples in the earnings space remains fixed at its 1999 level.

National Income and Product Accounts Table 2.5.4 provides detailed price indices for numerous components of personal consumption expenditures. According to those, the relative price of durable consumption to non-durable consumption halved in the period under consideration, while the relative price of housing operation, a category including electricity, gas, telephone and water, did not change over the time period under consideration. The change in a more narrow category, titled “kitchen and other household appliances” (item 30), was most dramatic. Table 6 reports the price index of this category relative to the price index of personal consumption expenditures. This series is normalized to 1 in 1999. We set the calibrated value and vary it across time in accordance with the price index given in Table 6.

How does this compare to the price series used in Greenwood et al. (2005)? That paper focuses on the period 1900–1980 and assumes a much more drastic decline (8.3% annual rate, or a 24-fold fall over 40 years), basing their assumption on price series documented in Gordon (1990). Taking a closer look at Gordon’s data reveals that prices of home appliances/amenities indeed experienced a much more dramatic fall in the first half of the 20th century.

### 6.3. Gender earnings gap experiment: aggregate and cross-sectional implications for female LFP

Fig. 5 summarizes the impact of the main counterfactual experiments performed in the framework of the calibrated model on the evolution of the fraction of 2E couples. The bold line represents the empirical trend. To assess the quantitative significance of the channels explored in this paper, we compare changes generated by our experiments with the corresponding changes in the data. The overall change in the fraction of two-earner couples in the data during the period 1959–1999 was 79% (from 0.33 to 0.76). We find that the GG experiment, which isolates the impact of changes in the earnings distribution due to changing gender-specific means, generates 70% of the observed rise in the fraction of 2E couples (from 0.43 to 0.76). It thus appears to be an important force behind the aggregate rise in married female LFP.

---

19 This category includes refrigerators, freezers, cooking ranges, dishwashers, washers and dryers, stoves, sewing machines, vacuum cleaners, microwaves and other appliances.

20 It is possible also that Gordon’s price index is slightly exaggerated because it includes TVs and VCRs, not the time-saving appliances we have in mind here. These are goods that complement leisure time. In fact, Vandenbroucke (2009) hypothesizes that the fall in prices of leisure goods (such as TVs and VCRs) should reduce market labor supply.
We conduct two additional experiments, which allow us to decompose the impact from changing the mean vector into the impact due to the increase in the purchasing power associated with it, \( m_1 + m_2 \) (Experiment GG, \( a \)), and the impact due to the change in the relative earnings, \( m_2/m_1 \) (Experiment GG, \( b \)).\(^{21}\) The increase in the purchasing power associated with the closing of the gender earnings gap is an important force behind the rise in female work participation.

![Labor Force Participation of Married Couples: Model v. Data](image1)

**Fig. 5.** The bold line represents the empirical trend for the fraction of two-earner couples among working age married couples in the US. The other two lines illustrate the rise in the fraction of two-earner couples generated by the two main experiments performed using the calibrated model. We conclude that the closing of the gender earnings gap is an important force behind the rise in female work participation.

![Gender Earnings Gap Exp: P(2E) by Interval of Husband’s Real Earnings](image2)

**Fig. 6.** Implications of the gender earnings gap experiment for female work participation as a function of the husband’s real earnings, by year. This is a model analog to the empirical pattern reported in Fig. 2. Exactly as seen in the data, female participation increases across all levels of the husband’s income.

We conduct two additional experiments, which allow us to decompose the impact from changing the mean vector into the impact due to the increase in the purchasing power associated with it, \( m_1 + m_2 \) (Experiment GG, \( a \)), and the impact due to the change in the relative earnings, \( m_2/m_1 \) (Experiment GG, \( b \)).\(^{21}\) The increase in the purchasing power associated with the

\[ \begin{align*}
\text{Labor Force Participation of Married Couples: Model v. Data} \\
\text{Year} \\
\text{Fraction} \\
\end{align*} \]

\[ \begin{align*}
P(2E) - \text{data} \\
\text{Gender Earnings Gap Exp} \\
\text{Home Appliances Exp} \\
\end{align*} \]

\[ \begin{align*}
\text{Interval: (0,$12,000),[$12,000, 2($12,000)), ... ,[9($12,000), \infty)} \\
P(2E) \\
\text{1959} \\
\text{1969} \\
\text{1979} \\
\text{1989} \\
\text{1999} \\
\end{align*} \]

\[ \begin{align*}
\text{Year} \\
\text{Interval: (0,$12,000),[$12,000, 2($12,000)), ... ,[9($12,000), \infty)} \\
P(2E) - \text{data} \\
\text{Gender Earnings Gap Exp} \\
\text{Home Appliances Exp} \\
\end{align*} \]

\[ \begin{align*}
\text{1959} \\
\text{1969} \\
\text{1979} \\
\text{1989} \\
\text{1999} \\
\end{align*} \]

\[ \begin{align*}
\text{Gender Earnings Gap Exp: P(2E) by Interval of Husband’s Real Earnings} \\
\text{P(2E)} \\
\text{1959} \\
\text{1969} \\
\text{1979} \\
\text{1989} \\
\text{1999} \\
\end{align*} \]

\[ \begin{align*}
\text{Fraction} \\
\text{P(2E) - data} \\
\text{Gender Earnings Gap Exp} \\
\text{Home Appliances Exp} \\
\end{align*} \]

\[ \begin{align*}
\text{Fig. 5.} \text{ Implications of the gender earnings gap experiment for female work participation as a function of the husband’s real earnings, by year. This is a model analog to the empirical pattern reported in Fig. 2. Exactly as seen in the data, female participation increases across all levels of the husband’s income.}
\end{align*} \]

\[ \begin{align*}
\text{Fig. 6.} \text{ Implications of the gender earnings gap experiment for female work participation as a function of the husband’s real earnings, by year. This is a model analog to the empirical pattern reported in Fig. 2. Exactly as seen in the data, female participation increases across all levels of the husband’s income.}
\end{align*} \]

\[ \begin{align*}
\text{We conduct two additional experiments, which allow us to decompose the impact from changing the mean vector into the impact due to the increase in the purchasing power associated with it, } m_1 + m_2 \text{ (Experiment GG, } a \text{), and the impact due to the change in the relative earnings, } m_2/m_1 \text{ (Experiment GG, } b \text{).}\(^{21}\) The increase in the purchasing power associated with the}
\end{align*} \]

\[ \begin{align*}
\text{in which we use the year-specific } m_1 \text{ and } m_2, \text{ while keeping } GG, CV_1, CV_2 \text{ and } \rho \text{ at their 1999 levels reported in Table 5. Similarly, } \{m_1^{GG, b}, S_1^{GG, b}\}_{t=1959\text{ to }1999} \text{ are computed from the same decomposition, except we use the year-specific } GG, \text{ while keeping } m_1 + m_2, CV_1, CV_2 \text{ and } \rho \text{ at their 1999 levels.}
\end{align*} \]
change in the mean vector is expected to facilitate the diffusion of home appliances, similar to a decline in the cost of home appliances, and could potentially free female time for market labor. We find that Experiment $GG_a$ generates a very small rise in female participation (from 0.745 to 0.76), while Experiment $GG_b$ generates a substantial rise (from 0.45 to 0.76). We conclude that it is the relative change rather than purchasing power associated with growth in potential female earnings that is behind the quantitative prediction of the gender earnings gap experiment.

Recall that Fig. 2 illustrates female participation as a function of the husband's labor income in 1999 dollars. Participation increased during each decade and for nearly all intervals of the husband's income, except for the second interval ($12,000$–$24,000$), in the 1990s. The magnitude of the increase was larger for women with husbands in the upper intervals.

The analogs to Figs. 2 and 3, as generated by the GG experiment, are Figs. 6 and 7. Exactly as seen in the data, female participation increases across all intervals of the husband's income during the period 1959–1999, but the increase is more significant for females with husbands in the upper range of the distribution (Table 7). Comparing the results reported in Table 7 to their data counterparts from Table 1 confirms that changes in the mean vector of the earnings distribution drives not only the overall increase in female LFP but also the cross-sectional schedule of female LFP as a function of the husband's income.

The asymmetric effect experienced by couples across different income intervals is driven by both, the increase in the purchasing power and the change in the relative earnings, associated with changing the mean vector. As a result of increasing purchasing power (Experiment $GG_a$), couples in the lowest interval increase participation by 3.8%, while couples in the top interval do by 53%. Due to the relatively low correlation of spousal earning ability, for most couples in the category of low husband income, the gender gap is already narrow in 1959. Moreover, females with husbands at the lower end of the distribution have lower reservation earnings. Hence, these women already experienced high participation rates in 1959 and had less to gain, despite being more strongly affected by the diffusion of home appliances. Note that there is no inconsistency of the result that couples across all income intervals are positively affected by the rise in purchasing power and the result, reported above, that its aggregate impact on participation is very small: due to the downward sloping schedule of female participation as a function of the husband's income, the effect of changing the composition of couples across the intervals obtained from this experiment ($m_{1999}^{GG_a} < m_{1999}^{GG_b}$) works to substantially reduce the aggregate impact. As a result of the change in the relative earnings (Experiment $GG_b$), female participation among couples in the lowest interval increases by 11.3%, while couples in the top interval experience a much larger increase of 105.6%. The intuition obtained from this experiment is similar to the one obtained from Experiment $GG_a$, except that diffusion of home appliances is even across all categories of husbands’ income.

As suggested in Bar and Leukhina (2009), female participation among many couples in this income range was negatively affected by the major expansion of the Earned Income Tax Credit in the 1990s. The model, however, generates participation rates in 1999 that are too high for low income intervals and too low for high income intervals. The reason is that our estimate of the correlation of spousal earnings is low, resulting in high relative earnings of females married to husbands at the bottom of the earnings distribution. In reality, husbands with low labor income may have other sources of income, not incorporated into our model (e.g., welfare or dividend income, income from informal activities, and family transfers).
Section 6.4: Home appliances cost experiment: aggregate and cross-sectional implications for female LFP

Fig. 5 reveals that the decline in the relative price of home appliances generates a modest aggregate increase in female LFP (from 0.73 to 0.76), accounting for only 5% of the observed increase. It generates a modest positive impact on wives’ participation across all levels of the husbands’ labor income, with a greater impact experienced by couples in the top intervals (Fig. 8). The impact ranges from less than 2% increase in participation for the lower two intervals to increases of 9% and 11% for the top two intervals. Thus, this mechanism works in the right direction and is qualitatively consistent with the cross-sectional change, but its impact on participation is quantitatively small simply because \( q \) did not fall much since 1960.

Section 6.5: Both experiments: implications for the diffusion of home appliances and trends in the time allocation outside of work

Up to this point, we have demonstrated that changes in the mean vector of the spousal earnings distribution account for a large part of the aggregate rise in female LFP as well as participation trends for groups of females disaggregated according to the husband’s income. Decomposing this impact reveals that it is the change in the relative female-to-male earnings that predominantly drives the aggregate and disaggregated participation trends, rather than the increase in the purchasing power this change entailed.

The remaining discussion will reveal that, reductions in the cost of home appliances, although modest in magnitude, had quantitatively important implications with respect to the couples’ time allocation outside of work. Intuitively, conditional on the type of couple, 1M or 2E, time allocation between housework and leisure depends on the amount of household appliances purchased in the market. We find that, despite being modest, reductions in the cost of appliances exerted more influence on the diffusion of home appliances than growing purchasing power associated with changes in the earnings distribution, and hence appear to be the main driving force behind group-specific trends in leisure and housework (Average expenditure on home appliances increased by 112% (60%) as a result of the HA experiment (GG experiment)).

Table 7: GG Exp: %Δ in female LFP by the interval of the husband’s earnings (in thousands of 2000 dollars), [1959–1999].

<table>
<thead>
<tr>
<th>Husband’s earnings</th>
<th>[0,12]</th>
<th>(12,24]</th>
<th>(24,..]</th>
<th>(36,..]</th>
<th>(48,..]</th>
<th>(60,..]</th>
<th>(72,..]</th>
<th>(84,..]</th>
<th>(96,..]</th>
<th>(108,+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Δ in Female LFP</td>
<td>25</td>
<td>54.9</td>
<td>80.8</td>
<td>99</td>
<td>112.4</td>
<td>122.6</td>
<td>130.7</td>
<td>137.2</td>
<td>142.6</td>
<td>153.2</td>
</tr>
</tbody>
</table>

*Fig. 8.* Implications of the home appliances cost experiment for female work participation, relative to the average female participation in that year. Each line corresponds to a given year. This is a model analog to the empirical pattern reported in Fig. 3. The increase is slightly more significant for females with husbands in the upper range of income.

Note that our calibration implies that nearly all 1M couples are in the case of complete specialization, in which the optimal production of the home good is reached with the wife’s time input alone (indeed, the average leisure time of men with stay-home wives is very close to \( 1 - l_m = 0.56 \)). Hence, stay-home wives do not share the gains from the diffusion of home appliances with their spouses and experience large increases in leisure time as seen in Fig. 9 (7% due to the HA experiment and 3.6% due to the GG experiment).
All 2E couples in the calibrated model reach an interior optimal solution. It is then optimal to allocate the same amount of leisure time to both spouses because $\lambda = 0.5$. The wife works fewer hours in the market ($l_2 < l_1$) but works more at home. Since both spouses work at home, they both enjoy an increase in leisure associated with the greater use of appliances as revealed in Fig. 10 (4.4% increase due to the HA experiment and 2.8% increase due to the GG experiment).

When comparing the implications of these experiments to Table 2, we see that the HA experiment explains a large part of the rise in working and non-working female leisure, about 60% and 50% of the observed change, respectively. Moreover, it provides the economic insight for why stay-home wives experienced larger leisure gains than working wives – because they did not share the benefits derived from home appliances with their spouses. It thus goes a long way in explaining leisure fact (1) from Section 2. The GG experiment helps explain it further, but it is much less important quantitatively.

Importantly, when the two exogenous changes are considered jointly, we obtain an approximately stable female leisure over time, exactly as it appears in the data, thus capturing leisure fact (2) from Section 2. The average female leisure can be expressed as

\[
\text{Model: Average Female Leisure, 1M Couples}
\]

\[
\text{Year} \quad \frac{\text{Fraction of Time Spent as Leisure}}{\text{Female Leisure, Gender Earnings Gap Exp}} \quad \text{Female Leisure, Home Appliances Exp}
\]

\[
\text{Fig. 9. Implications of both experiments for the average fraction of time stay-home wives spent in leisure. The home appliances cost experiment implies a larger gain.}
\]

\[
\text{Model: Average Female Leisure (=} \text{Average Male Leisure}, 2E Couples}
\]

\[
\text{Year} \quad \frac{\text{Fraction of Time Spent as Leisure}}{\text{Female and Male Leisure, Gender Earnings Gap Exp}} \quad \text{Female and Male Leisure, Home Appliances Exp}
\]

\[
\text{Fig. 10. Implications of both experiments for the average fraction of time spent in leisure by both spouses in two-earner households. The home appliances experiment implies a larger gain.}
\]
Reductions in $q$ generate most of the increase in the average leisure of working and non-working females, $1 - \frac{I_{f,2E}}{I_{f,1M}}$ while the closing of the gender earnings gap influence the composition of couples in favor of $P(2E)$. Since our model matches leisure time of working and non-working females fairly well in 1999, the joint experiment generates a relatively stable average female leisure. We conclude that both explanations are needed to be considered together in order to understand the evolution of female time allocation between home production, leisure, and work time.

Because work times are fixed in the model (and appear stable in the data), the above discussion also implies that when considered jointly, the HA and the GG experiments generate a large decline in the average time women spent doing

$$P(2E)\left(1 - \frac{I_{f,2E}}{I_{f,2E}} - \frac{I_{f,1M}}{I_{f,1M}}\right) + (1 - P(2E))(1 - \frac{I_{f,1M}}{I_{f,1M}}).$$

Fig. 11. Implications of both experiments for the relative male-to-female leisure among male-earner couples. As these couples are in the case of complete or almost complete specialization, stay-home wives do not share the gains from the diffusion of home appliances with their spouses.

Fig. 12. Implications of both experiments for the average fraction of time spent in leisure by men with stay-home wives. These men devote almost no time to home production and thus gain very little from the diffusion of home appliances.

We have, $1 - \frac{I_{f,2E}}{I_{f,2E}} = 0.46$ (0.43 in the data) and $1 - \frac{I_{f,1M}}{I_{f,1M}} = 0.61$ (0.614 in the data).
housework (Table 2). Again, group-specific declines in home production are mostly driven by falling $q$, while the closing gender earnings gap contributes to the drop in home production time even more by raising $P(2E)$, i.e. by changing the composition of women in favor of working women, which always worked less at home. So, leisure fact (3) is well captured when the two exogenous changes are considered jointly.

The prediction that both spouses among 2E couples experienced equal gains in leisure, shared by both experiments, is counterfactual. In fact, Table 2 reveals that the relative male-to-female leisure among 2E couples declined from 1.27 to 1.03 – something our model could produce only with a drop in $\lambda$, which we do not consider here. This suggests that the bargaining process has drastically changed among these couples and provides further motivation for works that explicitly model spousal bargaining (e.g., Knowles, 2008). Nonetheless, the HA experiment generates a drop in the relative male-to-female leisure among 1M couples because men with stay-home wives experienced almost no increase in leisure (Figs. 11 and 12), as very few of them devote any time to home production thus having something to gain from the diffusion of home appliances, while their wives gained the most.

7. Sensitivity analysis

7.1. Estimation of the earnings distribution using the heckman selection model

Recall that the first step in estimating changes in the parameters of the joint earnings distribution was to predict the missing female earnings, which was accomplished by using the estimated year-specific censored regression model in conjunction with the participation (censoring) rule implied by our model. Once the potential earnings dataset was completed with predicted earnings for non-working females, we inferred $\{m_t, S_t\}_{t=1959,1969}$ from their sample counterparts.

It is also possible to predict the missing female earnings using the Heckman selection model, instead of using the censored regression model together with the participation rule implied by our model. This is what we do here. The Heckman model is given by

$$\begin{align*}
    Y_i^* &= x_i \beta + u_i, \\
    Y_i &= \begin{cases} 
    Y_i^* > v_i, \\
    \text{otherwise}
    \end{cases} \\
    \begin{bmatrix} u_i \\ v_i \end{bmatrix} &\sim N \left( \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2 & \rho \sigma \\ \rho \sigma & 1 \end{bmatrix} \right).
\end{align*}$$

Again, $Y_i^*$ denotes the log of the potential earnings of female $i$, while $Y_i$ denotes the observed log of her potential earnings. We use the same components of $x$, as before. In addition to these, $w_t$ includes the log of the husband’s annual earnings. Using the maximum likelihood method, we estimate the model for each census year separately, finding that the marginal effect of the log of the husband’s earnings on probability of participation is always significantly negative, and it becomes less negative over time (from −0.16 in 1959 to −0.05 in 1999).

We record $\{m_t, S_t\}_{t=1959,1969}$ under this procedure, again obtaining a monotonic closing of the gender gap since $1959,(m_{1959}/m_{1969}),_{1999} = 0.2528,0.3064,0.3429,0.4268,0.4803$, although the closing is less drastic than that obtained in Section 5 (62% vs. 83%). It is possible to use these distribution parameters to repeat the experiments in the calibrated framework from Section 4. However, because the Heckman model uses the participation rule independent from our model, the parameters of the underlying normal distribution it implies for 1999 are substantially different from the ones reported in Table 2. Hence, when solving our calibrated model under $\{m_t, S_t\}_{t=1999}$ implied by the Heckman model, our calibrated model no longer delivers a good match of the empirical moments from Table 3. To ensure a good match, we recalibrate the model after setting the parameters of the earnings distribution to their empirical counterparts implied by the Heckman model. We normalize $q = 1$, and choose the remaining parameters $\theta, \rho, \lambda, \alpha$ to match $P(2E)$, $E(X–2E)$, and $E(Y–2E)$. This gives $\theta = 0.215, \rho = 0.181, \lambda = 0.49, \alpha = 0.35$.

We find that changes in the mean vector alone account for 40% of the increase in the proportion of dual earner couples, and in a manner consistent with the cross-sectional participation. The drop in the price of home appliances accounts for 4% of the increase in participation. Again, most of the aggregate and group-specific increases in participation are driven by the closing of the gender earnings gap, while declining $q$ is responsible for time allocation trends outside of work.

7.2. Adjusting the earnings of part-time workers

Clearly, a low income observation in our sample does not necessarily imply the person has a low earning ability, as he/she may be working only part-time. We repeated the entire analysis of this paper under an alternative definition of labor income,
which we denote as “adjusted income,” aimed to capture each person’s full time earnings based on his or her part-time earning ability. Precisely, we created an artificial income variable, which consists of the observed labor income adjusted by the discrepancy between his/her annual hours worked and the gender-specific and year-specific average hours in the sample. For example, if a person worked 1000 h in 1999, earning $20,000 in that year, while the average male hours were 2215.4, we create an adjusted income for that person of $20,000(2215.4/1000). We recalibrated the model, and following the procedure in Section 5, we estimated the parameters of the adjusted earnings distribution for each decade. We found that the gender adjusted earnings gap closed monotonically from 0.2 to 0.46. All the results are quantitatively similar to those obtained using unadjusted earnings.

8. Conclusions

In this paper, we quantitatively investigated the roles played by falling prices of home appliances and changes in the mean vector of the spousal earnings distribution in accounting for the observed changes in the time allocation of married individuals between market work, housework and leisure. We built a model of heterogeneous households and family-level decision making that allowed us to subject the two prominent explanations to a number of empirical tests, previously unexplored in this context.

Our main finding is that both, the closing of the gender earnings gap and the modest decline in the cost of home appliances, were important factors behind the dramatic changes in the time allocation of married couples since 1960. However, the roles of these two explanations were pronounced differently. First, we find that the closing of the gender earnings gap is the main force underlying the rise in the fraction of two-earner couples, accounting for over 70% of the observed rise. In close agreement with the data, it induces a higher response from females with husbands in the upper range of the earnings distribution. However, despite its large effect on families’ incomes, the closing of the gender earnings gap has a low quantitative impact on leisure/home production trends among working and stay-home women. Second, we find that the observed (modest) fall in the relative prices of home appliances, although a weak explanation for the aggregate participation trends, was the main force underlying changes in the time allocation outside of work. By encouraging the diffusion of home appliances, and notably much more so than the rise in the purchasing power associated with changes in the earnings distribution, it drove over 60% (and almost half) of the observed gains in leisure and the decline in home production time among working wives (and stay-home wives). Both changes must be considered jointly to understand the aggregate trends in time spent in market work, leisure and housework. Finally, our model provides economic insight into why stay-home wives enjoyed greater gains in leisure time – because most of them, being in the case of complete specialization, did not share the leisure benefits from the diffusion of home appliances with their spouses.

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Appendix A. US census data

See Bar and Leukhina (2010) for a more detailed record of the data analysis. We work with the US census data available through Steven et al. (2004). Although the census was conducted in 1960, 1970, …, 2000, income and worktime questions refer to the previous year. Hence, the observations used in this paper are for 1959, 1969, …, 1999. We match spouses using the household serial number and create a household-level dataset. Only non-farm married couples with each spouse between the ages of 25 and 64 are considered. We refer to an individual as an earner if he/she works a positive number of hours. No-earner couples and couples with a female as the only earner (around 6% of the original sample) are excluded.

We correct for the topcoding of all income types in 1959, 1969, 1979 only, because the topcoded observations in 1989 and 1999 are already replaced by the state mean or median. We infer labor income as the sum of wage and business incomes and convert all income observations into 1999 dollars using the 12 months averages of the seasonally adjusted consumer price index for the five census years: 29.17,36.68,72.58,123.94,166.58.

Worktime variables titled “actual weeks worked last year” and “usual weekly hours worked (last year)” are available since the 1980 census only. The 1960 and 1970 censuses, however, report information regarding the interval of weeks worked and the interval of weekly hours worked in the previous year. To choose the appropriate midpoints for each of the intervals, we compute gender-specific averages for each interval, using the information provided in the 1980 census on the actual and interivalled hours and weeks.

Table A.8 reports descriptive statistics for the married population sample that we work with.
Appendix B. Propositions 1 and 2

**Proposition 1.** In our model with (i) no home production or (ii) a Cobb-Douglas home production function, the decision rule threshold is a linear function passing through the origin.

**Proof**

(i) Suppose individual utility is \( \alpha \log(c^l) + (1 - \alpha)\log(1 - l^1 - l^2) \), i.e. the home good does not enter utility. Then no home production takes place, \( k = \bar{\ell}_j = \bar{l}_m = 0 \) and the decision threshold can be derived analytically as

\[
V_{1M}(w_m, r(w_m)) = V_{2E}(w_m, r(w_m)), \\
\alpha \log(w_m) = \alpha \log(w_m + r(w_m)) + (1 - \alpha)(1 - \lambda)\log(1 - \bar{l}_j), \\
r(w_m) = w_m(A - 1),
\]

where \( A = \exp\left(\frac{-(1 - \alpha)(1 - \lambda)\log(1 - \bar{l}_j)}{\alpha}\right) \).

(ii) Suppose \( f(k, l) = k^\lambda l^{1-\lambda} \). Consider the maximization problem of a 2E household, given in (2). The objective function becomes

\[
\alpha \log(w_m + w_f - qk) + \nu \left[ \theta \log k + (1 - \theta) \log (\bar{l}_m + \bar{l}_f) \right] + (1 - 2\alpha) \left[ \lambda \log \left( 1 - \bar{l}_m - \bar{l}_f \right) + (1 - \lambda) \log \left( 1 - \bar{l}_m - \bar{l}_f \right) \right] + \kappa.
\]

Because the marginal utility from \( k \) approaches infinity as \( k \) approaches zero, the optimal \( k \) is interior. It can be obtained by solving the first-order condition, \( \frac{\partial}{\partial w_m} \frac{\partial}{\partial w_f} \frac{\partial}{\partial qk} = \frac{\partial}{\partial \theta} \left( \frac{w_m + w_f}{q} \right) \), which yields \( k = \frac{\theta}{1 + \theta} \left( \frac{w_m + w_f}{q} \right) \). Finally, because the optimal time inputs into home production are independent of \( w_m \) and \( w_f \), the maximum value function associated with being a 2E household is of the form

\[
V_{2E}(w_m, w_f) = \alpha \log \left( \frac{w_m + w_f - \theta(w_m + w_f)}{1 + \theta} \right) + \nu \log\left( \frac{\theta}{1 + \theta} \left( \frac{w_m + w_f}{q} \right) \right) + \kappa_{2E}, \text{i.e.,}
\]

\[
V_{2E}(w_m, w_f) = (\alpha + \alpha \theta) \log(w_m + w_f) + \bar{k}_{2E}, \tag{B.1}
\]

where \( \kappa_{2E} \) and \( \bar{k}_{2E} \) are constants.

Similarly, the maximum value function associated with being a 1M household becomes

\[
V_{1M}(w_m, w_f) = (\alpha + \alpha \theta) \log(w_m) + \bar{k}_{1M}. \tag{B.2}
\]
Using the derivations in (B.1) and (B.2), we obtain the decision rule threshold \( r(w_m) \),
\[
V_{1M}(w_m, r(w_m)) = V_{2E}(w_m, r(w_m)),
\]
\[
(x + \alpha \theta) \log(w_m) + \tilde{\kappa}_{1M} = (x + \alpha \theta) \log(w_m + r(w_m)) + \tilde{\kappa}_{2M},
\]
\[
r(w_m) = w_m(B - 1),
\]
where \( B = \frac{\tilde{\kappa}_{1M} - \tilde{\kappa}_{2M}}{\alpha \theta} \).

**Proposition 2.** In our model, capital-augmenting technological progress in home production is equivalent to a decline in the relative price of home appliances.

**Proof.** In this version of the model, \( F(k,l) = [\delta(Ak)^{\rho} + (1 - \theta)]^{1/\rho} \). We want to show that an increase in \( A \) is equivalent to a proportional decrease in \( q \). Define the new variable \( \tilde{k} \equiv qk \) and rewrite the problem of the two-earner household as follows:
\[
V_{2E}(w_m, w_f) = \max_{c_m, c_f, Y_i} \lambda \left[ x (\log (c_m^1) + \log (c_m^2)) + (1 - 2x) \log \left( 1 - \frac{\tilde{l}_m}{l_m} - \frac{\tilde{l}_f}{l_f} \right) \right]
\]
\[
+ (1 - \lambda) \left[ x (\log (c_f^1) + \log (c_f^2)) + (1 - 2x) \log \left( 1 - \frac{\tilde{l}_f}{l_f} - \frac{\tilde{l}_m}{l_m} \right) \right]
\]
\[
s.t. c_m^1 + c_f^1 + \tilde{k} = w_m + w_f,
\]
\[
c_m^2 + c_f^2 \leq \left[ \theta \left( \frac{\tilde{k}}{q} \right)^{\rho} + (1 - \theta) \left( \frac{\tilde{l}_m}{l_m} + \frac{\tilde{l}_f}{l_f} \right)^{\rho} \right]^{1/\rho},
\]
\[
0 \leq \tilde{l}_j \leq 1 - \frac{\tilde{l}_j}{l_j}, j \in \{m,f\}.
\]
It is clear that \( A \) and \( q \) appear in this problem as a ratio. Hence, increasing \( A \) by a factor of \( \zeta \) is equivalent to decreasing \( q \) by the same factor. The same proof applies to \( V_{1M}(w_m, w_f) \).

**Appendix C. Details on the estimation of \( \{m_t, S_t\}_{t=1959, 1968} \).**

We derive the log-likelihood function. The contribution to the log-likelihood function made by observations with \( Y_i = \cdot \) is given by
\[
Pr(Y_i = \cdot) = Pr(x_i, \beta + u_i \leq R(X_i, \Omega)) = Pr \left( \frac{u_i}{\sigma} \leq \frac{R(X_i, \Omega) - x_i \beta}{\sigma} \right) = \phi \left( \frac{R(X_i, \Omega) - x_i \beta}{\sigma} \right),
\]
where \( \phi \) is the cumulative standard normal distribution function.

Conditional on being observed, the density of \( Y_i \) is \( f(Y_i | Y_i = \cdot) = f(Y_i) / Pr(Y_i = \cdot) \). Thus, we obtain the log-likelihood function,
\[
\log L = \sum_{Y_i = \cdot} \log \left( \frac{1}{\sigma} \phi \left( \frac{Y_i - x_i \beta}{\sigma} \right) \right) + \sum_{Y_i = \cdot} \log \left( \phi \left( \frac{R(X_i, \Omega) - x_i \beta}{\sigma} \right) \right)
\]
\[
= \sum_{Y_i = \cdot} -\frac{1}{2} \left( \log (2\pi) + \log \sigma^2 + \left( \frac{Y_i - x_i \beta}{\sigma} \right)^2 \right) + \sum_{Y_i = \cdot} \log \left( \phi \left( \frac{R(X_i, \Omega) - x_i \beta}{\sigma} \right) \right).
\]

| Table C.9 |
| Education record |
|---|---|
| None or preschool | 1 |
| Grade 1, 2, 3, or 4 | 2 |
| Grade 5, 6, 7, or 8 | 3 |
| Grade 9 | 4 |
| Grade 10 | 5 |
| Grade 11 | 6 |
| Grade 12 | 7 |
| 1–3 years of college | 8 |
| 4+ years of college | 9 |
The independent variable in the earnings equation is the natural log of female annual earnings. The dependent variables are the number of years of schooling, her experience, her experience squared, a dummy variable for the white race and a dummy variable for the black race. Next, we explain how “years of schooling” and the race dummies are constructed.

The US census distinguishes between 9 education codes. With each code, we associate a certain number of years of schooling. Our assumptions are summarized in the table below.

The US census defines nine different race codes: (1) White, (2) Black, (3) American Indian, (4) Chinese, (5) Japanese, (6) Other Asian or Pacific Islander, (7) Other race, n.e.c., (8) Two major races, (9) Three or more major races. We define a dummy variable “black_id” to equal 1 whenever code 2 is observed, and a dummy variable “white_id” equal 1 whenever codes 1, 4, 5, 6 are observed. (See Table C.9)

References