The Sex Ratio, Marriage and Bargaining: A Look at China

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Abstract

I study married people's time allocation decisions under an unbalanced sex ratio, to answer whether bargaining between spouses should be accounted for (e.g. the collective model of the household) or not (unitary model). I document a substantial increase in the leisure ratio between married women and men in China from 1990 to 2010, calibrate a model of marriage, bargaining and marital sorting to the baseline year, and compare the predictions of a collective and unitary versions in 2010. In the former the leisure ratio does increase, but not in the latter. Via a decomposition exercise I find that the sex ratio accounts for about four hours of extra leisure per week for married women, driven by a decrease in paid work. The effect on married men is of the same magnitude and opposite sign. My results suggest that accounting for bargaining seems to be crucial to explain the sex-specific impact of changes that affect differently men and women.

Keywords: Sex ratio, China, marriage, bargaining, time allocation

JEL Codes: J11, J12

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1 Introduction

When is it appropriate to model households as unitary (that is, assume that the household has a unique, stable utility function) and when is it better to use the collective model (i.e., allow for bargaining between spouses with separate utilities)? Micro-economists decidedly favor the latter after repeatedly finding it empirically superior, for example as in Fortin and Lacroix (1997), Chiappori et al. (2002) and Mazzocco (2007). Macro-economists still tend to model households as unitary and ignore intra-household bargaining.

An argument in favor for this practice is of the Occam's razor type: aggregate effects are small and it is costly to account for intra-household bargaining in macro models. Moreover, several macro studies have successfully replicated the rise in married women's labor supply in the United States in recent decades using standard unitary models, for example Greenwood et al. (2003) and Jones et al. (2015). However, the first study assumes men's labor supply is constant, while the results of the second one show a drop that is too large compared to the one seen in the data.

Knowles (2012) shows that a model that accounts for intra-household bargaining and home production can endogenously generate an increase in married women's labor supply with a constant leisure ratio between men and women as observed in the US data. He moreover concludes that accounting for bargaining is not always crucial, but appears to be essential to explain sex-specific behavior to changes that affect the value of single life differently across genders. Sex-specific behavior can in turn be an important driver of other macro-economic changes, like structural transformation (Ngai and Petrongolo, 2017) and employment polarization (Cerina et al., 2021).

In this paper, I study the importance of bargaining in the context of an unbalanced sex ratio. A variation in the sex ratio is an attractive scenario to study the importance of bargaining for time allocation decisions among married people. This is because it affects the outside options of men and women (the value of single life) and therefore their bargaining position (as discussed above), but not the relative prices of husband and wife's labor. Nevertheless, changes in the sex ratio can also influence marital sorting, which affects aggregate time allocation via composition effects.

I start by documenting trends in paid work and housework among married households and single individuals in China between 1990 and 2010. I find that total working hours have decreased more for married women than for their male counterparts, driven by both a decrease in paid work and housework. On the contrary, among singles the trends for men and women are similar. Therefore, the leisure ratio between married women and men increased. At the same time, the proportion of men relative to women increased, mainly due to an unbalanced sex ratio at birth since the 1980's.

I then build a model of marriage, bargaining and time allocation. The model features agents with different skill levels, and generates endogenous marital sorting. Therefore, it allows for the sex ratio to affect time allocation via both the bargaining and marital sorting channels.

I calibrate the model to replicate the observed time allocation and marital sorting along skill (based on educational attainment) in the baseline year of 1990. I then assess how the model performs in accounting for changes in time allocation patterns between 1990 and 2010, both under a unitary and a collective framework. I find that the unitary model misses entirely the increase in the leisure ratio, while the collective model does generate it. Moreover, while the collective model generates an increase in assortative mating that is smaller than the one observed in the data, time allocation results change very little when marital sorting is corrected. Therefore, in the collective model most of the observed changes in time allocation stem from bargaining and variation in relative prices.

China experienced very large socioeconomic transformations between 1990 and 2010 apart from the increase in the sex ratio. I therefore perform a decomposition exercise to isolate the effect of the most salient of these transformations: the increase in the sex ratio itself, changes in the skill distribution (which reflect increasing educational attainment), changes in the wage structure (secular increase in wages, increasing skill premium and gender wage gaps) and improvements in home production technology. I find that the increase in the sex ratio leads to a decrease of about four hours per week in paid work time for married women, with a commensurate increase in leisure. For men, the opposite is true. The effects of the sex ratio are relatively small compared to the effects attributable to the other factors, in particular to the effect of the changes in the skill distribution, which features women's skill levels increasing more than men's.

This paper is related to several lines of research. Most generally, it is related to the economic literature on marriage. Economists have been interested in it since the seminal work by Becker (1973, 1974), at the latest. Subsequent theoretical efforts to analyze marriage can be divided into two strands. The first one is derived from the observation that the search and matching framework (see Diamond (1981) and Mortensen and Pissarides (1994)) can be applied to couple formation, as in Burdett and Coles (1999). The second one takes a general equilibrium approach without the presence of frictions, as in Chiappori et al. (2006). This paper belongs to the former tradition. I contribute to this literature by proposing a way to structure a two-sided search model of the marriage market with heterogeneous agents that side-steps tractability and equilibrium-uniqueness issues, while still allowing for endogenous marital sorting.

Another line of research that this paper is related to is the study of time use. A pioneer in this area is Becker (1965), who highlighted the importance of accounting for non working-time, which had been neglected by economists at the time. A lot of effort has been put since then into documenting how people allocate their time into market work, housework and leisure, and how these allocations have changed in time. Prime examples of this are Aguiar and Hurst (2007) and Ramey and Francis (2009) for the United States, and Gimenez-Nadal and Sevilla (2012) for a panel of seven industrialized countries. This paper adds to this body of knowledge by documenting time allocation trends for China between 1990 and 2010.

A paper in the intersection of the research on marriage and time allocation that is an important forerunner for this study is the aforementioned Knowles (2012). The model I use here shares some elements with his. I go further by studying the importance of bargaining under an unbalanced sex ratio and skill heterogeneity.

Moreover, this paper joins a vast body of research on the effects of variations in the sex ratios on marriage prospects and female labor supply.[1] A classic paper by Angrist (2002) used the sex ratios among immigrants of different ethnicities in the United States as a natural experiment, and found that higher sex ratios (more men) led to increased marriage rates and decreased labor force participation for women. Grosjean and Khattar (2018) exploited the historically male-biased sex ratios in Australia that resulted from the British policy of sending (mostly male) convicts, and found similar effects that moreover persisted even after the sex ratios went back to the natural baseline. Abramitzky et al. (2011) analyzed the effect of the differential scarcity of males caused by World War I in France, and found that in areas where the scarcity was larger men were more likely to marry, while the opposite was true for women. Seitz (2009) develops a dynamic equilibrium model to account for the differences in marriage and employment rates between black and white populations in the United States. She finds that the lower sex ratio among blacks (fewer males) explains one fifth of the difference in marriage rates (lower for blacks) and between one fifth and one third of the difference in employment rates (lower for married black males and higher for married black females than for their white counterparts).[2] In sum, the literature seems to conclude that a higher sex ratio improves marriage prospects for women and decrease their labor supply. In this paper, I go a step further and look at the effect of it on time allocation (including leisure), not just market work, and I do it through the lens of a model

[1]There is also a branch of the literature that explores the effects of changes in the sex ratio on other outcomes. Two examples on China are Edlund et al. (2013), who look at the effect of the growing sex ratios on crime rates, and Wei and Zhang (2011), who propose that the rising sex ratios motivate parents with a son to save in order to improve his attractiveness in the marriage market.

[2]The lower sex ratio among blacks is due to a variety of factors including differences in the sex ratio at birth, homicide, accident and incarceration rates.

that accounts for the bargaining and marital sorting channels.

Finally, Wang (2018) looks at the effect of the unbalanced sex ratio on men and women's welfare in China, including its effect on the labor market. He also has a marriage market featuring skill heterogeneity. The main differences are that I account for housework while he does not, the structure of the marriage markets in the model (which allows me to obtain a closer marital sorting in the baseline calibration), and the ultimate research question, which is about collective versus unitary models of the household for me, and welfare for him.

The rest of the paper is organized as follows. Section 2 describes trends in time allocation patterns, sex ratios and other relevant socioeconomic variables in China between 1990 and 2010. Section 3 introduces the model of marriage, bargaining and time allocation. Section 4 lays out the calibration strategy and showcases the results. Section 5 compares the performance of the unitary and collective models. Section 6 contains the results of the decomposition exercise. Finally, section 7 concludes.

2 Time allocation, sex ratios and other relevant socioeconomic transformations in China

2.1 Time allocation patterns

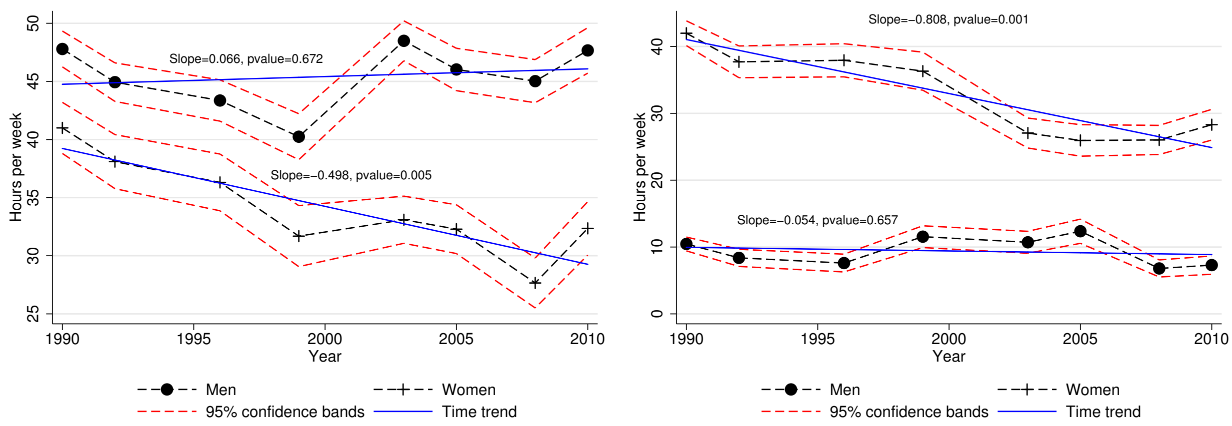
The data used to compute the time allocation patterns comes from the 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011 waves of the China Health and Nutrition Survey (CHNS).[3] The survey does not cover every Chinese province in every year, and the results may not be representative for all of China. However, to the best of my knowledge there is no other data source with detailed time use information going this far back in time, and hence this is the best one available for my purposes.

In figure 1, I plot the time used for paid work and housework among married people aged 20-35 in those Chinese provinces present in every wave of the CHNS between 1991 and 2011. The time allocation pattern for men seems stable and does not feature any significant trend. On the other hand, both paid work and housework for women show a clear downward trend.

[3] The CHNS is an international collaborative project between the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health at the Chinese Center of Disease Control and Prevention. The institutions responsible require the following text in all publications resulting from use of the CHNS data: "This research uses data from China Health and Nutrition Survey (CHNS). We thank the National Institute of Nutrition and Food Safety, China Center for Disease Control and Prevention, Carolina Population Center, the University of North Carolina at Chapel Hill, the NIH (R01-HD30880, DK056350, and R01-HD38700) and the Fogarty International Center, NIH for financial support for the CHNS data collection and analysis files from 1989 to 2006 and both parties plus the China-Japan Friendship Hospital, Ministry of Health for support for CHNS 2009 and future surveys."

Figure 1: Time allocation among married people aged 20-35 in selected Chinese provinces, 1990-2010

(a) Paid work (b) Housework



Source: Author's work with data from the CHNS.

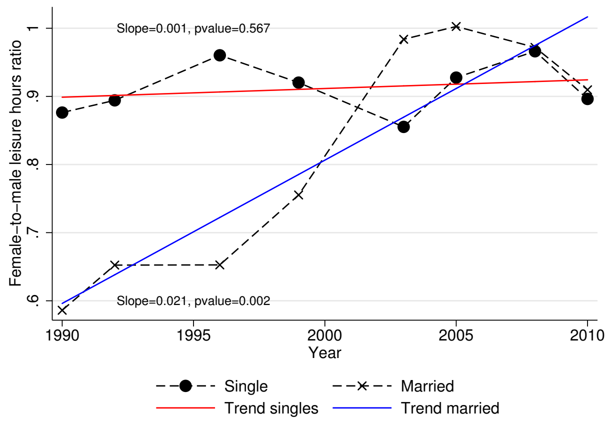
Notes: The provinces included are those present in every wave of the CHNS between 1991 and 2011: Jiangsu, Shangdong, Henan, Hubei, Hunan, Guanxi and Guizhou.

Using the data for paid work and housework I construct a measure of leisure for each year. I assume that of the 168 hours available per week, 50 are used for sleeping and personal care, as in Knowles (2012), and subtract from the remaining 118 hours the sum of paid work and housework to obtain leisure hours.

In figure 2, I plot the female-to-male leisure ratio for married and single people for the same population described above. Not surprisingly given the observed trends in figure 1, it increases substantially among married people. However among singles there is no trend at all. Indeed, the leisure ratio among married people, which initially was very unequal, tended to converge to the level observed among singles. In all years and across both groups women report longer combined paid and housework hours, and thus enjoy less leisure than men.

An important aspect to notice is that the changes in time allocation patterns presented here are different from the ones observed in industrialized countries by Aguiar and Hurst (2007), Ramey and Francis (2009) and Gimenez-Nadal and Sevilla (2012) among others, where married women's paid work increased while housework hours decreased, with the opposite happening for men.

Figure 2: Female-to-male leisure ratio among people aged 20-35 in selected Chinese provinces, 1990-2020



Source: Author's work with data from the CHNS.

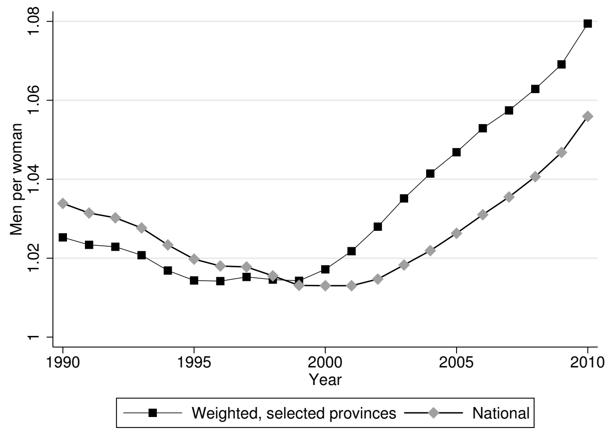
Notes: The provinces included are those present in every wave of the CHNS between 1991 and 2011: Jiangsu, Shangdong, Henan, Hubei, Hunan, Guanxi and Guizhou.

2.2 The sex ratio

Although it is generally accepted that the sex ratio in China is abnormally high, the real scale of the imbalance is a matter of debate, due to the possibility of sex-selective under-reporting of births. There are substantial inter-censal inconsistencies in the sex ratio, especially between the 2000 and 2010 censuses, as reported by Cai (2013). The most problematic cohorts are indeed those born in the 1980s, which are directly involved in our analysis. Moreover, since the time allocation data only covers seven provinces, and the sex ratio of interest is the one among people aged 20-35 (which constitutes the marriageable age), I need to compute the sex ratio in those places and for that demographic group. The micro data to do this with the 2010 census is not available, making such exercise challenging to carry out for that year.

Because of all these reasons, I follow Edlund et al. (2013) to calculate a weighted sex ratio for the desired population using the results of the 2000 census. Essentially, I compute a weighted average of the province-of-birth sex ratios among residents in the selected provinces, where weights are provided by the share of residents from each province. This procedure has the advantage that it accounts for the fact that marriage markets may not be fully local. In any case, the changes in the sex ratio computed thus track those of the national one among people aged 20-35. Figure 3 shows the results of these calculations between 1990 and 2010. The sex ratio for our population of interest goes from 1.02 to 1.08 males per female, and it

Figure 3: Sex ratio among people aged 20-35 in China, 1990-2010



Source: Author's work with data from the 2000 Population Census of the People's Republic of China.

Notes: The provinces included in the weighted sex ratio are those present in every wave of the CHNS between 1991 and 2011: Jiangsu, Shangdong, Henan, Hubei, Hunan, Guanxi and Guizhou.

seems that it kept rising beyond 2010 .

2.3 Other socioeconomic changes

The Chinese economy saw spectacular growth in the period between 1990 and 2010. According to the International Monetary Fund, GDP per capita rose on average 9.58% per annum between those years[4]. This growth translated into quite large wage gains, although they were not equally distributed between men and women, nor between people with different educational attainments.

Ge and Yang (2014) find that between 1992 and 2007 (roughly the period covered in our time allocation and sex ratio discussions) the wages for basic labor, the skill premium and the gender wage gap all increased significantly. Table 1 summarizes these findings.

The increasing skill premiums were accompanied by rising educational attainment. Figure 4 shows the skill distribution among women and men between 20 and 35 years old in our selected Chinese provinces between 1990 and 2010. The fraction of highly skilled (those with college or more) grew from less than 5% to more than 30% for both. An important change

[4] Growth rate of Gross Domestic Product per capita, constant prices in 2011 international dollars (PPP adjusted) as reported in the World Economic Outlook Databases, October 2018.

Table 1: Changes in the wage structure in China, 1992-2007

Classification	Wage growth (%) 1992-2007		Premium	
	Total	Annual	1992	2007
Overall	201.90%	7.60%	-	-
By education				
Low	135.00%	5.90%	-	-
Middle	170.40%	6.90%	6.44%	22.46%
High	240.00%	8.50%	28.63%	86.08%
By gender				
Female	182.00%	7.20%	-	-
Male	212.60%	7.90%	20.01%	33.04%

Source: Author's work using Table 1 in Ge and Yang (2014).

Notes: The original authors use a national sample of Urban Household Surveys to document the changes in the wage structure. The skill premium is computed with respect to low skill wages. The gender premium is computed with respect to female wages. An educational attainment of middle school or below is categorized as low skill, one of vocational or high school as middle skill and one of college or university as high skill.

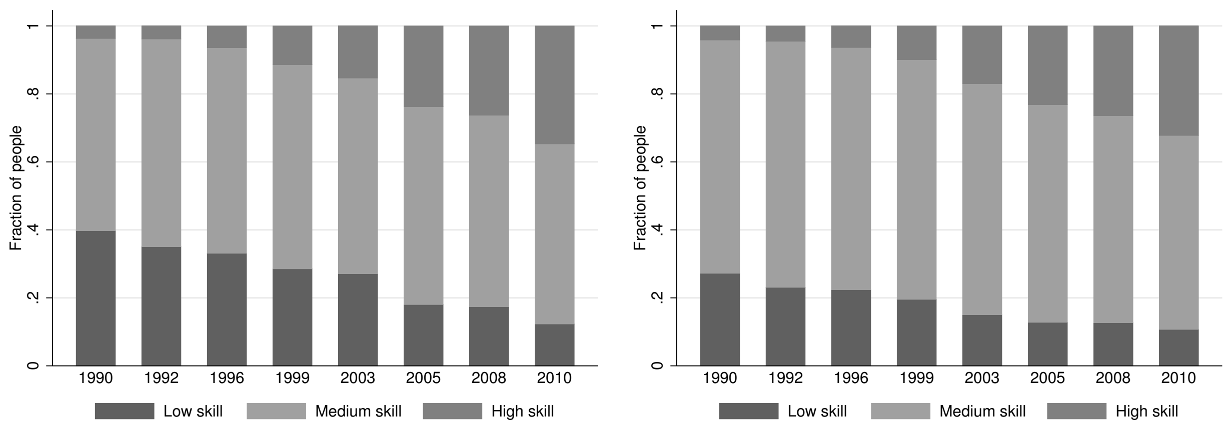
is that while in 1990 a larger fraction of men than that of women were highly skilled, but in 2010 the opposite is true. This reversal of the education gap has been observed in developed and even some middle-income countries as well.

Increasing sex ratios and skill premiums beg the question of what happened to marital sorting along skill during the period in question. Following Greenwood et al. (2014), I use data from the CHNS for our population of interest to compute three different measures of assortative mating, based on regression, rank correlation and contingency table approaches. Although the exact interpretation of each one is slightly cumbersome, for all three measures a larger value means more assortative mating.[5] A clear increase is observed in the rank correlation and contingency table based measures from 1990 to 2010, but not in the regression measure. Moreover, for reference in the United States in 2005 the numbers were around 0.07, 0.38 and 2 for the regression, rank correlation and contingency table measures, respectively. This is higher for the first and third, and in the same ballpark for the second one in China in 2010. In sum, assortative mating along skill in our Chinese provinces rose between 1990 and 2010, but is still lower than in the United States.

[5]For a detailed explanation see appendix A.

Figure 4: Skill distribution among people aged 20-35 in selected Chinese provinces, 1990-2010

(a) Females (b) Males

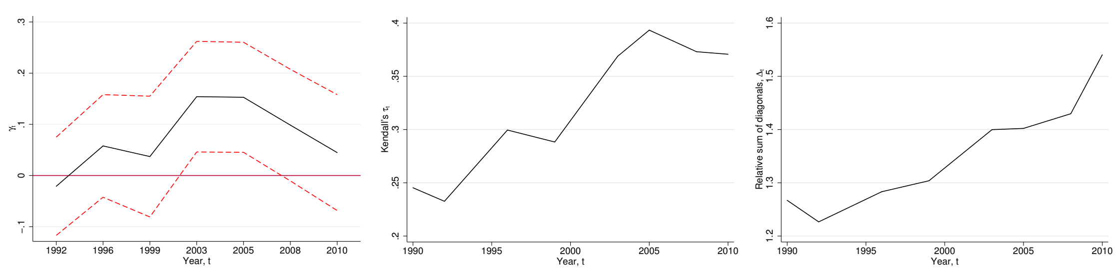


Source: Author's work with data from the CHNS.

Notes: The provinces included are those present in every wave of the CHNS between 1991 and 2011: Jiangsu, Shangdong, Henan, Hubei, Hunan, Guanxi and Guizhou.

Figure 5: Assortative mating among people aged 20-35 in selected Chinese provinces, 1990-2010

(a) Regression approach (b) Rank correlation approach (c) Contingency table approach



Source: Author's work with data from the CHNS.

Notes: The provinces included are those present in every wave of the CHNS between 1991 and 2011: Jiangsu, Shangdong, Henan, Hubei, Hunan, Guanxi and Guizhou. For panel a, the dashed lines represent 95% confidence intervals. These are not available for the measures in panels b and c. For all measures, a higher value is to be interpreted as more assortative mating.

3 The Model

To understand the effects of the socio-economic changes described in the previous section on time allocation, especially the increase in the sex ratio, I develop a model that includes a few essential ingredients. These are time allocation (including housework) and marriage decisions, heterogeneity in skills, endogenous marital sorting, and a mechanism for the conditions in the marriage market to affect the time allocation decisions. Such model is described in detail in this section.

3.1 Setup

The economy is populated by agents living for a stochastic amount of time. Each one is characterized by a gender $i \in \{f, m\}$ (female or male) and an skill type $z \in \mathcal{Z}$, both of which remain constant throughout the agent's life.[6] They can also be single or married. Time is discrete and infinite. Everyone discounts the future at a rate β and faces a constant probability of dying δ. In every period, measures 1 of females and θ_0 of males enter the economy to replace those who die. Therefore, the overall measures of females and males in the general population are $\frac{1}{\delta}$ and $\frac{\theta_0}{\delta}$, and the sex ratio is θ_0. A fraction $\mathcal{P}_i(z)$ of new entrants of gender i is of type z, $\forall z \in \mathcal{Z}$, $\sum_{z\in\mathcal{Z}} \mathcal{P}_i(z) = 1$, for $i \in \{f, m\}$. That is, $\mathcal{P}_i$ is the probability distribution of entrants of gender i over skill types. Both the measures of agents of each gender and the probability distributions over skill types among entrants are exogenous.

All agents enter the model as singles, and in each period may or may not have a marriage opportunity. Upon presented with one such opportunity, they can choose to take it or remain single. Both single and married households face a static time allocation and home production problem in each period. I will first describe this problem, and then proceed to characterize marriage decisions and the equilibrium in that market.

3.2 Time allocation and home production problem

3.2.1 Utility and constraints

The utility and constraints are similar to the ones in Knowles (2012). Agents derive utility from consumption of a private good bought in the market, a home-produced public (at the household level) good and leisure. The utility function takes the form of a weighted sum of constant relative risk aversion (CRRA) terms:

[6] Skill is based on educational attainment and therefore in this paper the terms can be used interchangeably.

$$u(c,l,g)=\frac{\sigma_c}{1-\sigma}c^{1-\sigma}+\frac{\sigma_l}{1-\sigma}l^{1-\sigma}+\frac{\sigma_g}{1-\sigma}g^{1-\sigma}.$$

The home-produced good g is created via a Cobb-Douglas technology, with housework time h and home equipment e as inputs:

$$g=G(h,e)=A_g\left[e^{1-\alpha_g}\right]h^{\alpha_g}.$$

For single households, housework time enters directly into the production function of the home-produced good. In the case of married households, wife and husband's housework times h_f and h_m are aggregated into effective household housework time via a constant elasticity of substitution (CES) function:

$$h=H(h_f,h_m)=\left[\eta_f h_f^{1-\eta}+(1-\eta_f)\,h_m^{1-\eta}\right]^{\frac{1}{1-\eta}}.$$

Each member of the household is endowed with one unit of time that has to be allocated between leisure, paid work and housework. Single households have a unique time constraint:

$$l+n+h=1,$$

while married ones have two:

$$l_f+n_f+h_f=1$$
$$l_m+n_m+h_m=1.$$

Paid work is compensated in the market with a wage that depends on the gender and skill type of the agent, which we denote $\omega_i(z)$. The price of home equipment is denoted by p_e. Both are taken as exogenous objects.

3.2.2 Single's problem

The problem solved in each period by a single person of gender i and skill type z is:

$$\max_{c,l,h,n,e_q,g} u\left(c,l,g\right) \tag{1}$$

$$\text{subject to}$$

$$l+n+h=1$$

$$g=G\left(h,e\right)$$

$$c=\omega_i\left(z\right)n-p_e e.$$

The closed-form demand functions for market goods, leisure and home produced goods are given by:

$$\{c_i(z),l_i(z),g_i(z)\}=\left\{\left(\frac{\sigma_c}{\lambda_i(z)}\right)^{\frac{1}{\sigma}},\left(\frac{\sigma_l}{\lambda_i(z)\omega_i(z)}\right)^{\frac{1}{\sigma}},\left(\frac{\sigma_g}{\lambda_i(z)D_i(z)}\right)^{\frac{1}{\sigma}}\right\},$$

while the inputs for home production are proportional to $g_i(z)$:

$$\{h_i(z),e_i(z)\}=\left\{\frac{g_i(z)}{x_i^g(z)},\frac{x_i^e(z)g_i(z)}{x_i^g(z)}\right\},$$

where $\lambda_i(z)$ is the Lagrange multiplier associated to the budget constraint, $D_i(z)$ is the effective marginal price of home-produced goods, $x_i^e(z)$ is the ratio of home equipment to housework and $x_i^g(z)$ is the ratio of of home production to housework. Closed-form expressions for these objects are derived in Appendix B. The value of the solution of problem 1 is denoted by $U_i^S(z)$.

3.3 Married household's problem

Married households maximize a welfare function that consists of a weighted sum of the utilities of each spouse, where the weight on the wife's utility is represented by χ_f. The problem solved in each period by a married household with wife's type z_f and husband's type z_m is therefore:

$$\max_{c_f,c_m,l_f,l_m,h_m,h_f,n_f,n_m,e,g} \{\chi_f u_f(c_f,l_f,g) + (1-\chi_f)\, u_m(c_m,l_m,g)\} \tag{2}$$

subject to

$$l_f + h_f + n_f = 1$$

$$l_m + h_m + n_m = 1$$

$$h = H(h_f, h_m)$$

$$g = G(h, e)$$

$$c_m + c_f = \omega_f(z_f)n_f + \omega_m(z_m)n_m - p_e e.$$

The allocations for married households are therefore the outcome of a problem that finds a point on the Pareto frontier, taking as given the Pareto weights. In the collective model of the household, these weights are the outcome of bargaining, and thus respond to the conditions in the marriage market (in particular, to the sex ratio).

The closed form demands for market goods, leisure and home production are:

$$\{c_i(z_f,z_m,\chi_f), l_i(z_f,z_m,\chi_f), g(z_f,z_m,\chi_f)\} =$$
$$\left\{ \left(\frac{\chi_f\sigma_c}{\lambda(z_f,z_m,\chi_f)}\right)^{\frac{1}{\sigma}}, \left(\frac{(1-\chi_f)\,\sigma_l}{\lambda(z_f,z_m,\chi_f)\omega_i(z_i)}\right)^{\frac{1}{\sigma}}, \left(\frac{\sigma_g}{\lambda(z_f,z_m,\chi_f)D(z_f,z_m,\chi_f)}\right)^{\frac{1}{\sigma}} \right\},$$

for $i \in \{f, m\}$. Home production inputs again are proportional to $g(z_f,z_m,\chi_f)$:

$$\{h_f(z_f,z_m,\chi_f), h_m(z_f,z_m,\chi_f), e_q(z_f,z_m,\chi_f)\} =$$
$$\left\{ \frac{x^f(z_f,z_m,\chi_f)g(z_f,z_m,\chi_f)}{x^g(z_f,z_m,\chi_f)}, \frac{g(z_f,z_m,\chi_f)}{x^g(z_f,z_m,\chi_f)}, \frac{x^e(z_f,z_m,\chi_f)g(z_f,z_m,\chi_f)}{x^g(z_f,z_m,\chi_f)} \right\}.$$

I denote the indirect utility flow accrued to an agent of sex i in a marriage of type $\{z_f, z_m\}$ with wife's Pareto weight χ_f by $U_i^M(z_f,z_m,\chi_f)$. That is, the value of the above problem in 2 is given by:

$$\chi_f U_f^M(z_f,z_m,\chi_f) + (1-\chi_f)\, U_m^M(z_f,z_m,\chi_f).$$

Closed-form expressions for $\lambda(z_f,z_m,\chi_f)$, $D(z_f,z_m,\chi_f)$, $x^g(z_f,z_m,\chi_f)$, $x^e(z_f,z_m,\chi_f)$,

$x^f(z_f, z_m, \chi_f)$ are derived in Appendix B.

3.4 Marriage decisions and market equilibrium

I use a search and matching framework to model marriage markets. This has been done before in the economic literature (see Burdett and Coles (1999), Greenwood et al. (2003), Knowles (2012) and Greenwood et al. (2016) among others). However, two-sided search models with heterogeneous agents like the one I need here are rare in the literature as they are typically intractable. The origin of this intractability is expectations: since the distribution of skills among single people is endogenous, agents need to form expectations about a multi-dimensional object in the future that affects their behavior today. The properties of any equilibrium that may arise from such model are not well understood, especially its uniqueness.[7]

A common workaround for this issue is the assumption that whenever a couple gets married, two identical agents flow into single-hood to replace them (such as in Greenwood et al. (2016)). However, when proceeding this way the primitives of the model are the distribution over types and the sex ratio *among singles*, not in the general population. This is not useful here since I am interested in generating counterfactual steady-state equilibria featuring different sex ratios *among the general population*. In other words, I precisely want to change the population flows into the model.

I therefore propose a structure for the marriage markets that side steps this issue. Upon entry, agents may be presented with a marriage opportunity with a random person of the opposite gender, of any skill type. However, in subsequent periods they may only receive marriage opportunities with agents of the same skill as themselves. This structure is inspired by Fernández et al. (2005).[8] In this way, agents do not need to form expectations about the skill distribution among singles, which is the source of intractability. However, agents may still face a decision between marrying someone outside of their skill level or waiting for a match with someone similar to them. Therefore marital sorting is still endogenous.

[7] Burdett and Coles (1997) describe the issue of multiplicity of steady-state equilibria in a two-sided search model under fully rational expectations and random search. Essentially, the cause is the presence of a sorting externality, which may lead to steady-state equilibria with distributions of singles that have more or less mass at the top of the distribution. The intuition goes as follows: suppose different types of agents can be arranged from most to least desirable, and that every agent agrees on this ordering. If those at the top of the distribution expect an abundance (paucity) of agents at the top on the other side, they will be more (less) selective, thus spending more time searching and generating the expected abundance (paucity). Moreover, this effect cascades down the distribution of types in complex ways. When an agent expects those on top of her to be more (less) selective, there are two opposing effects on her own selectiveness. On one hand, the probability of meeting someone with a higher type increases (decreases). On the other, conditional on meeting, the probability of that agent wanting to marry them decreases (increases).

[8] In their paper there are only two model periods and the sex ratio is balanced.

The first stage of the marriage market can be thought of as a reduced-form version of all the matching opportunities an agent may have earlier in life, when they meet people from a variety of backgrounds. A match in the first stage represents the best possible match in this period of life. As individuals leave the school system, enter adulthood and start working-age life, it becomes harder for them to meet individuals from a different education group. This is the second stage. In meetings featuring agents with different skill levels in the first stage, the higher-skilled agent faces a trade-off between keeping a potentially high-quality match, or waiting and getting matches with other high-skilled partners. This is the love-money trade-off, in the words of Fernández et al. (2005).

I will first describe the functioning of the multi-period marriage markets with homogeneous agents (where everyone has the same skill level), and then that of the single-period marriage market with heterogeneous agents (where entrants with all skill levels are pooled).

3.4.1 Multi-period markets with homogeneous agents

Agents that remain single upon entry face an optimal stopping problem similar to the one described by McCall (1970). In each period, single agents meet at most one agent of the opposite sex, with the measure of meetings given by

$$X\left(z\right)=\min\left\{A_X S_m(z)^{\alpha_X} S_f(z)^{1-\alpha_X}, S_f(z), S_m(z)\right\},$$

where $S_f(z)$ and $S_m(z)$ are the measures of single women and single men available in the market. Thus, the probabilities of meeting a potential spouse are obtained dividing $X(z)$ by $S_i(z)$ for $i \in \{f, m\}$:

$$\pi_i\left(\theta_S(z)\right)=\begin{cases}\min\left\{A_X\left(\frac{1}{\theta_S(z)}\right)^{1-\alpha_X}, 1, \frac{1}{\theta_S(z)}\right\} & \text{if } i=m,\\ \min\left\{A_X\theta_S(z)^{\alpha_X}, \theta_S(z), 1\right\} & \text{if } i=f.\end{cases}$$

Notice that the meeting probability for men decreases with the sex ratio among singles, while the opposite is true for women.

Upon meeting a potential spouse, agents draw a match quality q from a distribution with cumulative density function $Q_{z,z}$. This represents the flow value of companionship that each partner will enjoy from the marriage, which remains constant for the rest of their life. After observing q, agents must decide whether they want to get married. If they do, they remain married until they both die at the same time, which occurs with probability δ in every period. Moreover, I assume that there is full commitment.

Since the time allocation problem of a married household is static, and assuming wages and the price of home equipment remain constant, in steady-state equilibrium the value of a marriage between agents of type $z \in \mathcal{Z}$ for an agent of sex $i \in \{f, m\}$ and a Pareto weight χ_f is:

$$V_i^M\left(z, z, \chi_f, q\right) = \sum_{t=0}^{\infty} \left[\beta\left(1-\delta\right)\right]^t \left[U_i^M(z, z, \chi_f) + q\right] = \frac{U_i^M(z, z, \chi_f) + q}{1 - \beta\left(1-\delta\right)}. \tag{3}$$

Single agents face a probability of leaving the marriage market and become lifelong singles of ρ. This means that people can expect to spend on average $\frac{1}{\rho}$ periods being eligible for marriage. Apart from the utility derived from private goods consumption, leisure and the consumption of home-produced goods that results from solving problem 1, single agents experience a fixed utility flow per period ψ_i. This represents an intrinsic value of being single (which could be negative). The value of remaining single in steady-state is thus:

$$V_i^S\left(z, \theta_S^E(z)\right) = U_i^S\left(z\right) + \psi_i + \beta\left(1-\delta\right)\left\{\rho \frac{U_i^S\left(z\right) + \psi_i}{1-\beta\left(1-\delta\right)} + \right.$$
$$\left.\left(1-\rho\right)\left[\left[1 - \pi_i(\theta_S^E(z))\left(\theta_S\right)\right] V_i^S\left(z, \theta_S^E(z)\right) + \pi_i\left(\theta_S^E(z)\right) \int_{q \in \mathcal{Q}} V_i^X\left(z, z, q\right) dQ_{z,z}\right]\right\},$$

where $\theta_S^E(z)$ is the expected sex ratio among singles of type z and $V_i^X\left(z, z, q\right)$ is the value of a match between agents of type z for an agent of type i. The first two terms represent the current period's total utility flow. The term in curly brackets is the expected value of next period, which depends on the probability of exiting the single's market ρ, the discounted utility flow of being single for the rest of her life $\frac{U_i^S(z)+\psi_i}{1-\beta(1-\delta)}$ the probability of meeting a potential spouse $\pi_i(\theta_S^E(z))$, the value of a match and the value of being single.

Now, define reservation match quality in the marriage market among people with skill level z, $q_r\left(z, z, \theta_S^E(z)\right)$ as the lowest possible value for the draw of q such that marriage occurs when agents of types z meet, i.e.,

$$V_i^M\left(z, z, \chi_f, q\right) \geq V_i^S\left(z, \theta_S^E(z)\right) \text{ for both } i \in \{f, m\} \text{ for } q \geq q_r$$

then:

$$V_i^X(z,z,q)=\begin{cases} V_i^S\left(z,\theta_S^E(z)\right) & \text{if } q<q_r\left(z,z,\theta_S^E(z)\right) \\ V_i^M(z,z,\chi_f,q)=\frac{U_i^M(z,z,\chi_f)+q}{1-\beta(1-\delta)} & \text{if } q\geq q_r\left(z,z,\theta_S^E(z)\right). \end{cases}$$

Substituting into the value of being single:

$$V_i^S\left(z,\theta_S^E(z)\right)=U_i^S(z)+\psi_i+\beta(1-\delta)\left\{\rho\frac{U_i^S(z)+\psi_i}{1-\beta(1-\delta)}\right.$$
$$+(1-\rho)\left[\left[1-\pi_i\left(\theta_S^E(z)\right)+\pi_i\left(\theta_S^E(z)\right)Q_{z,z}\left[q_r\left(z,z,\theta_S^E(z)\right)\right]\right]V_i^S\left(z,\theta_S^E(z)\right)\right.$$
$$\left.\left.+\pi_i\left(\theta_S^E(z)\right)\left[1-Q_{z,z}\left[q_r\left(z,z,\theta_S^E(z)\right)\right]\right]\frac{U_i^M(z,z,\chi_f)+\mathbb{E}\left[q\mid q>q_r\left(z,z,\theta_S^E(z)\right)\right]}{1-\beta(1-\delta)}\right]\right\}. \quad (4)$$

The right hand side of the equation above has one term outside the curly brackets and three terms within. The former is the flow value of being single. Then, the three terms within are discounted at an effective rate $\beta(1-\delta)$. The first is the present value of being single for the rest of their life multiplied by the probability of leaving the marriage market. The last two terms are multiplied by the probability of staying in the marriage market. The first of these is the value of being single multiplied by the total probability of remaining single, i.e. the probability of not meeting anyone $(1-\pi_{iz}(\theta_{Sz}))$ plus the probability of meeting someone but marriage not happening $\left(\pi_i\left(\theta_S^E(z)\right)Q_{z,z}\left[q_r\left(z,z,\theta_S^E(z)\right)\right]\right)$. The final term is the expected value of getting married next period multiplied by the probability of marriage occurring.

The value of being single in the marriage market for types z can be obtained by solving for $V_i^S\left(z,\theta_S^E(z)\right)$ in equation 4.

3.4.2 Single-period market with heterogeneous agents

New entrants are matched randomly with other agents, that can potentially be any of type. With a sex ratio among entrants θ^0 above one, some men are going to be unmatched. The probability of being matched for a entrant male is $\frac{\theta^0-1}{\theta^0}$, and 1 for a woman. Conditional on being matched, the probability for a man that the match is with a women of type z_f is $\mathcal{P}_f(z_f)$, while the probability for a woman that the match is with a man of type z_m is $\mathcal{P}_m(z_m)$. For each such meeting, agents draw a match quality q from a distribution with cumulative density function Q_{z_f,z_m}. Marriage follows if the match quality draw q is such that both agents are better off marrying, that is:

$$V_i^M(z_f, z_m, \chi_f, q) \geq V_i^S\left(z_i, \theta_S^E(z_i)\right) \text{ for both } i \in \{f, m\},$$

where $V_i^S\left(z_i, \theta_S^E(z_i)\right)$ for $i \in f, m$ corresponds to the value of being single in the marriage market for types z_i derived in the previous section, and:

$$V_i^M(z_f, z_m, \chi_f, q) = \sum_{t=0}^{\infty} [\beta(1-\delta)]^t \left[U_i^M(z_f, z_m, \chi_f) + q\right] = \frac{U_i^M(z_f, z_m, \chi_f) + q}{1 - \beta(1-\delta)}.$$

Again, define reservation match quality between agents of types z_f and z_m in the pooled market $q_r\left(z_f, z_m, \theta_S^E(z_f), \theta_S^E(z_m)\right)$, as the lowest possible value for the draw of q such that marriage occurs when agents of types z_f and z_m meet when expectations for the sex ratio among singles in the homogeneous multi-period marriage markets are $\theta_S^E(z_f)$ and $\theta_S^E(z_m)$.

3.4.3 Flows

The reservation match qualities between agents of each combination of types $\{z_f, z_m\} \in \mathcal{Z} \times \mathcal{Z}$ in the pooled market for entrants imply endogenous flows of new singles into each of the homogeneous multi-period markets, given by:

$$S_i^0\left(z, \left\{\theta_S^E(z)\right\}_{z \in \mathcal{Z}}\right) =$$
$$\begin{cases} \mathcal{P}_f(z) \sum_{z_m \in \mathcal{Z}} \mathcal{P}_m(z_m) Q\left[q_r\left(z, z_m, \theta_S^E(z), \theta_S^E(z_m)\right)\right] & \text{if } i = f, \\ \mathcal{P}_m(z) \left\{\theta^0 - 1 + \sum_{z_f \in \mathcal{Z}} \mathcal{P}_f(z_f) Q\left[q_r\left(z_f, z, \theta_S^E(z_f), \theta_S^E(z)\right)\right]\right\} & \text{if } i = m. \end{cases}$$

Moreover, the reservation match qualities in each of the homogeneous markets imply marriage rates given by:

$$MR_i\left(z, \theta_S(z_i), \theta_S^E(z)\right) = \begin{cases} \pi_f(\theta_S(z))\left[1 - Q\left[q_r\left(z, z, \theta_S^E(z)\right)\right]\right] & \text{if } i = f, \\ \pi_m(\theta_S(z))\left[1 - Q\left[q_r\left(z, z, \theta_S^E(z)\right)\right]\right] & \text{if } i = m. \end{cases}$$

This flows result in an *actual* sex ratio among singles in the each of the homogeneous markets for type $z \in \mathcal{Z}$ given by:

$$\theta_S(z) = \frac{\frac{S_m^0\left(z,\left\{\theta_S^E(z)\right\}_{z\in\mathcal{Z}}\right)}{1-(1-\delta)\left(1-MR_m\left(z,\theta_S(z),\theta_S^E(z)\right)\right)}}{\frac{S_f^0\left(z,\left\{\theta_S^E(z)\right\}_{z\in\mathcal{Z}}\right)}{1-(1-\delta)\left(1-MR_f\left(z,\theta_S(z),\theta_S^E(z)\right)\right)}}$$

$$= \frac{S_m^0\left(z,\left\{\theta_S^E(z)\right\}_{z\in\mathcal{Z}}\right)\left[1-(1-\delta)\left(1-MR_f\left(z,\theta_S(z),\theta_S^E(z)\right)\right)\right]}{S_f^0\left(z,\left\{\theta_S^E(z)\right\}_{z\in\mathcal{Z}}\right)\left[1-(1-\delta)\left(1-MR_m\left(z,\theta_S(z),\theta_S^E(z)\right)\right)\right]}.$$

3.5 The Pareto weights

The Pareto weights in the utility of married households are a function of the surplus from marriage, defined as:

$$W_i\left(z_f, z_m, \chi_f, q, \theta_{Sz}^E\right) = V_i^M\left(z_f, z_m, \chi_f, q\right) - V_i^S\left(z, \theta_{Sz}^E\right).$$

I focus on the Egalitarian Bargaining solution proposed by Kalai and Smorodinsky (1975), i.e. the mapping from functions $W_f()$ and $W_m()$ to the Pareto weight for the wife that equalizes the surplus, i.e. χ_f solves:

$$W_f\left(z_f, z_m, \chi_f, q, \theta_S^E(z)\right) = W_m\left(z_f, z_m, \chi_f, q, \theta_S^E(z)\right).$$

Notice that even though the surplus from marriage for each agent depends on the match quality drawn q, the Pareto weight will not since q is the same for both potential partners and enters the value of marriage in an additive fashion.

3.6 Steady-state equilibrium

Suppose all agents believe that the sex ratios among singles in the homogeneous marriage markets are $\{\theta_S^E(z)\}_{z\in\mathcal{Z}}$.

Definition 1 *A steady-state equilibrium with Egalitarian Bargaining (SSEB), consists on reservation match qualities $q_r(z_f, z_m)$, Pareto weights for the wives $\chi_f(z_f, z_m)$, and values of being married $V_i^M(z_f, z_m, \chi_f, q)$ for all $\{z_f, z_m\} \in \mathcal{Z}_f \times \mathcal{Z}_m$, sex ratios among singles $\theta_S(z)$, expectations on the sex ratios among singles $\theta_S^E(z)$, and values of being single $V_i^S\left(z, \theta_S^E(z)\right)$ for all $z \in \mathcal{Z}$ and $i \in \{f, m\}$ such that:*

1. *The value functions solve the Bellman equations for men and women, i.e.:*

- *$V_i^M(z_f, z_m, \chi_f(z_f, z_m), q)$ satisfies equation 3 for all $\{z_f, z_m\} \in \mathcal{Z}_f \times \mathcal{Z}_m$,*
- *$V_i^S\left(z, \theta_S^E(z)\right)$ satisfies equation 4 for all $z \in \mathcal{Z}$ and $i \in \{f, m\}$.*

2. *The reservation match qualities set the marriage surplus to zero, i.e.:*

$$\begin{aligned} & W_f\left(z_f, z_m, \chi_f(z_f, z_m), q_r\left(z_f, z_m\right), \theta_S^E(z_f)\right) \\ +& W_m\left(z_f, z_m, \chi_f(z_f, z_m), q_r\left(z_f, z_m\right), \theta_S^E(z_m)\right) = 0 \quad \forall \{z_f, z_m\} \in \mathcal{Z} \times \mathcal{Z} \end{aligned}$$

3. *The allocations for married people implied by the Pareto weights equal those generated by Egalitarian Bargaining, i.e.:*

$$\begin{aligned} & W_f\left(z_f, z_m, \chi_f(z_f, z_m), q, \theta_S^E(z_f)\right) \\ =& W_m\left(z_f, z_m, \chi_f(z_f, z_m), q, \theta_S^E(z_m)\right), \quad \forall q \geq q_r\left(z_f, z_m\right), \quad \forall \{z_f, z_m\} \in \mathcal{Z} \times \mathcal{Z} \end{aligned}$$

4. *Expectations are correct, i.e.:*

$$\theta_S^E(z) = \theta_S(z), \quad \forall z \in \mathcal{Z}$$

3.7 Computing the SSEB

For a given set of parameters, the algorithm I use to find a SSEB goes as follows. First, I compute the utility flows for singles. Then, I guess a set of expectations for the sex ratio among singles in each of the same-skill markets $\{\theta_S^E(z) : z \in \mathcal{Z}\}$, and a set of Pareto weights $\{\chi_f(z) : z \in \mathcal{Z}\}$. Reasonable guesses are just the sex ratio among entrants and 0.5 for the Pareto weights. Then, for each market I find equilibrium reservation match qualities and Pareto weights for the current expected sex ratio among singles by applying iteratively the definitions of reservation match quality (marriage gains are zero) and Egalitarian Bargaining (marriage gains are equalized). Then, I compute the reservation match qualities and Pareto weights in the first-stage markets by using the continuation values implied by the same-skill markets. Next, I compute the steady-state sex ratio among singles implied by the reservation match qualities using the flow equations. Finally, I repeat the process with an expected sex ratio among singles equal to the steady-state sex ratio found in the last step. This procedure is repeated until the expected sex ratios converge with the steady-state ones. Appendix E contains detailed figures for this algorithm.

4 Calibration

The main goal of the calibration is to find values for the model's parameters such that the steady-state equilibrium replicates the time allocation and marital sorting patterns in the baseline year of 1990. I divide the parameters into three groups. The first one is externally chosen. The second group is chosen to match data targets with model counterparts, without the need of solving the model. The final group is chosen jointly to match a set of data targets with steady-state equilibrium model moments.

4.1 Model's primitives

The exogenous objects that for a certain set of parameters determine the steady state are the sex ratio among entrants θ_0, the skill distributions among male and female entrants, the wage structure, the price of home equipment p_e and the home productivity A_g.

I calculate the sex ratio and the skill distribution as discussed in section 2. This means that there are three types of people according to their skill: low-skilled (primary school), medium-skilled (high school) and high-skilled (college or more). Formally, $\mathcal{Z} = \{Low, Medium, High\}$.

The wage structure is based on the results from Ge and Yang (2014) presented in table 2. I normalize male low-skilled wages to 1 and use the wage premiums to obtain those for medium and high-skilled men. I then calculate the gender wage ratio from the average male and female wages, and apply it to each skill group to obtain the respective female wages. That is, there is a constant gender wage ratio across skill groups.

To the best of my knowledge, there is no data for home equipment prices in China going as far back as 1990. I follow Knowles (2012) and use data for the United States instead. In particular, I use BEA table 2.3.4, and divide the price index for furnishings and durable household equipment by the index for personal consumption expenditure, which comes to 1.82 for 1990. Home productivity is normalized to 1 in 1990.

4.2 Externally chosen parameters

The group of externally chosen parameters consists on the discount rate β, the death rate δ, the rate of exogenous exit from the marriage market ρ, the household's CRRA utility parameter σ, the parameters of the meeting technology A_x and α_x, the Cobb-Douglas share of time in home production α_g and the inverse elasticity of the CES time aggregator for married couples η.

The discount rate β is set to 0.96 for an implied interest rate of 4% a year. The death rate δ is assigned for a life expectancy of 49 years at 20, so that total life expectancy is 69 years as reported for China in 1990 by the United Nations Population Division. The exit rate of the marriage market δ is set so that the expected number of periods that a person stays in the market is 15 (between 20 and 35) years old. The parameters of the meeting technology are set to $A_x = 1$ and $\alpha_x = 0.5$. The CRRA utility parameter $\sigma = 1.5$ is taken from Attanasio et al. (2008). Since this number was estimated for the United States, I repeat the analysis with $\sigma = 1.25$ and $\sigma = 1$ in Appendix C. Knowles (2012) estimates that the share of expenditure in home equipment over total cost of home production fluctuates between 4% and 6% in the United States. I therefore set $\alpha_g = 0.95$, so that the share of home equipment is $1 - \alpha_g = 0.05$ or 5%. Finally, I follow him again again and set the parameter governing the elasticity of substitution between wife and husband's housework time in the married household time aggregator $\eta = 0.33$.

4.3 Parameters chosen before solving the model

The group of parameters chosen before solving the model are the weight of the wife's time in the household aggregator of married couple's home production time η_f, and the weights in the utility function for single people σ_c, σ_l and σ_g.

From the first order conditions of the married couple's problem we have:

$$\frac{h_f}{h_m} = \left[\frac{\eta_f}{1-\eta_f} \frac{\omega_m}{\omega_f} \right]^{\frac{1}{\eta}}.$$

I calculate the value of η_f so that the it matches the ratio of wife to husband's housework time in 1990, using the gender wage ratio for that year and the value of η already chosen.

Finally, I compute a different set of utility weights for single men and women, so that the time allocation among entrants matches the one observed in the data.

4.4 Parameters chosen jointly by matching moments in equilibrium

The rest of the parameters are jointly set by matching time allocation among married people and the marital sorting observed in the data in 1990 with steady-state equilibrium model counterparts. These are the weights in the utility function for married people, the flow utilities of being single ψ_i for $i \in \{f, m\}$ and the parameters of the distribution of the match quality draws.

In principle all parameters affect all moments in steady state equilibrium. However, the utility weights play a crucial role in determining the overall time allocation among married people. Larger values for the weights on private consumption of market goods σ_c, home-produce goods σ_g and leisure σ_l should, all other things equal, lead to more market work, home production and leisure hours, respectively.

Moreover, from the first order conditions of the married household problem we have:

$$\frac{l_f}{l_m} = \left[\frac{\chi_f}{1-\chi_f}\frac{\omega_m}{\omega_f}\right],$$

that is, the leisure time of married women relative to men depends on the Pareto weights. Now, these are equilibrium objects that depend on the outside value for men and women, in this case the value of being single. The utility flow of this state then affects the Pareto weights and therefore the relative leisure. With Egalitarian Bargaining only the difference between absolute utility flows matters for the determination of the Pareto weights. Therefore I normalize $\psi_m = 0$, and only calibrate ψ_f.

For the match quality draws I assume a normal distribution with standard deviation of 1, and include as parameters to calibrate the means for each combination of female and male skill types μ_{z_f,z_m} for $\{z_f, z_m\} \in \mathcal{Z} \times \mathcal{Z}$. These will affect the fraction of marriages with the corresponding skill combination, which should be as close as possible to the observed one.

The algorithm I use to calibrate the model can be described as a nested bisection. I choose initial values for σ_c and σ_l, with $\sigma_g = 1 - \sigma_c - \sigma_l$ and an initial guess for the means of the match quality draws. I then run a bisection algorithm for ψ_f until I find a value such that the steady-state average leisure ratio matches the one in the data, updating the means of the match quality draws in each iteration to have the marital sorting be as close as possible to the observed one. Then I compare the total paid work and leisure times and update the utility weights accordingly, increasing (decreasing) σ_c if paid work is too low (high), and doing the same with σ_l and leisure, and repeat the inner bisection. The process is repeated until the outer bisection converges for the utility weights.

4.5 Calibration results

The parameters obtained in the calibration are presented in tables 2 and 3. Several remarks are in order. The weight of the wife's time in the housework time aggregator is larger than 0.5, meaning that the wife's time is more valuable in home production. With respect to the utility, both female and male singles and married people put similar weights on private market consumption, but married people put more weight on the consumption of the home

Table 2: Calibrated parameters

Parameter	Value	Source or target(s)
Externally chosen:		
β	0.960	Implied by a 4% interest rate
δ	0.020	Life expectancy of 49 years
ρ	0.067	Expected 15 years max spouse search
σ	1.500	Attanasio et al. (2008)
α_g	0.950	Knowles (2012)
η	0.330	Knowles (2012)
Chosen before solving the model:		
η_f	0.330	Gender housework ratio, married people in 1990
Single women		
σ_c	0.383	Single women paid work hours per week
σ_l	0.577	Single women leisure hours per week
σ_g	0.041	Single women housework hours per week
Single men		
σ_c	0.373	Single men paid work hours per week
σ_l	0.623	Single men leisure hours per week
σ_g	0.004	Single men housework hours per week
Chosen jointly by matching moments in equilibrium:		
σ_c	0.388	
σ_l	0.450	
σ_g	0.163	Marital sorting and married people's time allocation
ψ_f	-0.540	
M	See table 3	

Table 3: Calibrated means of match quality draws

Female skill	**Male skill**		
	Low	**Medium**	**High**
Low	0.564	3.077	0.039
Medium	0.980	1.377	4.755
High	-1.656	1.442	-1.348

produced good than single women, and in turn the latter put more weight on it than single males. This makes sense, since married women have children, which are not included in the model but require more home production. The difference between single females and males may reflect cultural expectations about the role that women and men take in the household, with women expected to do more housework. In any case, these differences are needed to account for the time allocation patterns across gender and marital status. Furthermore, being single entails a utility cost for women in the model since ψ_f is negative. This is to be interpreted as women enjoying being single less than men, which can reflect cultural expectations as well. Finally, the interpretation of the means of the match quality draws is not a straightforward one given the structure imposed on the marriage markets, as the first period can be seen as a reduced form of all marriage opportunities people have outside their skill level. It is important though to remember that the match qualities do not affect the time allocation within a given skill combination with Egalitarian bargaining, and thus their impact on it in general is limited.

Tables 4 and 5 show the time allocation and marital sorting obtained by the model and the ones observed in the data. Unsurprisingly, the time allocation among single people is almost identical in model an data since it is the result of a straightforward minimization problem. However, the time allocation among married people is also very close to the observed one. In terms of marital sorting, by comparing the left and right columns in table 5 one can see that the model is very close to the data as well. Moreover, I computed a measure of assortative mating based on contingency tables as described in section 2, and obtained identical 1.267 for both.

The calibration therefore achieves the goal stated at the beginning of this section of obtaining a set of parameters for the model such that the steady state equilibrium yields results very close to the data targets for 1990.

5 Explaining changes in time allocation: comparing the collective and unitary models

China experienced vast socioeconomic transformations in the twenty year period between 1990 and 2010, as discussed in section 2. Having calibrated the parameters of the model to reflect the 1990 time allocation and marital sorting patterns, in this section I change the primitives in the model to reflect some of those transformations, and assess how the collective model, that accounts for bargaining between wife and husband, fares in reflecting the changes in time allocation patterns compared to the unitary model.

Table 4: Calibration results for time allocation (hours per week), 1990

Statistic	**Model**	**Data (1990)**
Married women housework	42.53	41.98
Married women paid work	40.74	41.00
Married women leisure	34.73	35.02
Married men housework	10.20	10.46
Married men paid work	48.54	47.79
Married men leisure	59.26	59.75
Single women housework	10.43	10.43
Single women paid work	48.01	48.00
Single women leisure	59.56	59.57
Single men housework	2.41	2.41
Single men paid work	47.62	47.60
Single men leisure	67.97	67.98

Table 5: Calibration results for marital sorting, 1990

	Husband's skill					
Wife's skill	**Low**		**Medium**		**High**	
	Data	**Model**	**Data**	**Model**	**Data**	**Model**
Low	0.167	0.174	0.249	0.246	0.004	0.004
Medium	0.076	0.075	0.456	0.452	0.024	0.024
High	0.000	0.000	0.012	0.011	0.013	0.014

Notes: For each entry, the number represents the fraction of all marriages in which the wife has the skill level indicated by the row, and the husband the skill level indicated by the column.

5.1 Model's primitives in 2010

Recall that the exogenous objects are the sex ratio among entrants θ_0, the skill distributions among male and female entrants, the wage structure, price of home equipment p_e and the home productivity A_g. The way these are computed is discussed in the previous section. Here I comment the most salient changes between 1990 and 2010.

First, the sex ratio increases from 1.025 in 1990 to 1.079 males per female in 2010. The underlying causes of this phenomenon, although fascinating in their own right, are not explored in this paper. I take demographics as exogenous and focus on the effects on time allocation patterns for married households. It is nevertheless reasonable to think that from the point of view of people participating in the marriage markets in 2010, the sex ratio is set in stone.

The distribution of skills for both genders changes substantially. First, there is an increase in the average skill level. The fraction of high-skilled individuals increases from less than 5% to more than 30% and the fraction of low-skilled falls from around 30% to about 10%, while the fraction of middle-skilled falls by 10 percentage points for men and only by 4 for women. Overall, the distributions become more similar in 2010 than in 1990. I do not dispute the fact that changes in the sex ratio can affect education decisions, but including the in this analysis is beyond the scope of the paper.

The most important changes in the wage structure are a 135% increase in wages for low skilled individuals, an increase in the skill premiums, and an increase in the gender wage gap from 22% to 33%. Notice again that China is different with respect to western countries, where the skill premium has also risen, but the gender wage gap has fallen in recent decades.

Prices of home equipment relative to general consumption fell from 1.82 in 1990 to 1.06 in 2010. The growth rate of home productivity is not directly observable, but I infer it from the behavior of single individuals. I estimate it by matching the decrease in housework time experienced by this group, and obtain an average annual growth rate of 9.47%. This number may seem large, but consider that according to the National Bureau of Statistics of China in 1990 less than half of Chinese urban households, and less than 2% of rural ones owned a refrigerator.[9] In 2010, the fractions were 96.61% and 45.19%. Ownership of other household appliances like microwave ovens and washing machines increased as well. The arrival of these durable goods to Chinese households certainly constitutes a major time-saving technological change, as was the case over a longer period of time in the United States according to Greenwood et al. (2005).

[9] China Statistical Yearbook 2021, chapters 6-10 and 6-15.

5.2 The collective and unitary model's predictions for married people's time allocation

The model presented in section 3 allows me to compare the predictions from the collective and unitary models of the household for 2010. To do so, I first compute a steady-state equilibrium with Egalitarian Bargaining using the calibrated parameters for the baseline year of 1990, but the primitives of 2010. This represents the collective model. In this new steady-state, the Pareto weights of the married household's problem adjust to reflect the new conditions in the marriage market. Some of these are unambiguously good for women, like the increased sex ratio. Others are unambiguously bad, like the larger gender wage gap. For other factors it is not easy to determine ex-ante whether women will benefit or not, like the new skill distribution. The time allocation in the new steady-state reflects the combination of all these.

The unitary model of the household does not account for intra-household bargaining. To represent this, I compute time allocation results for married people using the calibrated parameters for 1990 *including the Pareto weights*, and the primitives for 2010. At the household level thus the utility function remains constant. Notice that this gives me a time allocation result for each combination of wife-husband skill levels. I use therefore the *observed* marital sorting in 2010 to compute the average time allocation for all married people. The results of this exercise are presented in table 6.

Table 6: Unitary and collective model's fit for married people's time allocation, 2010

Statistic	**Hours per week**			**Δ 1990-2010**		
	Unitary	**Collective**	**Data**	**Unitary**	**Collective**	**Data**
Women housework	31.36	28.56	28.30	-10.62	-13.97	-13.68
Women paid work	42.94	19.23	32.36	1.94	-21.51	-8.64
Women leisure	43.70	70.21	57.34	8.68	35.48	22.32
Men housework	6.39	8.47	7.30	-4.07	-1.73	-3.16
Men paid work	35.50	55.07	47.67	-12.29	6.53	-0.13
Men leisure	76.12	54.45	63.04	16.37	-4.80	3.29

The collective model correctly predicts the direction of the changes in time allocation among women. The magnitude of the decrease in housework is spot on, but the decrease in paid work is too large and leads to a an excess 13 hours per week of leisure in the model compared to the data. For married men, the collective model predicts a 6 and a half hours per week increase in paid work, while in the data there is almost no change. This translates into a 5 hour per week decline of leisure, while in the data there is 3 hour increase.

Table 7: Collective model fit for marital sorting, 2010

Wife's skill	**Husband's skill**					
	Low		**Medium**		**High**	
	Data	**Model**	**Data**	**Model**	**Data**	**Model**
Low skill	0.067	0.060	0.072	0.069	0.003	0.010
Medium skill	0.043	0.019	0.436	0.364	0.091	0.172
High skill	0.008	0.002	0.102	0.158	0.179	0.146

Notes: For each entry, the number represents the fraction of all marriages in which the wife has the skill level indicated by the row, and the husband the skill level indicated by the column.

In the unitary model married women decrease housework slightly less than in the data, but market hours slightly increase for them instead of decreasing by 8 and a half hours like in the data. Therefore, leisure hours increase less than in the data. For married men, the unitary model is way off, predicting a large decrease in market work, and thus greatly overstating he increase in leisure among married men.

At this point it is useful to examine the wife/husband leisure ratio. In the data, it increases from 0.59 to 0.91 between 1990 and 2010. In the collective model it also increases, but all the way to 1.29. In the unitary model it falls slightly to 0.57.

Now I turn the attention towards marital sorting. The steady-state equilibrium with Egalitarian bargaining that represents the collective model features an endogenous marital sorting. This is presented in table 7.

It is apparent that the marital sorting is not as close to the data as it was for the results of the calibration for the baseline year of 1990. Computing the assortative mating measure based on this contingency tables confirms that in the model it is lower than in the data, 1.29 compared to 1.54.

To assess the effects of this extra marital sorting, I compute the average time allocation for married people using the Pareto weights obtained in the collective model, but aggregating them using the *observed* martial sorting in 2010. The results (shown in the appendix) are very similar to the ones in table 7.

This final piece of evidence suggests that the collective model with Egalitarian Bargaining exaggerates the improvement in women's bargaining position and generates a response in market hours for both men and women that is too large, which leads to an overreaction of the leisure ratio. On the other hand, the unitary model completely misses the increase in the leisure ratio among married people. Moreover, the effect of changes in marital sorting on time allocation seem to be second order compared to the effects of bargaining.

6 Quantitative experiment: decomposing the effects on time allocation in the collective model

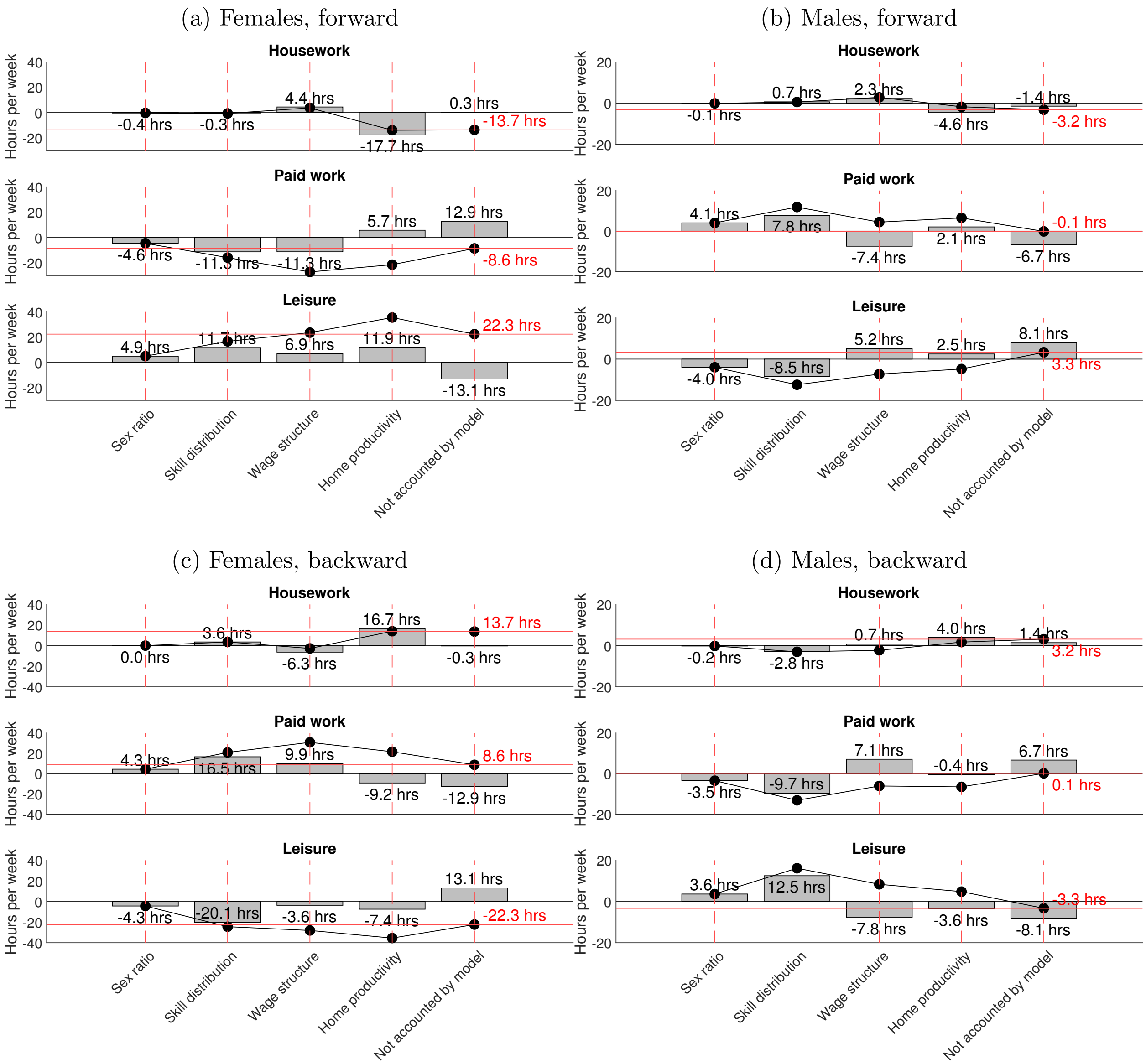
In the previous section, we analyzed the model's steady-state for 2010, which is the result of the combined effects of all the demographic and economic changes included as primitives. In this section, I perform a decomposition exercise that intends to isolate the effect of each of these factor on time allocation among married people.

The way that I proceed is as follows. I start with the model in steady-state in 1990. Then I change, one-at-a-time and cumulatively, the sex ratio, skill distribution among entrants, the wage structure and the home production parameters (both the price of equipment and the productivity at home at the same time, I call it simply home productivity). Every time I change a factor, I compute a new SSEB. Naturally, as there are all sort of non-linearities and complementarities involved, the order of the decomposition matters. To account for this, I repeat the procedure starting from 2010, and change the primitives in the same order. I call the first decomposition forward, and the second backward. Moreover, since there are differences between the model's steady-states and observed time allocations (small in 2010, larger in 2010), I include a fifth category and call it "not accounted by the model". The results of the decomposition exercise are shown in figure 6.

The first thing to notice is that the forward and backward decompositions are roughly mirror images of each other. The magnitudes are surely different, but the relative contributions of each factor do not change dramatically. For example, both the forward and backward decomposition show that home productivity is by far the most important contributor to changes in female housework time, with the wage structure coming a distant second.

It seems to make sense that both the drop in prices and improvements in the availability and quality of home equipment between 1990 and 2010 in China had a first order effect on the time people devote to home production, especially for married women. The absolute effect on men's time allocation seem small, but recall that men were also doing much less housework in the baseline year of 1990. The other factor that seems to play some role for the changes in housework time in the model is the change in the wage structure. Recall that the gender wage gap increased during the period. This should cause households to optimally switch wife's housework time for husband's, and the opposite for paid work. We observe this happening for the former, but for the latter. The changes in the wage structure increase

Figure 6: Decomposition of the changes in married people time allocation, 1990-2010



Notes: The solid line with circle markers represents the cumulative change between 1990 and 2010, up to that factor. The bars and the numbers next to them are the contributions of each factor by itself. The solid line and the number next to the last circle marker are the total change in hours for each time use between 1990 and 2010. Forward decomposition starts in 1990. Backward decomposition starts in 2010. The "home productivity" stage includes changes in price of equipment p_e and home productivity A_g.

both wife and husband's paid work time in the forward decomposition, and decrease them in the backward one. This is because there are large income effects stemming from the wage growth experienced during the period. This causes everyone to work less in 2010. But notice that the effect of the wage structure is larger on women's paid work time than on men's, which is again accounted for by the fact that the gender wage gap increased.

Going back to the effect of home productivity, notice that by itself it has the effect of increasing paid work hours and leisure for women. The model therefore implies a role of home productivity as an engine of liberation in China, much in the spirit of Greenwood et al. (2003). That is, improvements in home production technology free up time for women's paid work and leisure.

One of the main goals of this paper is to assess the effect of the changes in the sex ratio on time allocation patterns. A reason to be interested in it is that it does not directly affect the relative prices of wife and husband's market time. It may affect the marital sorting, which in turns affects average time allocation via composition. However, in the previous section we discussed how the marital sorting seems to have a small effect on aggregate time allocation. Therefore, the effect of the sex ratio is almost *pure* bargaining, unlike that of the wage structure, which has a relative price component. The results of the simulation show an effect for the sex ratio on paid work and leisure of about four hours per week. For context, Aguiar and Hurst (2007) find an increase in leisure for women in the Unites States between 1965 and 2010 of four to eight hours per week, which they call "dramatic". However, the overall effect is small compared with the other factors. Moreover, if we consider that the model overstates the magnitude of the increase in leisure time by women, roughly one third, the effect in all likelihood is smaller.

Finally, the effect of the changes in the skill distribution is the factor that causes the largest changes in time allocation in the model. Most of it goes in the direction of increasing men's paid work and decreasing their housework time, with the opposite for women. Why is this? Education levels became more similar across genders between 1990 and 2010. The fraction of highly skilled women in fact is slightly higher than that of men in 2010. The changes in the skill distribution have the largest effects on the average Pareto weight of the wife.[10] Therefore, the fact that women are equally or even more highly skilled than men in 2010 allows them to bargain a more favorable time allocation within marriage. While this effect is overstated in the model it is nevertheless interesting that it seems to be an important driving force for the changes in time allocation.

[10]See the appendix for a table with the full decomposition.

7 Conclusions

This paper studies married household's time allocation decisions under an unbalanced sex ratio. It does so in the context of China, a country that experienced a large increase in the number of men relative to the number of women of marriageable age between 1990 and 2010, along with other momentous socioeconomic transformations.

I document a substantial increase in the leisure time of married women relative to men from 1990 to 2010. Then, I calibrate a model featuring marriage and time allocation decisions to the initial year. I compare the model's performance in 2010 both allowing for bargaining between spouses (the collective model of the household) and not (the unitary model). I find that the former completely misses the increase in the wife to husband leisure ratio, while the latter does generate it. The collective model generates an increase in assortative mating that is smaller than the one observed in the data. However, correcting for this doesn't change the time allocation substantially. This implies that the main mechanism operating on average time allocation is bargaining.

I then decompose the contribution to time allocation changes in the model. Apart from the sex ratio, the skill distribution, the wage structure and home productivity experienced big transformations. I find that the increase in the sex ratio leads to about four additional hours per week in married women's leisure, via a decrease in paid work. The opposite happens for men. The magnitude of this change is however relatively small with respect to the effect of the other factors, especially the changes in the skill distribution.

One explanation for the collective model overstating the increase in married women's leisure time relative to men may be that husbands compensate wives through means other than time allocation. For example, Wei and Zhang (2011) show that there is competition among families to provide male sons with real state (a house) to improve their standing in the marriage markets. Moreover, as suggested by Grosjean and Khattar (2018), social norms surrounding female labor supply are persistent, which could lead prevent adjustment in paid hours induced by bargaining. Extending the model presented here to account for other types of compensation in marriage or persistence in social norms is left for future research.

Moreover, in this paper I take human capital accumulation decisions as given. However, the combination of increasing sex ratios, skill premiums and gender wage gap observed in China certainly affects such decisions. This is another area that provides exciting research questions. New high-quality data sources on Chinese households, like the China Family Panel Studies launched in 2010, may provide good opportunities to tackle such questions.

Finally, the bottom line of this paper should be that to understand the effects of the momentous transformations in China on married people's behavior, accounting for bargaining between spouses seems to be crucial. Similar demographic or socio-economic changes elsewhere should motivate macro-economists to take intra-household bargaining seriously.

A Assortative mating measures

For the first measure, I regress wife's education level on her husband's:

$$EDU^w_{my} = \alpha + \beta \times EDU^h_{my} + \sum_{t \in T} \gamma_t \times EDU^h_{my} \times YEAR_{ty} + \sum_{t \in T} \theta_t \times YEAR_{ty} + \epsilon_{my}$$

In the specification above, EDU^y_{mw} and EDU^y_{mh} represent wife's and husband's years of education in marriage m and year y, and $YEAR_{ty}$ is a time dummy that takes the value of 1 when $t = y$ and 0 otherwise, whith $T = \{1992, 1996, 1999, 2003, 2005, 2008, 2010\}$. The coefficient β measures the correlation between wife's and husband's education in the base year (1990), the θ_t's control for the secular rise in education. I am interested in the γ_t's which measure the difference between wife and husband's correlation in year t and the baseline year. If γ_t rises with t, there's evidence of increasing assortative mating over time.

For the next two measures, I collapse the levels of education into three categories: low skill (primary or less), medium skill (High school) and high skill (college).

The second measure of assortative mating I use is Kendall's τ rank correlation. A value of 1 means perfect positive rank correlation, that is, the man with the highest education level is married with the woman with the highest education level, the man with the second highest education level is married with the woman with the second highest education level and so forth. A value of -1 means the opposite, i.e perfect negative rank correlation. The closer Kendall's τ is to 1, the higher the assortative mating. I measure τ_t for $t \in \{1990, 1992, 1996, 1999, 2003, 2005, 2008, 2010\}$. Again, if τ_t rises with t, this points to increasing assortative mating over time.

Finally, I compute a measure of assortative mating based on contingency tables, as the one shown in table 8 for 1990. Each cell has two entries: the one on the left gives the observed fraction of married households with the combination of wife and husband's education for that row and column. The second gives the fraction of households there would be in that cell if matching was random. This is obtained by multiplying the total fraction of women in her education category (the sum of elements in that row) by the total fraction of men in his (the sum of elements in that column). The values along the diagonal are the fractions of marriages where both spouses have the same education level. To measure assortative mating, I take the sum along the diagonal for both the observed and random matches, and divide the first by the second. This is denoted Δ_t, and I compute it again for $t \in \{1990, 1992, 1996, 1999, 2003, 2005, 2008, 2010\}$. Values of Δ_t above 1 mean that there is positive assortative mating, as the observed fraction of matches in which spouses have the

Table 8: Contingency table for marriages in China, 1990

Wife	Husband						
	Low skill		Medium skill		High skill		Marginal
Low skill	**0.251**	**0.164**	0.247	0.317	0.006	0.023	0.504
Medium skill	0.074	0.153	**0.371**	**0.294**	0.023	0.021	0.468
High skill	0.001	0.009	0.011	0.018	**0.017**	**0.001**	0.028
Marginal	0.326		0.629		0.046		

Source: Author's calculations using the China Health and Nutrition Survey.

same education is larger than the one random matching would produce. Once more, if Δ_t rises with t, there's evidence of increasing assortative mating.

B Solutions for the time allocation and home production problems

Singles

The problem of a single agent of sex $i \in \{f, m\}$ and type z can be written as

$$\begin{aligned} U_S^i(z) = & \max_{c,l,h,e} u(c, l, G(h, e)) \\ & \text{subject to} \\ & c = \omega_i(z)(1 - l - h) - p_e e \end{aligned}$$

the corresponding Lagrangian is:

$$\mathcal{L} : \frac{\sigma_c}{1-\sigma} c^{1-\sigma} + \frac{\sigma_l}{1-\sigma} l^{1-\sigma} + \frac{\sigma_g}{1-\sigma} \left[A_g \left[e^{1-\alpha_g}\right] h^{\alpha_g}\right]^{1-\sigma} + \lambda_i(z) \left[\omega_i(z)(1 - l - h) - p_e e\right]$$

the first order conditions are given by:

$$\sigma_c c^{-\sigma} - \lambda_i(z) = 0 \implies c = \left(\frac{\sigma_c}{\lambda_i(z)}\right)^{\frac{1}{\sigma}} \tag{SFOC 1}$$

$$\sigma_l l^{-\sigma} - \lambda_i(z)\omega_i(z) = 0 \implies l = \left(\frac{\sigma_l}{\lambda_i(z)\omega_i(z)}\right)^{\frac{1}{\sigma}} \tag{SFOC 2}$$

$$\sigma_g g^{-\sigma} A_g \alpha_g \left[e^{1-\alpha_g}\right] h^{\alpha_g - 1} - \lambda_i(z)\omega_i(z) = 0 \tag{SFOC 3}$$

$$\sigma_g g^{-\sigma} A_g (1 - \alpha_g) \left[e^{-\alpha_g}\right] h^{\alpha_g} - \lambda_i(z) p_e. \tag{SFOC 4}$$

From SFOC 1 and SFOC 2 we have derived demands for market goods and leisure. From SFOC 3 and SFOC 4 we can derive an expression for the ratio between home equipment use and housework:

$$\begin{aligned} \frac{\sigma_g g^{-\sigma} A_g \alpha_g \left[e^{1-\alpha_g}\right] h^{\alpha_g - 1}}{\omega_i(z)} &= \frac{\sigma_g g^{-\sigma} A_g (1 - \alpha_g) \left[e^{-\alpha_g}\right] h^{\alpha_g}}{p_e} \\ \iff x_i^e(z) \equiv \frac{e}{h} &= \frac{(1 - \alpha_g)\,\omega_i(z)}{\alpha_g p_e}. \end{aligned}$$

Furthermore, the ratio of home production to housework can be expressed as a function of $x_i^e(z)$:

$$x_i^g(z) \equiv \frac{g}{h} = \frac{A_g \left[e^{1-\alpha_g}\right] h^{\alpha_g}}{h} = A_g \left(\frac{e}{h}\right)^{1-\alpha_g} = A_g \left[x_i^e(z)\right]^{1-\alpha_g}.$$

From SFOC 3 we can derive an expression for the demand of home produced goods that is a function of $x_i^e(z)$ and the Lagrange multiplier:

$$g = \left(\frac{\sigma_g}{\lambda_i(z) D_i(z)}\right)^{\frac{1}{\sigma}},$$

where $D_i(z) = \frac{\omega_i(z)}{A_g \alpha_g \left[x_i^e(z)\right]^{1-\alpha_g}}$ is the effective marginal price of home goods. Moreover, $h = \frac{g}{x_i^g(z)}$ and $e = \frac{x_i^e(z) g}{x_i^g(z)}$.

Substituting the expressions for c, l, h and e in the budget constraint:

$$\left(\frac{\sigma_c}{\lambda_i(z)}\right)^{\frac{1}{\sigma}} = \omega_i(z) \left[1 - \left(\frac{\sigma_l}{\lambda_i(z)\omega_i(z)}\right)^{\frac{1}{\sigma}} - \frac{g}{x_i^g(z)}\right] - p_e \frac{x_i^e(z) g}{x_i^g(z)},$$

and substituting the expression for g, we can solve for the Lagrange multiplier:

$$\left(\frac{\sigma_c}{\lambda_i(z)}\right)^{\frac{1}{\sigma}} = \omega_i(z) \left[1 - \left(\frac{\sigma_l}{\lambda_i(z)\omega_i(z)}\right)^{\frac{1}{\sigma}} - \frac{\left(\frac{\sigma_g}{\lambda_i(z) D_i(z)}\right)^{\frac{1}{\sigma}}}{x_i^g(z)}\right] - p_e \frac{x_i^e(z) \left(\frac{\sigma_g}{\lambda_i(z) D_i(z)}\right)^{\frac{1}{\sigma}}}{x_i^g(z)}$$

$$\implies \lambda_i(z) = \left[\frac{\sigma_c^{\frac{1}{\sigma}} + \omega_i(z) \left(\frac{\sigma_l}{\omega_i(z)}\right)^{\frac{1}{\sigma}} + \frac{\omega_i(z)}{x_i^g(z)} \left(\frac{\sigma_g}{D_i(z)}\right)^{\frac{1}{\sigma}} + \frac{p_e x_i^e(z)}{x_i^g(z)} \left(\frac{\sigma_g}{D_i(z)}\right)^{\frac{1}{\sigma}}}{\omega_i(z)}\right]^{\sigma}.$$

Notice that the above expressions for $x_i^g(z)$, $D_i(z)$, $x_i^e(z)$ (and thus $\lambda_i(z)$) depend only on parameters of the model. Thus, we have found a closed-form solution for the time allocation problem. This solution will be always interior for singles, as the marginal utilities of market goods consumption, leisure and home produced goods all go to infinity when paid work, leisure or housework time go to zero, respectively.

Married households

The problem of a married household with wife's type z_f and husband's type z_m can be written as:

$$\max_{c_f,c_m,l_f,l_m,h_m,h_f,e} \left\{ \chi_f u_f\left(c_f, l_f\right) + \left(1-\chi_f\right) u_m\left(c_m, l_m\right) + \frac{\sigma_g}{1-\sigma} G\left[H\left(h_f, h_m\right), e\right]^{1-\sigma} \right\}$$

subject to

$$c_f + c_m = \omega_f(z_f)\left(1 - l_f - h_f\right) + \omega_m(z_m)\left(1 - l_m - h_m\right) - p_e e$$

the Lagrangian of this problem is:

$$\mathcal{L}:$$
$$\chi_f\left(\frac{\sigma_c}{1-\sigma}c_f + \frac{\sigma_l}{1-\sigma}l_f\right) + \left(1-\chi_f\right)\left(\frac{\sigma_c}{1-\sigma}c_m + \frac{\sigma_l}{1-\sigma}l_m\right) + \frac{\sigma_g}{1-\sigma}G\left[H\left(h_f, h_m\right), e\right]^{1-\sigma}$$
$$+ \lambda(z_f, z_m)\left[\omega_f(z_f)\left(1 - l_f - h_f\right) + \omega_m(z_m)\left(1 - l_m - h_m\right) - p_e e - c_f - c_m\right].$$

The first order conditions are:

$$\chi_f \sigma_c c_f^{-\sigma} - \lambda(z_f, z_m) = 0 \implies c_f = \left(\frac{\chi_f \sigma_c}{\lambda(z_f, z_m)}\right)^{\frac{1}{\sigma}} \tag{MFOC 1}$$

$$\left(1-\chi_f\right)\sigma_c c_m^{-\sigma} - \lambda(z_f, z_m) = 0 \implies c_m = \left(\frac{\left(1-\chi_f\right)\sigma_c}{\lambda(z_f, z_m)}\right)^{\frac{1}{\sigma}} \tag{MFOC 2}$$

$$\chi_f \sigma_l l_f^{-\sigma} - \lambda(z_f, z_m)\omega_f(z_f) = 0 \implies l_f = \left(\frac{\chi_f \sigma_l}{\lambda(z_f, z_m)\omega_f(z)}\right)^{\frac{1}{\sigma}} \tag{MFOC 3}$$

$$\left(1-\chi_f\right)\sigma_l l_m^{-\sigma} - \lambda(z_f, z_m)\omega_m(z_m) = 0 \implies l_m = \left(\frac{\left(1-\chi_f\right)\sigma_l}{\lambda(z_f, z_m)\omega_m(z_m)}\right)^{\frac{1}{\sigma}} \tag{MFOC 4}$$

$$\sigma_g g^{-\sigma} G_h H_{h_f} - \lambda(z_f, z_m)\omega_f(z_f) = 0 \tag{MFOC 5}$$

$$\sigma_g g^{-\sigma} G_h H_{h_m} - \lambda(z_f, z_m)\omega_m(z_m) = 0 \tag{MFOC 6}$$

$$\sigma_g g^{-\sigma} G_e - \lambda(z_f, z_m) p_e, \tag{MFOC 7}$$

where:

$$
\begin{aligned}
G_h &= \frac{\partial G}{\partial h} = \alpha_g A_g \left[e^{1-\alpha_g}\right] h^{\alpha_g - 1} = \alpha_g A_g \left[\frac{e}{h}\right]^{1-\alpha_g} \\
G_e &= \frac{\partial G}{\partial e} = \left(1-\alpha_g\right) A_g \left[e^{-\alpha_g}\right] h^{\alpha_g} = \left(1-\alpha_g\right) A_g \left[\frac{e}{h}\right]^{-\alpha_g} \\
H_{h_f} &= \frac{\partial H}{\partial h_f} = \frac{1}{1-\eta}\left[\eta_f h_f^{1-\eta} + \left(1-\eta_f\right) h_m^{1-\eta}\right]^{\frac{1}{1-\eta}-1} \left(1-\eta\right) \eta_f h_f^{-\eta} \\
&= h^{\eta} \eta_f h_f^{-\eta} \\
H_{h_m} &= \frac{\partial H}{\partial h_m} = h^{\eta}\left(\eta_f\right) h_m^{-\eta}.
\end{aligned}
$$

Now, define $x^g(z_f, z_m) \equiv \frac{g}{h}$, $x^e(z_f, z_m) \equiv \frac{e}{h_m}$, $x^f(z_f, z_m) \equiv \frac{h_f}{h_m}$ and $x^h(z_f, z_m) \equiv \frac{h}{h_m}$. From MFOC 7:

$$
g = \left(\frac{\sigma_g G_e}{\lambda(z_f, z_m) p_e}\right)^{\frac{1}{\sigma}} = \left[\frac{\sigma_g \left(1-\alpha_g\right) A_g \left(\frac{e}{h}\right)^{-\alpha_g}}{\lambda(z_f, z_m) p_e}\right]^{\frac{1}{\sigma}}.
$$

Since $\frac{e}{h} = \frac{x^e(z_f, z_m)}{x^h(z_f, z_m)}$, then:

$$
g = \left[\frac{\sigma_g \left(1-\alpha_g\right) A_g \left(\frac{x^e(z_f, z_m)}{x^h(z_f, z_m)}\right)^{-\alpha_g}}{\lambda(z_f, z_m) p_e}\right]^{\frac{1}{\sigma}} = \left(\frac{\sigma_g}{\lambda(z_f, z_m) D(z_f, z_m)}\right)^{\frac{1}{\sigma}},
$$

where $D = \frac{p_e\left(\frac{x^e(z_f, z_m)}{x^h(z_f, z_m)}\right)^{\alpha_g}}{A_g(1-\alpha_g)}$ is the effective marginal price of home goods.

From MFOC 5 and MFOC 6 we can derive a closed form expression for $x^f(z_f, z_m)$:

$$
\begin{aligned}
& \frac{\sigma_g g^{-\sigma} G_h H_{h_f}}{\omega_f(z_f)} = \frac{\sigma_g g^{-\sigma} G_h H_{h_m}}{\omega_m(z_m)} \\
\Longrightarrow\ & \frac{H_{h_f}}{\omega_f(z_f)} = \frac{H_{h_m}}{\omega_m(z_m)} \\
\Longrightarrow\ & \frac{h^{\eta} \eta_f h_f^{-\eta}}{\omega_f(z_f)} = \frac{h^{\eta}\left(\eta_f\right) h_m^{-\eta}}{\omega_m(z_m)} \\
\Longrightarrow\ & x^f(z_f, z_m) \equiv \frac{h_f}{h_m} = \left[\frac{\eta_f \omega_m(z_m)}{\left(1-\eta_f\right)\omega_f(z_f)}\right]^{\frac{1}{\eta}}.
\end{aligned}
$$

Using the expression above, we can derive one for $x^h(z_f, z_m)$. Substituting

$$h_f = \left[\frac{\eta_f \omega_m(z_m)}{(1-\eta_f)\,\omega_f(z_f)}\right]^{\frac{1}{\eta}} h_m$$

into the expression for h:

$$\begin{aligned} h &= \left\{\eta_f \left[\frac{\eta_f \omega_m(z_m)}{(1-\eta_f)\,\omega_f(z_f)}\right]^{\frac{1-\eta}{\eta}} h_m^{1-\eta} + (1-\eta_f)\, h_m^{1-\eta}\right\}^{\frac{1}{1-\eta}} \\ \implies x^h(z_f, z_m) \equiv \frac{h}{h_m} &= \left[\eta_f \left(\frac{\eta_f}{1-\eta_f}\frac{\omega_m(z_m)}{\omega_f(z_f)}\right)^{\frac{1-\eta}{\eta}} + 1 - \eta_f\right]^{\frac{1}{1-\eta}}. \end{aligned}$$

From MFOC 6 and MFOC 7 we can derive an expression for $x^e(z_f, z_m)$ that depends on $x^h(z_f, z_m)$ (for which we already have a closed form solution):

$$\begin{aligned} &\frac{\sigma_g g^{-\sigma} G_h H_{h_m}}{\omega_m(z_m)} = \frac{\sigma_g g^{-\sigma} G_e}{p_e} \\ \implies &\frac{\alpha_g A_g \left[\frac{e}{h}\right]^{1-\alpha_g} h^{\eta}\,(\eta_f)\, h_m^{-\eta}}{\omega_m(z_m)} = \frac{(1-\alpha_g)\, A_g \left[\frac{e}{h}\right]^{-\alpha_g}}{p_e} \\ \implies &\frac{x^e(z_f, z_m)}{x^h(z_f, z_m)} x^h(z_f, z_m)^{\eta} = \frac{(1-\alpha_g)\,\omega_m(z_m)}{\alpha_g p_e\,(1-\eta_f)} \\ \implies &x^e(z_f, z_m) = \frac{(1-\alpha_g)\,\omega_m(z_m) x^h(z_f, z_m)^{1-\eta}}{\alpha_g p_e\,(1-\eta_f)}. \end{aligned}$$

We derive also an expression for $x^g(z_f, z_m)$ that depends on $x^e(z_f, z_m)$ and $x^h(z_f, z_m)$:

$$\begin{aligned} g &= A_g \left(e^{1-\alpha_g}\right) h^{\alpha_g} = A_g x^e(z_f, z_m)^{1-\alpha_g} x^h(z_f, z_m)^{\alpha_g} h_m \\ \implies x^g(z_f, z_m) \equiv \frac{g}{h_m} &= A_g x^e(z_f, z_m)^{1-\alpha_g} x^h(z_f, z_m)^{\alpha_g}. \end{aligned}$$

We are almost ready to derive an expression for the Lagrange multiplier. We just have to notice that $h_m = \frac{g}{x^g(z_f, z_m)}$, $h_f = \frac{g x^f(z_f, z_m)}{x^g(z_f, z_m)}$ and $e = \frac{g x^e(z_f, z_m)}{x^g(z_f, z_m)}$, and substitute these along with the expressions for c_f, c_m, l_f, l_m and g in the budget constraint:

$$\left(\frac{\chi_f \sigma_c}{\lambda(z_f, z_m)}\right)^{\frac{1}{\sigma}} + \left(\frac{(1-\chi_f)\,\sigma_c}{\lambda(z_f, z_m)}\right)^{\frac{1}{\sigma}} = \omega_f(z_f)\left[1 - \left(\frac{\chi_f \sigma_l}{\lambda(z_f, z_m)\omega_f(z_f)}\right)^{\frac{1}{\sigma}} - \frac{g x^f(z_f, z_m)}{x^g(z_f, z_m)}\right]$$
$$+ \omega_m(z_m)\left[1 - \left(\frac{(1-\chi_f)\,\sigma_l}{\lambda(z_f, z_m)\omega_m(z_m)}\right)^{\frac{1}{\sigma}} - \frac{g}{x^g(z_f, z_m)}\right] + p_e \frac{x^e(z_f, z_m) g}{x^g(z_f, z_m)}.$$

Finally, the closed form expression for the Lagrange multiplier is:

$$\lambda(z_f, z_m) = \left(\frac{B(z_f, z_m)}{\omega_f(z_f) + \omega_m(z_m)}\right)^{\sigma},$$

where:

$$B(z_f, z_m) = (\chi_f \sigma_c)^{\frac{1}{\sigma}} + [(1-\chi_f)\,\sigma_c]^{\frac{1}{\sigma}} + \omega_f(z_f)\left(\frac{\chi_f \sigma_l}{\omega_f(z_h)}\right)^{\frac{1}{\sigma}} + \omega_m(z_m)\left[\frac{(1-\chi_f)\,\sigma_l}{\omega_m(z_m)}\right]^{\frac{1}{\sigma}}$$
$$+ \left(\frac{\sigma_g}{D(z_f, z_m)}\right)^{\frac{1}{\sigma}}\left[\frac{\omega_f(z_f)}{x^g(z_f, z_m)} x^f(z_f, z_m) + \frac{\omega_m(z_m)}{x^g(z_f, z_m)} + \frac{p_e x^e(z_f, z_m)}{x^g(z_f, z_m)}\right].$$

Solutions may not always be interior for the married household problem. In particular, for some parameter configurations h_f, h_m, n_f or n_m could optimally be zero, i.e., there may be solutions in which one of the spouses doesn't do paid work or housework. Whenever solutions are not interior I rely on numerical methods to find the optimal quantities for married households.

C Time allocation results under different values for σ

Table 9 presents the time allocation results for the collective model for different values of σ. Recall that σ regulates the elasticity of substitution between consumption of the market good, consumption of the home-produced good and leisure. Lower values of σ generate even larger drops of female labor force participation and increases in leisure for married women, and the opposite for men. This is because compensating the utility of remaining single requires larger increases in time allocation to generate the same change in utility within marriage. Moreover, lower values of sigma imply smaller income effects net of substitution effects associated to wage growth. Therefore, overall leisure is lower the lower σ is. A value of $\sigma = 1.5$ better reflects changes in housework and paid work, $\sigma = 1.25$ seems to better reflect changes in leisure and $\sigma = 1$ seems bad across the board.

Table 9: Time allocation in 2010 under different values of σ

Statistic	$\boldsymbol{\sigma = 1.5}$	$\boldsymbol{\sigma = 1.25}$	$\boldsymbol{\sigma = 1}$	**Data**
Married women housework	28.56	36.35	43.24	28.30
Married women paid work	19.23	16.73	15.60	32.36
Married women leisure	70.21	64.92	59.15	57.34
Married men housework	8.47	9.48	10.30	7.30
Married men paid work	55.07	59.54	66.22	47.67
Married men leisure	54.45	48.98	41.48	63.04
Single women housework	6.69	8.68	10.43	6.66
Single women paid work	40.45	43.28	48.00	45.48
Single women leisure	70.86	66.03	59.57	65.87
Single men housework	1.50	1.98	2.41	1.66
Single men paid work	37.94	41.66	47.60	42.85
Single men leisure	78.56	74.36	67.98	73.49

D Full decomposition results

Table 10: Full results of the forward decomposition

Statistic	**Data 1990**	**Sex ratio**	**Skill**	**Wages**	**Home**	**Model 2010**	**Data 2010**
Married women housework	41.98	42.53	42.17	41.83	46.24	28.56	28.30
Married women paid work	41.00	40.73	36.16	24.82	13.50	19.23	32.36
Married women leisure	35.02	34.74	39.67	51.35	58.27	70.21	57.34
Married men housework	10.46	10.20	10.12	10.78	13.04	8.47	7.30
Married men paid work	47.79	48.55	52.61	60.40	52.99	55.07	47.67
Married men leisure	59.75	59.25	55.27	46.82	51.97	54.45	63.04
Single women housework	10.43	10.43	10.43	10.52	11.62	6.69	6.66
Single women paid work	48.00	48.01	48.01	47.31	38.83	40.45	45.48
Single women leisure	59.57	59.56	59.56	60.17	67.54	70.86	65.87
Single men housework	2.41	2.41	2.41	2.43	2.71	1.50	1.66
Single men paid work	47.60	47.62	47.62	47.02	37.59	37.94	42.85
Single men leisure	67.98	67.97	67.97	68.55	77.70	78.56	73.49
Married women consumption	-	0.24	0.28	0.38	0.89	1.09	-
Married men consumption	-	0.47	0.44	0.39	0.88	0.93	-
Average wife's Pareto weight	-	0.28	0.34	0.49	0.50	0.55	-
Assortative mating	1.27	1.27	1.29	1.29	1.29	1.29	1.54

Table 11: Full results of the backward decomposition

Statistic	**Data 2010**	**Model 2010**	**Sex ratio**	**Skill**	**Wages**	**Home**	**Data 1990**
Married women housework	28.30	28.56	28.59	32.15	25.86	42.53	41.98
Married women paid work	32.36	19.23	23.54	40.06	49.98	40.73	41.00
Married women leisure	57.34	70.21	65.86	45.79	42.16	34.74	35.02
Married men housework	7.30	8.47	8.31	5.48	6.22	10.20	10.46
Married men paid work	47.67	55.07	51.60	41.92	48.97	48.55	47.79
Married men leisure	63.04	54.45	58.09	70.60	62.81	59.25	59.75
Single women housework	6.66	6.69	6.69	6.57	5.97	10.43	10.43
Single women paid work	45.48	40.45	40.45	42.07	49.85	48.01	48.00
Single women leisure	65.87	70.86	70.86	69.36	62.17	59.56	59.57
Single men housework	1.66	1.50	1.50	1.48	1.34	2.41	2.41
Single men paid work	42.85	37.94	37.94	39.22	48.02	47.62	47.60
Single men leisure	73.49	78.56	78.56	77.30	68.64	67.97	67.98
Married women consumption	-	1.09	1.02	0.56	0.29	0.24	-
Married men consumption	-	0.93	0.98	1.09	0.50	0.47	-
Average wife's Pareto weight	-	0.55	0.51	0.29	0.32	0.28	-
Assortative mating	1.54	1.29	1.28	1.24	1.24	1.27	1.27

E Algorithms to solve and calibrate the model

In this section I call the full set of parameter values Ξ. Moreover, $\Xi = \Xi_1 \cup \Xi_2$, where Ξ_1 are the parameters chosen externally and before solving the SSEB, and Ξ_2 is the set of parameters chosen jointly by matching moments in SSEB.

inputs : parameters of the model Ξ, expected sex ratio among singles θ_S^E, initial Pareto weights χ_f^0
outputs: reservation match quality q_r, Pareto weights χ_f

find an initial match reservation quality for the initial Pareto weights and the expected sex ratio among singles: set $q_r : W_f(q_r, \chi_f^0; \theta_S^E) + W_m(q_r, \chi_f^0; \theta_S^E) = 0$
set tolerance for convergence tol;
set initial error larger than tolerance $error > tol$;
while $\underline{error > tol}$ **do**
  set prior reservation match quality equal to current one: $q_r^{prior} = q_r$;
  set prior Pareto weight equal to current one: $\chi_f^{prior} = \chi_f$;
  update Pareto weight according to the bargaining rule: set $\chi_f : W_f(q_r, \chi_f; \theta_S^E) = W_m(q_r, \chi_f; \theta_S^E)$;
  update reservation match quality by setting the marriage gains to zero: set $q_r : W_f(q_r, \chi_f; \theta_S^E) + W_m(q_r, \chi_f; \theta_S^E) = 0$;
  update error: $error = \max\{|q_r - q_r^{prior}|, |\chi_f - \chi_f^{prior}|\}$;
end

Algorithm 1: Find reservation match qualities and Pareto weights for a single one of the segregated multi-period marriage markets, given and expected sex ratio among singles.

inputs : parameters of the model Ξ, initial guesses for the sex ratio among singles $\{\theta_S^0(z)\}_{z\in\mathcal{Z}}$, initial guesses for the Pareto weights $\{\chi_f^0(z)\}_{z\in\mathcal{Z}}$

outputs: reservation match qualities $\{q_r(z_f, z_m)\}_{z\in\mathcal{Z}}$, Pareto weights $\{X_f(z_f, z_m)\}_{z\in\mathcal{Z}}$, sex ratio among singles $\{\theta_S(z)\}_{z\in\mathcal{Z}}$

set tolerance for convergence tol;
set initial error larger than tolerance $error > tol$;
for $\underline{z \in \{1, 2, 3\}}$ **do**
  set $\theta_S^E = \theta_S(z)$;
  set $\chi_f = \chi_f^0(z)$;
  do Algortihm 1 to obtain q_r and χ_f;
  set $q_r(z, z) = q_r$ and $X_f(z, z) = \chi_f$
end
solve the marriage market for entrants ;
update $\theta_S(z_f, z_m)$ by using the equations for flows;

Algorithm 2: Update the sex ratio among singles

inputs : parameters of the model Ξ, initial guesses for the sex ratio among singles $\{\theta_S(z)\}_{z\in\mathcal{Z}}$

outputs: reservation match qualities $\{q_r(z_f, z_m)\}_{z\in\mathcal{Z}}$, Pareto weights $\{X_f(z_f, z_m)\}_{z\in\mathcal{Z}}$, sex ratio among singles $\{\theta_S(z)\}_{z\in\mathcal{Z}}$

while $\underline{error > tol}$ **do**
  set $\theta_S(z)^{prior} = \theta_S(z)$, $\forall z \in \mathcal{Z}$;
  do Algortihm 2 to update $\{\theta_S(z)\}_{z\in\mathcal{Z}}$;
  update error: $error = \sum_{z\in\{Z\}} |\theta_S(z) - \theta_S(z)^{prior}|$;
end

Algorithm 3: Compute the full SSEB

inputs : parameters of the model chosen before solving the SSEB Ξ_1
outputs: parameters of the model chosen jointly by matching data targets in SSEB Ξ_2

choose $\bar{\sigma}_c$, $\underline{\sigma}_c$, $\bar{\sigma}_g$ and $\underline{\sigma}_g$;
choose a set $\{\mu_{z_f,z_m}\}_{\{z_f,z_m\}\in\mathcal{Z}\times\mathcal{Z}}$;
set tolerance for convergence of outer bisection tol_o;
set initial error larger than tolerance $error_o > tol_o$;
while $\underline{error_o > tol_o}$ **do**
  set $\sigma_c = \frac{\bar{\sigma}_c+\underline{\sigma}_c}{2}$, $\sigma_g = \frac{\bar{\sigma}_g+\underline{\sigma}_g}{2}$ and $\sigma_l = 1 - \sigma_c - \sigma_g$;
  choose $\bar{\psi}_f$, $\underline{\psi}_f$;
  set tolerance for convergence of inner bisection tol_i;
  set initial error larger than tolerance $error_i > tol_i$;
  while $\underline{error_i > tol_i}$ **do**
    set $\psi_f = \frac{\bar{\psi}_f+\underline{\psi}_f}{2}$;
    do algorithm 3 to compute the SSEB ;
    compute $\{\mu_{z_f,z_m}\}_{\{z_f,z_m\}\in\mathcal{Z}\times\mathcal{Z}}$ that minimizes the quadratic distance of the contingency matrix in the model and the data ;
    do algorithm 3 to compute again the SSEB with the new match quality draw means ;
    if $\underline{(l_f/l_m)_{model} < (l_f/l_m)_{data}}$ **then**
      set $\bar{\psi}_f = \psi_f$;
    else
      set $\underline{\psi}_f = \psi_f$;
    end
    update $error_i = \bar{\psi}_f - \underline{\psi}_f$;
  end
  if $\underline{(n_f + n_m)_{model} > (n_f + n_m)_{data}}$ **then**
    set $\bar{\sigma}_c = \sigma_c$;
  else
    set $\underline{\sigma}_c = \sigma_c$;
  end
  if $\underline{(h_f + h_m)_{model} > (h_f + h_m)_{data}}$ **then**
    set $\bar{\sigma}_g = \sigma_g$;
  else
    set $\underline{\sigma}_g = \sigma_g$;
  end
  update $error_o = \max\{\bar{\sigma}_c - \underline{\sigma}_c, \bar{\sigma}_g - \underline{\sigma}_g\}$;
end

Algorithm 4: Compute the parameters jointly chosen to match data targets with model's moments in SSEB

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