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

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Abstract

We study marriage and time allocation decisions in the context of an increase in the sex ratio, as observed in China between 1990 and 2010. First, we document a rise in the leisure time ratio between married women and men during this period. Then we develop a model of marriage and time allocation decisions, and compare the predictive power of unitary (no bargaining) and collective versions (Egalitarian and Nash bargaining). We find that the collective model with Nash bargaining provides the best fit in terms of time allocation. To isolate the effect of changes in the sex ratio from other factors such as rising wages and increasing wage inequality, we perform a decomposition exercise. The rise in the sex ratio accounts for an additional hour and a half of weekly leisure for married women, with the opposite effect observed for men.

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

JEL Codes: J11, J12, J22

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1 Introduction

Bargaining between spouses can be important to explain aggregate trends in time allocation.[1] In this paper, we study its importance in the context of an imbalanced sex ratio by using China as a case study. A changing 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.[2] However, it can also influence marital sorting, which affects aggregate time allocation via composition effects, so it is important to account for household formation too.

We start by documenting trends in paid work and housework among married households and single individuals in China between 1990 and 2010. We 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 ratio of women's to men's leisure time increased. At the same time, the proportion of men relative to women aged 20-35 (what we call marriageable age) increased from 1.02 to 1.08, mainly due to an imbalanced sex ratio at birth since the 1980's.

How much of this increase in leisure time by married women relative to men is explained by a better bargaining position due to the surplus of men in the marriage markets in 2010 relative to 1990? To answer this question, we 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. China experienced very large socioeconomic transformations between 1990 and 2010 in addition to the increase in the sex ratio. Some of these are potentially very important for time allocation: changes in the skill distribution (which reflect increasing educational attainment, especially for women), changes in the wage structure (secular increase in wages, increasing skill premium and gender wage gaps) and improvements in home production technology (cheaper and more technologically advanced home equipment). These constitute the primitives of the model, i.e. the factors that are exogenous in both years.

We 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.e. with the primitives set to their values in that year), under two different types of bargaining solutions: Egalitarian

[1] See for example Knowles (2012).

[2] If there are more men than women, as it is the case in China, the latter will find it easier to meet a husband, raising the option value of staying single, while the opposite is true for men.

and Nash. We then assess how different versions of the model perform in predicting time allocation patterns in 2010. That is, we feed the 2010 primitives to the model with parameters calibrated to 1990. We find that the unitary model, in which bargaining plays no role, misses entirely the increase in the leisure ratio. A model with Egalitarian bargaining generates an increase that is too large and one with Nash bargaining an increase that is slightly too small. Overall, the latter does best, by a wide margin. Failing to account for the role of bargaining altogether leads to predictions that are out of line with the data.

Moreover, we perform a decomposition exercise to distinguish the effect of the increasing sex ratios from that of the changes in the other primitives. This is done by changing each of the exogenous factors one at a time. We find that in the Nash bargaining model (the best fitting one), the increase in the sex ratio leads to a decrease of about one hour and a half per week in paid work time and 0.2 hours in housework for married women, with a commensurate increase in leisure. For men, the opposite is true. As a comparison with the literature, Aguiar and Hurst (2007) find that women's leisure hours increased between four and eight hours per week in the United States between 1965 and 2003, a change which the authors consider very large. Moreover, the sex ratio has an sizable effect on the leisure ratio of married couples, as it simultaneously increases female and decreases male leisure time, whereas the effect of the other primitives tends to go in the same direction for both.

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 emerged from the realization 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. We 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. This is an alternative to the directed competitive search mechanic proposed by Shimer (2005) and employed by Knowles and Vandenbroucke (2019) to study marriage rates in a dynamic framework. The advantage of our approach is that the marriage market equilibrium is easier to compute, which is useful in this case because we add complexity through the introduction of bargaining.

Another line of research that this paper is related to is the study of time use. Again, Becker (1965) is a pioneer in this area by highlighting 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) (mentioned previously) 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 Knowles (2012), which develops a model that accounts for intra-household bargaining, and is able to generate an increase in married women's labor supply with a constant leisure ratio between men and women observed in the US data. We contribute by studying the importance of bargaining under an imbalanced 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.[3] A classic paper by Angrist (2002) used the sex ratios among immigrants of different ethnicity 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.[4] 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).[5] 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, we go a step further and look at the effect of it on time allocation

[3]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.

[4]Lafortune (2013) uses the same setting to explore instead how gender scarcity may impact educational investments.

[5]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.

(including leisure, not just market work), and we do it through the lens of a model that accounts for the bargaining and marital sorting channels.

Finally, Wang (2018) looks at the effect of the imbalanced 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 we account for housework while he does not, the structure of marriage markets in the model (which allows us to obtain a closer marital sorting in the baseline calibration), and the ultimate research question, which is about time allocation and the importance of bargaining for us, 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).[6] The survey does not cover all provinces in every year. While the results are representative at the province level whenever available, they likely are not 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.

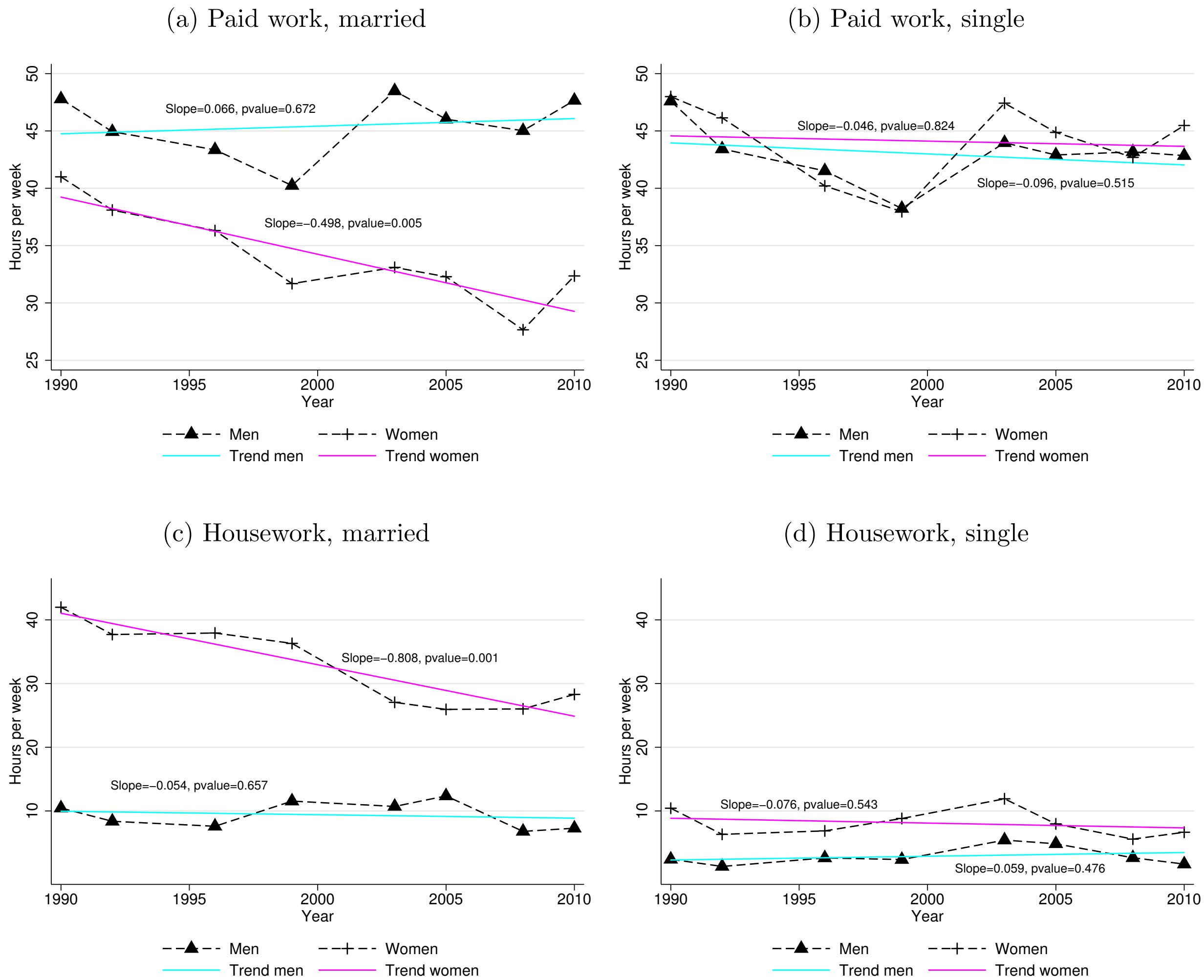
For each person in the CHNS, we compute measures of paid work and housework time.[7] In Figure 1, we plot the results by marital status among people aged 20-35 in those Chinese

[6]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."

[7]See Appendix A for details on the construction of these measures.

provinces present in every wave of the CHNS between 1991 and 2011. Time allocation patterns for married men and singles seem stable and do not feature any significant trend. On the other hand, both paid work and housework for married women show clear downward trends.

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

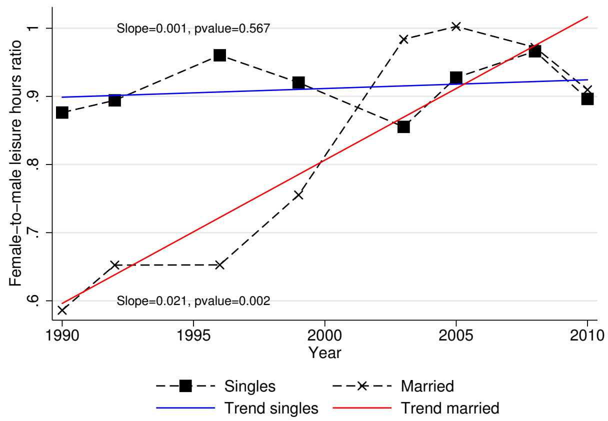


Source: Author's work with data from the CHNS.

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 we construct a measure of leisure for each year. we assume that of the 168 hours available per week, 50 are used for essential sleeping and personal care, as in Knowles (2012), and subtract from the remaining 118 hours the sum

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.

of paid work and housework to obtain leisure hours.

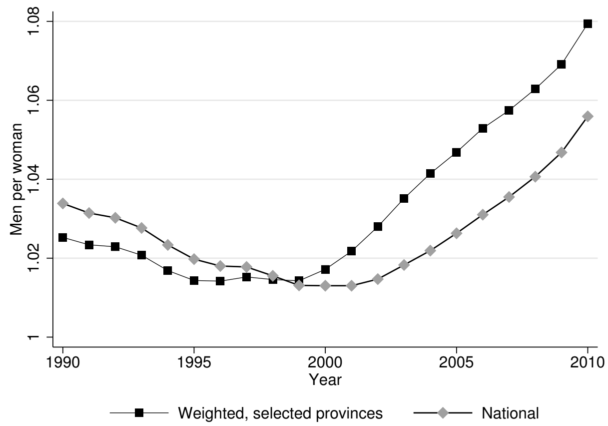
In Figure 2, we plot the female-to-male leisure ratio for married and single people for the same population described above. Not surprisingly given the observed trends in Figure 1, it increases substantially among married people. However among singles there is no trend at all. Indeed, the leisure ratio 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.

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,

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. The sex ratio for the period 2000-2010 is projected from the populations at younger ages in the 2000 census.

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), we 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, we follow Edlund et al. (2013) to calculate a weighted sex ratio for the desired population using the results of the 2000 census. Essentially, we 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 seems that it kept rising beyond 2010 .

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.

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[8]. 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.

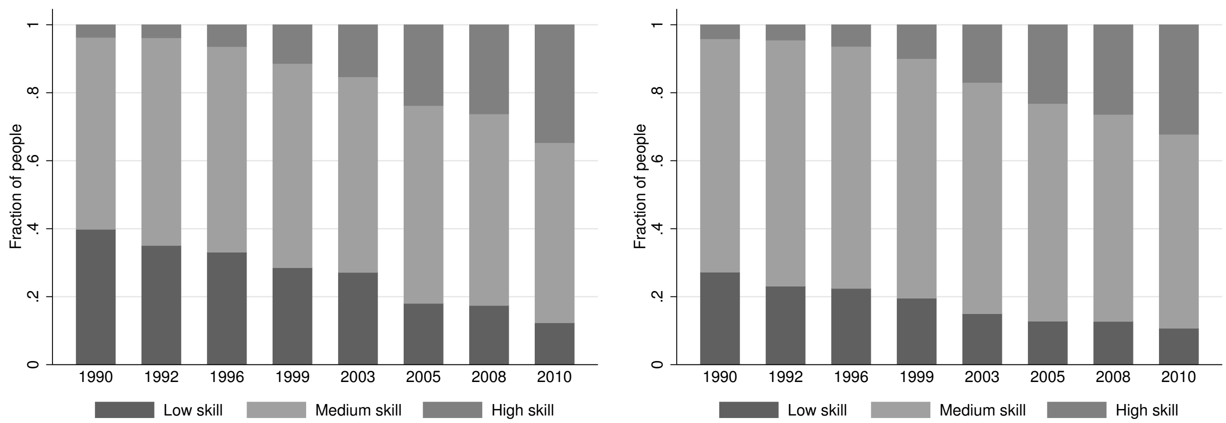
Ge and Yang (2014) find that between 1992 and 2007 (roughly the period covered in our time allocation and sex ratio discussions) the wages for basic labor, the skill premium and the gender wage gap all increased significantly. Table 1 summarizes these findings.

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 is that while in 1990 a larger fraction of men than that of women were highly skilled, but in

[8]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.

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.

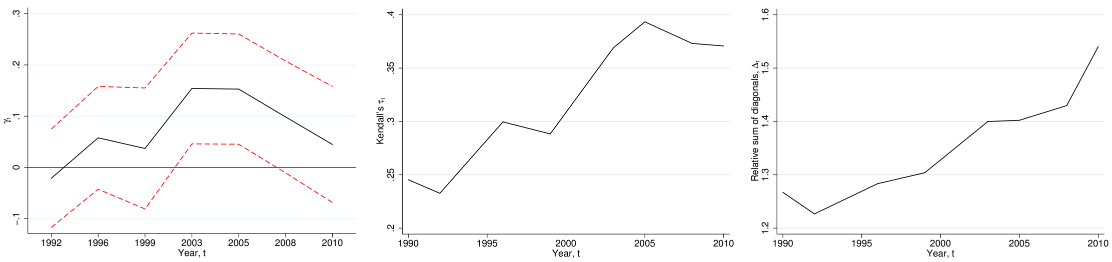
2010 the opposite is true. This reversal of the education gap has been observed in developed and even some middle-income countries as well.

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), we 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.[9] 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.

[9]For a detailed explanation see appendix B.

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, we 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 a skill type $z \in \mathcal{Z}$, both of which remain constant throughout the agent's life.[10] 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

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

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 being 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. We 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 good that is public at the household level, and leisure. The utility function takes the form of a weighted sum of constant relative risk aversion (CRRA) terms:

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

where $\sigma_c + \sigma_l + \sigma_g = 1$.

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

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

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:

$$\begin{aligned} l_f + n_f + h_f &= 1 \\ l_m + n_m + h_m &= 1. \end{aligned}$$

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:

$$\begin{aligned} &\max_{c,l,h,n,e_q,g} u(c, l, g) \qquad (1) \\ &\text{subject to} \\ &l + n + h = 1 \\ &g = G(h, e) \\ &c = \omega_i(z)\, n - p_e e. \end{aligned}$$

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 home production to housework. Closed-form expressions for these objects are derived in Appendix C. 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:

$$
\begin{aligned}
&\max_{c_f,c_m,l_f,l_m,h_m,h_f,n_f,n_m,e,g} \left\{\chi_f u\left(c_f, l_f, g\right) + \left(1-\chi_f\right) u\left(c_m, l_m, g\right)\right\} \qquad (2)\\
&\text{subject to}\\
&l_f + h_f + n_f = 1\\
&l_m + h_m + n_m = 1\\
&h = H\left(h_f, h_m\right)\\
&g = G\left(h, e\right)\\
&c_m + c_f = \omega_f(z_f)n_f + \omega_m(z_m)n_m - p_e e.
\end{aligned}
$$

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:

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

for $i \in \{f, m\}$, where $\chi_m = 1 - \chi_f$. 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 C.

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). Two-sided random matching search models with heterogeneous agents like the one we 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.[11]

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

[11] 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).

distribution over types and the sex ratio *among singles*, not in the general population. This is not useful here since we am interested in generating counterfactual steady-state equilibria featuring different sex ratios *among the general population*. In other words, we precisely want to change the population flows into the model.

Moving away from random matching is another way to address the issue. Shimer (2005) proposes a directed competitive search framework that features a unique equilibrium, which Knowles and Vandenbroucke (2019) use to study marriage rates in a dynamic setting.

I propose here an alternative based on a two-step structure for the marriage markets. 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).[12] In this way, agents do not need to form expectations about the skill distribution among singles, which is the source of multiple equilibria in the random matching framework. 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 endogenous. Moreover, each of the same-skill marriage markets is essentially a McCall (1970) model, which is very simple to solve given a sex ratio, and at the same time provides the outside option value for the heterogeneous skill matches occurring upon entry. Thus, computing the marriage market equilibrium requires to first solve each same-skill market, and then use the continuation values to solve each of heterogeneous markets, separately. In contrast, the approach used by Knowles (2012) requires to solve a system of nonlinear equations that solves all sub-markets simultaneously. Adding bargaining would expand the dimensionality of the system and additionally complicate its solution.

In terms of intuition, 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 single-period marriage market with heterogeneous agents (where entrants with all skill levels are pooled), and then that of the multi-period marriage markets with homogeneous agents (where everyone has the same skill level).

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

3.4.1 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 woman 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}. This represents the flow value of companionship that each partner will enjoy from the marriage, which remains constant for the rest of their life. Notice that we allow for this distributions to be different depending on the skill levels of the potential partners. We assume that once a pair of agents gets married, they remain so until they both die at the same time, which occurs with probability δ in every period. Moreover, we assume that there is full commitment, i.e. the allocations agreed upon marriage are respected in all following periods. Agents decide to get married if the match quality draw q is such that both agents are better off doing so, 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, which we will derive in the next sub section.

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_f and $z_m \in \mathcal{Z}$ for an agent of sex $i \in \{f, m\}$ and a Pareto weight χ_f is:

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

Define as reservation match quality between agents of types z_f and z_m in the pooled market $q_r\left(\theta_S^E(z_f), \theta_S^E(z_m)\right)$ 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 $\theta_S^E(z_m)$.

3.4.2 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

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

where $S_f(z)$ and $S_m(z)$ are the measures of single women and single men available in the market, A_X the efficiency of the meeting function and α_X is the elasticity of the measure of meetings with respect to the measure of single men ($1 - \alpha_X$ being the analogous for single women). Thus, the probabilities of meeting a potential spouse are obtained dividing $X(z)$ by $S_i(z)$ for $i \in \{f, m\}$:

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

where $\theta_S(z) = \frac{S_m(z)}{S_f(z)}$ is the sex ratio among singles in the sub market of skill level z. Notice that the meeting probability for men decreases with $\theta_S(z)$, while the opposite is true for women.

Single agents face a probability of leaving the marriage market and becoming lifelong singles of ρ per period. This means that people can expect to spend on average $\frac{1}{\rho}$ periods being eligible for marriage, conditional on surviving. 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). Upon meeting a potential spouse, just like in the single-period meetings, agents draw a match quality q from a distribution with cumulative density function $Q_{z,z}$. Given all this, the value of being single in steady-state is:

$$\begin{aligned} V_i^S\left(z, \theta_S^E(z)\right) = U_i^S(z) + \psi_i + \beta(1-\delta) \Bigg\{ \rho \frac{U_i^S(z) + \psi_i}{1 - \beta(1-\delta)} + \\ (1-\rho) \left[\left[1 - \pi_i(\theta_S^E(z))\right] V_i^S\left(z, \theta_S^E(z)\right) + \pi_i\left(\theta_S^E(z)\right) \int_{q \in \mathcal{Q}} V_i^X(z,q)\, dQ_{z,z} \right] \Bigg\}, \end{aligned} \tag{4}$$

where $\theta_S^E(z)$ is the expected sex ratio among singles of type z and $V_i^X(z,q)$ is the value of a match between agents of type z with a match quality draw q for an agent of sex 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 is discounted at a rate $\beta(1-\delta)$, i.e. discount rate times survival probability. In the next period either the agent exits the marriage market or not, and if not either she meets a potential spouse or not. Therefore, the expected value of next period is the probability of exiting the marriage market ρ multiplied by the discounted utility flow of being single for the rest of her life $\frac{U_i^S(z)+\psi_i}{1-\beta(1-\delta)}$ plus the probability of not exiting the marriage market $1-\rho$ multiplied by the value of being in the marriage market next period, which is the term in square brackets. This value is given by the probability of not meeting anyone $1-\pi_i(\theta_S^E(z))$ times the value of staying single plus the probability of meeting a potential spouse $\pi_i(\theta_S^E(z))$ times the expected value of such a meeting $\int_{q\in\mathcal{Q}} V_i^X(z,q)\,dQ_{z,z}$.

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

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

Using this definition, we can write the value of a match between agents of type z for an agent of sex i as:

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

where we have used the value of marriage from Equation 3. Thus, we can write the expected value of a match in sub market z as:

$$\int_{q\in\mathcal{Q}} V_i^X(z,q)\,dQ_{z,z} = Q_{z,z}\left[q_r\left(\theta_S^E(z)\right)\right] V_i^S\left(z,\theta_S^E(z)\right) + \int_{q>q_r\left(\theta_S^E(z)\right)} \frac{U_i^M(z,z,\chi_f)+q}{1-\beta(1-\delta)}dQ_{z,z},$$

where the first term is the probability of not marrying (match quality is too low) times the value of staying single, and the second one is the expected value of marriage conditional on match quality being high enough so that it occurs.

We can obtain an expression for the value of being single in the marriage market for types z by substituting the previous equation into 4 and solving for $V_i^S\left(z,\theta_S^E(z)\right)$.

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:

$$S_i^0\left(z, \left\{\theta_S^E(z)\right\}_{z\in\mathcal{Z}}\right) = \begin{cases} \mathcal{P}_f(z)\sum_{z_m\in\mathcal{Z}}\mathcal{P}_m(z_m)Q\left[q_r\left(\theta_S^E(z),\theta_S^E(z_m)\right)\right] & \text{if } i=f, \\ \mathcal{P}_m(z)\left\{\theta_0 - 1 + \sum_{z_f\in\mathcal{Z}}\mathcal{P}_f(z_f)Q\left[q_r\left(\theta_S^E(z_f),\theta_S^E(z)\right)\right]\right\} & \text{if } i=m. \end{cases}$$

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

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

To guarantee that the same-sex marriage markets indeed take place, it is required that the flows of singles of all skill levels and both sexes into their respective markets are positive. That is, $S_i^0\left(z,\left\{\theta_S^E(z)\right\}_{z\in\mathcal{Z}}\right) > 0, \forall i \in \{f,m\}, z\in\mathcal{Z}$. A sufficient condition for this to be true is that Q_{z_f,z_m} has full support in $\mathbb{R}$. That is, the probability of marriage in the first stage is strictly less than 1. Intuitively, this means that when a couple with any combination of skills meets in the first stage, there is always a probability that the match quality is low enough so that they decide not to marry. This condition is satisfied if we assume that the draws are normally distributed, with means that are allowed to vary across skill combinations, and a standard deviation of one in all cases.

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

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

3.5 The Pareto weights

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

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

for $i \in \{f, m\}$.

I consider two solutions for the bargaining problem of sharing the marriage surplus. First, the Egalitarian Bargaining solution proposed by Kalai (1977), 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.

Second, we consider the Nash Bargaining solution proposed by Nash (1950). The Pareto weight in this case solves (with equal bargaining power):

$$\max_{\chi_f} W_f\left(z_f, z_m, \chi_f, q, \theta_{Sz}^E\right) W_m\left(z_f, z_m, \chi_f, q, \theta_{Sz}^E\right),$$

which yields the first-order condition:

$$\frac{W_f\left(z_f, z_m, \chi_f, q, \theta_{Sz}^E\right)}{W_m\left(z_f, z_m, \chi_f, q, \theta_{Sz}^E\right)} = -\frac{\partial W_f\left(z_f, z_m, \chi_f, q, \theta_{Sz}^E\right)/\partial \chi_f}{\partial W_m\left(z_f, z_m, \chi_f, q, \theta_{Sz}^E\right)/\partial \chi_f}.$$

Intuitively, the Nash Bargaining solution takes into consideration the curvature of the Pareto frontier, which arises from the concavity of the utility function. Since the cost of transferring utility from one party to the other is increasing, this solution should yield time allocations that are less responsive to changes in the outside option than the Egalitarian Bargaining solution.

3.6 Steady-state bargaining 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 bargaining equilibrium (SSBE) consists on reservation match qualities* $q_r(z_f, z_m)$*, Pareto weights for the wives* $\chi_f(z_f, z_m, q)$*, 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.:*
   - $V_i^M(z_f, z_m, \chi_f(z_f, z_m, q), q)$ *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.:*

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

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

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

   or

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

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

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

3.7 Computing the SSBE

For a given set of parameters, the algorithm we use to find a SSBE goes as follows. First, we compute the utility flows for singles. Then, we 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 we 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 bargaining (either the Egalitarian or Nash condition). Then, we 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, we compute the steady-state sex ratio among singles implied by the reservation match qualities using the flow equations. Finally, we 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 those implied by the agents' optimal decisions given the expectations. Appendix G 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. We 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 determine the steady state, given a set of parameters, 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 1. We normalize male low-skilled wages to 1 and use the wage premiums to obtain those for medium and high-skilled men. We 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. We follow Knowles (2012) and use data for the United States instead. This is unlikely to be a big issue because home appliances are tradeable goods. Indeed, in other major economies like the European Union, we observe falling prices of home appliances relative to general consumption in the last 20 years. Moreover, by 1990 China was already opening its economy to international trade and becoming a part of global value-added chains. Thus, we use BEA Table 2.3.4, and divide the price index for furnishings and durable household equipment by the index for personal consumption expenditure. Measured this way, prices of home equipment fell by 45% between 1990 and 2010. Home productivity is normalized to 1 in 1990.

4.2 Externally chosen parameters

The group of externally chosen parameters consists of 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, we repeat the analysis with $\sigma = 1.25$ and $\sigma = 1$ in Appendix E.

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. Comparable estimates for China are exceedingly hard to produce, especially dating back in time. We produced a rough approximation by extrapolating backwards the size of China's home appliance market in 2019 and comparing it with total private consumption. Between 1990 and 2010, home appliances as a fraction of total expenditures goes from a low of 0.82% to a high of 8.53%, depending on the assumptions made on the growth rate of this market. The midpoint of these estimates is 4.68%.[13] We therefore set $\alpha_g = 0.95$, so that the share of

[13] Appendix D goes into details about how the estimates are produced.

home equipment is $1-\alpha_g = 0.05$ or 5%. Finally, we follow him 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, we 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:

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

that is, the leisure time of married women relative to men depends on the Pareto weight. 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 being unmarried, ψ_i, does not affect single people's time allocation, but does affect the Pareto weight and thus the relative leisure if they get married. Notice that there could be many different combinations of these parameters for men and women that would allow the model to match the data, since what matters are the *relative* outside values. We therefore normalize $\psi_m = 0$, and only calibrate ψ_f.

For the match quality draws we 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 we use to calibrate the model can be described as a nested bisection. We 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. We then run a bisection algorithm for ψ_f until we 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 we 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. First, 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 weights for married people, they are very close to each other under Egalitarian and Nash bargaining. The weight on private market consumption is very similar among singles of both sexes and married couples, but the latter put a larger weight on consumption of the home-produced good than single women, who in turn put a larger weight than single men. This makes sense, since married couples may have children, which are not included in the model but require more time that is classified as home production. The difference between single females and males may reflect cultural expectations about the roles of women and men 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, notice that ψ_f is negative both under Egalitarian and Nash bargaining, meaning that being single entails a utility cost for women relative to men. In other words, they enjoy being single less. This can be a reflection of cultural expectations as well, with social pressures for women to marry being more severe. Moreover, this utility cost is larger under Nash bargaining. The reason behind it is that this solution takes into consideration the curvature of the Pareto frontier, which the Egalitarian bargaining does not. Thus, in order to make sense of the low female-male leisure ratio observed in the data among married people, it requires the outside option to be worse for women, since the marginal utility of forgone leisure is increasing.

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 under Egalitarian bargaining, i.e. the Pareto weights are the same for all couples that do decide to marry. In the Nash bargaining solution, they do depend on the match quality: the larger it is, the closer the Pareto weights will be to 1/2. We can see why by looking at the first-order condition in the Nash bargaining problem in section 3. If q increases, for a given value of χ_f the ratio of surpluses on the left-hand side becomes closer to 1 (q enters the surplus additively). Thus, to preserve the equality, the right-hand side should move closer to 1, which is achieved by bringing the Pareto weights closer together. Intuitively, if the match quality is very high, large transfers of utility are not required since both parties would be happy with the union.

Tables 4 shows the time allocation obtained by the model and observed in the data. Unsurprisingly, the two are almost identical among single people, since the weights for them are the result of a straightforward minimization problem that seeks to reduce their distance. Notice moreover that single people's time allocation is identical under both bargaining solutions, since it is chosen on a period-by-period basis, and the conditions in the marriage market do not affect this choice in the model. Time allocation patterns among married people are replicated quite well under both bargaining solutions.

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. The Egalitarian bargaining model does a better job replicating the marital sorting patterns. This is likely due to the fact discussed above regarding match qualities not affecting time allocation within skill type matches, thus allowing the minimization routine to more freely set the means of the reservation match qualities without disturbing the time allocation fit. The measure of assortative mating based

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	0.572	Gender housework ratio, married people in 1990
Single women		
σ_c	0.382	Single women paid work hours per week
σ_l	0.576	Single women leisure hours per week
σ_g	0.041	Single women housework hours per week
Single men		
σ_c	0.371	Single men paid work hours per week
σ_l	0.624	Single men leisure hours per week
σ_g	0.004	Single men housework hours per week
Chosen jointly by matching moments in equilibrium:		
Egalitarian barganing		
σ_c	0.388	
σ_l	0.450	
σ_g	0.163	
ψ_f	-0.540	Time allocation among married people
Nash bargaining		
σ_c	0.382	
σ_l	0.449	
σ_g	0.169	
ψ_f	-2.508	

Table 3: Calibrated means of match quality draws

Female skill	Male skill		
	Low	**Medium**	**High**
Egalitarian bargaining			
Low	0.564	3.077	0.039
Medium	0.980	1.377	4.755
High	-1.656	1.442	-1.348
Nash bargaining			
Low	-0.257	2.192	-0.520
Medium	0.450	0.421	3.840
High	-3.381	0.655	-1.651

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

Statistic	**Egalitarian**	**Nash**	**Data**
Married			
Female housework	42.5	42.8	42.0
Female paid work	40.7	41.1	41.0
Female leisure	34.7	34.2	35.0
Male housework	10.2	10.3	10.5
Male paid work	48.5	47.8	47.8
Male leisure	59.3	59.9	59.8
Singles			
Female housework	10.4		10.4
Female paid work	48.0		48.0
Female leisure	59.6		59.6
Male housework	2.4		2.4
Male paid work	47.6		47.6
Male leisure	68.0		68.0

on contingency tables described in section 2 comes to 1.267 for both data and Egalitarian bargaining model, and to 1.173 for the Nash model. That is, there is less assortative mating in the former.

Altogether the calibration 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 close to the data targets for 1990.

Table 5: Calibration results for marital sorting in 1990

Wife's skill	Husband's skill					
	Low		Medium		High	
	Model	Data	Model	Data	Model	Data
Egalitarian bargaining						
Low	0.174	0.167	0.246	0.249	0.004	0.004
Medium	0.075	0.076	0.452	0.456	0.024	0.024
High	0.000	0.000	0.011	0.012	0.014	0.013
Nash bargaining						
Low	0.144	0.167	0.278	0.249	0.004	0.004
Medium	0.085	0.076	0.444	0.456	0.027	0.024
High	0.000	0.000	0.013	0.012	0.006	0.013

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 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 we 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.

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 we 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. We take demographics as exogenous and focus on the effects on time allocation patterns for married households. It is nevertheless reasonable to think that people participating in the marriage markets in 2010 take the sex ratio they face in said market as given.

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. We do not dispute the fact that changes in the sex ratio can affect education decisions, but including this mechanism in the analysis is beyond the scope of this 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 we infer it from the behavior of single individuals. We 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.[14] 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).

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, we first compute a steady-state equilibrium with 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 unambiguously improve women's relative outside option, like the increased sex ratio. Others unambiguously worsen it, like the larger gender wage

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

gap. For other factors this is not easy to determine ex-ante, 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, we 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. We 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, Egalitarian and Nash bargaining models fit for married people's time allocation in 2010

Statistic	**Unitary**	**Egalitarian**	**Nash**	**Data**
Female housework	31.36	28.56	32.79	28.30
Female paid work	42.94	19.23	27.73	32.36
Female leisure	43.70	70.21	57.49	57.34
Male housework	6.39	8.47	6.38	7.30
Male paid work	35.50	55.07	41.05	47.67
Male leisure	76.12	54.45	70.57	63.04
Female-male leisure ratio	0.57	1.29	0.81	0.91

The unitary model predicts rises in male and female leisure time that maintain the ratio constant. The collective model with Egalitarian bargaining predicts a decrease in female paid work and an increase for males. This generates a large swing in the female-male leisure ratio, which ends up being much higher than in the data. Finally, the Nash bargaining model predicts rising leisure for both males and females, but more so for the former. Therefore, the leisure ratio increases, but not so much as in the data. This result mirrors that of Knowles (2012): while Egalitarian bargaining generates responses in relative time allocation that are too large with respect to the data, the responses under Nash bargaining are too small. In this case, it is apparent that the latter yields the best predictions overall, by a wide margin.

Looking into the individual components of time allocation, there are a few things to notice. The Nash model predicts almost perfectly the change in leisure hours for females, but it does so by underestimating the change in housework and overestimating the one in paid work hours. Nevertheless, it correctly predicts a decline in both of the order of 10 hours per week or 25% (both start at around 40 hours per week). When it comes to men's time, it predicts a larger increase in leisure hours than the in the data, mostly driven by a decline in paid work. In reality, paid work remained constant. while leisure increased around 3 hours per week driven by housework reduction (which the model does capture as well). On the other hand, the Egalitarian model does a good job capturing the decline in housework, but predicts very large changes in paid work. While women did indeed reduced their hours in this category, they did so by a lower amount, while the increase in men's hours the model predicts is not observed at all in the data. The unitary model predicts correctly the decline in housework, but the predictions on paid work are completely off. This suggests that bargaining is important to account for working decisions among married people.

Now we turn the attention towards marital sorting, which is endogenous in the steady-state bargaining equilibrium. 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, 1.09 and 1.29 (Nash and Egalitarian models respectively) compared to 1.54.

It is possible that the underlying preferences of people in China regarding partner's education have changed, which could have generated extra assortative mating. This could be for example because parent skill became more important in the production of human capital for children, with spouses' skills being complementary. Moreover, notice that high skill females were relatively much more rare in 1990. This points to the fact that a lot of high ability women aged 20-35 in 1990 did not have access to education. If ability influenced matching, and the correlation between it and observed skill level increases over time, the model calibrated to match assortative mating along the latter in 1990 would not reflect its increase in 2010.

More generally, this also would be true if matching is influenced by socioeconomic status, which is not observable, and whose correlation with observed skill changed over time. During the Cultural Revolution, between 1966 and 1976 (which corresponds roughly to the period were people aged 20-35 in 1990 would attend school), there was a great effort to homogenize the population economically. This likely had the effect of reducing the correlation between social class and skill level. Alesina et al. (2020) however provide firm evidence that the socioeconomic ranking reverted back to its pre-Cultural Revolution standing after 1976. This would have increased the correlation between social class and skill level in 2010 with respect to 1990 among people aged 20-35.

To assess the effects of this extra marital sorting, we 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 for the Nash bargaining model display a reduced female-male leisure ratio of 0.74. This suggests that the increase in assortative mating not captured by the model would dampen the equalizing effects of

Table 7: Collective model fit for marital sorting, 2010

Wife's skill	Husband's skill					
	Low		Medium		High	
	Model	Data	Model	Data	Model	Data
Egalitarian bargaining						
Low	0.060	0.067	0.069	0.072	0.010	0.003
Medium	0.019	0.043	0.364	0.436	0.172	0.091
High	0.002	0.008	0.158	0.102	0.146	0.179
Nash bargaining						
Low	0.043	0.067	0.080	0.072	0.017	0.003
Medium	0.036	0.043	0.365	0.436	0.201	0.091
High	0.000	0.008	0.164	0.102	0.094	0.179

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.

bargaining. In the next subsection, we look at time allocation by skill level in the model and in the data, which relates to this point. .

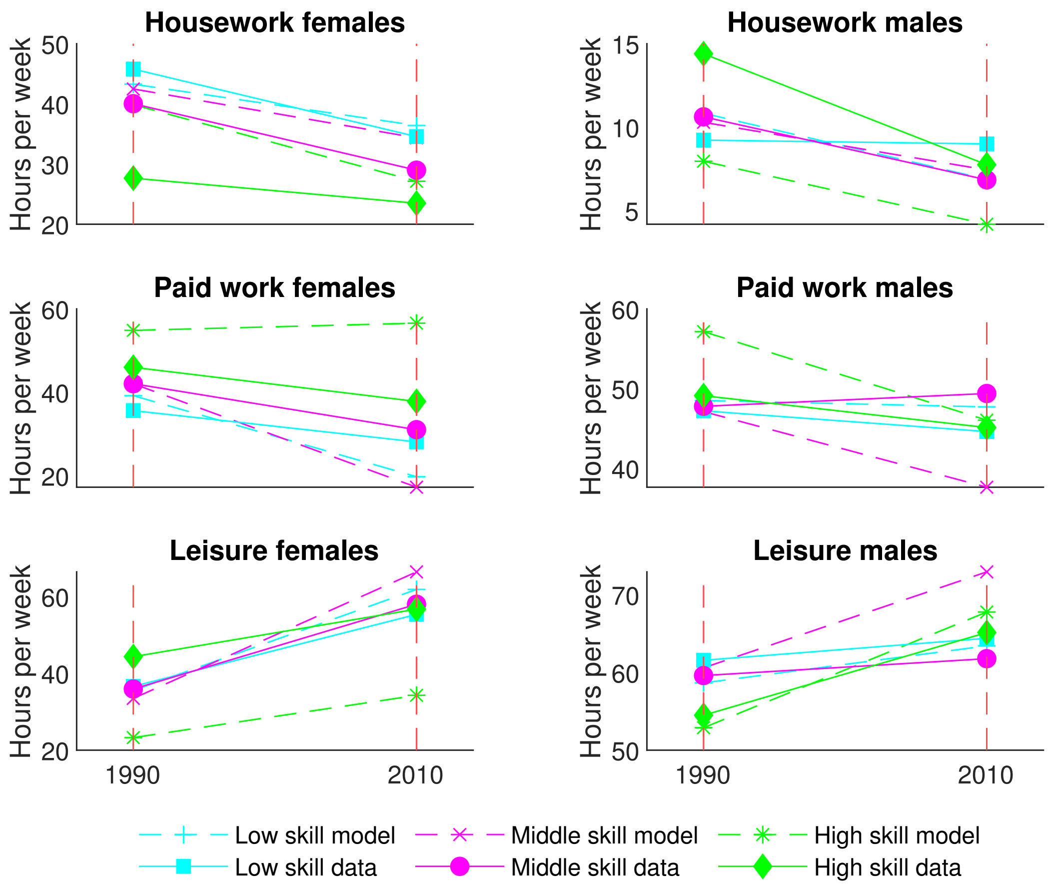
5.3 Time allocation by skill level

In order to shed additional light on the aspects which the model may not be capturing and that could explain the differences between the actual and predicted time allocations, here we look into the performance of the model's time allocation predictions by skill level. Since the Nash bargaining model is the one that most closely follows the average changes, we focus on it. Figure 6 shows the number of hours spend in each category in the model and in the data by skill level and sex for both 1990 and 2010.

First, the model captures the gradient in time allocation for females. Both in 1990 and in 2010, low-skilled individuals spend more time doing housework than middle-skilled, and these in turn spend more time than high-skilled ones. The reverse pattern is observed for paid work. However, the model has high-skilled women doing more of both housework and paid work than in the data, thus amplifying the difference with respect to the other skill groups when it comes to paid work, and underestimating it for housework. The result is a large gap in leisure hours for high-skilled women between the model and the data for in both years.

Among males, a strange phenomenon occurs in 1990, where high-skilled ones appear to do more housework in the data, while the model predicts a similar gradient as for women.

Figure 6: Married people's time allocation according to the Nash bargaining model in 1990 and 2010



When it comes to paid work, the situation is similar as with women: the differences in paid work are exaggerated.

Overall, there are three ways in which the model departs from the data: it predicts too little leisure for high-skilled women both in 1990 and 2010, too much paid work and too little housework for high-skilled men in 1990, and it predicts a decline in paid work and an increase in leisure for middle-skilled men, while in the data these remained roughly constant.

There are two hypotheses that could account for this. First, high-skilled women may have additional bargaining power or better outside options not captured by the model in 1990. This would allow them to negotiate more leisure with their spouses than the model predicts. Moreover, it could be that they dislike housework more than other women, which would explain why high-skilled men (which is whom they are mostly married to) appear to do so much housework in 1990. Nonetheless, since there are so few high-skilled people in 1990, the fact that the model misses here does not affect aggregate hours that much.

Second, preferences of high-skilled people may have became so that they like each other more in 2010.[15] This would mean two things. First, there would be fewer middle-skilled males that marry high-skilled females in the model (notice in Table 7 that there are more of these type of marriages in the model than in the data). All else equal, these types of marriages feature more paid hours by the woman and fewer by the man, because their relative wages are closer than in a marriage where both parties have the same skill level. These effects go in the direction of middle-skilled men working more and assortative mating being higher in 2010, which are two of the main shortcomings of the model.

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, we perform a decomposition exercise that intends to isolate the effect of each of these factor on time allocation among married people.

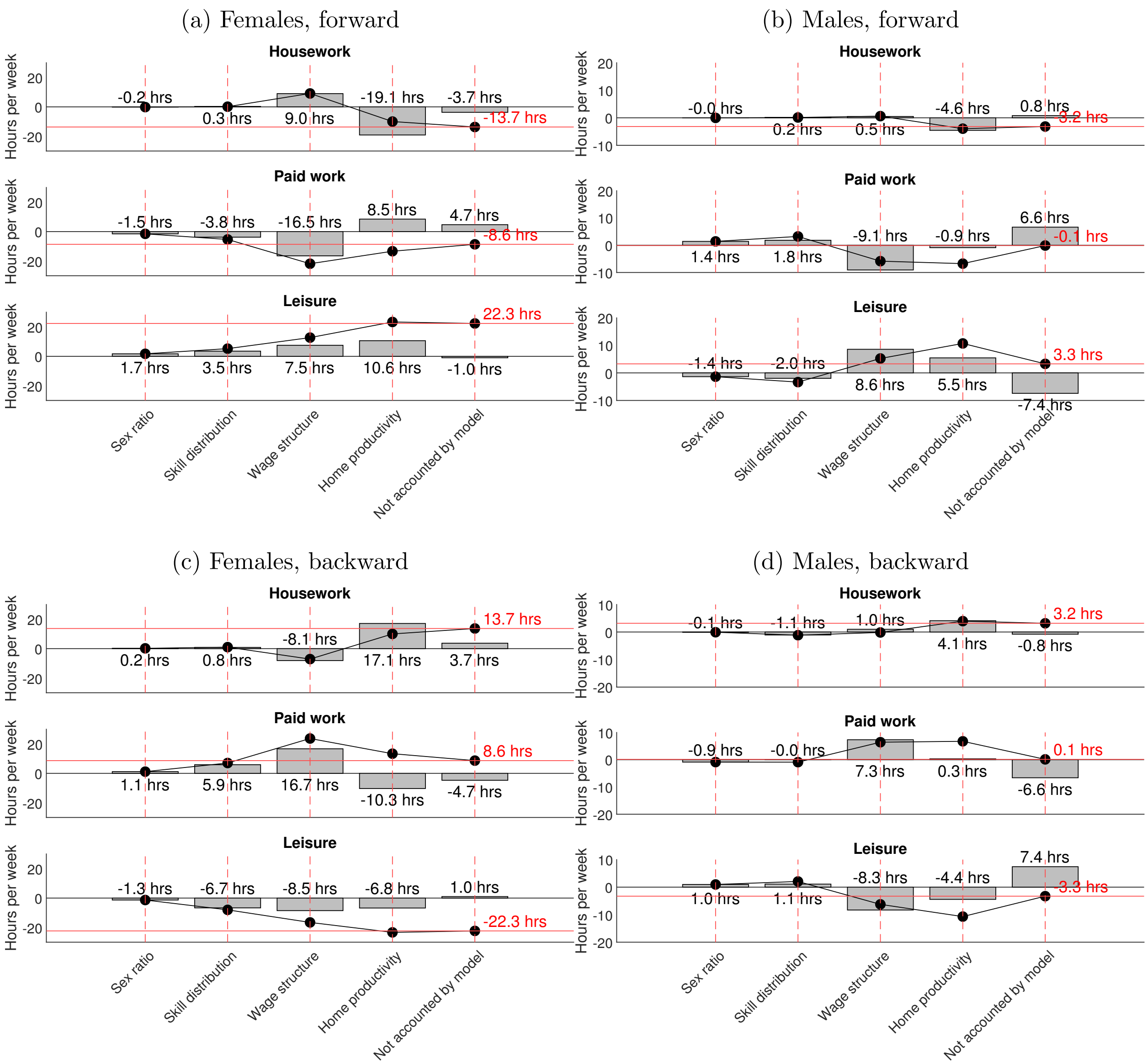
The way that we proceed is as follows. We start with the model in steady-state in 1990. Then we change, one-at-a-time and cumulatively, the sex ratio, skill distribution among entrants, the wage structure and the home production parameters (both the price of equipment and the productivity at home at the same time, we call it simply home productivity). Every time we change a factor, we compute a new SSBE. Naturally, as there are all sort of non-linearities and complementarities involved, the order of the decomposition matters. To account for this, we repeat the procedure starting from 2010, and change the primitives in the same order. We call the first decomposition forward, and the second backward.[16] Moreover, since there are differences between the model's steady-states and observed time allocations (small in 1990, larger in 2010), we include a fifth category and call it "not accounted by the model". Given that Nash bargaining best predicts the changes in time allocation, here we show the results of the decomposition exercise for this model, in Figure 7. The results for the Egalitarian bargaining model can be found in Appendix F.

The first thing to notice is that the forward and backward decompositions are roughly mirror images of each other: they have similar magnitudes with opposite signs. Moreover, the relative contributions of each factor do not change dramatically. For example, both

[15] In the model, an increase between 1990 and 2010 in the mean of the distribution of the match quality draws when both parties are high-skilled would have this effect.

[16] I perform one additional robustness check, consisting in a forward decomposition, i.e. starting in 1990 and finishing in 2010, but altering the order in which the primitives are changed. In particular, the sex ratio changes last. The results are shown in Appendix F. They are very similar to the ones shown here.

Figure 7: Decomposition of the changes in married people time allocation according to the Nash bargaining model, 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.

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 decrease both wife and husband's paid work time in the forward decomposition, and increase 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 change was not at all that big in the model. Therefore, the effect of the sex ratio is almost *pure* bargaining, unlike that of other factors such as 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 one hour and a half per week for both men and women. For context, Aguiar and Hurst (2007) find an increase in leisure for women in the Unites States between 1965 and 2003 of four to eight hours per week, which they consider very large. In the absence of an increase in the sex ratio, the female-male leisure ratio in the model would have been approximately 0.777, instead of 0.815, a 4.6% difference.

Finally, changes in the skill distribution account for larger changes for women than for men. This is due to the fact that the skill distribution changed more for women: while in 1990 there was a larger proportion of high-skilled men, by 2010 the situation had reversed.

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.

We document a substantial increase in the leisure time of married women relative to men from 1990 to 2010. Then, we calibrate a model featuring marriage and time allocation decisions to the initial year. We compare the model's performance in 2010 both allowing for bargaining between spouses under two different types of solutions, Egalitarian and Nash (the collective model of the household) and not (the unitary model). We find that the former completely misses the increase in the wife to husband leisure ratio, the Egalitarian model generates an increase that is too large, and the Nash model one that is only slightly too small. The Egalitarian bargaining model is better able to replicate assortative mating patterns, but fails to generate an increase in assortative mating.

Moreover, we decompose the time allocation changes in the model with Nash bargaining, which performs the best in terms of predicting the time allocation patterns in 2010. Apart from the sex ratio, the skill distribution, the wage structure and home productivity experienced big transformations. We find that the increase in the sex ratio leads to about one additional hour per week in married women's leisure, via a decrease in paid work. The opposite happens for men. The magnitude of this change is relatively small with respect to the effect of the other factors, but it plays an important to for the leisure ratio.

The model presented in this paper does not consider other potential channels through which partners compensate each other. For example, Wei and Zhang (2011) show that there is competition among families to provide male sons with real estate (a house) to improve their standing in the marriage markets. Moreover, as suggested by Grosjean and Khattar (2018), social norms surrounding female labor supply and housework are persistent, which could prevent adjustment in time allocation 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 we take human capital accumulation decisions as given. However, the combination of increasing sex ratios, skill premiums and gender wage gap observed in China could certainly affect such decisions, just like Lafortune (2013) shows for the United

States. 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.

A Time allocation measures

The CHNS includes variables containing the average number of days per week and hours per day worked last year, as well as a number of variables containing time spent on several home production activities: food buying, food preparing, clothes washing, house cleaning, parent care and child care. Not all of these are present in all waves: house cleaning is only available after 1997, and parent caring is only present in 1989. Moreover, there are too many missing and implausible values in these variables for them to be a part in the analysis. Table 8 summarizes this and shows the original variable names.

Table 8: Original variables used for time allocation measures

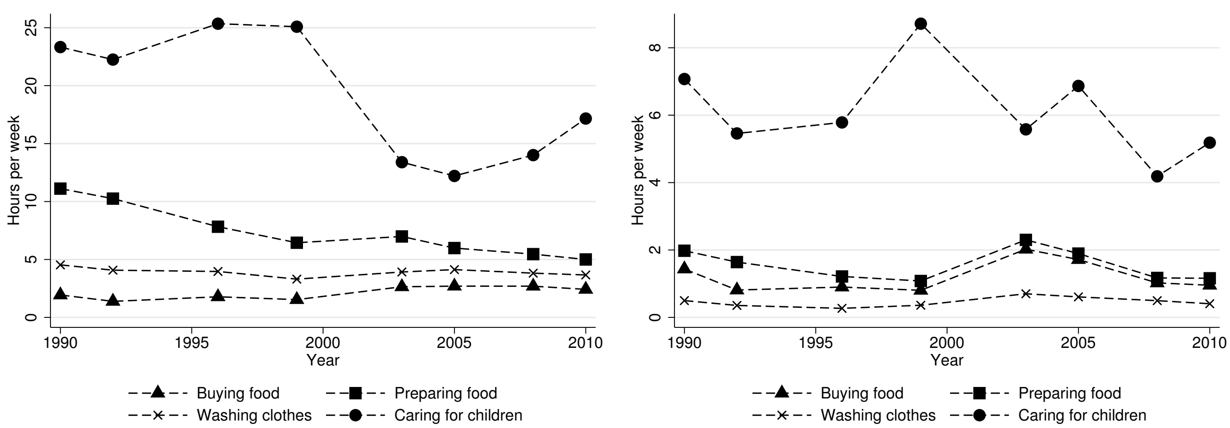
CHNS name	**Contents**	**Years present**
Paid work		
C5	Average number of days per week worked last year	All
C6	Average number of hours per day worked last year	All
Housework		
K3	Time spent buying food	All
K4	Time spent preparing food	All
K7	Time spent washing clothes	All
K7C	Time spent cleaning house	1997+
K11	Time spent caring for elderly parents	All
K12	Time spent caring for own children	1989

I construct the weekly paid hours variable simply by multiplying the average number of days per week and hours per day. To obtain housework hours per week, we use the four variables that are present in all years: food buying, food preparing, clothes washing and child care. Caution must be taken when adding these variables to obtain the final housework hours per week, since they are reported in different units by different responders. The units in which these times are expressed are contained in variables K3A, K5A, K7A, K13A, respectively, which can be hours per day, hours per week, minutes per day or minutes per week. After harmonizing the units to hours per week for each observation, we compute housework time by adding them up.

Figure 8 shows the behavior of each component of my housework time measure between 1990 and 2010. The main drivers in the decrease of women's housework during this period in absolute terms are childcare and food preparation, with each falling by roughly 5 hours per week each. In percent terms, the former declined around 25% while the latter did by more than 50%. Clothes washing also experienced a decline in percent terms of around 20%, but a smaller absolute decline (1 hour per week). It seems highly unlikely that house cleaning and parent caring time to have increased in such a way so as to offset these trends. Moreover, throughout the whole period, the one-child policy was in place in China, meaning that large changes in the number of children per married household cannot account for the fall in childcare hours per week. Even if a small decrease in this number is partly behind the reduction in this component of housework, it is telling that such a reduction it is not accompanied by an increase in paid hours by women, which suggests a role for bargaining.

Figure 8: Housework components for married people aged 20-35 by sex in selected Chinese provinces, 1990-2010

(a) Women (b) Men



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.

B Assortative mating measures

For the first measure, we 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, with $T = \{1992, 1996, 1999, 2003, 2005, 2008, 2010\}$. 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. We 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, we 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 we 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. We 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, we compute a measure of assortative mating based on contingency tables, as the one shown in Table 9 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, we 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 we 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 9: 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.

C 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

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

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:

$$\sigma_c c^{-\sigma} - \lambda_i(z) = 0 \implies c = \left(\frac{\sigma_c}{\lambda_i(z)}\right)^{\frac{1}{\sigma}} \tag{SFOC 1}$$
$$\sigma_l l^{-\sigma} - \lambda_i(z)\omega_i(z) = 0 \implies l = \left(\frac{\sigma_l}{\lambda_i(z)\omega_i(z)}\right)^{\frac{1}{\sigma}} \tag{SFOC 2}$$
$$\sigma_g g^{-\sigma} A_g \alpha_g \left[e^{1-\alpha_g}\right] h^{\alpha_g - 1} - \lambda_i(z)\omega_i(z) = 0 \tag{SFOC 3}$$
$$\sigma_g g^{-\sigma} A_g (1-\alpha_g) \left[e^{-\alpha_g}\right] h^{\alpha_g} - \lambda_i(z) p_e = 0. \tag{SFOC 4}$$

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:

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

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:

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

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

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

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

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:

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

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:

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

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

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

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

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

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

$$\sigma_g g^{-\sigma} G_e - \lambda(z_f,z_m)p_e = 0, \quad \text{(MFOC 7)}$$

where:

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

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:

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

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

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

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 $x^f(z_f, z_m)$:

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

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 we rely on numerical methods to find the optimal quantities for married households.

D Estimating home production parameters and primitives

To produce estimates of the fraction of home appliances on total consumption expenditures in China we rely on different data sources. We estimate total consumption by multiplying GDP data from the International Monetary Fund by the share consumption in GDP reported by the National Bureau of Statistics of China. Then, we take data from the China Home Appliances Blue Book produced by Fitch Ratings. In 2019, the size of the home appliance market in China was around 131 billion USD. The growth rate between 2014 and 2019 was 3.7% per year, while it was around 20% from 2008 to 2014. We then produce three set of estimates by projecting backwards using different growth rates for the home appliances markets between 1990 and 2008. The low growth estimate assumes the growth rate in the 2014-2019 period, The mid estimate assumes the growth rate to be the average between the 2008-2014 and 2014-2019 periods, i.e. 10.85% per year. The high estimate assumes the growth rate in the 2008-2014 period. Table 10 shows the numbers for each year between 1990 and 2019. The estimated fraction of home appliances expenditure on consumption varies from 8.53% in 1991 in the low growth scenario to 0.82% in 1990 in the high growth one.

Table 10: Estimates of the fraction of home appliance expenditure on total consumption

Year	GDP	C/GDP	C	Low	Low %	Mid	Mid %	High	High %
1990	396.6	63.3%	251.0	21.0	8.38%	6.3	2.52%	2.1	0.82%
1991	413.2	61.9%	255.8	21.8	8.53%	7.0	2.75%	2.4	0.95%
1992	492.1	59.8%	294.3	22.6	7.69%	7.8	2.65%	2.9	0.97%
1993	617.4	58.5%	361.2	23.5	6.50%	8.6	2.39%	3.4	0.94%
1994	561.7	58.5%	328.6	24.3	7.41%	9.6	2.91%	4.0	1.21%
1995	731.0	59.3%	433.5	25.2	5.82%	10.6	2.45%	4.7	1.09%
1996	860.5	60.3%	518.9	26.2	5.04%	11.8	2.27%	5.6	1.07%
1997	958.0	59.9%	573.8	27.1	4.73%	13.0	2.27%	6.6	1.14%
1998	1024.2	60.7%	621.7	28.1	4.53%	14.4	2.32%	7.7	1.24%
1999	1088.3	62.9%	684.6	29.2	4.26%	16.0	2.34%	9.1	1.33%
2000	1205.5	63.9%	770.3	30.3	3.93%	17.8	2.30%	10.8	1.40%
2001	1333.6	62.2%	829.5	31.4	3.78%	19.7	2.37%	12.7	1.53%
2002	1465.8	61.2%	897.1	32.5	3.63%	21.8	2.43%	15.0	1.67%
2003	1657.0	58.1%	962.7	33.7	3.51%	24.2	2.51%	17.7	1.84%
2004	1949.4	55.4%	1080.0	35.0	3.24%	26.8	2.48%	20.9	1.93%
2005	2290.0	54.3%	1243.5	36.3	2.92%	29.7	2.39%	24.6	1.98%
2006	2754.1	52.5%	1445.9	37.6	2.60%	32.9	2.28%	29.1	2.01%
2007	3555.7	50.9%	1809.8	39.0	2.16%	36.5	2.02%	34.3	1.89%
2008	4577.3	50.0%	2288.6	40.5	1.77%	40.5	1.77%	40.5	1.77%
2009	5089.0	50.2%	2554.7	47.7	1.87%	47.7	1.87%	47.7	1.87%
2010	6033.8	49.3%	2974.7	56.3	1.89%	56.3	1.89%	56.3	1.89%
2011	7492.2	50.6%	3791.1	66.5	1.75%	66.5	1.75%	66.5	1.75%
2012	8539.6	51.1%	4363.7	78.5	1.80%	78.5	1.80%	78.5	1.80%
2013	9624.9	51.4%	4947.2	92.6	1.87%	92.6	1.87%	92.6	1.87%
2014	10524.2	52.3%	5504.2	109.2	1.98%	109.2	1.98%	109.2	1.98%
2015	11113.5	53.7%	5968.0	113.3	1.90%	113.3	1.90%	113.3	1.90%
2016	11226.9	55.1%	6186.0	117.5	1.90%	117.5	1.90%	117.5	1.90%
2017	12265.3	55.3%	6782.7	121.8	1.80%	121.8	1.80%	121.8	1.80%
2018	13841.8	55.8%	7723.7	126.3	1.64%	126.3	1.64%	126.3	1.64%
2019	14340.6	54.7%	7844.3	131.0	1.67%	131.0	1.67%	131.0	1.67%

Source: Author's estimates using GDP in billions of USD from the IMF's World Economic Outlook, fraction of consumption on GDP from Table 3-10 of the 2022 Statistical Yearbook of the National Bureau of Statistics of China, and value of the home appliances market from 2008 to 2019 from Fitch Ratings China Home Appliances Blue Book.

Notes: GDP, Consumption (C), Low, Mid and High estimates in billions of USD. Low %, Mid % and High % are percentages of consumption. The following growth rates were used for the estimates between 1990 and 2008: 3.7% (low), 10.85% (mid), 20% (high).

E Time allocation results under different values for σ

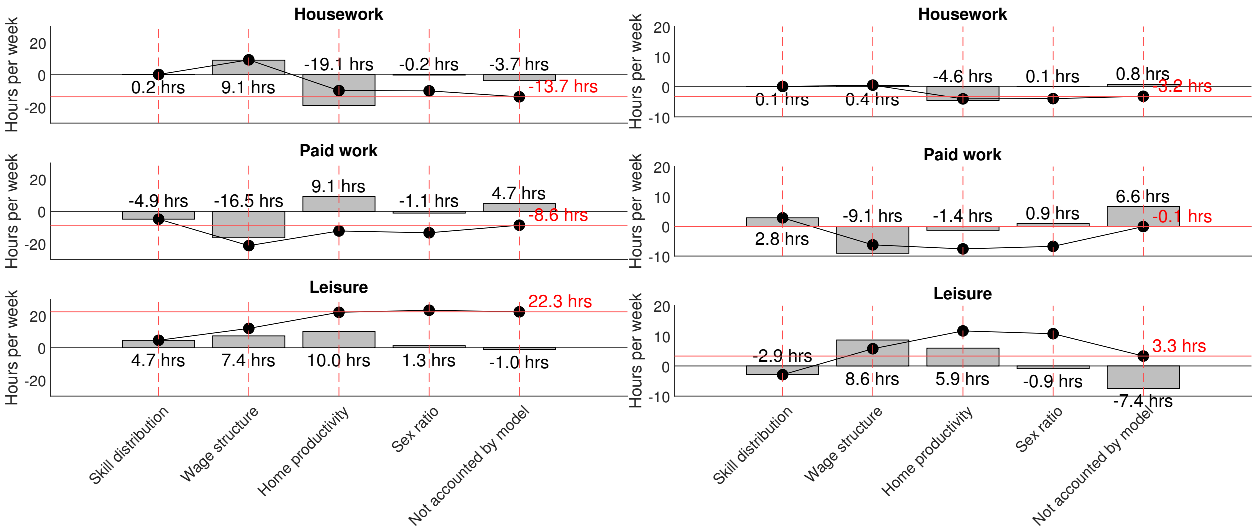
Table 11 presents the time allocation results for the collective model for different values of σ. Recall that σ regulates the elasticity of substitution between consumption of the market good, consumption of the home-produced good and leisure. Lower values of σ generate even larger drops of female labor 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 11: 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

Figure 9: Decomposition of the changes in married people time allocation according to the Nash bargaining model, 1990-2010

(a) Females, forward (b) Males, forward



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.

F Additional decomposition results

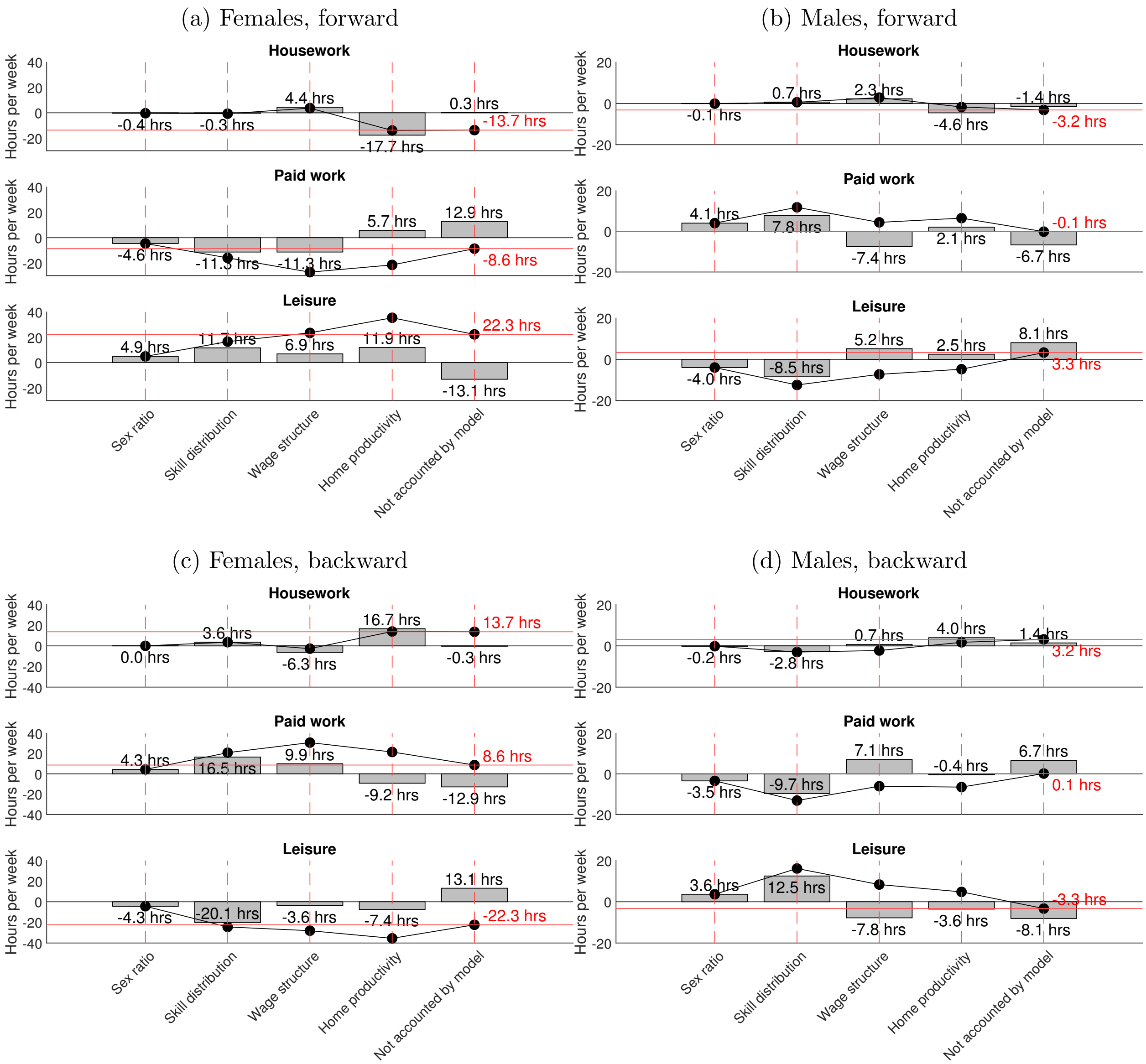
Figure 9 shows the result of an alternative forward decomposition, in which the sex ratio changes last. Notice that the magnitude of the effect of the sex ratio is very close to the results shown in section 6. Changes in the skill distribution account for close to an additional hour of leisure for women with respect to the baseline forward decomposition, while the opposite is true for men. Thus, it seems that the changes in the sex ratio mute the effects of those in the skill distribution.

Figure 10 shows the decomposition exercise according to the Egalitarian bargaining model. Like in the Nash bargaining case, the forward and backward decompositions are roughly mirror images of each other. The main difference with respect to the latter is that the change in the skill distribution is the factor that causes the largest changes in time allocation. Most of it goes in the direction of increasing men's paid work and housework time (this decreasing leisure), 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.[17] 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. This effect is hugely overstated in the model, and probably the main reason why the Egalitarian bargaining solution overestimates the change in the leisure ratio.

In term of the effect of the changes in the sex ratio on time allocation patterns, here we have that they explain a larger shift in leisure hours from men to women. This is consistent again with the fact that Egalitarian bargaining generates too large response in the Pareto weights. The leisure ratio in the model in 2010 would've been 1.133 instead of 1.289, a 12% difference. The effect is still small compared with the other factors.

[17] See below for tables with the full decomposition results.

Figure 10: Decomposition of the changes in married people time allocation according to the Egalitarian bargaining model, 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.

Table 12: 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 13: 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

G Algorithms to solve and calibrate the model

In this section we 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 SSBE, and Ξ_2 is the set of parameters chosen jointly by matching moments in SSBE.

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 $error > tol$ **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;
  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 $z \in \{1, 2, 3\}$ **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 $\overline{\theta_S(z)^{prior}} = \theta_S(z)$, $\forall z \in \mathcal{Z}$;
  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 SSBE

inputs : parameters of the model chosen before solving the SSBE Ξ_1
outputs: parameters of the model chosen jointly by matching data targets in SSBE 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 $error_o > tol_o$ **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 $error_i > tol_i$ **do**
        set $\psi_f = \frac{\bar{\psi}_f+\underline{\psi}_f}{2}$;
        do algorithm 3 to compute the SSBE ;
        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 SSBE with the new match quality draw means ;
        if $(l_f/l_m)_{model} < (l_f/l_m)_{data}$ **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 $(n_f + n_m)_{model} > (n_f + n_m)_{data}$ **then**
        set $\bar{\sigma}_c = \sigma_c$;
    else
        set $\underline{\sigma}_c = \sigma_c$;
    end
    if $(h_f + h_m)_{model} > (h_f + h_m)_{data}$ **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 SSBE

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