# A Quantitative Model of Non-Marriage and Fertility*

*Bargaining over Leisure*

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**ABSTRACT** This paper introduces a new factor contributing to the decline in marriage and fertility: the growth of leisure technology. Over recent decades, high-income countries have experienced two notable shifts in household and family dynamics. First, there has been a significant decline in marriage rates and fertility. Second, time has increasingly been allocated to leisure activities. This paper presents a unified model of marriage and fertility, incorporating intra-household bargaining dynamics. The model, calibrated using data from Japan between 2018 and 2022, is employed to assess the impact of leisure technology growth on marriage and fertility during 2005-2009. The findings highlight that leisure technology growth makes single life relatively more appealing compared to marriage and parenthood. The model explains nearly the entire decline in fertility and accounts for 27% of the decline in marriage in Japan during this period.

## 1 Introduction

Most of the developed countries have been facing a decline in marriage (or partnerships) and fertility rates. The decline in fertility is often viewed as a major policy concern, and many governments implement family-friendly policies to encourage childbearing. A substantial body of labor and macroeconomics literature investigates the mechanism behind fertility decline and the design of optimal policies. However, the connection between household formation and fertility, the factors driving the decline in marriage rates, and their potential influence on fertility decisions are not fully understood.

This paper proposes a new driver of the decline in marriage and fertility: the improvements in leisure technology. Leisure technology, such as video games and social media, has been dramati-

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cally improved in the last decade, and the value of leisure has increased. One potential impact of the growth of leisure technology could be the increased value of being single. Singles can enjoy their hobbies and leisure time without any constraints. At the same time, married couples have to compromise their leisure time with their partners and children, lowering incentives for marriage and partnerships.

In this paper, I study the impact of leisure technology growth on the marriage and fertility decline in Japan. Several factors make Japan an ideal case for studying low fertility. First, marriage and childbirth are still strongly associated in Japan. According to OECD data, the share of births outside of marriage in Japan was 2.4% in 2020, the lowest among the OECD countries. Hence, to understand low fertility in Japan, it is crucial to study the entry into marriage and how married couples choose the number of children. Second, the fertility rate in Japan has been declining since 2000. Panel (a) of Figure 1 shows the fertility rate of women at age 45. The fertility rate started to decline from 2000 and reached 1.47 in 2022. During the same period, the share of those who have never married has dramatically increased in the past decades in Japan. Panel (a) of Figure 1 shows the share of those who were never married at age 45-54. For men, the share of those who are never married has gradually increased from 1980 and reached 27.1% in 2020. For women, the share started to increase from 2000 when the fertility rate began to decline and reached 17.2% in 2020. Since childbirth outside of marriage is very uncommon in Japan, the increase in the share of never-married is likely to be a significant contributor to the decline in fertility.

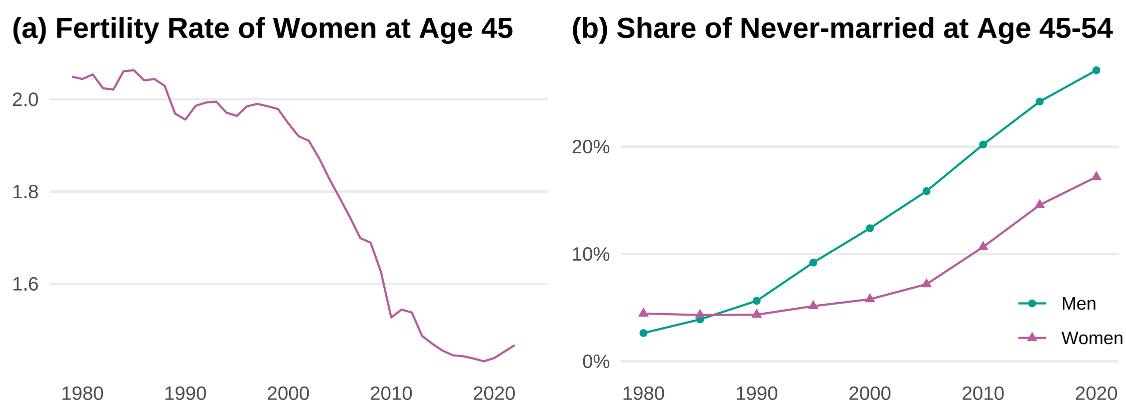


**Figure 1: Marriage and Fertility in the Past Decades in Japan**. Panel (a) shows the fertility rate of women at age 45. The data is from the Human Fertility Database. Panel (b) shows the share of those who have never married at age 45-54. The data is from the Japanese Censuses.

To explore the impact of leisure technology on the decline in marriage and fertility in Japan, I begin by documenting key patterns, including the reasons for remaining single, the time allocation differences between singles and married couples, and the trends in marriage and fertility rates. First, survey data reveals that 22 % of men and 24 % of women choose to remain single to pursue hobbies, while 27 % of men and 31 % of women prefer the freedom of being single. This indicates that the desire and opportunity to enjoy more leisure time as a single person can discourage marriage, as singles believe their leisure time will decrease after marriage. I refer to this as the “marriage penalty on leisure.” Second, panel data analysis shows that wives experience a significantly greater decline in leisure time than their husbands, which I term the "child penalty on leisure." Finally, I document that the distribution of leisure time between married couples is influenced by their relative wages, with the lower-wage partner having less leisure time. This finding aligns with household bargaining, where the higher-earning partner enjoys more leisure time, contributing to the marriage penalty on leisure.

To quantify the impact of leisure technology on the decline in marriage and fertility, I develop a model of time allocation and household formation. This model includes single and married individuals, each with a stochastic life cycle. Individuals differ in their labor market productivity. In each period, singles are randomly matched with other singles, and marriage occurs if both parties agree. Married individuals must decide how to allocate their time among work, household work, and leisure, as well as when and where to have children. While children bring utility, they also increase the household workload for parents. Household work is modeled as a time requirement that must be met by aggregating time inputs from husbands and wives. The parameters of this aggregation are allowed to change over time to reflect changes in the social norms, which become more egalitarian.

Marriage has economic value due to resource pooling and a random utility value that reflects the match quality between partners. Although married couples have more resources, their time allocation is more constrained. A couple jointly decides how to allocate time and how many children to have, with bargaining power determined by their relative wages. Individuals with lower wages have less leisure time and experience a more significant reduction in leisure time when they have children. Households get utility from consumption, children, and leisure. The utility weight of leisure is allowed to change over time to capture changes in the leisure technology. When deciding whether to marry, individuals consider the value of remaining single, including potential opportunities to meet other partners. The distribution of potential partners is endogenous and is determined by the decisions of all individuals.

I estimate the parameters of the structural model using data for the 2018-2022 period. The model generates the observed pattern of household time allocation, marriage, and fertility rates. It also captures the heterogeneous marriage rate by earnings and the child penalty on leisure, which are not targeted in the calibration.

I then apply the model to examine the factors driving the decline in marriage and fertility in Japan over recent decades, with a particular focus on the impact of leisure technology growth. In addition to leisure technology, I also consider the effects of rising female wages and changes in gender roles within households. These two factors have also undergone significant shifts in the past decade and have been extensively studied in the literature regarding their influence on marriage and fertility rates.

The model successfully accounts for a substantial portion of the observed decline in marriage and fertility over the last decade, explaining 27% of the decline in marriage and 139% of the decrease in fertility. Decomposition analysis reveals that the growth of leisure technology has been the most significant factor contributing to the decline in fertility, as it increases the relative value of leisure compared to having children.

**Related Literature** My first contribution is to introduce the leisure technology growth as a new driver of the marriage and fertility decline The impact of leisure technology growth on the labor supply and the value of leisure has been studied by others. Kopecky (2011) builds a model of endogenous retirement with leisure production and shows that the decline in the price of leisure goods makes retirement more attractive. Aguiar et al. (2021) show that the leisure technology growth in computer games can explain the 2% decline in the labor supply of young men in the US in the last decade. Kopytov, Roussanov, and Taschereau-Dumouchel (2023) also show the decline in prices of recreational activities can explain a large proportion of the decrease in the labor working hours in some OECD countries.[2] However, little is known about the impact of leisure technology growth on the marriage and fertility decline. By incorporating the growth of leisure technology into the model, I show that leisure technology growth can explain a significant proportion of the decline in marriage and fertility in the last decade.

This paper also contributes to the labor and macroeconomics literature that studies changes in marriage and fertility in high-income countries.[3] As an early work, Ahn and Mira (2002) points out the negative correlation between fertility and female labor force participation in high-income countries. Female earnings and labor market arrangements that affect female labor supply have been studied as a key factor in the recent marriage and fertility decline (Santos and Weiss (2016); Adda, Dustmann, and Stevens (2017); Blasutto (2023); Guner, Kaya, and Marcos (2023); Cruces (2024)). In this literature, Greenwood et al. (2016) build a dynamic marriage model with growth in home production technology. While their model explains the decline in marriage rates in the US by the decrease in the price of home production inputs, the model does not include an endogenous fertility decision or leisure choice. Baudin, De La Croix, and Gobbi (2015) build a model of endogenous marriage and fertility. However, their model is static and does not consider a dynamic household formation.[4]

Another related literature focuses on the importance of the bargaining power and intra-household decision-making.[5] Knowles (2013) studies intra-household bargaining and labor supply and shows that gender asymmetry in bargaining power explains the time trends of female labor supply in the US from 1970 to 2001. Burda, Hamermesh, and Weil (2013) document a negative relationship between GDP per capita and gender differences in total work and emphasize the role of social norms and intra-household bargaining. To study the relationship between bargaining power and fertility, Doepke and Kindermann (2019) build a Nash-bargaining model of fertility. While these models highlight the importance of relative bargaining power in explaining intra-household decision-making, the partnership formation with the bargaining after the marriage is absent. The current model endogenizes the marriage given the expectation of household decision-making after the marriage.

[2] For the United States, González-Chapela (2007) studied the negative impact of the decline in the price of recreational goods on hours in the labor market from 1976 to 93 and Vandenbroucke (2009) from 1900 to the 1950s.

[3] See Greenwood, Guner, and Marto (2023) and Doepke et al. (2023) for comprehensive reviews of this literature.

[4] Myong, Park, and Yi (2021) extend the model of Baudin, De La Croix, and Gobbi (2015) by incorporating the social norms and explain the marriage and fertility decline in South Korea.

[5] Basu (2006) and Iyigun and Walsh (2007) provide theoretical models of endogenous bargaining power.

Finally, this paper deepens the economic understanding of the decline in marriage and fertility in Japan. Kitao and Nakakuni (2024) build a static model of marriage and fertility and show that one of the main drivers of the marriage and fertility decline in Japan from 1970 to 2020 is the change in home production technology and the increase in time and financial costs of childcare. While this paper captures the trends in marriage and fertility rates in the past decades, it does not consider the impact of leisure technology growth and gender asymmetries in bargaining power. Lise and Yamada (2019) study the collective model of intra-household allocation and welfare analysis in Japan, and Guo and Xie (2024) extend it by incorporating the arrival of the first child. While these papers focus on intra-household decision-making, the current paper investigates the marriage market and family formation, given the expectation of intra-household bargaining.

The rest of the paper is organized as follows. Section 2 documents the stylized facts of the decline in marriage and fertility. Section 3 presents the model of time allocation and household formation. Section 4 describes the calibration strategy. Section 5 estimates the model parameters using the census and the household survey. Section 6 shows the model's ability to reproduce the observed pattern of the marriage and fertility rates. Section 7 concludes the paper.

# 2 Facts

This section investigates the reasons why people do not get married and provides stylized facts to help the model construction. The results point out the importance of leisure time in the marriage decision and suggest that intra-household bargaining power might disincentivize people from marriage and childbirth.

## 2.1 Data and Samples

The primary data source for the empirical analysis is the Japanese Household Panel Survey (JHPS). JHPS is a panel data that started in 2004, with the most recent data wave from 2022. The original 2004 sample was nationwide and contained 4000 households and 7000 individuals older than 20. Additional samples were added in 2007 (1400 individuals), 2009 (4000 individuals), and 2012 (1000 individuals). The survey has information on earnings, working hours, and other labor market outcomes, as well as on family structure, fertility, and other demographic variables. For details on the data, see Section B.1.

The survey also has information on hours spent on housework and childcare, and I define the hours spent on leisure as the residuals of the total time budget. For the following discussion, I will use the terms "working hours" and "hours worked" to refer to the sum of hours spent on the market and commuting. "Domestic labor" refers to the sum of hours spent on housework and childcare, and "leisure" refers to the residual. I assume the total time budget is 16 hours per day, and $16 \times 7 = 112$ hours per week. Hence, the weekly leisure hours are calculated as the total time budget (112 hours) minus the sum of working hours and domestic labor per week.

The sample is restricted to people aged 25-54 in the period 2005-2022. The data in 2004 is not used because the domestic labor data is not available. The singles sample is restricted to those with a job, a positive leisure time, and no children. The sample of married couples is also restricted to those with a positive leisure time. However, it includes non-working individuals.

As a supplemental data source, I use aggregated statistics from the National Fertility Survey (NFS), which investigates the situation and issues regarding marriage, childbirth, and child-rearing every five years. I mainly use the questions about the reasons why people do not get married.

## 2.2 Why People Do Not Marry

What is the main reason why people do not get married? The NFS provides information on the main reasons people do not get married. Figure 2 shows the top 5 reasons in 2021.[6] The sample is restricted to singles aged 25-34.

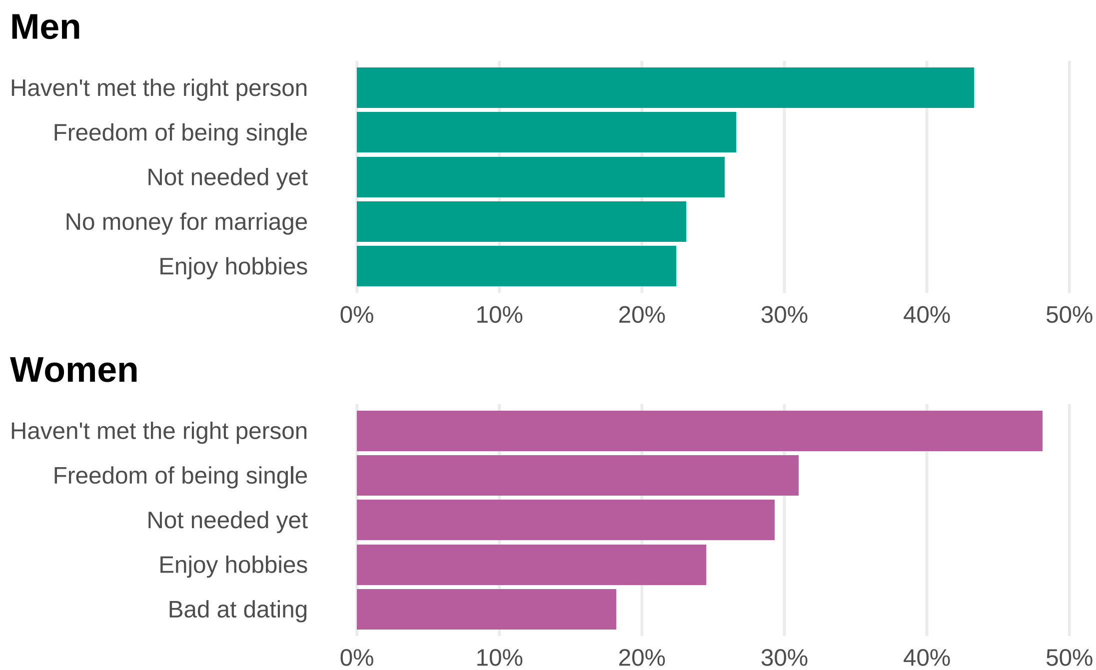


**Figure 2: Top 5 Reasons Why Do not Get Married**. The share of the top 5 reasons why do not get married. The data is from the National Fertility Survey, and the sample is restricted to the age group 25-34 in 2021.

For both men and women, the top reason is "I haven't met the right person", which implies their difficulty in finding a partner with whom they spend a better time than being single. The third reason for both, "Not needed yet", can also be interpreted in this context. They might expect their life will not improve with their potential partner. These elements will be represented in the model as a matching process with a potential partner and their marriage decision based on their expected value of being single and married.

"Freedom of being single" and "Enjoy hobbies" are also important reasons for both men and women. It implies that they expect marriage to restrict their lives and not allow them to enjoy

[6] I plot the time trends of these reasons from 1992 to 2021 in Figure A.3 . The share of the top reasons does not change much over time. However, given that the share of never-married people is increasing and the survey sample is limited to singles, the number of people who agree with these reasons might be growing.

their hobbies enough. In other words, once they get married, they cannot live as well as they did when they were single. In the model, this will be represented as a couple's joint decision of time allocation and the bargaining power between them. If they get married, especially with a partner with a higher bargaining power, they may have less leisure time, and their utility could be lower than if they remained single.

## 2.3 Child Penalty on Leisure

Another important motivation for marriage is having children. On the other hand, raising a child is time-consuming and reduces parents' leisure time. Hence, the reasons why people do not get married, "Freedom of being single" and "Enjoy hobbies", might be related to childbearing and its implications for time allocations within marriage.

I conduct an event study analysis to investigate the impact of childbirth on leisure time. The specification is given by

$$y_{it} = \alpha_i + \lambda_t + \sum_{q \neq -1, -\infty} \beta_q \mathbb{1}\{C_i + q = t\} + \varepsilon_{it}. \tag{1}$$

The $y_{it}$ is the time allocation of individual $i$ at time $t$, $\alpha_i$ is the individual fixed effect, $\lambda_t$ is the time fixed effect, and $\varepsilon_{it}$ is the error term. The $C_i$ is the time of the first childbirth of individual $i$, so the $k$ represents the relative years to the first childbirth. The sample consists of the individuals who had their first childbirth during the sample period and the individuals who did not have a child in the sample period. For the individuals who did not have a child, the $C_i$ is set to $\infty$, and the $k$ is set to $-\infty$. While this is in line with "child penalty" literature starting from Kleven, Landais, and Søgaard (2019), this specification includes the individual fixed effect to make a unit comparison. The importance of the individual fixed effect for the child penalty is discussed in Arkhangelsky, Yanagimoto, and Zohar (2024).

Figure 3 shows the coefficient $\beta_k$ of the event study (1) . For women, childbirth has a huge negative impact on working hours (-20 hours at $q = 1$) and a positive impact on domestic labor (79 hours). The impact on men is relatively small (2 hours for working hours and 10 hours for domestic labor). Interestingly, the impact on women's leisure is negative and larger (-63 hours at $q = 1$) than men's leisure (-11 hours). This implies that a pure specialization is not held. If the difference in their wages is the reason why husbands work more in the market and wives work more in the house, the decline of leisure after childbirth should be similar for men and women. This child penalty on leisure might discourage women from having children.[7]

[7] Guo and Xie (2024) also show the child penalty on leisure in Japan by the specification of Kleven, Landais, and Søgaard (2019).

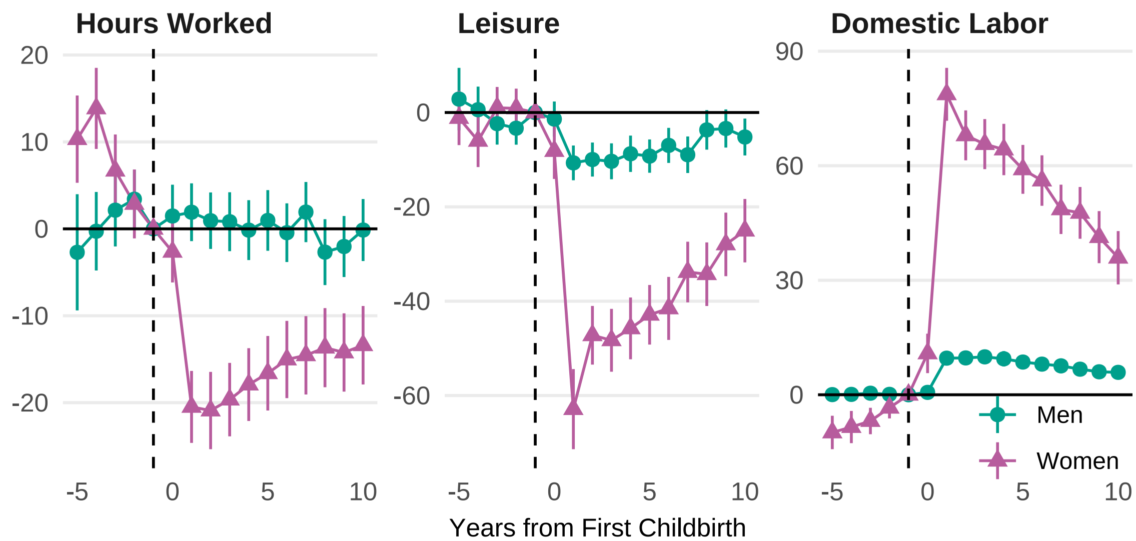


**Figure 3: Event Study of Time Allcation by Childbirth**. The child penalty on leisure for singles and married couples. The data is from the JHPS, and the sample is restricted to the age group 25-54 in 2005-2022.

## 2.4 Intra-Household Time Allocation and Bargaining Power

Where does the child penalty on leisure come from? One possible explanation is the intra-household bargaining. If a husband has a higher wage than his wife, he might have more bargaining power on household time allocations. As a result, the wife might have less leisure time than the husband.

To highlight the role of bargaining, I study how the relative wages of husbands and wives affect leisure time allocations within households. I use bin-scatter (Cattaneo et al. 2024) with a couple of fixed effects and estimate the following relation. For a couple $i$ at time $t$, I relate their relative leisure time allocations to their relative wages:

$$\log l_{it}^{m} - \log l_{it}^{f} = \phi\left(\log w_{it}^{m} - \log w_{it}^{f}\right) + \alpha_i + \varepsilon_{it} \tag{2}$$

For $g \in \{m, f\}$, $m$ is for the husband and $f$ is for the wife, $l_{it}^{g}$ is the leisure hours. The $w_{it}^{g}$ is their wages, and $\alpha_i$ is the couple fixed effect. The $\phi(\cdot)$ is an arbitrary function of the log difference in wages, which will be non-parametrically estimated in the bin-scatter algorithm. The sample is restricted to couples both of whom have jobs, to observe the bargaining power based on wages.

Figure 4 shows the relationship between the log difference in wages and the leisure time allocation. An interesting result is that the relationship for leisure is positive, i.e., the partner with higher wages has more leisure time. This implies that the husband has more bargaining power on leisure and might suggest that the bargaining power is a mechanism behind the child penalty on leisure.

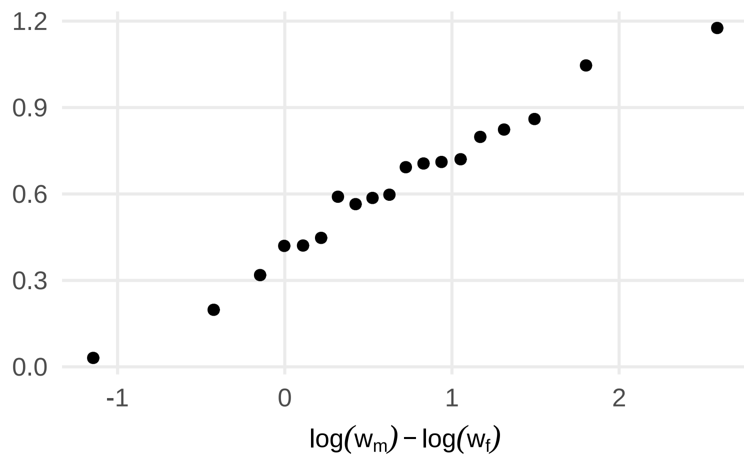


**Figure 4: Intra-Household Leisure Time Allocation**. A bin-scatter plot of the intra-household leisure time allocation for dual-working married couples. The data is from the JHPS, and the sample is restricted to the age group 25-54 from 2005 to 2022. The specification is given by equation (2) .

# 3 Model

## 3.1 Setup

The model economy consists of an equal mass continuum of men (gender $m$) and women (gender $f$). Individuals are distinguished by their discrete level of exogenous hourly wage, denoted $w_g \in \mathscr{W}$ for gender $g \in \{m, f\}$. It will be assumed that $w_g$ is log-normally distributed so that $\log w_g \sim \mathcal{N}\left(\mu_{w_g}, \sigma_{w_g}\right)$. Some individuals of each gender will be married, but the rest will never. Divorce is not allowed in this model. Married couples can have up to three children, while singles are not allowed to have children.

Individuals live forever but stochastically age and die. There are three states of life: young ($Y$), middle-aged ($M$), and old ($O$). A person faces a constant probability of aging and death. $\kappa_0$ is the probability of aging from $Y$ to $M$ and $\kappa_1$ is the probability of aging from $M$ to $O$. From $O$, a person dies with probability $\delta$. Upon death, an individual is replaced by a new single individual with the age $Y$ and the wage $w_g \in \mathscr{W}$.

Marriage and having a new child are allowed only for the couple with age $Y$ or $M$, and they can only marry someone of the same age. Also, there are two states of the age of children, 0 and 1. Children age from 0 to 1 when their parents age from $Y$ to $M$ or $M$ to $O$.

Each individual is endowed with one unit of time each period. Households (single or couple) are also required to perform domestic labor based on their marital status and the age and number of children. This requirement captures housework and childcare that have to be done by the household members. The household decides how to allocate time for the labor market, leisure, and domestic labor. Domestic labor decisions imply how time requirement is shared between the household members. A married couple with age $Y$ or $M$ also decides to have a new child or not if they do not have three children yet.

At the end of each period, a single person will meet someone else of the opposite gender from the set of singles of the same age. The couple will then draw a match-specific bliss shock $b \in \mathscr{B}$, taken from a distribution $G(b)$, which is assumed to be a normal distribution $\mathcal{N}(\mu_b, \sigma_b)$. In a marriage, the bliss shock stays constant over time, and the couple enjoys the same shock during each period.

Last, let everyone have a common subjective discount factor $\beta$. People with age $Y$ and $M$ discount the future at rate $\beta$, and people with age $O$ discount the future at rate $\beta(1-\delta)$. Suppose that for married, tastes over the consumption of market goods $c$, leisure hours $l$, and the number of children $N$ are represented by

$$u(c, l, N) = \frac{c^{1-\gamma_c}}{1-\gamma_c} + \alpha_l \frac{l^{1-\gamma_l}}{1-\gamma_l} + \alpha_n \frac{(1+N)^{1-\gamma_n} - 1}{1-\gamma_n}. \tag{3}$$

Note that the singles do not have children in this model, so the number of children $N$ is always zero, and their utility function is simplified as

$$u(c, l) = \frac{c^{1-\gamma_c}}{1-\gamma_c} + \alpha_l \frac{l^{1-\gamma_l}}{1-\gamma_l}.$$

## 3.2 Singles

Consider the consumption and time allocation decision facing a single individual. This is a purely static problem and does not depend on the age of the single. For a single individual with wage $w_g$, the problem is given by

$$v_g\left(w_g\right) = \max_{c_g, h_g, l_g, k_g} u\left(c_g, l_g\right), \tag{4}$$

subject to

$$\begin{aligned} c &= w_g h_g, && \text{(Budget Constraint)} \\ d_g &= \psi_g^S, && \text{(Domestic Labor Constraint)} \end{aligned}$$

and

$$h_g + l_g + d_g = 1. \quad \text{(Time Constraint)}$$

The domestic labor requirement for singles is a gender-specific constant: $\psi_m^S$ for men and $\psi_f^S$ for women.

Next, consider the marriage decision facing a single. Suppose a single individual of wage $w_g$ with age $a \in \{Y, M\}$ meets an opposite gender single of wage $w_{g'}$, and the potential couple draws a bliss shock $b$. They decide to marry based on the expected lifetime utility of being single and being married. Let $W_g^a\left(w_g\right)$ be the expected lifetime utilities. Both parties will realize if they remain single in the current period. Likewise, let $V_g\left(w_g, w_{g'}, b\right)$ be the expected lifetime utility associated with a marriage in the current period. A marriage will occur if and only if

$$V_m^a\left(w_m, w_f, b\right) > W_m^a(w_m) \text{ and } V_f^a\left(w_f, w_m, b\right) > W_f^a(w_m). \tag{5}$$

Define an indicator function $\mathbb{1}^a\left(w_m, w_f, b\right)$ as taking the value 1 if the couple marries and 0 otherwise. The value function for a single individual of wage $w_g$ with age $a$ can be written as

$$\begin{aligned} W_g^Y\left(w_g\right) &= v\left(w_g\right) + \beta(1-\kappa_0)\int_{\mathcal{B}}\int_{\mathcal{W}}\left(1-\mathbb{1}^Y\right)W_g^Y\left(w_g\right) + \mathbb{1}^Y V_g^Y\left(w_g, w_{g'}, 0, 0; b\right) d\hat{S}_{g'}^Y\left(w_{g'}\right)dG(b) \\ &\quad + \beta\kappa_0\int_{\mathcal{B}}\int_{\mathcal{W}}\left(1-\mathbb{1}^M\right)W_g^M\left(w_g\right) + \mathbb{1}^M V_g\left(w_g, w_{g'}, 0, 0; b\right) d\hat{S}_{g'}^M\left(w_{g'}\right)dG(b) \\ W_g^M\left(w_g\right) &= v\left(w_g\right) + \beta(1-\kappa_1)\int_{\mathcal{B}}\int_{\mathcal{W}}\left(1-\mathbb{1}^M\right)W_g^M\left(w_g\right) + \mathbb{1}^M V_g^M\left(w_g, w_{g'}, 0, 0; b\right) d\hat{S}_{g'}^M\left(w_{g'}\right)dG(b) \\ &\quad + \beta\kappa_1 W_g^O\left(w_g\right) \\ W_g^O\left(w_g\right) &= v\left(w_g\right) + \beta(1-\delta)W_g^O\left(w_g\right) \end{aligned} \tag{6}$$

A single individual at age $Y$ enjoys $v\left(w_g\right)$ in this period. Next period, he gets aged to $M$ with probability $\kappa_0$ or remains at age $Y$ with probability $1-\kappa_0$. Then they meet another opposite gender single from the distribution $\hat{S}_{g'}^a\left(w_{g'}\right)$ for $a \in \{Y, M\}$. Since marrriage behavior is different by wage, the wage distribution of the potential partner is an endogenous object, which will be determined in the equilibrium and formally defined in Section 3.4.

## 3.3 Couples

The consumption and time allocation decisions a couple faces are also static problems. A couple with age $a \in \{Y, M, O\}$, wage $w_m$ and $w_f$, and $N_0$ children of age 0 and $N_1$ children of age 1 solves

$$\max_{c,h_m,h_f,l_m,l_f,d_m,d_f} \left(1-\lambda\left(w_m, w_f\right)\right)u\left(\frac{c}{\Gamma(N_0, N_1)}, l_m, N_0+N_1\right) + \lambda\left(w_m, w_f\right)u\left(\frac{c}{\Gamma(N_0, N_1)}, l_f, N_0+N_1\right) \tag{7}$$

subject to

$$\begin{aligned} c &= w_m h_m + w_f h_f, && \text{(Budget Constraint)} \\ D\left(d_m, d_f\right) &= \psi^M + \psi^N \mathbb{1}\{N_0 > 0\}, && \text{(Domestic Labor Constraint)} \end{aligned}$$

and

$$h_g + l_g + d_g = 1 \text{ for } g \in \{m, f\} \text{ (Time Constraint)} .$$

The bargaining power of the wife is given by

$$\lambda\left(w_m, w_f\right) = \frac{w_f^\rho}{w_m^\rho + w_f^\rho}, \text{ with } \rho \geq 0.$$

Hence, if the husband's wage is higher than the wife's wage, the husband has more bargaining power, especially for his leisure $l_m$, since consumption of the market goods and the number of children are public goods in the household. The curvature parameter $\rho$ captures the strength of the bargaining power by relative wage. If $\rho = 0$, the bargaining power becomes equal ($\lambda\left(w_m, w_f\right) = \frac{1}{2}$) and does not depend on wage difference. If $\rho = 1$, the bargaining power is determined by the share of the wife's wage in the total wage. Section A.2 shows that if $\rho = 1$, the optimal leisure time of the married couple is equal, i.e., $l_m = l_f$. If $\rho > 1$, the bargaining power is larger than the relative wage difference, which, given the observed gender wage gaps, strengthens the husbands' bargaining power. Section A.2 also shows the positive correlation between the intra-household wage gaps and leisure time happens if and only if the bargaining power $\rho$ is larger than 1.

The $\psi^M$ represents the domestic labor requirement for married couples without children, and $\psi^N$ represents the additional domestic labor requirement for small children.[8] The production function of domestic labor is given by a Cobb-Douglas function,

$$D\left(d_m, d_f\right) = d_m^{1-\theta} d_f^{\theta}. \tag{8}$$

The $\theta$ parameter represents the relative productivity of the wife in domestic labor and potentially captures the social norms of gender roles in domestic labor. This is because the higher $\theta$ incentivizes the wife to do more domestic labor and the husband to do less. I formulate the role of $\theta$ in Section A.3.

For ages $Y$ or $M$, the couple also decides whether to have a new child or not. The couple decides to have a new child with the same bargaining power $\lambda_{mf} = \lambda\left(w_m, w_f\right)$ as the time allocation decision. Hence, the young couple solves

$$\begin{aligned}\max_{N_0{}' \in \{N_0, N_0+1\}, N_0{}' \leq 3} & (1-\kappa_0)\Big[\left(1-\lambda_{mf}\right)V_m^Y\left(w_m, w_f, N_0{}', 0; b\right) + \lambda_{mf} V_f^Y\left(w_f, w_m, N_0{}', 0; b\right)\Big] \\ & + \kappa_0\Big[\left(1-\lambda_{mf}\right)V_m^M\left(w_m, w_f, 0, N_0{}'; b\right) + \lambda_{mf} V_f^M\left(w_f, w_m, 0, N_0{}'; b\right)\Big]\end{aligned} \tag{9}$$

and the middle-aged couple solves

$$\begin{aligned}\max_{N_0{}' \in \{N_0, N_0+1\}, N_0{}' + N_1 \leq 3} & (1-\kappa_1)\Big[\left(1-\lambda_{mf}\right)V_m^M\left(w_m, w_f, N_0{}', N_1; b\right) + \lambda_{mf} V_f^M\left(w_f, w_m, N_0{}', N_1; b\right)\Big] \\ & + \kappa_1\Big[\left(1-\lambda_{mf}\right)V_m^O\left(w_m, w_f, 0, N_0{}' + N_1; b\right) + \lambda_{mf} V_f^O\left(w_f, w_m, 0, N_0{}' + N_1; b\right)\Big].\end{aligned} \tag{10}$$

The first term in (9) captures the couple's expected lifetime utility if they do not age to $M$. If they don't have three children yet, they can choose to have a new child or not, and the number of children at age 0 will be $N_0{}'$. The second term represents the expected lifetime utility of the couple if they age to $M$. When they age to $M$, their children will age from 0 to 1, and as a result, the number of children at age 0 will be zero, and the number of children at age 1 will be $N_0{}'$. Note that this stochastic aging of children also applies to their newborn child, i.e., the newborn child will be aged to 1 in the next period.[9] The middle-aged couple's decision (10) is similar to the young couple's decision.

[8] In the Appendix, Figure A.4 shows that domestic labor hours significantly increase with the existence of children but do not change much with the number of children.

[9] This assumption is made for computational reasons, to reduce the dimensions of the state space.

Let the indirect utility functions derived from the couple's time allocation problem be $v_g\left(w_g, w_{g'}, N_0, N_1\right)$ for $g \in \{m, f\}$, which does not depend on the age of the couple. Given the child-birth decision $N_0^*$, the value function for a married man of wage $w_m$ and with $N_0$ children age 0 and $N_1$ children age 1 and a bliss shock $b$ can be written as

$$
\begin{aligned}
V_g^Y\left(w_g, w_{g'}, N_0, 0; b\right) &= v_g\left(w_g, w_{g'}, N_0, 0\right) + b \\
&\quad + \beta(1-\kappa_0)V_g^Y\left(w_g, w_{g'}, N_0^*, 0; b\right) + \beta\kappa_0 V_g^M\left(w_g, w_{g'}, 0, N_0^*; b\right) \\
V_g^M\left(w_g, w_{g'}, N_0, N_1; b\right) &= v_g\left(w_g, w_{g'}, N_0, N_1\right) + b \\
&\quad + \beta(1-\kappa_1)V_g^M\left(w_g, w_{g'}, N_0^*, N_1; b\right) + \beta\kappa_1 V_g^O\left(w_g, w_{g'}, 0, N_0^* + N_1; b\right) \\
V_g^O\left(w_g, w_{g'}, 0, N_1; b\right) &= v_g\left(w_g, w_{g'}, 0, N_1\right) + b + \beta(1-\delta)V_g^O\left(w_g, w_{g'}, 0, N_1; b\right).
\end{aligned}
\tag{11}
$$

## 3.4 Equilibrium

The dynamic programming problem for a single person, or equation (6) , depends on the problem's solution for a married person, as given by equation (11) . In addition, solving the single's problem requires knowing the steady-state wage distribution of potential mates (opposite gender $g'$) in the marriage market $S_{g'}^a$ for $a \in \{Y, M, O\}$. The non-normalized steady-state wage distributions for singles are given by

$$
\begin{aligned}
S_g^Y\left(w_g\right) &= (1-\kappa_0)\int_{\mathscr{B}}\int_{\mathscr{W}_{g'}}\int_{\mathscr{W}_g}^{w_g}\left(1 - \mathbb{1}^Y\left(w'_g, w'_{g'}, b\right)\right) dS_g^Y\left(w'_g\right) d\hat{S}_{g'}^Y\left(w'_{g'}\right) dG(b) \\
&\quad + \frac{\delta\kappa_0\kappa_1}{\kappa_0\kappa_1 + \delta(\kappa_0+\kappa_1)}\int_{\mathscr{W}}^{w_g} dF_g\left(w'_g\right), \\
S_g^M\left(w_g\right) &= \kappa_0\int_{\mathscr{B}}\int_{\mathscr{W}}\int_{\mathscr{W}}^{w_g}\left(1 - \mathbb{1}^Y\left(w'_g, w'_{g'}, b\right)\right) dS_g^Y\left(w'_g\right) d\hat{S}_{g'}^Y\left(w'_{g'}\right) dG(b) \\
&\quad + (1-\kappa_1)\int_{\mathscr{B}}\int_{\mathscr{W}}\int_{\mathscr{W}}^{w_g}\left(1 - \mathbb{1}^M\left(w'_g, w'_{g'}, b\right)\right) dS_g^M\left(w'_g\right) d\hat{S}_g^M\left(w'_{g'}\right) dG(b), \\
S_g^O\left(w_g\right) &= \kappa_1\int_{\mathscr{B}}\int_{\mathscr{W}}\int_{\mathscr{W}}^{w_g}\left(1 - \mathbb{1}^M\left(w'_g, w'_{g'}, b\right)\right) dS_g^M\left(w'_g\right) d\hat{S}_{g'}^M\left(w'_{g'}\right) dG(b) \\
&\quad + (1-\delta)\int_{\mathscr{W}}^{w_g} dS_g^O\left(w'_g\right).
\end{aligned}
\tag{12}
$$

In the above equations, $\hat{S}_{g'}^a$ represents the normalized distribution of singles of the opposite gender for age $a \in \{Y, M\}$ and is given by

$$
\hat{S}_{g'}^a\left(w_f\right) = \frac{S_{g'}^a\left(w_{g'}\right)}{\int_{\mathscr{W}} dS_{g'}^a\left(w_f'\right)}. \tag{13}
$$

The first term of the $S_g^Y\left(w_g\right)$ in equation (12) counts those singles who did not marry in the current period and did not age to $M$. The second term represents the arrival of new adults. The mass of new arrivals is normalized as the total mass of singles and married couples is 1 in the steady state. For its derivation, see Section A.1. $S_g^M(w_g)$ consists of the flow of singles who did not marry in the current period and aged to $M$ and singles at age $M$ who remained single and did not age to $O$. Since singles at age $O$ do not marry, $S_g^O(w_g)$ consists of singles at age $M$ who did not marry in the current period and aged to $O$ and singles at age $O$ who did not die in the current period.

**Definition 3.4.1** (Stationary Matching Equilibrium): A *stationary matching equilibrium* is a set of value functions for singles $W_m^a(w_m)$ and $W_f^a(w_f)$ and couples $V_m^a(w_m, w_f, N_0, N_1; b)$ and $V_f^a(w_f, w_m, N_0, N_1; b)$; matching rules for singles $\mathbb{1}^a(w_m, w_f, b)$; and *stationary distributions for singles* $S_m^a(w_m)$ and $S_f^a(w_f)$ such that:

1. The value function $W_m^a(w_m)$ and $W_f^a(w_f)$ solve the single's recursion (6) , taking as given their indirect utility functions $v_m(w_m)$ and $v_f(w_f)$ from problem (4) , the value functions for a married person $V_m^a(w_m, w_f, N_0, N_1; b)$ and $V_m^a(w_m, w_f, N_0, N_1; b)$, the matching rule for singles $\mathbb{1}^a(w_m, w_f, b)$ from (5) , and the wage distribution of potential mates $\hat{S}_m^a(w_m)$ and $\hat{S}_f^a(w_f)$ defined in (13) .
2. The value function $V_m^a(w_m, w_f, N_0, N_1; b)$ and $V_f^a(w_f, w_m, N_0, N_1; b)$ solve the couple's recursion (11) , taking as given their indirect utility functions $v_m(w_m, w_f, N_0, N_1)$ and $v_m(w_f, w_m, N_0, N_1)$ from the couple's problem (7) , and the childbirth decision $N_0^*$ from the couple's problem (9) or (10) .
3. The matching rule for singles $\mathbb{1}^a(w_m, w_f, b)$ is determined by the equation (5) , taking as given the value functions for $W_m^a(w_m)$, $W_f^a(w_m)$, $V_m^a(w_m, w_f, N_0, N_1; b)$, and $V_f^a(w_f, w_m, N_0, N_1; b)$.
4. The stationary distribution for singles $S_g^a(w_g)$ solves the equation (12) , taking as given the matching rule for singles $\mathbb{1}^a(w_m, w_f, b)$.

# 4 Calibration

The model developed will now be fit to the Japanese data for the period 2018-2022. Some parameters are exogenously determined based on a priori information or taken directly from data. Most of the parameters, however, will be estimated using a minimum distance procedure. In Section 6, the model will be simulated using female wages, social norms, and leisure technology from the period 2005-2009. It will be assumed that the model is in a steady state for each of these years. A comparison between two steady states will determine the key factors that can account for changes in marriage and fertility behavior.

## 4.1 Exogenous Parameters

The length of a model period is one year. Let $\beta$ (the subjective discount factor) be 0.96, as the standard value in macroeconomics studies, such as in Prescott (1986). All the targets for the estimation are calculated for individuals between the ages of 25 and 54, which corresponds to an operational lifespan of 30 years. Let the aging and death probability $\kappa_0 = \kappa_1 = \delta = 1/10 = 0.1$, so that individuals in the model also live 30 years on average. Finally, following the Organization for Economic Co-operation and Development (OECD) equivalence scale, set $\chi_0 = 0.5$ and $\chi_1 = 0.3$.

Next, some parameters are directly computed from the data. Given the time constraint of the single's problem (4) , domestic labor requirements for singles, $\psi_m^S$ and $\psi_f^S$, are equal to their time spent on domestic labor, $d_m$ and $d_f$. Using the mean value of singles' $d_m$ and $d_f$ from the JHPS in the period 2018-2022, set $\psi_m^S = 0.03$ and $\psi_f^S = 0.058$. The domestic labor productivity parameter $\theta$ from (8) is fully characterized by the first-order condition for the maximization problem in (7)[10]:

$$\theta = \frac{w_f d_f}{w_m d_m + w_f d_f}. \tag{14}$$

Using the mean values $\frac{w_f d_f}{w_m d_m + w_f d_f}$ from the married couple from JHPS in the period 2018-2022, set $\theta = 0.681$.

Given the estimated $\theta$, the domestic labor requirements for married couples, $\psi^M$ and $\psi^N$, are computed by the data. For each married couple, I compute their domestic production $D\left(d_m, d_f; \theta\right) = d_m^{1-\theta} d_f^{\theta}$. Using the mean values of $D\left(d_m, d_f; \theta\right)$ of married couples without small children (up to 6 years old), set $\psi^M = 0.132$. The mean value of $D\left(d_m, d_f; \theta\right)$ of married couples with small children is 0.266, so set $\psi^N = 0.134$ by subtracting $\psi^M$.

To sum up, the parameter values endogenously determined are summarized in Table 1 .

**Table 1:** Exogenous Parameters

| Parameter values | Source |
|---|---|
| $\chi_0 = 0.5, \chi_1 = 0.3$ | OECD scale |
| $\beta = 0.96$ | Prescott (1986) |
| $\kappa_0 = \kappa_1 = \delta = \frac{1}{10}$ | 30-year Lifespan |
| $\psi_m^S = 0.03, \psi_f^S = 0.058$ | JHPS 2018-2022 |
| $\theta = 0.681$ | JHPS 2018-2022 |
| $\psi^M = 0.132, \psi^N = 0.134$ | JHPS 2018-2022 |

## 4.2 Estimated Parameters

Now, 12 parameters will be estimated using a minimum distance procedure. There are five preference parameters, $\{\gamma_c, \gamma_l, \gamma_n, \alpha_l, \alpha_n\}$; three wage distribution parameters, $\left\{\mu_{w_m}, \mu_{w_f}, \sigma_{w_m}, \sigma_{w_f}\right\}$; two parameter for bliss shock, $\{\mu_b, \sigma_b\}$; and one parameter for the bargaining power $\rho$. As a normalization, the mean of log wage is set to zero, $\mu_{w_m} = 0$. The remaining 11 parameters are estimated so that the model matches a set of 11 data moments for the period 2018-2022.

Table 2 shows the selected targeted moments and their corresponding values computed from the data in the fourth column. Although all parameters in the model have an impact on all the targets, the table highlights the target that is most influenced by each specific parameter.

[10]See Section A.3 for its derivation.

The curvature parameters of the utility function, $\gamma_c$, $\gamma_l$, and $\gamma_n$, directly affect the time allocation. As a result, the mean of leisure time of singles and married women are targeted. The preference strength for leisure, $\alpha_l$, and the one of children, $\alpha_n$, relate to the marriage and fertility decisions, and I choose the cohort fertility rate and the share of the women without children as the targets. The domestic labor requirements, $\psi^M$ and $\psi^N$ bind the domestic labor time of married women with and without children. The wage distribution parameters, $\mu_{w_m}$, $\mu_{w_f}$, $\sigma_{w_m}$, and $\sigma_{w_f}$, are chosen to match the female relative wage and the wage dispersion of singles. The bliss shock parameters, $\mu_b$ and $\sigma_b$, are related to the share of never-married women and also the wage gap between singles and married. Finally, the correlation between husband and wife's wages reflects the bargaining power $\rho$ in the model because the bargaining power penalizes the singles to marry with a higher-wage partner.

**Table 2:** Parameters Estimated (Minimum Distance)

| | Value | Target | Source | Data | Model |
|---|---|---|---|---|---|
| $\gamma_c$ | 1.617 | Mean of single $l_m$ | JHPS 2018-2022 | 0.555 | 0.566 |
| $\gamma_l$ | 1.161 | Mean of single $l_f$ | JHPS 2018-2022 | 0.572 | 0.535 |
| $\gamma_n$ | 1.460 | Mean of married $l_f$ | JHPS 2018-2022 | 0.469 | 0.461 |
| $\alpha_l$ | 2.763 | Cohort fertility rate | HFD 2018-2022 | 1.446 | 1.446 |
| $\alpha_n$ | 1.376 | Share of women without children | HFD 2018-2022 | 0.279 | 0.272 |
| $\mu_{w_f}$ | −0.294 | Single's $\log w_m - \log w_f$ | JHPS 2018-2022 | 0.128 | 0.127 |
| $\sigma_{w_m}$ | 0.670 | S.D. of single $\log w_m$ | JHPS 2018-2022 | 0.689 | 0.691 |
| $\sigma_{w_f}$ | 0.737 | S.D. of single $\log w_f$ | JHPS 2018-2022 | 0.786 | 0.779 |
| $\mu_b$ | −0.292 | Share of never-married women | Census 2020 | 0.172 | 0.171 |
| $\sigma_b$ | 0.354 | Married's $\log w_m$ - single's $\log w_f$ | JHPS 2018-2022 | 0.471 | 0.445 |
| $\rho$ | 1.449 | Correlation of $\log w_m$ and $\log w_f$ | JHPS 2018-2022 | 0.174 | 0.182 |

*Note:* The first and second columns show the estimated value of the model parameters. The third column is the calibration targets and the fourth column is its source. The fifth and sixth columns are their moment values in the data and the baseline model. The distance between these columns is minimized by the method of simulated moments.

While most of the targets are from the JHPS 2018-2022, there are two targets from the Human Fertility Database (HFD) 2018-2022 and one from the 2020 Japanese Census. I choose the cohort fertility rate and the share of women without children in a cohort as the targets. I use the mean of the values of 1974-1978 cohorts, who reached age 44 in 2018-2022. For the model economy, I use the number of children for women with age $O$. The share of never-married is reported by each 5-year age group in the 2020 Japanese Census. I use the mean of the share of the never-married aged 45-54 as the target. The model moment is also computed for women with age $O$.

# 5 Baseline Economy

## 5.1 Estimated Parameters

The second column in Table 2 shows the estimated parameter values. By comparing the fourth and the fifth columns, which are the moments in the data and the model, we can see that the model matches all the targets reasonably well.

The estimate of the degree of curvature in the utility function for market goods ($\gamma_c = 1.62$) is in line with the macroeconomics literature, which typically uses a coefficient of relative risk aversion of either 1 or 2. The other curvatures, the one for leisure time ($\gamma_l = 1.16$) and for number of children ($\gamma_n = 1.46$), are also in the range between 1 and 2. The preference strength of leisure ($\alpha_l = 2.76$) is significantly higher than the one for market goods (since it is normalized to 1), which may reflect the high value of leisure time these days.

While the variance of the log wage ($\sigma_{w_m} = 0.67$ for men and $\sigma_{w_f} = 0.74$ for women) takes close values to the observed log wage dispersion of the singles (0.69 for men and 0.79 for women), the gender gap in the mean of the log wage ($\mu_{w_m} - \mu_{w_f} = 0.29$) is significantly larger than the gaps in singles data (0.13). It suggests that the marriage rate gaps between people with high and low wages, and it will be shown in Figure 5 in Section 5.2.

The bliss shock parameters, $\mu_b = -0.29$ and $\sigma_b = 0.35$, suggest that the bliss shock is negative in the most of the matching (79%). This is a downforce for the singles to marry while marriage could improve their utility by the economy of scale ($\chi_0 = 0.5$) and the possibility of having children.

Finally, the fact that bargaining parameter $\rho = 1.45$ is larger than 1 is consistent with the positive correlation between intra-household gaps in wages and the leisure time shown in Figure 4 .[11]

## 5.2 Marriage Rate by Earnings

Next, I show how the model economy performs along dimensions that are not targeted in the calibration. Figure 5 shows the marriage rate by earnings deciles, i.e., the first decile contains 0-10% of the population by earnings, and so on. The bars show the share of married individuals with age $O$ in each decile of earnings in the baseline model. For the data moments, I use the Employment Status Survey 2022, which reports the number of people by earnings, age, and marital status. Since the data reports categorical earnings, I compute the cumulative density function of the earnings distribution and calibrate the marriage rate by earnings deciles by linear interpolation. For the details, see Section B.2.

[11] See Section A.2 for the proof.

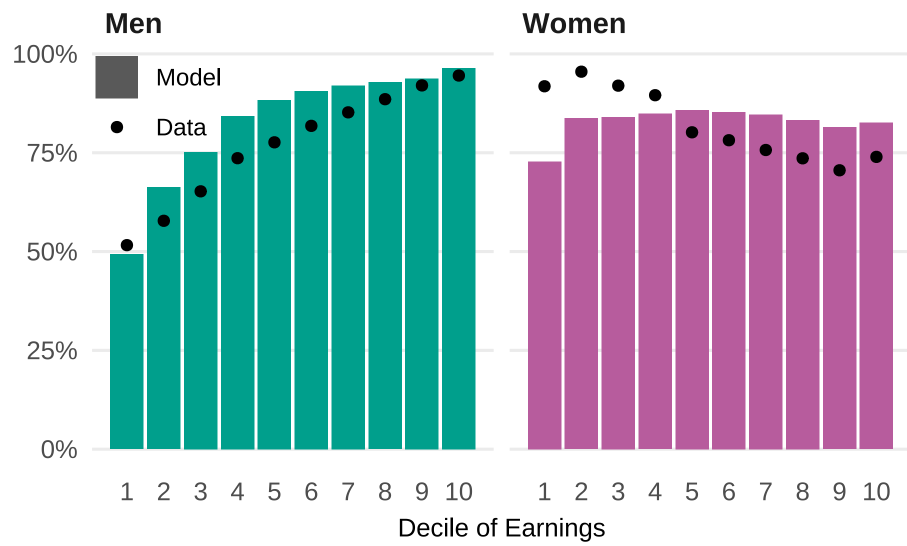


**Figure 5: Marriage Rate by Earnings Decile**. The bars show the share of married individuals in each decile of earnings in the baseline model. The points show the marriage rate estimated from the Employment Status Survey 2022.

The model economy captures the general pattern of the marriage rate by earnings. In particular, the model economy reproduces the positive correlation between the marriage rate and earnings for men. For women, the data shows that the marriage rate is higher for the lower deciles of earnings, while the model economy does not. One of the potential reasons for this discrepancy is that the model economy does not consider the exemption for low-income spouses in the income tax system.[12] The exemption incentivizes married women to reduce working hours or to stay at home, which may lead to a higher marriage rate for the lower deciles of earnings.

## 5.3 Child Penalty on Leisure

In Section 2, I show that the time allocation changes around the first childbirth differ between men and women. Female leisure time decreases significantly more than male leisure time. Figure 6 shows a similar event study using the baseline model. I created a ten thousand single young men and women with wages drawn from $\mathcal{N}\left(\mu_{w_m}, \sigma^2_{w_m}\right)$ and $\mathcal{N}\left(\mu_{w_f}, \sigma^2_{w_f}\right)$, respectively. I simulate their time allocations and life events, such as marriage, childbirth, and death until 30 periods. The specification is the same as (1) , however, I do not include time-fixed effects $\lambda_t$ since time does not play a role in the simulation.

Figure 6 shows the results. To make a comparison with the data, the hours are re-scaled to weekly hours, i.e., $h + l + d = 16 \times 7 = 112$ hours. As in the data, the model economy shows a decline in working hours and a larger increase in domestic labor for women. The model economy also shows a decrease in leisure time for both men and women, which is consistent with the data. While it is also consistent with data that the decrease in leisure time is larger for women, the model economy

[12] Tax exemption for spouses in Japan and its effect on labor market outcomes are discussed in Kitao and Mikoshiba (2022).

shows a smaller difference in the decrease in leisure time between men and women (in one year after the first childbirth, 52.2 hours in the data and 1.9 hours in the model).

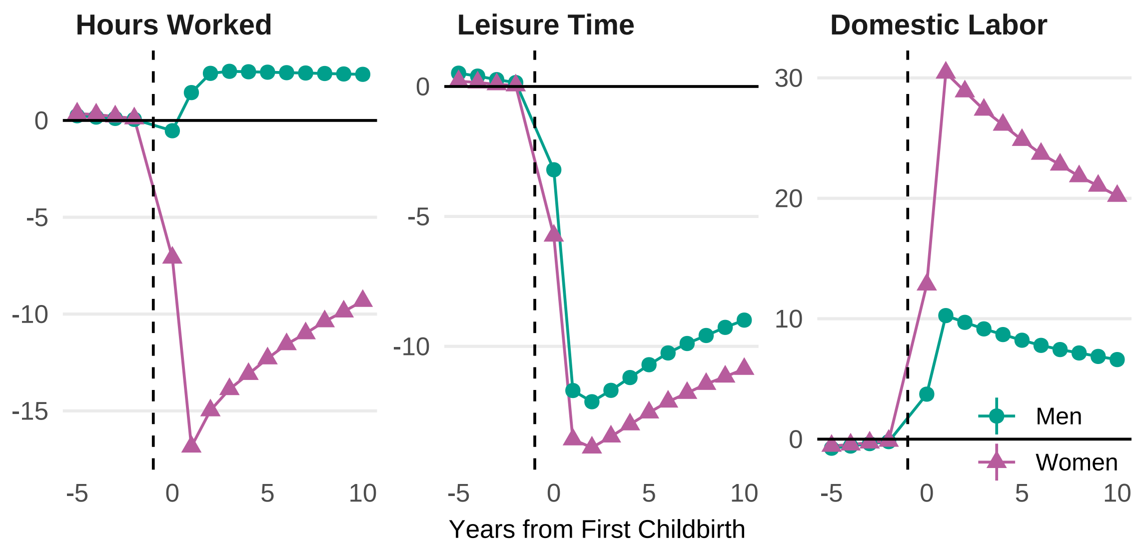


**Figure 6: Child Penalty in the Baseline Model**. The figure shows the event study of time allocation around the first childbirth in the baseline model.

# 6 Back to 2005-2009

In this section, I simulate for the 2005-2009 period. The main goal of this analysis is to disentangle the main drivers of the recent decline in the marriage rate and fertility rate in Japan. To answer the question, I show the three stylized facts that significantly changed in the past decades and may affect marriage and fertility decisions. Given the facts, I choose three model parameters that capture the three changes: female wage growth, change in social norms, and leisure technology growth. With all other parameters kept at the baseline values, I simulated the model to evaluate the impact of each factor on the marriage and fertility decisions.

## 6.1 What has changed since 2005-2009?

In this section, I will show the time trend of factors that may affect marriage and fertility decisions. As in the previous section, I will use the samples aged between 25-54 in the JHPS. The single sample is defined as those who work, are not married, and have no children. The married couple sample is defined as those who are married and have at most 3 children.

Panel (a) in Figure 7 shows the gender gap in the log wage of singles. Each point represents the differences in the average log wage and the linear fit is also plotted. From 2005, the female relative wage has increased by around 5%. Since this is not a small change, I will calibrate the parameter $\mu_{w_f}$ to capture this trend.

Panel (b) in Figure 7 shows the husband's share in domestic labor of married couples. The husbands' share in domestic labor has almost doubled from 2005 to 2022. I interpret this as the change in social norms on gender roles, and I will discuss its impact on marriage and fertility decisions by calibrating the parameter $\theta$.

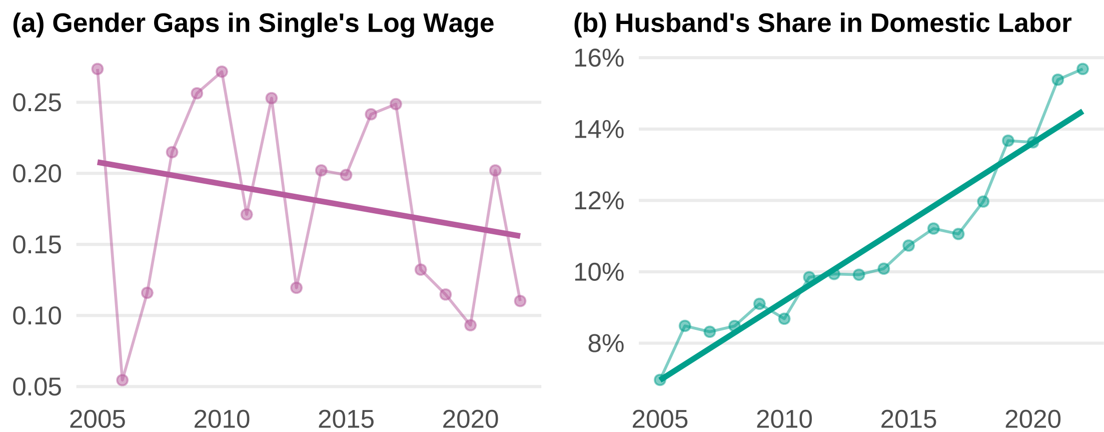


**Figure 7: Female Wage Growth and Husband's Domestic Labor**. Panel (a) shows the gaps in the average log wages of singles aged between 25-54. Panel (b) shows the husband's share in domestic labor of married couples aged between 25-54. In both panels, each dot represents the data point and the center line is the linear fit. The data from JHPS and see the text for the sample selection.

Finally, Figure 8 shows the average hours worked and leisure time of singles. Each point represents the average hours worked and leisure time for each year and the linear fit is also shown. The hours worked are decreasing, and the leisure time is increasing over time. I interpret this as the increase in leisure technology, and I will estimate the parameter $\alpha_l$ to study its impact on marriage and fertility decisions.

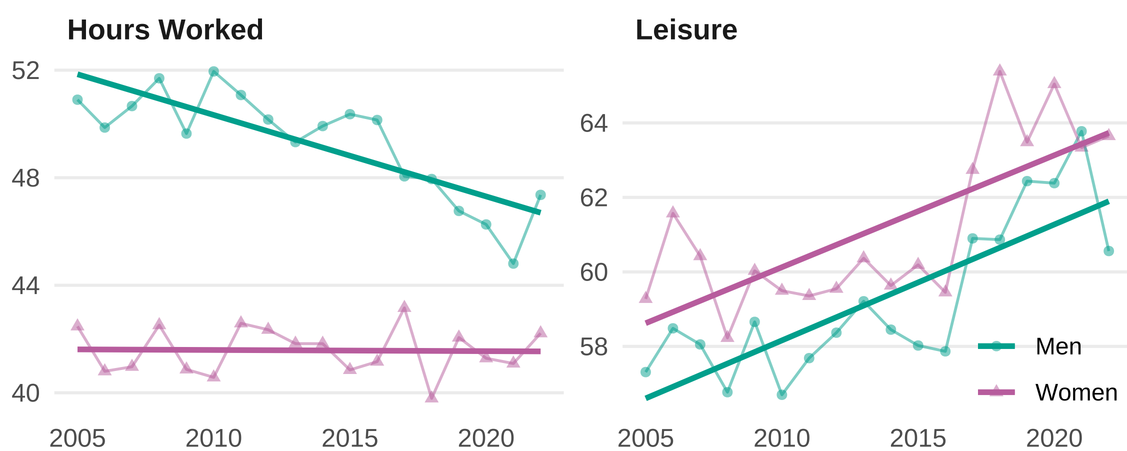


**Figure 8: Single's Hours Worked and Leisure Time** The figure shows the average hours worked and leisure time of singles aged between 25-54. Each dot represents the average hours worked and leisure time in a year and the center line is the linear fit. The data from JHPS and see the text for the sample selection.

## 6.2 Driving Forces

Section 6.1 points out the three important factors that may affect marriage and fertility decisions: female wage growth, change in social norms, and leisure technology growth. I interpret these factors as the changes in the parameters $\mu_{w_f}$, $\theta$, and $\alpha_l$, respectively. The mean of log female wage, $\mu_{w_f}$, is directly connected to the female relative wage. The parameter $\theta$ is related to the social norms on domestic labor because it captures the relative productivity of the husband for domestic labor. The leisure technology growth is captured by the parameter $\alpha_l$ because larger $\alpha_l$ means the higher utility given the same amount of leisure.

The parameter $\theta$ is similarly calibrated as in the baseline model. Using the mean values of (14) from the married couple data in the period 2005-2009, set $\theta = 0.751$. The larger value than the baseline model (0.681) captures the trend in the husband's share in domestic labor in Figure 7 .

The parameter $\alpha_l$ is estimated based on the first-order condition of the single's problem (4) . Substituting $k = \psi^S$, $h = 1 - l - k$, and $c = wh$, the first order condition with respect to $l$ is

$$w^{1-\gamma_c}\left(1 - l - \psi^S\right)^{-\gamma_c} = \alpha_l l^{-\gamma_l}.$$

Using $h = \left(1 - l - \psi^S\right)$, we have

$$\alpha_l = w^{1-\gamma_c} h^{-\gamma_c} l^{\gamma_l}. \tag{15}$$

In the model, the male median wage is normalized to one. I use the hours worked and leisure time of singles at median wage to estimate $\alpha_l$. In the pooled data of single and married males in the period 2005-2009, the 45th percentile of the wage is 1193 JPY and the 55th percentile is 1358 JPY. Using the mean of the hours worked and leisure time of singles between the 45th and 55th percentiles, I calibrate $\hat{h}$ and $\hat{l}$ as the choice of singles at median wage. Given the estimated parameters $\gamma_c$ and $\gamma_l$ from the baseline model, I estimate $\alpha_l = \hat{h}^{-\gamma_c}\hat{l}^{\gamma_l} = 1.616$ from (15) .

Last, the parameter $\mu_{w_f}$ is estimated by the simulated method of moments (SMM). Similarly to the baseline model, I choose the gender gaps in log wage of singles in the period 2005-2009 as the target moment, i.e., $\log w_m - \log w_f = 0.182$. I use the above-estimated parameters $\theta$ and $\alpha_l$ and keep the other parameters as in the baseline model. By minimizing the data and model moments, I estimate $\mu_{w_f} = -0.342$. The summarized calibrated parameters are shown in Table 3 .

**Table 3:** Calibrated Parameters in 2005-2009 and 2018-2022

| Parameter | 2005-2009 | 2018-2022 |
|---|---|---|
| $\mu_{w_f}$ | $-0.342$ | $-0.294$ |
| $\theta$ | 0.751 | 0.681 |
| $\alpha_l$ | 1.616 | 2.763 |

## 6.3 Why did the Marriage and Fertility Decline?

Given the calibrated parameters in Section 6.2, I simulate the model in the period 2005-2009, and Table 4 shows the results. The first row shows the baseline model for the period 2018-2022, and the last row shows the model with all the calibrated parameters in 2005-2009. To evaluate the model, I use the marriage rate from the Japanese Census 2005 and the cohort fertility rate (CFR) from the Human Fertility Database (HFD) 2005-2009, which are the targets in the baseline calibration.

**Table 4:** Decomposition of the Marriage Rate and CFR in 2005-2009

| | | | | Marriage Rate | | CFR | |
|---|---|---|---|---|---|---|---|
| | $\mu_{w_f}$ | $\theta$ | $\alpha_l$ | Model | Data | Model | Data |
| Baseline (2018-2022) | | | | 0.829 | 0.828 | 1.446 | 1.446 |
| Female Wage | ✓ | | | 0.828 | | 1.427 | |
| Social Norms | | ✓ | | 0.843 | | 1.509 | |
| Leisure Technology | | | ✓ | 0.843 | | 1.780 | |
| All (2005-2009) | ✓ | ✓ | ✓ | 0.855 | 0.928 | 1.810 | 1.709 |

*Note*: The model is simulated with the calibrated parameters in 2005-2009. The mark ✓ means the values in 2005-2009 are used. The marriage rate is from the Japanese Census 2005 and 2020 and the cohort fertility rate (CFR) is from the Human Fertility Database (HFD) 2005-2009 and 2018-2022.

Overall, the model with the calibrated parameters in 2005-2009 can capture 27% marriage rate and almost all changes in the CFR. To study the role of the three factors, I simulated the model with each calibrated parameter in 2005-2009 and showed the results in the second to the fourth rows of Table 4 . The second row suggests that female wage growth has almost no impact on the marriage rate and CFR (changes by −0.001 and −0.019). This might be because the female wage growth increases both the value of being single and married. The female values of singles are improved by the income shock but the value of marriage is also increased by the income shock, rise in her bargaining power, and the affordability of children.

The third row suggests that the smaller value of $\theta$, or weaker norms on gender roles, reduces the marriage rate (by 0.014) and CFR (by 0.063). Given the higher wages of men, the smaller $\theta$ is a negative productivity shock for domestic labor and reduces the value of marriage. The fourth row shows that the leisure technology growth has a negative impact on the marriage rate (by 0.014) and CFR (by 0.334). The impact is especially large on CFR because the leisure technology growth increases not only the value of being single but also the relative value of children to leisure.

# 7 Conclusion

In this paper, I build a model that can account for the marriage and fertility decline in the last decade. The key ingredients of the model are intra-household bargaining, leisure technology growth, and the social norms on gender roles. The baseline model explains almost all the fertility decline from 2005 to 2022 and 27% of the marriage decline from 2005 to 2020.

I also decompose the three drivers of the marriage and fertility decline. The simulation results show that the leisure technology growth has a significant impact on the fertility decline, which suggests that the leisure technology growth has increased the value of being single and also the child penalty on leisure for married couples.

# Appendix

## A Mathematical Derivations

### A.1 Mass of the New Arrivals

**Proposition 1.1.1** (Mass of the New Arrivals): In the equation (12) , the mass of new arrivals is given by the following formula:

$$D^N = \frac{\delta\kappa_0\kappa_1}{\kappa_0\kappa_1 + \delta(\kappa_0 + \kappa_1)}.$$

*Proof.* Define the mass of each $a \in \{Y, M, O\}$ as $D^a$. Given the aging probability $\kappa_0, \kappa_1$ and the probability of dying $\delta$, the mass of new arrivals is given by the following equation:

$$\begin{aligned} D^Y &= D^N + (1-\kappa_0)D^Y \\ D^M &= \kappa_0 D^Y + (1-\kappa_1)D^M \\ D^O &= \kappa_1 D^M + (1-\delta)D^O \\ 1 &= D^Y + D^M + D^O. \end{aligned}$$

Solving the above equations, we get the mass of each group as follows:

$$\begin{aligned} D^N &= \frac{\delta\kappa_0\kappa_1}{\kappa_0\kappa_1 + \delta(\kappa_0 + \kappa_1)} \\ D^Y &= \frac{\delta\kappa_1}{\kappa_0\kappa_1 + \delta(\kappa_0 + \kappa_1)} \\ D^M &= \frac{\delta\kappa_0}{\kappa_0\kappa_1 + \delta(\kappa_0 + \kappa_1)} \\ D^O &= \frac{\kappa_0\kappa_1}{\kappa_0\kappa_1 + \delta(\kappa_0 + \kappa_1)}. \end{aligned}$$

### A.2 Bargaining Power and Leisure Time

In Figure 4 , we have shown that the intra-household gaps in earnings are positively correlated with leisure time. This is consistent with the model economy, where the bargaining power $\rho$ is larger than 1.

**Proposition 1.2.1** (Positive Correlation in Intra-Household Gaps in Wages and Leisure): In the married couple's time allocation problem, the gaps in log wages ($\log w_m - \log w_f$) and leisure time ($\log l_m - \log l_f$) are positively correlated if and only if the bargaining power curvature $\rho$ is larger than 1.

*Proof.* From the first order condition of the utility function in (7) with respect to $l_m$ and $l_f$, we have the following equation:

$$(1-\lambda)\alpha_l l_m^{-\gamma_l} = \eta w_m$$
$$\lambda \alpha_l l_f^{-\gamma_l} = \eta w_f$$

where $\eta$ is a Lagrange multiplier for the budget constraint. From the above equations and $\lambda = \frac{w_f^\rho}{w_m^\rho + w_f^\rho}$, we can derive the following equation:

$$\log l_m - \log l_f = \frac{\rho - 1}{\gamma_l}\left(\log w_m - \log w_f\right).$$

Since $\gamma_l > 0$, the positive correlation between the intra-household gaps in wages and leisure time happens if and only if the bargaining power $\rho$ is larger than 1.

The last equation leads to the following proposition.

**Corollary 1.2.1**: If the bargaining power curvature $\rho$ is 1, the optimal leisure time of the married couple is the same $l_m = l_f$.

## A.3 Domestic Labor Productivity $\theta$

**Proposition 1.3.1** (Calibration of Domestic Labor Productivity): The domestic labor productivity parameter $\theta$ from (8) is fully characterized by the first-order condition for the maximization problem in (7) :

$$\theta = \frac{w_f d_f}{w_m d_m + w_f d_f}.$$

*Proof.* The cost minimization problem of joint domestic labor is given by

$$\min_{d_m, d_f} w_m d_m + w_f d_f$$

subject to

$$D\left(d_m, d_f\right) = d_m^{1-\theta} d_f^{\theta} = \psi^M + \psi^N \mathbb{1}\{N_0 > 0\}.$$

The first order conditions with respect to $d_m$ and $d_f$ are

$$w_m = \eta(1-\theta) d_m^{-\theta} d_f^{\theta}$$

$$w_f = \eta\theta d_m^{1-\theta} d_f^{\theta-1}$$

where $\eta$ is a Lagrange multiplier for the cost minimization problem. From the above equations, we can derive the following equation

$$\frac{w_m}{w_f} = \frac{1-\theta}{\theta}\frac{d_f}{d_m},$$

and we will get the equation of the proposition.

# B Data Description

## B.1 Japanese Household Panel Survey (JHPS)

The analysis is mostly based on the Japanese Household Panel Survey (JHPS). The JHPS has been implemented annually since 2004 by the Panel Data Research Center at Keio University and was originally named the Keio Household Panel Survey (KHPS). The purpose of the KHPS is to collect panel data on households and individuals reflecting the population composition of society as a whole, as in the Panel Study of Income Dynamics (PSID) in the U.S. and the European Community Household Panel (ECHP) in Europe. KHPS started in 2004 with 4000 households and 7,000 individuals nationwide and added a cohort of about 1400 households and 2500 individuals from 2007 to compensate for sample dropout. In 2009, the Panel Data Research Center at Keio University started a new survey, the JHPS, targeting 4000 male and female subjects nationwide in parallel with the KHPS. The JHPS collects data focused on education and health/healthcare in addition to economic status and employment status. In 2014, the KHPS was merged with the JHPS.

As described in Section 2.1, the sample is restricted to people aged 25-54 in the period 2005-2022. The sample of singles is restricted to those who have a job, a positive leisure time, and have no children. The sample of married couples is also restricted to those who have a positive leisure time, however, it includes the case of non-working individuals. Table A.1 and Table A.2 show the summary statistics of singles and married couples, respectively.

**Table A.1:** Summary Statistics of Singles in JHPS2005-2022

| | Men (N = 1019) | | Women (N = 961) | |
|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. |
| Hours worked (per week) | 49.2 | 16.92 | 41.7 | 15.8 |
| Leisure (per week) | 59.4 | 17.41 | 60.7 | 16.9 |
| Domestic labor (per week) | 3.5 | 5.33 | 9.7 | 10.1 |
| Hourly wage (JPY) | 1661.4 | 1562.52 | 1382.7 | 2060.2 |

*Notes:* The table shows the summary statistics of singles aged 25-54 in the period 2005-2022. The sample of singles is restricted to those who have a job, a positive leisure time, and have no children.

**Table A.2:** Summary Statistics of Married Couples in JHPS2005-2022

| | Men (N = 1860) | | Women (N = 1924) | |
|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. |
| Hours worked (per week) | 49.2 | 20.67 | 22 | 19.0 |
| Leisure (per week) | 58.5 | 21.27 | 53 | 22.7 |
| Domestic labor (per week) | 4.3 | 7.08 | 37 | 23.5 |
| Hourly wage (JPY) | 2339.0 | 2126.04 | 1241 | 1427.9 |

*Notes:* The table shows the summary statistics of married couples aged 25-54 in the period 2005-2022. The sample of married couples is restricted to those who have a positive leisure time and have up to three children.

## B.2 Marriage Rate by Earnings Decile

In Figure 5 , I show the marriage rate by earnings deciles from the Employment Status Survey 2022. In this survey, the number of people by earnings, age, and marital status is reported. Figure A.1 shows the original data of the number of people aged between 45 and 54 by earnings and marital status.


**Figure A.1: Number of People Aged between 45 and 54 by Earnings and Marital Status.** The data is from the Employment Status Survey 2022.

To estimate the marriage rate by earnings deciles, I compute the cumulative density of the earnings distribution by marital status. Since the original data reports only the 16 categories of earnings, I estimate the cumulative density by linear interpolation. Figure A.2 shows the estimated cumulative density of earnings by marital status.

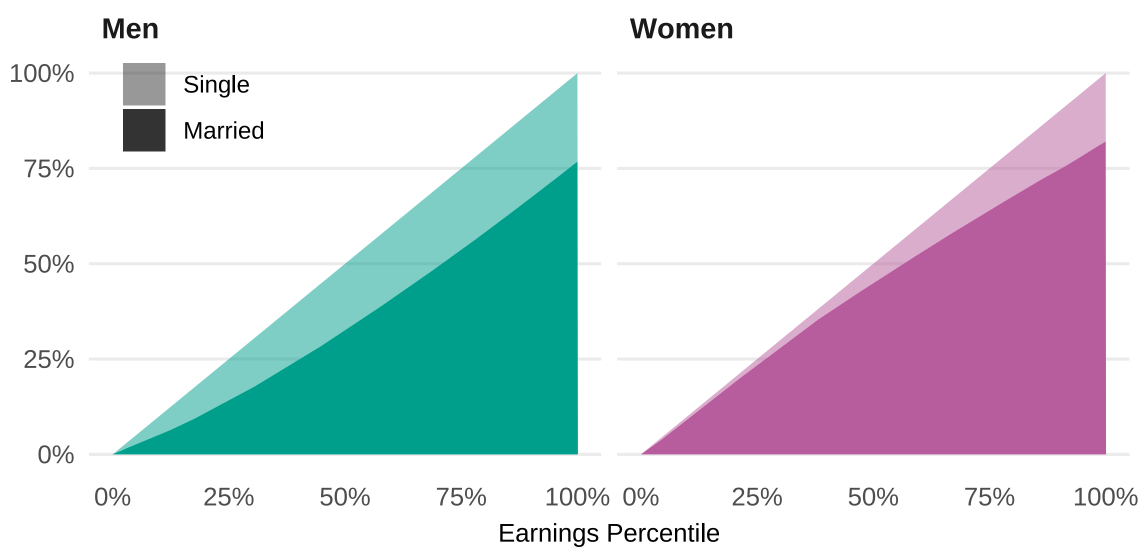


**Figure A.2: Cumulative Density of Earnings by Marital Status.** The data is from the Employment Status Survey 2022.

The marriage rate by earnings deciles is defined as the ratio of the mass of married individuals to the cumulative density of single and married individuals. Since the denominator is 10% by definition, the marriage rate by earnings decile is given by

$$\text{Marriage Rate}_n = \frac{\widehat{M}(0.1n) - \widehat{M}(0.1(n-1))}{0.1},$$

where $\widehat{M}(q)$ is the estimated cumulative density of married individuals at the $q$-th percentile of earnings.

# C Supplemental Figures

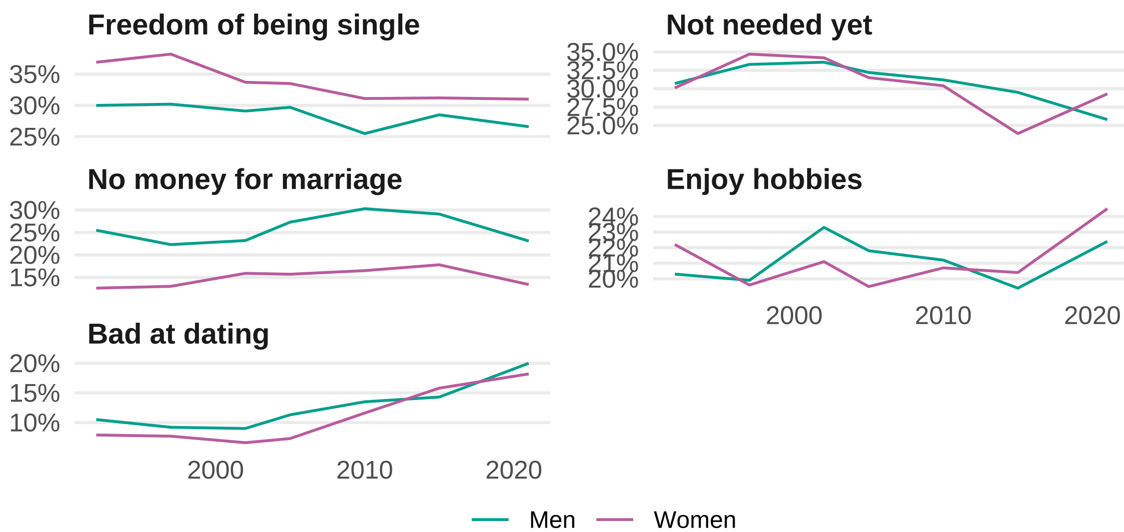


**Figure A.3: Time Series of Reasons Why Do not Get Married**. The figure shows the time trends of the share of the main reasons why do not get married. The data is from the National Fertility Survey from 1992 to 2021 and the sample is restricted to the age group 25-34.

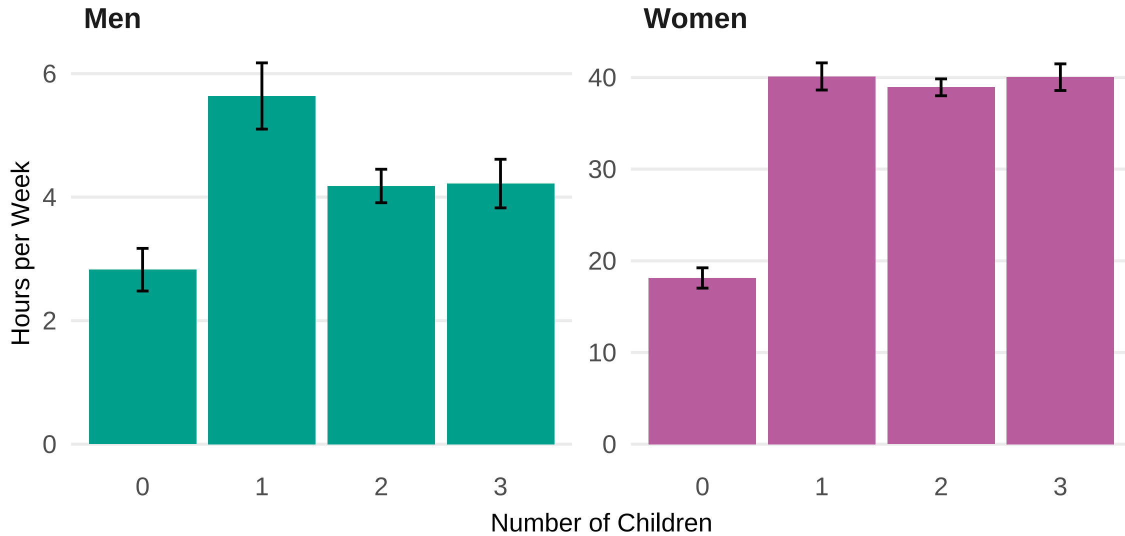


**Figure A.4: Domestic Labor Hours by Number of Children** The figure shows the average hours of domestic labor by the number of children. The error bar shows the 95% confidence interval with the standard error clustered by household. The data is from the Japanese Household Panel Survey from 2005 to 2022 and the sample is restricted to married individuals with age 25-54.

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