On the Trends of Technology, Family Formation, and Women's Time Allocations*

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Abstract

We develop a model that explains the secular trend of fertility, marriage, education and women's time allocations, and quantify the effects of technological development and the costs associated with raising children on the time trends surrounding families in Japan over the past fifty years. We let factor-biased technological progress determine the paths of gender and skill-specific wages, while allowing individuals to make decisions regarding family formation and time allocation to market work, home production, leisure, and childcare. We find that skill-biased technological change contributes to a rise in fertility rates and investment in education. The growth of gender-biased technology has the opposite effect on the number of children, but increases educational attainment. Additionally, it leads to a decline in the marriage rate and an increase in married women's work hours, resulting in less time for leisure and housework. Neutral technological growth increases fertility, reduces education investment, and allows women to shift time from market work to childcare. A rise in the financial and time costs of basic childcare reduces fertility rates but increases skill investment, while a rise in education costs has the opposite effect.

Keywords: Fertility, Marriage, Home Production, Women's Time Allocations, Skill-biased Technological Change, Gender-biased Technological change, Japan.
JEL Classification:

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1 Introduction

The last several decades have seen a secular transformation of the family structure and time allocations within households and a major change in the wage structure in nearly all advanced economies. Marriage rates declined and couples have fewer children, while they send a larger share of children to college to acquire skills, despite the rapidly rising cost of education. The skill premium has increased, and the gender gap has narrowed, implying that women face higher opportunity costs when it comes to spending their time on childcare and housework. The advancement of home production technology has also helped alleviate the time constraint of households.

All the factors, demographics, family formation, technology at home and in the market, and time allocations, influence each other and ought to be considered simultaneously within a unified framework if we aim to account for the trend in any of these factors. The goal of this paper is to make such an attempt.

We build a model of individuals who meet a potential partner and decide whether to marry or remain single, and allocate disposable time for different activities including market work, home production, leisure, and childcare. Married couples decide the number of children and their education level, facing the Barro-Becker trade-off (Becker and Barro 1988; Barro and Becker 1989).

Wages are determined in the competitive market and the production function distinguishes between high and low-skilled labor as well as between men and women as separate factors of production. Technology of the market production has three components: factor neutral technology (or total factor productivity, TFP), skill-biased technological change (SBTC) and gender-biased technological change (GBTC).

In the quantitative exercise, we calibrate the model to Japan, a country that experienced a most dramatic decline in fertility rates and marriage probability during the last several decades. Japan has seen a decline in the gender gap but there still remains a large difference in wages and time allocations between men and women, although there is almost no difference in the college enrollment rates. We use various micro data including the Survey on Time Use and Leisure Activities to obtain data on the time allocations of men and women, and the Basic Survey of Wage Structure to obtain the wage rates by gender and skill to calibrate the technological parameters. We also use the price data of house-assisting durable goods to quantify the technological development of home production.

We find that on the the growth of skill-biased technology leads to a rise in fertility rates and investment in children's skills, but the GBTC has the opposite effect on the number of children, but increases education attainment. The GBTC also leads to a decline in the marriage rate and an increase in married women's work hours, resulting in less time for leisure and housework. Comparing the baseline economy and the transition without the GBTC, we find that married women would work 12% less. Considering the general equilibrium, the effects would be mitigated as the lower supply is associated with higher wage, but qualitative effects remain the same.

Neutral technological growth increases fertility, reduces education investment, and allows women to shift time from market work to childcare. The decline in the price of house-assisting goods contributed to a decline in the time which households allocate to housework. Moreover, it had a positive effect on work hours of married women and fertility rates.

We also find that an increase in financial and time costs of basic childcare leads to a decline in fertility rates but increases skill investment, thereby shifting the quantity and quality trade-off towards the former. A rise in the education costs has the opposite effects, increasing the number of children and decreasing the education level along the simulated transition path.

The paper contributes to the growing literature of family and macroeconomics, that focuses on the role of intra-household decisions as to family formation, production in the market and at home, and labor supply of family members in accounting for the movements of important variables that shape the macroeconomy.[1] Doepke et al. (2023) survey the recent literature on the economics of fertility and show that classic theory that implies the negative relationship between income and fertility no longer holds. Various factors that influence the compatibility between family's objectives and women's career play critical roles in accounting for the trends of fertility.

Papers that endogenize family formation and women's labor supply include Caucutt et al. (2002), who build a model decisions on fertility, marriage, and labor supply and show that the rise in returns to women's labor market experience plays a critical role in accounting for the fertility delay observed in the U.S. Greenwood et al. (2016) develop a framework that endogenize the dynamics of the marriage market, and demonstrate important roles played by the advancement of the home production technology in explaining the trend of marriage, divorce, and women's labor force participation.[2]

Baudin et al. (2015) develop a model to replicate the cross-sectional observations in the U.S. regarding marriage, childlessness, the number of children and education, and investigate the determinants of childlessness. Goussé et al. (2017) build a search model of marriage and study how wages, education and family attitudes affect marriage and intra-

[1] For an overview of recent papers, see, for example, Doepke and Tertilt (2016).

[2] There are also papers that use a life-cycle framework to model the decisions of families and especially women's. Santos and Weiss (2016) construct an equilibrium search model populated by overlapping generations and show that the rise in income volatility accounts for a significant portion of the decline and delay in marriage observed in the US in 1970-2000. Eckstein et al. (2019) build a life-cycle model to study the trends of fertility and marriage decisions of cohorts born in 1935 and 1975, and find that the advancement of contraception technology explains half of the fertility decline between the two cohorts and better labor market opportunities play an important role for the decline in the marriage rate.

household resource allocations. Kim et al. (2023) build a model with status externalities and endogenous fertility to link the education fever and low fertility rate in South Korea.

Closest to our model is that of Greenwood et al. (2023), who propose a theory of endogenous marriage, fertility and labor supply, with home production technology. They calibrate the model to approximate the trends of these variables in the U.S. since the early 19th century. They abstract, however, from gender differences, which in our model play critical roles in accounting for the time trends of the key variables including marriage probability, fertility, education investment and time allocations.

Men and women in our model differ in many dimensions, consistently with the data. The disproportionatelly large burden of childcare on women has a major influence on the family's fertility and labor supply decisions and considering how such differences evolved during the past half century is essential in understanding the evolution of families' behavior.

The market wage structure influences not only men and women's career choice but also decisions of marriage, fertility and childcare, as they constitute the opportunity costs associated with the allocation of limited disposable time. The overall growth of the economy, the skill and gender-biased technological change, and a shift in work hours of men and women, as well as the skill distribution, together account for the dynamics of the wage structure[3] Our study confirms the importance of considering the dynamics of the factor-biased technological change in the analysis of family decisions.

To the best of our knowledge, our paper makes the first attempt to build a unified model of fertility, marriage, education, and women's time allocations with the endogenous wage structure. We show that these factors influence each other and are necessary ingredients for the quantitative model to simultaneously account for the trends surrounding the family and macroeconomy, which we present in the next section.

The rest of the paper is organized as follows. Section 2 presents various data and the trends of family and macroeconomic variables of our interest. Section 3 describes the quantitative model and Section 4 discusses parametrization of the model. Numerical results are presented in Section 5 and Section 6 concludes.

2 The Time Trends of Family Facts

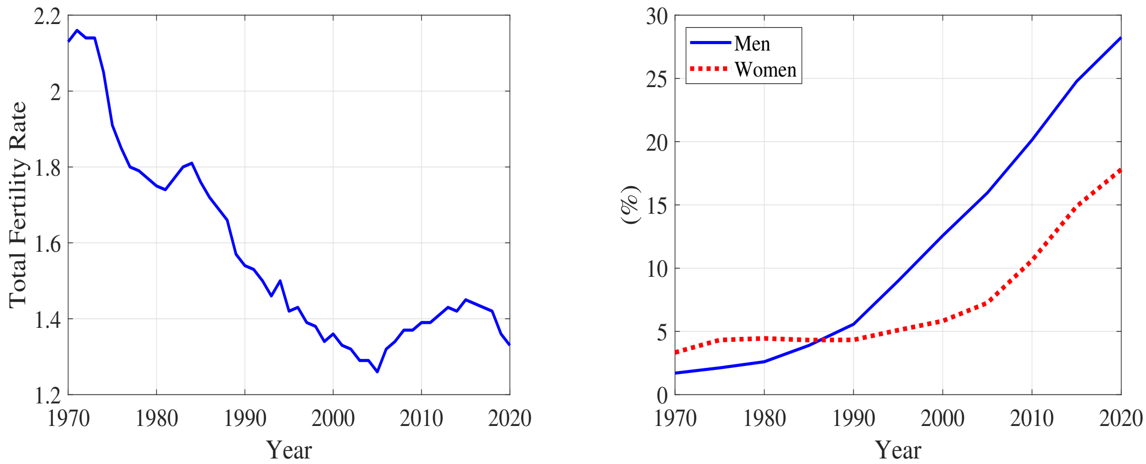
In this section, we examine the trends of various facts surrounding families in Japan and factors that affect decisions of the family formation and married women's time allocations.

Figure 1(a) shows the path of the total fertility rates in Japan, which represents the average number of children per woman.[4] In the early 1970s, the fertility rate exceeded

[3]See Krusell et al. 2000 and Heathcote et al. 2010 on the skill-biased technological change and Abbott et al. 2019) on the wage dynamics distinguishing labor supply by gender and skill.

[4]More precisely, it is computed as the average number of children that a hypothetical cohort of women

the replacement rate that is needed to keep the population from decreasing, but started to decline quickly thereafter. By the mid-2000s, it fell below 1.3 and stayed at around 1.3 to 1.4 until 2020.



(a) Total Fertility Rate

(b) Fraction of Never-Married at Age 50

Figure 1: Fertility and Marriage

Source: Vital Statistics, Ministry of Health, Labour and Welfare

The fall in fertility rates occurred at the same time as the marriage rates declined. Figure 1(b) shows the fraction of men and women aged 50 who are never married in their life. The share was less than 5% for until the late 1980s for men and the early 1990s for women, but it rose quickly and reached 28% for men and 18% for women by 2020.

The cost of raising a child also increased during the last decades. As shown in Figure 2, the college enrollment rate increased from less than 30% in 1970 to almost 60% for men in 2020. The rise is more dramatic for women and it rose from less than 10% to above 50% in 2020. The cost of college also increased at the same time, as shown in the path of the average college tuition the figure.

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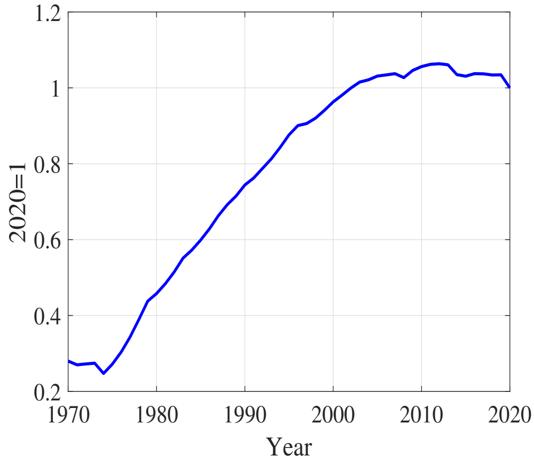
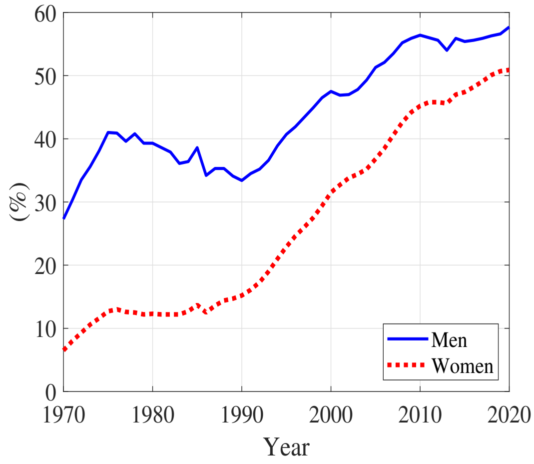
would have if she was subject to the fertility rates of a given year during her whole life.



(a) College Tuition



(b) College Enrollment Rate

Figure 2: College Costs and Enrollment

Source: Consumer Price Index, Ministry of Internal Affairs and Communications. (a) depicts the price index of college tuition fees relative to the headline CPI. 4-year college enrollment rates are from the Basic School Survey by the Ministry of Education, Culture, Sports, Science and Technology.

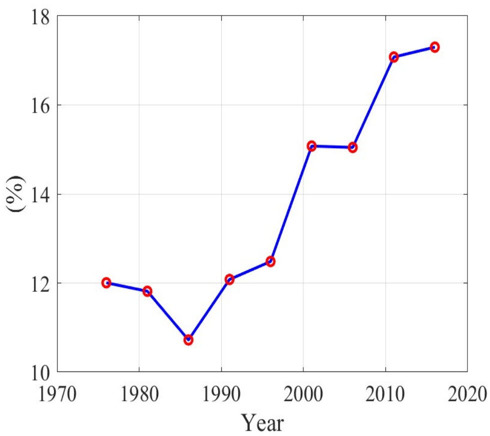
It is not just the financial cost, but the time that parents spend for raising children also increased during the last half century. Table 1 shows the time allocation of married men and women of working age. Both men and women spend more time on childcare and women especially allocate much more time, and the share increased from 12.0% to 17.3%. This occurred at the same time as the number of children decreased and time for childcare per child rose even more rapidly. Figure 3 shows the path of women's time allocation to childcare and also the time spent for each child on average.

As shown in other rows of Table 1, while women spend more time on childcare, they allocate significantly less of the time on housework. The time for market work changed only slightly and the leisure time increased from 18.9% to 21.5%.

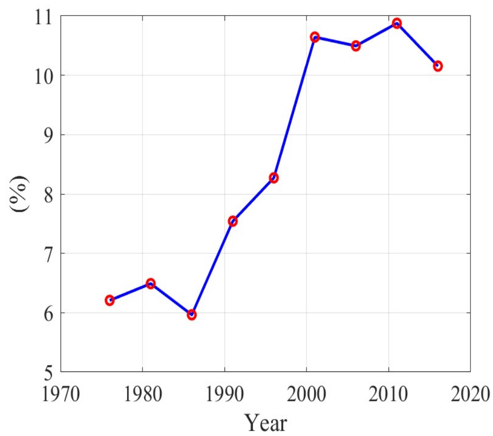
Table 1: Time Allocation of Married Men and Women (% of total disposable time)

	Men		Women	
	1976	2016	1976	2016
Market work	76.90	71.17	27.71	26.60
Housework	0.59	2.26	41.35	34.57
Childcare	0.83	3.74	12.01	17.30
(per child)	(0.38)	(2.21)	(5.45)	(10.88)
Leisure	21.68	22.84	18.93	21.53
Total	100.0%	100.0%	100.0%	100.0%

Source: Survey on Time Use and Leisure Activities. Statistics Bureau, Ministry of Internal Affairs and Communications. Average time use of married men and women aged 25-59.



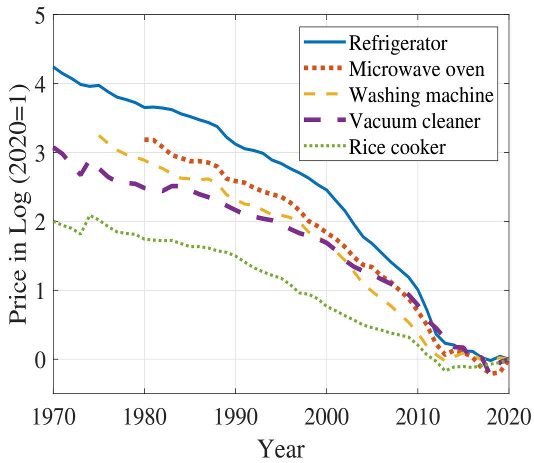
(a) Total Childcare Time



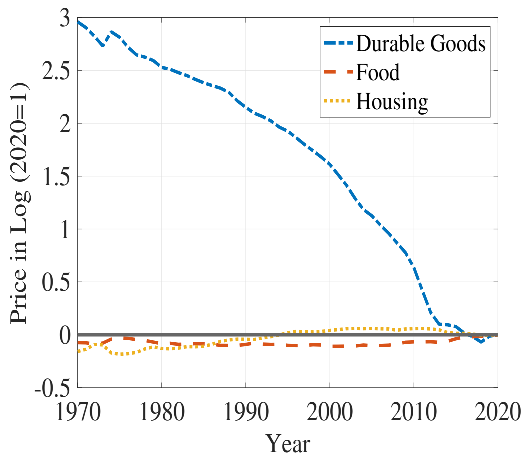
(b) Per Child

Figure 3: Time for Childcare: Married Women
Source: Survey on Time Use and Leisure Activities. Statistics Bureau, Ministry of Internal Affairs and Communications.

The decline in the hours of housework occurred at the same time as the development of household appliances that assist housework. Figure 4 shows the price index of major household appliances such as refrigerators, washing machines and vacuum cleaners. The price declined at an annual rate of 4 to 8%. Figure 4(b) shows the path of the price index of housework-assisting goods, which declined at 5.75% between 1970 and 2020.



(a) Price of Major Home Durables



(b) Price Index

Figure 4: Price of Housework-assisting Durable Goods

Source: Consumer Price Index. Each plotted line indicates the price index relative to the headline CPI. "Durable Goods" in the legend on (b) represents the price index of *Durable Goods Assisting Housework*, including refrigerator, microwave oven, washing machine/dryer, vacuum cleaner, rice cooker, and gas cooking table, relative to the headline CPI. Statistics Bureau, Ministry of Internal Affairs and Communications.

The changes in the households discussed above, such as a shift in fertility and marriage rates, time allocations of married men and women, and the development of household appliances and reduced time for housework, occurred with the changes in the labor market and macroeconomic environment.

Table 2 shows the wage rates by gender and skill in 1970 and 2020, where high-skill represents those with college degree or above. The wage rate of low-skilled women in 1970 is normalized to 1. Wages increased for all groups, and the growth rate is higher for high-skill wage of both men and women. Women's wage growth is also higher among both low and high-skilled workers.

The skill premium defined as the ratio of high-skill wage to low-skill wage is 1.44 for women and rose to 1.53 in 2020, as also shown in the bottom section of Table 2. The gender gap is defined as the ratio of women's wage to men's wage and it has narrowed during the five decades, from 0.55 to 0.74 on average. Note that the change in the gender gap is larger on average rather than that within the skill group, since there was also a change in the composition of worker skills by gender, as shown in Table 3.

Table 2: Wages by Gender and Skill, Gender Gap and Skill Premium

		1970	2020	Ann. Growth
Women	Low	1.00	1.74	1.11%
	High	1.44	2.65	1.23%
Men	Low	1.65	2.38	0.73%
	High	2.35	3.40	0.75%
Gender Gap	Low	0.60	0.73	–
	High	0.61	0.78	–
	Weighted Avg.	0.55	0.74	–
Skill Premium	Men	1.42	1.43	–
	Women	1.44	1.53	–
	Weighted Avg.	1.53	1.47	–

Source: Basic Survey of Wage Structure (BSWS). Wage of low-skilled women in 1970 normalized to 1.0. *Gender gap* is defined as the ratio of women's wage to men's wage. *Skill premium* is deined as the ratio of high-skill wage to low-skill wage.

The share of women in the labor force rose from less than 20% in 1970 to almost 30% in 2020, and the rise is driven by the rise in the number of high-skilled women in the labor force, as shown in the lower part of Table 3. Low-skilled men had a 55% share in the labor market in 1970 and the share declined by 20 percentage points and both low and high-skilled men constitute 35% of the labor force, respectively.

We use these observations to calibrate the technological progress during the last half century in Section 4. It is important to consider the dramatic change in the composition of labor supply to account for the shift in the wage and productivity of different types of labor inputs.

Table 3: Distribution of Workers by Gender and Skill

	1970	2020
Men		
Low Skill	55.4%	35.3%
High Skill	25.3%	35.4%
Total	80.6%	70.8%
Women		
Low Skill	17.8%	16.7%
High Skill	1.6%	12.5%
Total	19.4%	29.2%
Total	100.0%	100.0%

Source: Census Data.

3 Model

3.1 Overview

An individual of our model enters the economy as single and is matched with another single person upon entry. The pair chooses to get married if the value of marriage exceeds the value of staying single for both of them and remain single otherwise.

A married couple chooses consumption of market goods and non-market goods. The latter is produced at home, using durable goods and housework time as inputs. The couple also chooses whether to have a child and if so how many. Parents derive utility from the quantity and quality of children, taking into account the time and money cost of raising children and educating them. The couple allocates the disposable time to leisure, home production, market work, and childcare.

Single individuals consume market and non-market goods and allocate their time to leisure, home production and market work. They spend resources for the purchase of market consumption goods and durable goods.

Output is produced using skilled and unskilled labor supplied by male and female workers and wages are determined in the competitive market.

3.2 Preferences

A single individual of gender $g = \{m, f\}$ derives utility from consumption of market goods c, non-market goods n, and leisure l. The utility function is denoted as $u_g^S(c, n, l)$ and given as follows.

$$u_g^S(c,n,l) = \alpha_g \frac{c^{1-\rho}-1}{1-\rho} + \beta_g \frac{n^{1-\nu}-1}{1-\nu} + \mu_g \frac{l^{1-\lambda}-1}{1-\lambda} \quad (1)$$

Married households derive utility from a couple's consumption of market goods c, non-market goods n, leisure $l = l_m + l_f$, the number of children k, and the quality of children q. The utility function is denoted as $u^M(c/\eta, n/\eta, l, k, q)$, where η represents the equivalence scale of consumption goods for the couple. The utility function is given as follows.

$$u^M(c/\eta, n/\eta, l, k, q) = \alpha \frac{(c/\eta)^{1-\rho}-1}{1-\rho} + \beta \frac{(n/\eta)^{1-\nu}-1}{1-\nu} + \mu \frac{l^{1-\lambda}-1}{1-\lambda} + \phi \frac{k^{1-\kappa}-1}{1-\kappa} + \xi \frac{q^{1-\psi}-1}{1-\psi}, \quad (2)$$

where the leisure l of a married household is the sum of leisure time of a husband and a wife, $l = l_m + l_f$. Utility function $\widehat{u}_g^M$ of a married individual of gender g is defined similarly to (2), with leisure l_g of each individual, rather than that of a household.

3.3 Children

A married couple derives utility from both the number of children k, as well as the quality of children q. Raising children is costly for parents in two ways: time and money for basic childcare and money for education. Basic childcare is required for any child and education investment is their choice. For the basic childcare, a married couple must spend a financial cost b per child, and each parent of gender g must also spend time ζ_g per child.

Parents also choose how much to invest in child education, which raises the quality of children. We assume that parents choose the mix of skills for their children, with a fraction s of high skill and $1-s$ of low skill. It costs χs per child to equip them with skill s, which enables them to enjoy the skill premium, denoted as w_h/w_l, where w_h and w_l represent high and low-skill wages, respectively.

We assume that parents derive utility from the quality of children q, which is increasing in the skill level of their children and also on how the skill is valued in the market. We define the quality of children as

$$q = \frac{w_h}{w_l} s, \quad (3)$$

where the first term represents the skill premium and the second term is the skill level. Skill premium is exogenous to parents and determined endogenously in the labor market, and the skill level is chosen by parents.

We assume that parents do not differentiate educational investment based on the gender of children and children's gender does not enter the problem of married individuals.

3.4 Home Production

Home goods n are produced with durable goods d, and housework hours h, as inputs.

$$n = [\omega d^\sigma + (1-\omega) h^\sigma]^{1/\sigma} \quad (4)$$

σ is the parameter that determines the elasticity of substitution between durable goods and labor input, which are priced at π per unit. For married households, h is the sum of housework hours supplied by a husband and a wife, $h = h_m + h_f$.

3.5 Market Production and Wages

A representative firm produces output Y with unskilled labor L and skilled labor H according to the production function:

$$Y = F(L, H) = Z\left[(1-\theta_h)L^{\varphi} + \theta_h A H^{\varphi}\right]^{1/\varphi}, \tag{5}$$

where Z represents the neutral technology level and A governs the gender-neutral skill-biased technological change. L and H are composites of male and female labor of each skill type, L_g and H_g for $g \in \{m, f\}$, defined as follows.

$$L = \left[(1-\theta_{l,f})L_m^{\gamma} + \theta_{l,f} B L_f^{\gamma}\right]^{1/\gamma} \tag{6}$$

$$H = \left[(1-\theta_{h,f})H_m^{\gamma} + \theta_{h,f} A_f B H_f^{\gamma}\right]^{1/\gamma}, \tag{7}$$

where B represents the gender-biased technological change and A_f denotes the skill-biased technological change that is specific to female workers, respectively.

The firm rents labor from individuals at the market wage rates. The labor market is competitive and the wages for unskilled and skilled labor of each gender are determined as the marginal product of each input. A firm's problem is given as follows.

$$\max_{L_m, L_f, H_m, H_f} \left\{ F(L, H) - \sum_g (L_g w_{g,l} + H_g w_{g,h}) \right\}$$

In equilibrium, market wages are given as marginal product of each type of labor.

$$\begin{aligned} w_{g,l} &= F_{L_g} \\ w_{g,h} &= F_{H_g} \end{aligned}$$

3.6 Household Problems and Equilibrium Conditions

The value function of single individuals of gender g is denoted as S_g. Married couples jointly solve the problem and the value function of a married household is denoted as M. The value of married individuals of gender g is denoted as $\widehat{M}_g$.

Single Households: Single individuals allocate the disposable time normalized to 1 to leisure l, home production h, and market work $1 - l - h$. They allocate income to the consumption of market goods c, and durable goods d at price π.

The value function of single individuals of gender g is given as follows.

$$S_g = \max_{c,d,l,h} \left\{ u_g^S(c,n,l) \right\} \tag{8}$$

s.t.

$$c + \pi d = w_g(1 - l - h) \tag{9}$$

where w_g denotes the wage rate of individuals of gender g. Substituting the equation for the home production (4) and the budget constraint (9) in the utility function (1), the value function reads as

$$S_g = \max_{d,l,h} \left\{ \alpha_g \frac{[w_g(1-l-h) - \pi d]^{1-\rho} - 1}{1-\rho} + \beta_g \frac{[\omega d^\sigma + (1-\omega)h^\sigma]^{\frac{1-\nu}{\sigma}} - 1}{1-\nu} + \mu_g \frac{l^{1-\lambda} - 1}{1-\lambda} \right\}$$

Married Households: Married couples choose to allocate after-tax earnings of a husband and a wife net of costs of childcare to consumption of market goods c and durable goods d. Married households also choose the number of children k and education investment for children s. The household decision for the investment in children determines the quality q of children.

We assume that the time allocation of married men is exogenous and they supply labor at home and in the market inelastically and their time contribution to the home production and childcare is also exogenously given. Therefore, the time allocation decision of the couple is about the wife's time allocation for leisure l_f, home production h_f, and market work, which is given by $(1 - \zeta_g k - l_g - h_g)$, the total disposable time net of time spent for childcare, leisure, and home production.

The value function of married households is defined as

$$M = \max_{c,d,l_f,h_f,k,s} \left\{ u^M(c/\eta, n/\eta, l, k, q) \right\} \tag{10}$$

s.t.

$$c + \pi d + \chi sk + bk = \sum_g w_g(1 - \zeta_g k - l_g - h_g) \tag{11}$$

where the housework $h = h_m + h_f$, leisure $l = l_m + l_f$ and the quality of children $q = (w_h/w_l)s$. Substituting the home production equation (4) and the budget constraint (11) in the utility function (2), the value function of married households reads as

$$\begin{aligned} M \;&=\; \max_{d,l_f,h_f,k,s} \left\{ \alpha \frac{\left\{ [\sum_g w_g(1-\zeta_g k - l_g - h_g) - \pi d - \chi sk - bk]/\eta \right\}^{1-\rho} - 1}{1-\rho} \right. \\ &+\; \left. \beta \frac{\left\{ \left[(\omega d^\sigma + (1-\omega)h^\sigma)^{1/\sigma} \right]/\eta \right\}^{(1-\nu)} - 1}{1-\nu} + \mu \frac{l^{1-\lambda} - 1}{1-\lambda} + \phi \frac{k^{1-\kappa} - 1}{1-\kappa} + \xi \frac{q^{1-\psi} - 1}{1-\psi} \right\}, \end{aligned}$$

The value of a married individual of gender g is given as

$$\widehat{M}_g = \widehat{u}_g^M(c^*/\eta, n^*/\eta, l_g^*, k^*, q^*), \tag{12}$$

where a variable with an asterisk denotes the optimal choice from the above problem of married households.

Marriage Decision: Upon individuals' entry to the economy, each individual is matched with a potential partner. The pair makes a draw of a common joy shock r from the distribution $F(r)$.

Given that we focus on the time allocation decision of married women, and also for simplicity, we focus on the marriage decision of women and abstract from that of men. Women choose to marry if the value of marriage for them plus the joy exceeds the value of staying single. Otherwise the pair will not marry and remain single. The decision rules are given as follows.

$$\begin{cases} \text{marry if} & \widehat{M}_f + r \geq S_f \\ \text{single if} & \widehat{M}_f + r < S_f \end{cases}$$

4 Calibration

We would like the model presented above to match the facts presented in Section 2. We assign some parameter values directly from the data and outside of the model and other parameter values are determined to fit the transition path of the data, consistently with the model's equilibrium conditions. In particular, we focus on the data during the last five decades between 1970 and 2020 and set some of the parameter values to match the data pattern of the transition between the two periods. This strategy follows the method undertaken by Greenwood et al. (2023). Appendix A. provides more details of the data used in the calibration.

4.1 Preference Parameters

4.1.1 Strategy

We use the equilibrium conditions of the household problems presented in Section 3.6 to pin down main preference parameters that enter the utility functions (1) and (2). We do so to match the target moments in two periods, 1970 and 2020, as explained in more details below.

The first order conditions of married households problem with respect to d, l_f, h_f, k, and s, respectively, are given as follows.

$$d: \quad \alpha(1/\eta)^{1-\rho}c^{-\rho}\pi = \beta(1/\eta)^{1-\nu}n^{1-\sigma-\nu}\omega d^{\sigma-1} \tag{13}$$

$$l_f: \quad \alpha(1/\eta)^{1-\rho}c^{-\rho}w_f = \mu(l_m + l_f)^{-\lambda} \tag{14}$$

$$h_f: \quad \alpha(1/\eta)^{1-\rho}c^{-\rho}w_f = \beta(1/\eta)^{1-\nu}n^{1-\sigma-\nu}(1-\omega)(h_m + h_f)^{\sigma-1} \tag{15}$$

$$k: \quad \alpha(1/\eta)^{1-\rho}c^{-\rho}(w_m\zeta_m + w_f\zeta_f + \chi s + b) = \phi k^{-\kappa} \tag{16}$$

$$s: \quad \alpha(1/\eta)^{1-\rho}c^{-\rho}\chi k = \xi q^{-\psi}(w_h/w_l) \tag{17}$$

The condition (16) equates the marginal benefit of having a child through direct utility from the larger number of the children, with the marginal cost of raising a child, the time to spare for the basic childcare and education. In equation (17), the marginal cost of time to educate the children is equated with the higher utility from the better quality of children.

The first order conditions of single households problem with respect to d, l, and h, respectively, are given as follows.

$$d: \quad \alpha_g c^{-\rho}\pi = \beta_g n^{1-\sigma-\nu}\omega d^{\sigma-1} \tag{18}$$

$$l: \quad \alpha_g c^{-\rho}w_g = \mu_g l^{-\lambda} \tag{19}$$

$$h: \quad \alpha_g c^{-\rho}w_g = \beta_g n^{1-\sigma-\nu}(1-\omega)h^{\sigma-1} \tag{20}$$

4.1.2 Married Households

For the utility function of married households (2), we set the weight parameter α to 1.0 for normalization and the risk aversion parameter to 3.0. The rest of the preference parameters, 4 weight parameters and 4 curvature parameters, are pinned down to match target data moments of (1) leisure (μ and λ), (2) fertility (ϕ and κ), (3) schooling (ξ and ψ) and (4) housework hours (β and ν). We exploit changes in these data between 1970 ($t = 0$) and 2020 ($t = 0$) to pin down elasticity parameters and the levels in one of the years to set the weight parameters.

Leisure: From the first order conditions (14) and (11),

$$\mu(l_{m,t} + l_{f,t})^{-\lambda} = \alpha(1/\eta)^{1-\rho}c_t^{-\rho}w_{f,t} \tag{21}$$

where

$$c_t = \sum_g w_{g,t}(1 - \zeta_{g,t}k_t - l_{g,t} - h_{g,t}) - \pi_t d_t - \chi_t s_t k_t - b_t k_t$$

Taking the ratio of (21) at time $t = 0$ and 1,

$$\left(\frac{l_{m,1} + l_{f,1}}{l_{m,0} + l_{f,0}}\right)^{-\lambda} = \left(\frac{c_1}{c_0}\right)^{-\rho}\frac{w_{f,1}}{w_{f,0}} \tag{22}$$

The condition (22) describes the response in leisure to the changes in consumption and wages, representing income and substitution effects, respectively. The parameter λ plays a key role in representing elasticitieses of leisure. (22) pins down λ to match the target response in leisure, $l_{f,1}/l_{f,0}$, to changes in consumption and wages. λ is set, the preference weight on leisure μ is derived by from (21) evaluated at $t = 0$.

Fertility: From the first order conditions (16) with (11) and (14),

$$\phi k_t^{-\kappa} = \mu(l_{m,t} + l_{f,t})^{-\lambda}(w_{f,t}\zeta_{f,t} + \chi_t s_t + b_t)/w_{f,t} \tag{23}$$

Using the condition for $t = 0$ and 1,

$$\left(\frac{k_1}{k_0}\right)^{-\kappa} = \left(\frac{l_{m,1} + l_{f,1}}{l_{m,0} + l_{f,0}}\right)^{-\lambda} \frac{(w_{f,1}\zeta_{f,1} + \chi_1 s_1 + b_1)/w_{f,1}}{(w_{f,0}\zeta_{f,0} + \chi_0 s_0 + b_0)/w_{f,0}} \tag{24}$$

From (24), we pin down κ to match the response in fertility to a change in leisure and the total marginal cost of childcare in terms of a wife's wage. Once κ is set, compute ϕ from (23) for $t = 0$.

Education: Using the first order condition (17) with (3) and (14),

$$\xi q_t^{-\psi}(w_{h,t}/w_{l,t}) = \mu(l_{m,t} + l_{f,t})^{-\lambda}\chi_t k_t/w_{f,t} \tag{25}$$

Taking the ratio of the condition at $t = 0$ and 1,

$$\left(\frac{q_1}{q_0}\right)^{-\psi} \frac{w_{h,1}/w_{l,1}}{w_{h,0}/w_{l,0}} = \left(\frac{l_{m,1} + l_{f,1}}{l_{m,0} + l_{f,0}}\right)^{-\lambda} \frac{\chi_1 k_1/w_{f,1}}{\chi_0 k_0/w_{f,0}} \tag{26}$$

We pin down ψ from (26) and ξ from (25).

Housework Hours: Using the first order condition (15) with (14),

$$\beta(1/\eta)^{1-\nu}\left[\omega d_t^\sigma + (1-\omega)(h_{m,t} + h_{f,t})^\sigma\right]^{\frac{1-\sigma-\nu}{\sigma}}(1-\omega)(h_{m,t}+h_{f,t})^{\sigma-1} = \mu(l_{m,t}+l_{f,t})^{-\lambda} \tag{27}$$

A rise in d_t implies a decline in h_t, provided $(1-\sigma-\nu) < 0$, and the effect is larger if σ is larger (h_t and d_t are more substitutable) or ν is larger. Taking the ratio of the conditions in two periods,

$$\left(\frac{\omega d_1^\sigma + (1-\omega)(h_{m,1} + h_{f,1})^\sigma}{\omega d_0^\sigma + (1-\omega)(h_{m,0} + h_{f,0})^\sigma}\right)^{\frac{1-\sigma-\nu}{\sigma}} \left(\frac{h_{m,1} + h_{f,1}}{h_{m,0} + h_{f,0}}\right)^{\sigma-1} = \left(\frac{l_{m,1} + l_{f,1}}{l_{m,0} + l_{f,0}}\right)^{-\lambda} \tag{28}$$

The parameter value of ν is set from (28) and β from (27).

4.1.3 Single Households

We set the weight parameter $\alpha_g = 1$ for normalization and set weight parameters β_g and μ_g for each gender g to match the target time allocations of single individuals at time $t = 0$ (1970). We assume the same values for the curvature parameters ρ, ν and λ as married households.

4.1.4 Marriage Decisions

We assume that the joy shock is drawn from the Gumbel distribution $F(r)$ and calibrate the two parameters that define the distribution to match the fraction of married individuals and the change in the share of married households between the two time periods.

Each matched pair of a man and a woman draws a joy shock r from the Gumbel distribution. Define r^* as

$$r^* = S_f - \widehat{M}_f.$$

The pair will marry if $r \geq r^*$ and remain single otherwise. Therefore the probability of being single is given as

$$1 - m = G(r^*) = \exp\left\{-\exp\left[-\frac{r^* - \mathbf{a}}{\mathbf{d}}\right]\right\}$$

Taking logs twice,

$$\ln[-\ln(1-m)] = -\frac{r^* - \mathbf{a}}{\mathbf{d}} \tag{29}$$

Taking the ratio of (29) for $t = 0$ (1970) and 1 (2020),

$$\frac{\ln[-\ln(1-m_1)]}{\ln[-\ln(1-m_0)]} = \frac{r_1^* - \mathbf{a}}{r_0^* - \mathbf{a}} \tag{30}$$

We choose $\mathbf{a}$ to match the change in the marriage probability m_t in (30). Given the value of $\mathbf{a}$, we set the scale parameter $\mathbf{d}$ to match the share of single individuals at $t = 0$ from (29).

4.1.5 Data Targets

As described above, we need data target moments related to fertility, marriage, time allocation and schooling, to pin down the values of preference parameters from the first order conditions.

Fertility and Marriage Probability: The average numbers of children per married couple, k_0 and k_1, are computed as $k_t = TFR_t/m_t$, where TFR_t is the total fertility rate at time t and m_t is the fraction of married individuals. The total fertility rates are 2.13 and 1.33 in 1970 and 2020, respectively, based on the Vital Statistics. The marriage probabilities are 0.967 and 0.822 in 1970 and 2020, respectively, based on the Census data. These imply $k_0 = 2.203$ and $k_1 = 1.618$.

Time Allocations: For the data on time allocations of single and married men and women, we use the Survey on Time Use and Leisure Activities and the data for individuals aged between 25 and 59.[5] The time allocations of married and single men and women for market work hr, housework h, leisure l and basic childcare ζ are reported in Table 4, expressed in terms of the share of the total disposable time.

[5] https://www.stat.go.jp/data/shakai/2016/index.html

Schooling: For s_t, we use the data from the Basic School Survey, and the fraction of high skilled individuals is 0.169 and 0.543 in 1970 and 2020, respectively. Those values correspond to the mean of men's and women's college enrollment rates each year.

Table 4: Preference Parameters: Data Targets and Model

		Data		Model	
Parameter	Description	1970	2020	1970	2020
Marriage and Fertility					
m	Fraction of married	0.967	0.822	0.967	0.822
k	Number of children	2.203	1.618	2.203	1.618
–	Total fertility rate	2.130	1.330	2.130	1.330
Time Allocation of Married Households					
hr	Market work hours (men)	0.769	0.712	0.769	0.712
	Market work hours (women)	0.277	0.266	0.277	0.266
h	Housework hours (men)	0.006	0.023	0.006	0.023
	Housework hours (women)	0.414	0.346	0.414	0.346
l	Leisure (men)	0.217	0.228	0.217	0.228
	Leisure (women)	0.189	0.215	0.189	0.215
Time Allocation of Single Households					
hr	Market work hours (men)	0.703	0.663	0.703	0.596
	Market work hours (women)	0.637	0.584	0.637	0.480
h	Housework hours (men)	0.034	0.030	0.034	0.033
	Housework hours (women)	0.140	0.119	0.140	0.147
l	Leisure (men)	0.263	0.307	0.263	0.371
	Leisure (women)	0.222	0.297	0.222	0.372
Schooling					
s	Fraction of college graduates	0.169	0.543	0.169	0.543

4.2 Home Production and Durable Goods

For the home production function (4), we follow McGrattan et al. (1997) and Greenwood et al. (2005) and set σ to 0.282 and ω is set for normalization so that the durable goods consumption in 1970 is 1.0.

The path of durable goods price π is based on the Consumer Price Index data between 1970 and 2020, as shown in Figure 4. The price index of housework-assisting durable goods declined at an annual rate of 5.75% and we use this value for the transition of the durable goods price. We set the price in 1970 so that the average share of household expenditures of durable goods matches the data.

4.3 Costs of Childcare

The time for basic childcare, ζ_g, is computed based on the Survey on Time Use and Leisure Activities. We divide the average time spent for childcare by men and women by the number of children per married couple k_t in each year.

The financial cost of basic childcare b is computed based on the sum of the fees for school and extracurricular activities. The data is obtained from the Survey on Children's Learning Expenses conducted by the Ministry of Education, Culture, Sports, Science and Technology.

The education cost χ represents the costs of sending a child to college. We use the data from the Student Life Survey conducted by the Japan Student Services Organization (JASSO), based on the sum of the tuition fees and living costs of a student enrolled in a college. See Appendix A. for more details about the data source and composition of the education cost.

4.4 Production Technology

There are three different technological parameters that represent the productivity level in the production function. First, Z_t stands for the level of general productivity, or total factor productivity (TFP), and second, A_t and $A_{f,t}$ represent skill-biased technological change (SBTC). A_t is applicable to both men and women and $A_{t,f}$ is gender-specific SBTC for women. Lastly, B_t describes gender-biased technological change (GBTC), specific to female labor supply of both skill types.

We use data from the Basic Survey on Wage Structure (BSWS) to obtain the wage and distribution of workers by skill and gender, as well as the average work hours of each group, in 1970 and 2020, respectively. We assume that the distribution and average work hours change at a constant rate between the two time periods and compute the path of labor supply, L_g and H_g for $g \in \{m, f\}$ for low and high-skilled workers.[6]

We compute the paths of the productivity levels using the labor supply of men and women and the two skill types based on (5), (6) and (7). See Appendix B. for more details of the computation.

For other parameters in the production function, we set the φ to 0.7 following the

[6]Due to data limitation, we have not been able to obtain wage rates by gender and skill in years between 1970 and 2020, and assume constant growth rates from 1970 to 2020. The BSWS started to ask the education level of "short-hour" workers (*tanjikan rodosha*) only after 2020 and we can use the information to compute the skill and gender-specific wages in 2020. Also, the BSWS had reported wage data for all workers by gender and skill, including short-hour workers, up to 1970 and we use this data for the wages in the model's initial year of 1970.

We also do not have data for average work hours of each type of workers in years between 1970 and 2020 and therefore assume that all variables including wage, hours and distribution change at a constant rate, in computing the path of the technology levels.

estimates used in Abbott et al. (2019) The value implies the elasticity of substitution between low and high skill labor of around 3.3, which is in the range of estimates in the literature. We set γ, that is related to the elasticity between male and female labor, to 0.55 and the share parameters θ_h, $\theta_{l,f}$ and $\theta_{h,f}$ are set to 0.55, 0.40 and 0.38, respectively, following Abbott et al. (2019), who estimate the production function that consists of three levels of education. We adjust the estimates to our model of two education levels.

For the equivalence scale η, we assume the OECD equivalence scale and set to 1.5 for married households.

Table 5: Calibration Parameters

Parameter	Description	Value
Preference		
ρ, α	Curvature and weight: consumption (married)	3.0, 1.0
ν, β	Curvature and weight: home goods (married)	7.669, 0.0001
λ, μ	Curvature and weight: leisure (married)	3.946, 0.0168
κ, ϕ	Curvature and weight: child (married)	0.624, 0.1088
ψ, ξ	Curvature and weight: child quality (married)	0.5038, 0.0362
β_g	Weight: home goods (single)	>0.000 (men)
		>0.000 (women)
μ_g	Weight: leisure (single)	0.0042 (men)
		0.0097 (women)
Childcare Costs		
$\zeta_{m,t}$	Basic childcare time (men)	0.004 (1970), 0.023 (2020)
$\zeta_{f,t}$	Basic childcare time (women)	0.055 (1970), 0.107 (2020)
b_t	Basic childcare fin. cost	0.046 (1970), 0.084 (2020)
χ_t	Education cost	0.084 (1970), 0.190 (2020)
Home Production		
σ	EOS b/w durables and housework	0.282
ω	Share of durables	0.0135
π	Durable goods price, time-varying	-0.0575 (growth)
Market Production and Technology		
Z_t	Neutral technology	0.0023 (growth)
A_t	High-skill productivity (SBTC)	0.0042 (growth)
$A_{f,t}$	High-skill productivity (women) (SBTC)	0.0137 (growth)
B_t	Women's productivity (high) (GBTC)	0.0057 (growth)
φ	EOS b/w low and high-skill labor	0.70
γ	EOS b/w men and women	0.55
θ_h	Share of high-skill labor	0.55
$\theta_{l,f}$, $\theta_{h,f}$	Share of women (low, high)	0.40, 0.38
Other Parameters		
η	Equivalence scale	1.5
d, a	Marriage joy shock distribution	0.803, 0.659

5 Numerical Results

In this section we first present the outcome of the baseline model and then show how various factors of the model contribute to the trends of key variables of interest. We do this by simulating the model while eliminating or changing the magnitude of each factor one by one, keeping all the other elements unchanged from the baseline model.

5.1 Baseline Model

Figure 5 shows how the model's predicted paths of women's time allocation compare with the data. The model generates a secular decline in the housework, a mild decline in market work and a gradual increase in leisure in line with the transition of the data. The time for child care increases throughout the transition, while the number of children declines, as shown in Figure 6(a).

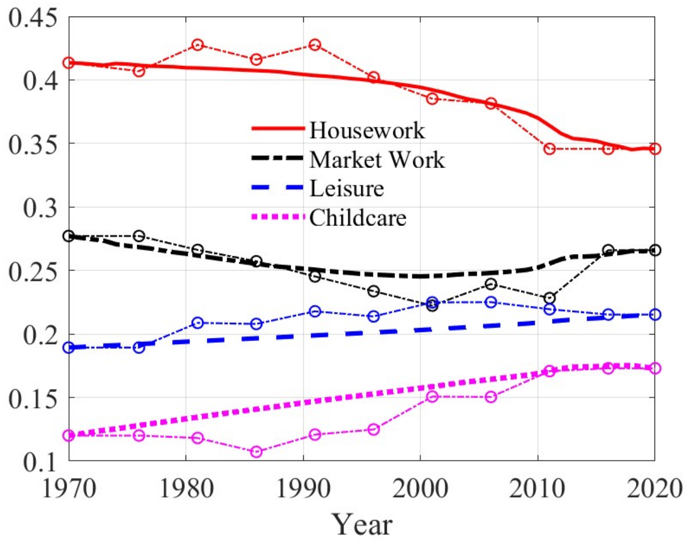
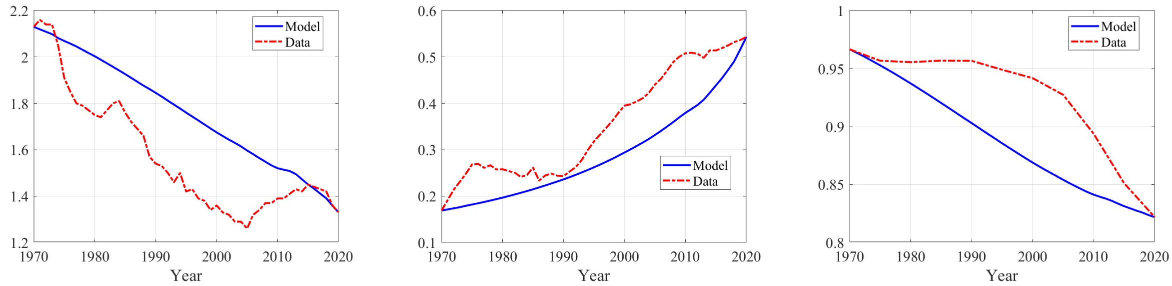


Figure 5: Time Allocations of Married Women: Baseline Model (lines) and Data (circles)

Married couples choose to have fewer children over time, as the cost of childcare increases and so is the opportunity cost of raising children in terms of women's foregone wages. The marriage rates decline over time as shown in Figure 6(c), as the relative attractiveness of being married wanes over time. The merit of the marriage stems from the possibility of having children and sharing resources and enjoy economies of scale. The decline in the optimal number of children, higher level of income due to the technological growth, and cheaper input of home production to substitute housework all work in favor of remaining single.

The model also generates the rising investment in education, following the upward trajectory of the share of college graduates in the data. Given the rising fixed cost of children and higher income, parents choose more education over more children, faced with the quantity and quality trade-off.

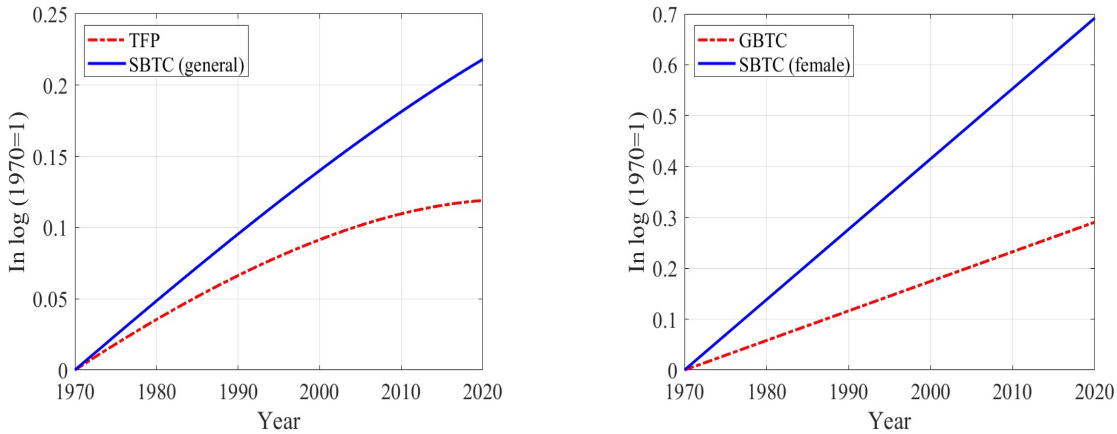
As described in Section 4.4, we compute the technology level B_t, $A_{f,t}$, A_t and Z_t from



(a) Total Fertility Rates (b) Schooling (c) Marriage Probability

Figure 6: Fertility, Marriage and Schooling: Baseline Model and Data

the gender and skill-specific wages and labor supply of each type of workers and the paths are presented in Figure 7. The annualized growth rate of Z_t between 1970 and 2020 is 0.23%, 0.42% and 1.37% for A_t and $A_{f,t}$, respectively, and 0.57% for B_t, as also reported in Table 5. In Section 5.2, we simulate various scenarios in which the technological growth is assumed to follow alternative paths.



(a) TFP and SBTC (general) (b) GBTC and SBTC (female)

Figure 7: Technological Growth

5.2 Roles of Technology

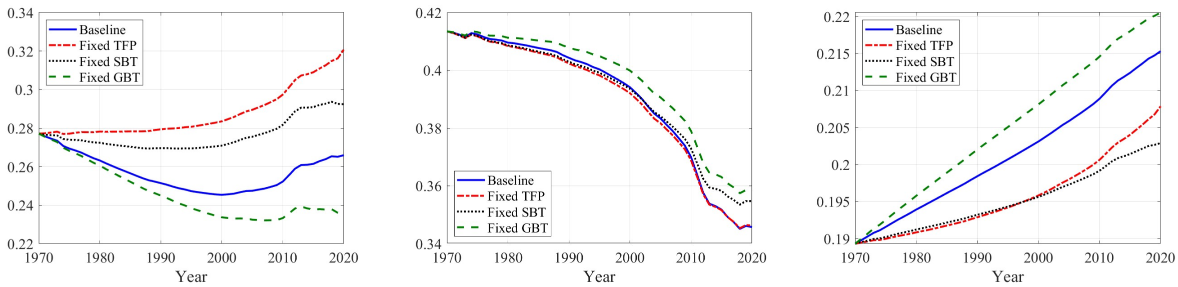
In this section, we consider how the technological progress during the last half century affects the trends of household variables. We adjust the wage rates by shifting the values of technological levels and simulate the transition of the model which otherwise is identical to the baseline model.

In addition to these partial equilibrium (PE) simulations, we also run the general equilibrium (GE) version of experiments, in which wages also adjust with an endogenous adjustment of the labor supply driven by the change in the work hours of individuals and of the skill composition due to a shift in the education investment of married households.

We run four sets of counterfactual experiments. First, we assume that the level of general technology, or the TFP, will remain the same level as in 1970, that is, $Z_t = Z_{1970}$ for all t. Second, we mute the skill-biased technological change (SBTC) and set $A_t = A_{1970}$ and $A_{f,t} = A_{f,1970}$ throughout the transition. Third, we assume that there is no gender-biased technological changes (GBTC) and set $B_t = B_{1970}$. Finally, we let the home production technology remain constant and the price of house-assisting durable goods stay at the level in 1970, $\pi_t = \pi_{1970}$ for all t.

Figure 9 shows the paths of married women's time allocations to market work, home production and leisure, under the three alternative assumptions about the productivity levels. When there is no TFP or skill-biased technological growth, household income will be lower as husbands' earnings decline. Although women's wages are lower and the return from additional work declines, income effects dominate and married women increase work hours and reduce leisure.

When the gender-biased technological growth is absent, wages of women decline while mens' wages remain the same and couples choose to reduce work hours of women and allocate more time to housework and leisure. Table 6 summarizes the changes in key variables in the economy of 2020. Without the GBTC, market work in 2020 will decline by about 12% from 26.6% of married women's time in the baseline model to 23.5%. Hours for leisure and housework will increase by 2.8% and 3.5%, respectively.



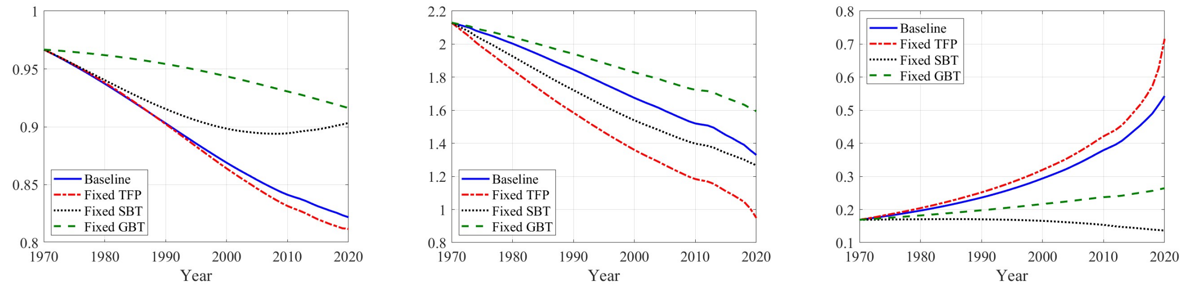
(a) Work Hours (b) HouseWork (c) Leisure

Figure 8: Roles of Technology (1)

Since the lack of SBTC and GBTC would lower the wage and economic status of women relative to men, marriage becomes more attractive to women (recall that SBTC was stronger for women), resulting in the higher marriage probability as shown in Figure 9(a). Married households, however, become poor under these experiments, they can afford fewer children and total fertility rates decline.

Figure 9(c) shows that the schooling declines in the transition with no SBTC and GBTC. The decline is much more pronounced without the SBTC, since households no longer enjoy the higher return in the form of the skill premium from the education investment.

Without the GBT, women's opportunity cost of work is lower and they will spend more time on not only housework and leisure, but also on childcare. The demand of families regarding children will tilt toward quantity from quality, and as a result, the total fertility rates increase while the schooling declines under the fixed GBT, as shown in Figures 9(b) and 9(c). The time married women spend on childcare will increase by 7.5%, from 17.3% of their time in the baseline to 18.6% under the experiment.



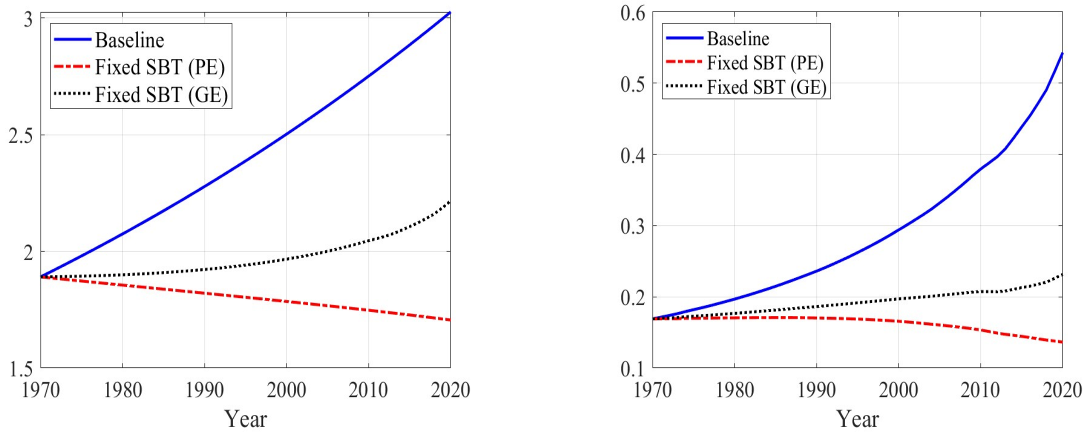
(a) Marriage Probability (b) Total Fertility Rate (c) Schooling

Figure 9: Roles of Technology (2)

Partial vs General Equilibrium Analysis: In the above experiments, we considered the effects of only the direct effects of the technological change on wages. We now consider full general equilibrium effects of the technology, allowing changes in the market work hours and education investment to affect labor supply and wages.

In general, if lower wages due to a decline in the technology level reduce work hours or education investment, incorporating general equilibrium effects will mitigate the negative effects on wages. We consider the case of fixed SBTC to highlight such effects. See the last columns of Table 6 for the summary of experiments in general equilibrium.

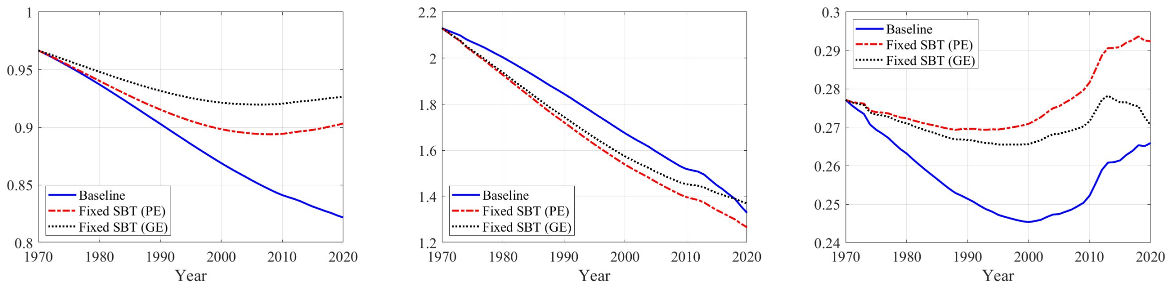
Figure 10(a) compares the paths of high-skill wage in the baseline, two cases of fixed SBTC, with and without general equilibrium (GE) effects. As seen above, removing the SBTC will increase work hours and reduce education investment. Since the latter effect dominates the former with the significant disincentives to acquire skills, the high-skill labor supply declines. In the general equilibrium, this effect increases the equilibrium wage of high-skill labor and mitigates the negative direct effect. The change will partially restore the education investment and the share of the high-skilled will increase as shown in Figure 10(b).



(a) High-skill Wage (Men & Women Avg.) (b) Schooling

Figure 10: Roles of SBTC: Partial and General Equilibrium (1)

Figure 11 shows the paths on marriage probability, fertility and married women's work hours. Similarly to the paths of wages, the effects are also mitigated in general when the general equilibrium effects are considered.

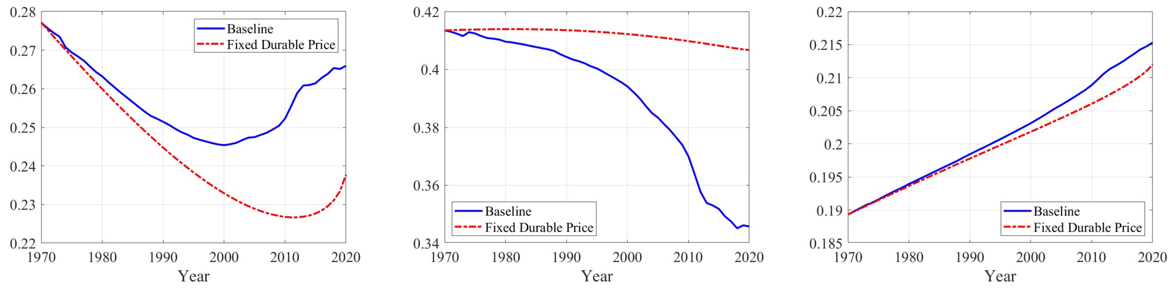


(a) Marriage Probability (b) Total Fertility Rate (c) Work Hours

Figure 11: Roles of SBTC: Partial and General Equilibrium (2)

Roles of Home Production Technology: We now consider the roles of the development of home production technology. As shown in Figure 4, the price of house-assisting durable goods declined throughout the half century and contributed to a decline in the cost of home-produced goods. We simulate the transition assuming that the price remains unchanged, that is, $\pi_t = \pi_{1970}$ throughout the transition.

We would no longer see a decline in housework hours as shown in Figure 12(b) and this is compensated by a decline in work hours and leisure relative to the baseline model. The additional hours for housework reduces time married women can allocate to childcare and the fertility rate declines, as shown in Table 6. Parents instead spend more resources on education and the share of the high-skilled is higher.



(a) Work Hours (b) Housework (c) Leisure

Figure 12: Roles of Home Production Technology

Table 6: Roles of Technology. Removing Factors One by One

			Partial Eq.				*General Eq.*			
	1970	2020	TFP	SBT	GBT	Dur. Pr.	TFP	SBT	GBT	Dur. Pr.
Family and Education										
Fertility (TFR)	2.203	1.618	1.169	1.403	1.740	1.343	1.311	1.480	1.550	1.453
Schooling	0.169	0.543	0.716	0.136	0.264	0.741	0.541	0.232	0.422	0.599
Marriage	0.967	0.822	0.812	0.903	0.916	0.814	0.825	0.927	0.905	0.796
Time Allocation of Married Women										
Work Hours	0.277	0.266	0.321	0.292	0.235	0.238	0.304	0.271	0.257	0.231
Leisure	0.189	0.215	0.209	0.203	0.221	0.212	0.209	0.213	0.221	0.209
Housework	0.414	0.346	0.346	0.354	0.358	0.407	0.348	0.358	0.357	0.405
Childcare	0.120	0.173	0.125	0.150	0.186	0.144	0.140	0.158	0.166	0.155

5.3 Childcare Costs

As we discussed in Section 2, households have faced rising costs of childcare both in terms of financial expenses and parental time. In this section, we consider and simulate three alternative scenarios in which the rise of these costs is mitigated during the transition.[7] Long-run effects of key variables are summarized in Table 7.

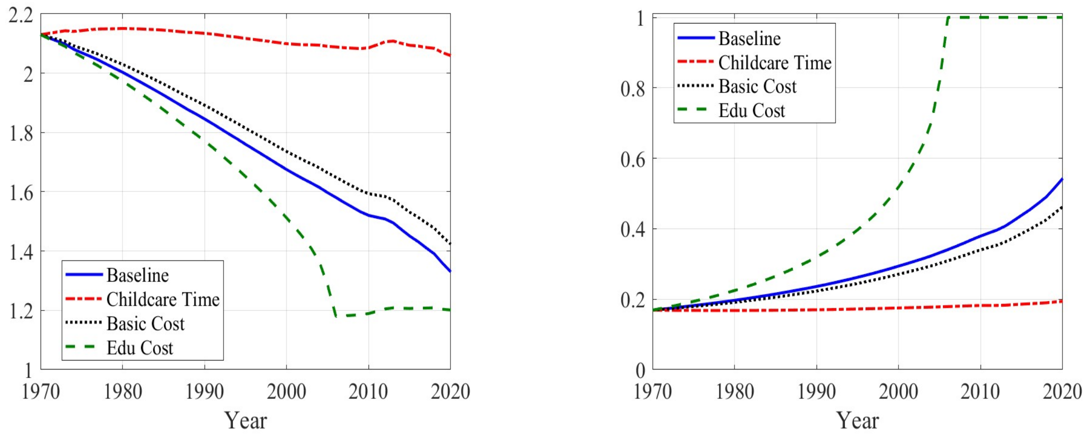
In the first scenario, we assume that the increase in the time for childcare per child is limited to 50% of that in the baseline model. We let the time for childcare will rise by 48.1% between 1970 and 2020 in the experiment, instead of 96.2% in the baseline model.

In the second and third scenarios, the basic cost of childcare b_t and education cost χ_t are assumed to increase at the same speed as the average earnings of married couples in the baseline economy. In other words, there is no "childcare cost inflation" and child-related costs move in parallel with the income levels of parents. We let the two types of financial costs rise by 66.7% in real terms over the 50-year period, instead of 81.0% and

[7] In the experiments of childcare costs, we abstract from general equilibrium through changes in factor prices and focus on the direct effects.

125.1%, for the basic childcare and education costs, respectively, assumed in the baseline model.

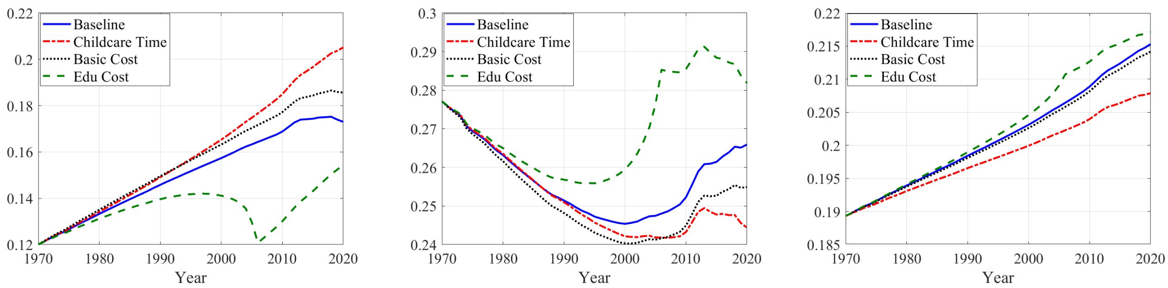
As shown in Figure 13(b), when the education cost is lower, married couples would raise the education investment. They allocate more resources on quality rather than quantity and total fertility rate is lower than in the baseline transition as shown in Figure 13(a). When the cost of basic childcare is lower, both in terms of time and fiance, parents would increase the number of children and instead reduce the education investment.



(a) Total Fertility Rate (b) Schooling

Figure 13: Roles of Childcare Cost

In terms of married women's time allocations, when fertility rates are higher with lower childcare costs, they spend more time on childcare and reduce work hours and leisure, as shown in Figure 14. When the education cost per child is lower, they spend more on schooling and time saved from fewer childcare hours is directed towards market work.



(a) Childcare Time (b) Work Hours (c) Leisure

Figure 14: Roles of Childcare Cost

Table 7 summarizes the changes in key variables in 2020 under the experiments about the childcare costs.

Table 7: Roles of Childcare Costs: Adjusting Factors One by One

			Childcare Cost		
			Basic	Basic	Edu
	1970	2020	Time	Money	Cost
Family and Education					
Fertility (TFR)	2.203	1.618	2.542	1.736	1.446
Schooling	0.169	0.543	0.194	0.463	1.000
Marriage	0.967	0.822	0.810	0.820	0.831
Time Allocation of Married Women					
Work Hours	0.277	0.266	0.244	0.255	0.282
Leisure	0.189	0.215	0.208	0.214	0.217
Housework	0.414	0.346	0.343	0.345	0.347
Childcare	0.120	0.173	0.205	0.186	0.155

We note that the quantitative results need to be interpreted with some caution. For example, if the government were to introduce a policy to fully pay the childcare costs or even to cover the childcare time on behalf of parents, would they allocate the saved time and financial resources to something else, as the results suggest? The model assumption is that these time and money costs are exogenous to the agents and also in the model. Parents, however, may well respond to such a policy by spending an additional money and effort per child. More demand for childcare may also alter the price that we treat as given. The fact that per-child time and financial costs have continued to increase during the last half century at a pace beyond the growth of the income suggests that such response is plausible. To fully account for this, we would need a model to explain the evolution of childcare efforts and this is something we leave for future research.

6 Conclusion

Many developed countries have experienced the secular decline in fertility rates and marriage probability and a shift in women's time allocations over the last half century. At the same time, the technological development drove the dynamics of the wage structure, through the general productivity growth and skill and gender-biased technological changes, affecting the trade-off in the time and resource allocation of families.

We develop a tractable model of heterogeneous individuals who make decisions about marriage, fertility and time allocations for different activities including market work, home production, leisure, and childcare. Married couples also face the quantity and quality trade-off associated with the decisions of child bearing and skill investment.

We calibrate the model to the macro and micro data of Japan, which experienced a rapid decline in fertility and marriage rates, and shrinkage of the population and family size during the last five decades. Our quantitative analysis shows that while the growth of neutral and the skill-biased technological growth contributes to a rise in fertility rates and children's skill investment, the gender-biased technological change works in the opposite direction. We also find that while the increase in financial and time cost of basic childcare leads to a decline in fertility rates, the rise in the education cost does the opposite.

The analysis demonstrates that it is critical to consider the interaction of micro and macro factors, including the technological change and wage structures and family's time and resource constraints, in accounting for the trend of the family formation and families' time allocations. In this paper, we did not unravel what accounts for the observed trends of the technology and the shift in various family constraints such as childcare and education costs in the context of our framework. These are important questions left for future research.

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Appendix A. Data Targets

Marriage Probability We use the Census data to construct the time series of marriage probability. For each gender, age group, and year,[8] the data records the fraction of four different marital statuses: ever-married, being married, divorced (and currently not married), and widows/widowers. We compute the fraction of ever-married individuals aged 50 for men and women for every five years from 1970 to 2020.[9] Finally, we compute the simple average of the fraction of ever-married men and women each year as a proxy of the never-married rate. The marriage rate is constructed as one minus this never-married rate.

Time Allocations: The Survey on Time Use and Leisure Activities provides information on individuals' time allocation at five-year intervals since 1976. We use the data to draw the time allocation patterns for men and women with different marital statuses, following the steps outlined below. First, for each year and agent (married male, married female, unmarried male, and unmarried female), we calculate the time spent on four different activities (housework, childcare, leisure, and market work) for specific age groups of 25-29, 30-39, 40-49, and 50-59. "Leisure" encompasses the combined time spent on activities such as "Rest and relaxation," "Hobbies and amusements," "Sports," "Volunteer and social activities," and "Social life." Second, for each year and agent, we take a simple average of time spent on each activity over different age groups, providing a snapshot of the lifetime time allocation through age 25 to 59 for each year and agent. Third, we calculate the timeshare of each activity for each year and agent, which gives us profiles of lifetime time allocations at nine specific points (every five years from 1976 to 2016) for each agent. We exclude the latest data for 2021 due to concerns that it may be anomalous, as it reflects a period shortly after the onset of the Coronavirus epidemic. For 1970, we extrapolate the timeshare from the available 1976 data. Similarly, for 2020, we use the 2016 data, and for 1995 (midpoint), we rely on the 1996 data. The remaining data for 1981, 1986, 1991, 2001, 2006, and 2011 are used to interpolate between 1971-1994 and 1996-2019 with equally spaced points. Note that the time spent on "childcare" here is the total time spent on childcare. To compute the per-child childcare time for married men and women, we divide the total childcare time by the total fertility rate.

Costs of Childcare The financial cost of basic childcare b is computed using the Survey on Children's Learning Expenses. It records the average education expenditures for children before high school graduation for several categories, such as school and extracurricular activities, since 1994. From 1994 to 2018, where the latest year before the

[8]The survey is conducted every five years.

[9]More specifically, we calculate the ever-married rate for men and women aged 45-49 and 50-54, and compute the simple average of the two values for each gender.

Coronavirus epidemic, it turns out that the income share of each expenditure remained almost constant: computing the lifetime income for married households (total labor earnings from age 25 to 59) from the Family Income and Expenditure Survey, the average expenditure for raising a child until 18 years old amounted to about 2.9% of the household income each year in 1994-2018. Due to data limitation for the education expenditure in years before 1994, we assume that the income share of the child-related spending is constant across 1970-2020 (recall that the assumption matches the reality at least for 1994-2018).

We use the Student Life Survey to set the education costs χ for each year. According to the data in 2018, the average annual expenditure for college students amounted to 1.91 million yen, comprised of 0.93 million yen of college related-expenditures, such as tuition fees, and 0.98 million yen of living costs, such as housing and food expense. While we have the time series of college tuition fees from the price index, no other datasets record the expenditures arising from college enrollment, except tuition fees, before 2004, when the survey started. Hence, we assume that the income share of the expenditures aside from tuition fees is constant across 1970-2020. Combining the series and price index for college tuition fees, we finally compute the total education costs χ for each year.

Appendix B. Computation of Technological Growth

This appendix describes how we compute the transition paths of the technology levels, $\{Z_t, A_t, A_{f,t}, B_t\}$ between 1970 and 2020.

We compute the paths of gender-biased technology level B_t from the ratios of female and male low-skill wage equations:

$$\frac{w_{l,f,t}}{w_{l,m,t}} = B_t \frac{\theta_{l,f}}{1-\theta_{l,f}} \left(\frac{L_{f,t}}{L_{m,t}}\right)^{\gamma-1}$$

With B_t, the gender-specific skill-biased technology level $A_{f,t}$ is computed from:

$$\frac{w_{h,f,t}}{w_{h,m,t}} = A_{f,t} B_t \frac{\theta_{h,f}}{1-\theta_{h,f}} \left(\frac{H_{f,t}}{H_{m,t}}\right)^{\gamma-1}$$

We then compute the aggregate low and high-skill labor L_t and H_t for all t using (6) and (7), and obtain the general skill-biased technology level A_t for from the ratios of low and high-skill wage equations:

$$\frac{w_{h,m,t}}{w_{l,m,t}} = A_t \frac{\theta_h}{1-\theta_h} \left(\frac{H_t}{L_t}\right)^{\varphi-\gamma} \frac{1-\theta_{h,f}}{1-\theta_{l,f}} \left(\frac{H_{m,t}}{L_{m,t}}\right)^{\gamma-1}$$

Finally, we set Z_t to the path of $w_{l,m,t}$. Note that we set Z_t in the initial period of 1970 so that $w_{l,f,0} = 1$ for normalization.

$$w_{l,m,t} = Z_t \left[(1-\theta_h) L_t^{\varphi} + \theta_h A_t H_t^{\varphi}\right]^{\frac{1}{\varphi}-1} (1-\theta_h) L_t^{\varphi-\gamma} (1-\theta_{l,f}) L_{m,t}^{\gamma-1}$$