Career Choices, Timing of Childbirth, and Perceptions of Fecundity*

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Abstract

How does perception of age-dependent ability to bear children, which may not align with the medical data, affect the optimal reproductive decisions of households and career development of women? We build a life cycle model that endogenizes decisions of marriage and childbirth, as well as women's career choices, and quantify how the awareness of fecundity affects these decisions. Our findings reveal that aligning optimistic beliefs in fertility with medical data encourages households to opt for childbirth at younger ages, when fecundity is higher. This shift results in more women making earlier decisions about marriage and childbirth, subsequently altering their employment choices from regular to contingent jobs or opting out of the workforce altogether. Additionally, we incorporate decisions about infertility treatments and study how the government subsidy affects the take-up rates and decisions of households.

Keywords: Japan, fertility, fecundity, female labor force participation, life-cycle, human capital accumulation, infertility treatment, sex education
JEL Classification:

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1 Introduction

It is never too late to start, but sometimes is. Unlike other living organisms that engage primarily in reproductive behavior to produce offspring, humans factor in various elements into this decision. Throughout their careers, humans work, earn, and accumulate human capital. The act of childbirth often interrupts this process, potentially leading to a depreciation of human capital during the period of absence from the workforce.

Fecundity, defined as the natural ability to reproduce, diminishes with age. As couples delay childbirth in favor of accumulating human capital, their likelihood of achieving the desired number of children reduces. This reduction is particularly pronounced in females, whose fecundity significantly decreases over time. While male fecundity also diminishes, it often relates more to inherent inabilities or other factors.[1] Konishi et al. (2018) investigates the "time to pregnancy" (TTP) across various age groups, as given in Table 1 revealing that the cumulative probability of conception within 12 months post-contraception discontinuation is 80% for the age group 24-26, 66% for 30-32, and 31% for 39-44.

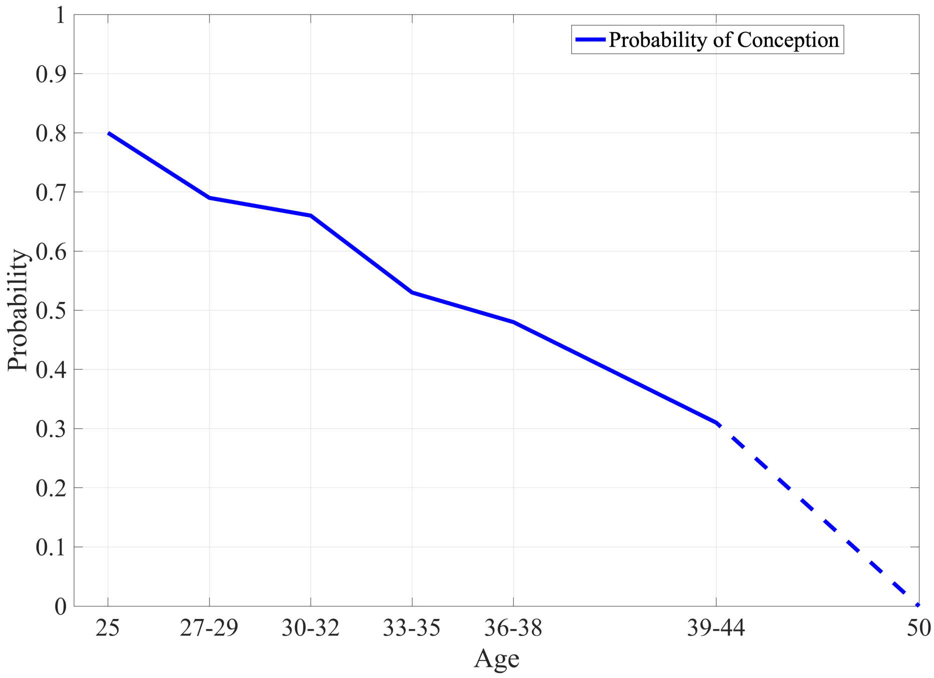


Figure 1: Probability of Conception after 12 month

This paper poses the question: do individuals optimize their lifetime utility by aligning with medical fecundity? While the timing of childbirth is a personal choice for each couple and poses no issue if it aligns with their understanding of medical fecundity, a

[1] It is acknowledged that male fecundity also deteriorates over time, although this is often due to intrinsic factors.

misalignment due to an overestimation of fecundity could lead to potential losses at both the individual and macroeconomic levels. Such miscalculations may exacerbate societal aging.

Table 1, based on a survey by the Health and Global Policy Institute (HGPI)[2], presents data on perceived fecundity. Participants were asked about the age until which they believe pregnancy is feasible through natural intercourse or fertility treatments, and the age beyond which achieving pregnancy becomes exceedingly difficult. The first two rows of the table display results for natural intercourse from female and male perspectives, respectively, while the third and fourth rows relate to infertility treatments.

The findings reveal several noteworthy insights. First, there is a discernible gender gap in perceptions of fecundity regarding natural intercourse. Females generally have a more pessimistic view compared to males. In the table, values in red indicate the highest percentage of responses, with the peak age for females at 35 and for males at 40. Second, even females tend to overestimate their fecundity compared to medical evidence. According to van Noord-Zaadstra et al. (1991), the "critical age" for female fertility is approximately 31 years. This "critical age" is defined as the age beyond which the probability of conception falls rapidly, significantly lower than the majority of responses indicate. In the context of infertility treatment, both male and female responses converge, with many identifying 40 years as the threshold beyond which pregnancy becomes significantly more challenging.

Table 1: Survey on Subjective Fecundity

		25	30	35	40	45	50	55	60
Natural Intercourse	Female	5.0%	14.1%	39.1%	27.5%	9.3%	3.6%	0.4%	1.1%
	Male	3.7%	10.2%	31.5%	36.8%	10.8%	4.6%	0.5%	1.9%
Infertility Treatment	Female	1.9%	4.0%	16.5%	44.8%	23.2%	7.4%	0.8%	1.4%
	Male	2.2%	4.3%	13.3%	41.4%	24.6%	10.4%	1.2%	2.7%

Source: "The Public Opinion Survey on Child-Rearing in Modern Japan (Final Report)", Health and Global Policy Institute, March 4, 2022.

In the context of Japan's labor market, an important distinction emerges between regular and contingent employment. There is a significant wage disparity between these two types of employment, with regular employees generally receiving higher wage. This dichotomy in the labor market presents a critical backdrop against which individuals make their career and family planning decisions, especially considering the potential impact of childbirth and child-rearing on career trajectories and financial stability.

[2]The survey was conducted in 2022. The demographic breakdown of respondents is as follows: 50.4% biologically male and 49.6% biologically female, distributed across age groups: 25-29 (15.8%), 30-34 (16.5%), 35-39 (22.1%), 40-44 (18.6%), and 45-49 (26.9%).

In our study, we develop a quantitative life-cycle model populated by heterogeneous agents. In this model, we focus on several important life choices including marriage, childbirth, and the use of infertility treatments, as well as decisions of consumption and labour. Each period, single individuals decide whether to marry, and married couples decide whether to have children, taking into account the likelihood of getting pregnant at their current age.

The calibration of our model uses data from the Japan Panel Survey of Consumers (JPSC), focusing on cohorts born in the 1960s and later 1980s. In the baseline scenario, agents are modeled to optimize their life decisions, aiming to maximize lifetime utility. This optimization is based on subjective fecundity perceptions, which tend to be more optimistic compared to actual medical fecundity rates.

Our analysis encompasses three distinct series of counterfactual estimations: the adjustment from subjective to medical fecundity beliefs, the implementation of cost-free infertility treatment, and a combination of both interventions. The preliminary findings from these experiments are as follows: fertility rates increased by 0.049, 0.021, and 0.051, respectively, under each scenario. Correspondingly, overall employment rates showed a decrease of 0.16%, 0.08%, and 0.2%, respectively. In terms of average income at age 45, a decrease of 4.2%, 1.1%, and 4.4% occurred, respectively.

All experimental scenarios resulted in an increase in fertility rates and a decrease in employment rates, predominantly driven by a more pronounced decline in regular-type employment compared to the rise in contingent-type employment. However, the magnitude and nature of these effects varied across the different scenarios. In the first scenario, the increase in fertility treatment uptake was more significant than in the second. The fertility rate notably increased in earlier life stages, while it decreased in later stages. Regarding employment, the first experiment led to a decrease in regular-type jobs and an increase in contingent-type jobs across all age groups. In contrast, the second scenario primarily affected employment in the later stages of life. The final scenario, combining both fecundity belief updates and free infertility treatment, mirrored the results of the first scenario but with slightly greater magnitudes.

Our model integrates three key aspects: female career choices, the endogenous and dynamic choice of childbirth, and decisions regarding infertility treatment. Furthermore, it is constructed and calibrated using age-specific medical and subjective fecundity data derived from medical research.

First, for the dynamic choice of childbirth and intention to have a child, our structure of the model from the aspect is the closest to Doepke and Kindermann (2019). The seminal contributions to the discussion of fertility in the field of economics are attributed to Becker and Barro (1988) and Barro and Becker (1989). Furthermore, the fundamental analysis linking fertility decisions with the accumulation of human capital is extensively explored in Becker et al. (1990).

Second, the choice of infertility treatment is build based on the structure following Sommer (2016) that asseses the potential impact of ART on fertility choices. de la Croix and Pommeret (2021) also discusses the potential uses of infertility treatment using quantitative model. However, none of the above work takes into account the aspect of subjective fecundity.

Lastly, our quantitative model is based on the Kitao and Mikoshiba (2022) study, particularly in its approach to female career choices in Japan. Adda et al. (2017) examines the interplay between women's career progression and birth rates, highlighting the significant impact of childbirth-related career interruptions. Eckstein et al. (2019) also explores the dynamic relationship between career decisions and fertility, analyzing how family planning decisions influence and are influenced by career choices. Doepke et al. (2023) builds two-period model that takes into account the trade-off between fecundity and human capital accumulation.

In the field of medicine, extensive research has been conducted on the decline in fecundity with age. Studies like Konishi et al. (2018), which estimates the time to pregnancy for Japanese females in various age groups, and Dunson et al. (2002), indicating a significant decline in fertility starting from the late 20s, provide a contextual backdrop for this research. Additionally, Habbema et al. (2015) discusses the age by which couples should consider having children, considering both natural intercourse and in vitro fertilization (IVF).

Furthermore, papers such as Lampic et al. (2005) and Hammarberg et al. (2017) reveal a lack of awareness about fecundity decline. For instance, many Swedish female university students plan to have children after 35, unaware of the significant fertility decline in their late 30s. These studies collectively serve as motivating facts, highlighting the relevance and urgency of the issues addressed in this research.

The rest of the paper is organized as follows. In Section 2, we present our quantitative life-cycle model, and Section 3 describes the parametrization of the model. Section 4 presents numerical results, and Section 5 presents the concluding remarks.

2 Model

2.1 Overview

The life cycle in this model can be divided into three parts. Young and fecund, young but not fecund, and retired. When young and fecund, in addition to consumption and labor choices, agents choose to get married if they are single or try to have children if they are married. In the young but not fecund period, they make consumption and labor decisions, while in the retired period they only make consumption decisions.

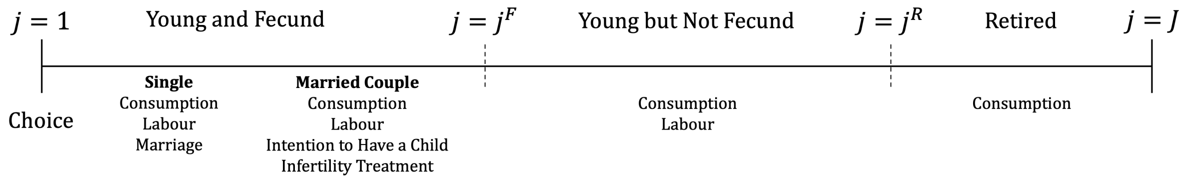


Figure 2: Life Cycle

The timing of events for the young and fecund periods is shown in Fighre 3. If single, after making consumption and labor decisions in period t, they decide whether or not to get married in the next period based on the joy shock. If they are married, they will receive shocks on infertility and joy shocks on children. After that, they make decisions about consumption, labor, and having children, and finally the stochastic realization of whether or not they will have children comes.

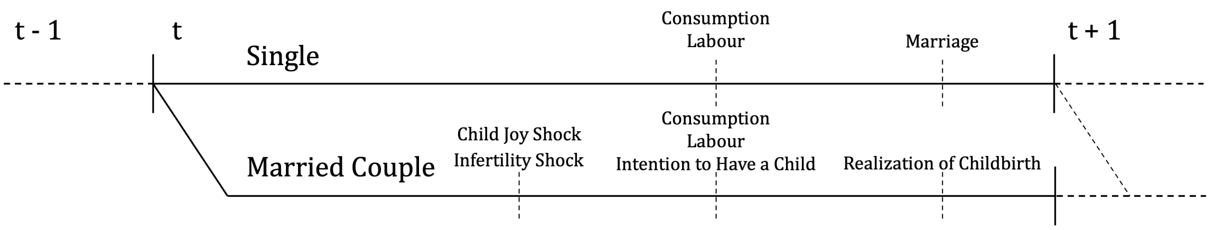


Figure 3: Young and Fecund Period

2.2 Demographics

Individuals enter the economy at age $j = 1$ and live up to a maximum age of J. There is no stochastic death and every agent survives until age J. The age at which agents are no longer fertile is denoted by j^F, and the retirement age, at which agents begin receiving social security benefits, is denoted by j^R. The variable $g = \{m, f\}$ represents gender.

Marital status is indicated by $q = \{S, M\}$, where S and M represent being single and married, respectively. Agents enter the economy with an initial marital status. The decision to marry for single agents is determined endogenously. An individual with gender g and skill level s is matched with a spouse possessing skill level s', according to the probability $\pi_g(s, s')$, reflecting the concept of assortative mating. The model simplifies by excluding same-gender marriages and assumes that agents marry others of the same age. Single agents are not permitted to have children within their households.

The variable $\chi \in \{0, 1\}$ signifies the presence of a young child in a married household. The presence of a child incurs a participation cost for females. The state of the household evolves stochastically, based on decisions made within the married household, as elaborated in subsequent sections.

2.3 Endowment

Individuals are endowed with an ex-ante skill level $s \in \{L, H\}$, which remains constant throughout their lifetime. In this model, male labor supply is inelastic, and earnings are deterministically determined based on age and skill.

Female employment status, at each age, is chosen from $e \in \{R, C, N\}$, where R, C, and N represent employment in regular jobs, employment in contingent jobs, and not in the labor force (NILF), respectively. The earnings of a female worker are given by:

$$y_f = \phi \cdot I_e$$

where ϕ denotes female human capital and I_e is an indicator function that equals 1 for $e = R$ or $e = C$ and 0 for $e = N$.

The evolution of human capital is a function of previous human capital, current employment status, skill levels, and age, expressed as:

$$\phi' = \mathcal{H}(\phi, s, e). \tag{1}$$

2.4 Preference

Single households derive utility from their consumption c and leisure l_g for $g \in \{m, f\}$. The utility function for a single individual is defined as:

$$u^S(c, l_g) = \frac{\left(\left(\frac{c}{\eta}\right)^{\omega} l_g^{1-\omega}\right)^{1-\sigma}}{1-\sigma}$$

where η denotes the consumption equivalence.

During fertile periods, a fecund married couple derives utility from family consumption, leisure, and a preference shock related to children. The utility function for a married couple is given by:

$$u^M(c, l_m, l_f, b, v) = \frac{\left(\left(\frac{c}{\eta}\right)^{\omega} l_m^{1-\omega}\right)^{1-\sigma}}{1-\sigma} + \frac{\left(\left(\frac{c}{\eta}\right)^{\omega} l_f^{1-\omega}\right)^{1-\sigma}}{1-\sigma} + b \cdot \nu_{(j,h)}$$

where l_m and l_f represent the leisure of the husband and wife, respectively. b is an indicator of the realization of a child in the current period. $\nu_{(j,h)}$ represents a preference shock related to children, which follows a Gumbel distribution, influenced by their age and childbirth history h. Note that the probability of having a child is not guaranteed even when attempted. Here, i is an indicator variable representing the intention to have a child. The indicator b is a function of this decision and their age, $b(i, j)$. Infecund couples no longer consider decisions regarding childbirth.

The leisure time for a single female is defined as:

$$l_f = L - \varpi_{S,e} - \kappa_{e_{-1},e}$$

where L represent the total available leisure time. $\varpi_{S,e}$ denotes the disutility of labor participation for a single female with employment type e, and $\kappa_{e_{-1},e}$ represents the cost of switching employment status, with e_{-1} and e indicating previous and current employment types, respectively.

For married females, leisure time is determined by:

$$l_f = L - \varpi_{M,e} - \kappa_{e_{-1},e} - \chi\psi \tag{2}$$

where ψ represents the additional cost of participation when there is a young child in the household.

Leisure time for men and retirees is fixed, denoted by $l_m = \bar{l}_m$ and $l_r = \bar{l}_r$, respectively.

2.5 Marriage Decision

In this model, single females make a decision to marry in a given period by comparing the utility values of remaining single versus getting married. The decision incorporates a joy shock, which is modeled to follow a Gumbel distribution:

$$F(\zeta_j) = \exp\left[-\exp\left\{-\left(\frac{\zeta_j - a_j}{d_j}\right)\right\}\right] \tag{3}$$

This joy shock is independent and identically distributed (iid) across each period and individual. The Gumbel distribution is characterized by location parameters a_j and scale parameter d_j. These parameters are calibrated to align with empirical data, specifically matching the marriage rates observed among cohorts 1985 and 1960.

Let S and M represent the utility values of remaining single and getting married in the next period, respectively. An individual decides to marry if the following condition is met:

$$M + \zeta \geq S$$

where ζ represents the joy shock experienced in the current period.

2.6 Pregnancy Decision

This decision (i) is based on the perceived value of having a child, denoted as $\nu_{(j,h)}$, where h represents the number of children the couple currently has. i is an indicator which takes value 1 if they intend to have a child and 0 if not.

The value of having a child, $\nu_{(j,h)}$, is assumed to follow a Gumbel distribution:

$$G(\nu_{(j,h)}) = \exp\left[-\exp\left\{-\left(\frac{\nu_{(j,h)} - \varrho_{(j,h)}}{\varsigma_{(j,h)}}\right)\right\}\right] \tag{4}$$

where $\varrho_{(j,h)}$ and $\varsigma_{(j,h)}$ are the location and scale parameters, respectively.

The couple decides to attempt conception if having a child increases expected utility given the realized shock.

Medical Fecundity: For a married couple not intending to have a child in a given period, the probability of being endowed with a child is zero. Conversely, if they intend to conceive, the likelihood of pregnancy is stochastic and dependent on age and fertility.

In households with an existing child, there is a probability, denoted as o_j, that the child leaves the household.

Consequently, the transition matrix for the state of having a child, when the couple does not intend to conceive, is given by:

$$\pi_j^n(\chi, \chi') = \begin{pmatrix} 1 & 0 \\ o_j & 1 - o_j \end{pmatrix} \tag{5}$$

In contrast, when the couple intends to have a child, the transition matrix is:

$$\pi_j^i(\chi, \chi') = \begin{pmatrix} 1 - q_j & q_j \\ o_j & 1 - o_j \end{pmatrix} \tag{6}$$

where q_j denotes the medical probability that one can get pregnant at age j.

Subjective Fecundity: In this model, agents base their decisions not on actual medical probability of conception, but rather on a subjective perception of fecundity, which they tend to overestimate. This overestimation is captured by the term φ_j, used here with a slight deviation from conventional notation. Therefore, the transition matrix used by agents to optimize their decisions, when they intend to conceive, is represented as:

$$\pi_{j,h}^s(\chi, \chi') = \begin{pmatrix} 1 - \varphi_j q_j & \varphi_j q_j \\ o_j & 1 - o_j \end{pmatrix} \tag{7}$$

When agents do not intend to conceive, the transition matrix remains the same as the medical one.

Infertility Treatment: In each period, agents are subject to a shock that may result in infertility. The state variable ξ indicates fertility, taking the value of 0 when agents are fertile and 1 when they become infertile. Once an agent becomes infertile, this status is permanent for the remainder of their life.

Upon becoming infertile, agents can no longer become pregnant via natural intercourse. However, they may still achieve conception through infertility treatments, by paying a fixed cost. The total cost of this treatment is denoted as Ω, and the specific out-of-pocket costs borne by households will be discussed subsequently.

When agents take infertility treatment, the probability of conception is ρ_j, and $q_j \geq \rho_j$ for all j. Assuming that a household opts for infertility treatment, the transition matrix for the presence of a young child in the household is given by:

$$\pi_j^f(\chi, \chi') = \begin{pmatrix} 1-\rho_j & \rho_j \\ o_j & 1-o_j \end{pmatrix}. \tag{8}$$

When households do not pursue infertility treatment, the transition matrix remains the same as that for natural conception.

2.7 Government

The government's role in the economy encompasses the collection of taxes and the operation of social insurance systems. Taxes are levied on various sources of income, including consumption, capital gains, and labor earnings. Additionally, the government administers a comprehensive social insurance system. This system includes provisions for public pensions and offers subsidies or insurance for infertility treatment.

Taxes: The economic framework includes three distinct types of taxation: taxes on consumption, capital income, and labor income. The consumption tax, denoted by τ_c, is implemented as a proportional rate that varies over time.

The tax on capital income is indicated by τ_a, and it affects the net return on capital, calculated as $R = 1 + (1 - \tau^a)r$, where r represents the interest rate.

The final category is the tax on labor income, characterized by a progressive structure with varying deductions based on marital status and income levels. Individuals may qualify for spousal deductions if their income falls below certain thresholds. These taxes are represented by $\tau_S^l(y_g)$ for single individuals and $\tau_M^l(y_m, y_f)$ for married individuals, considering their respective incomes.

Public Pension: The government administers a public pension system, denoted as p_g for each gender. Pension benefits commence at age $j = j^R + 1$.

Infertility Treatment: In cases where a married couple opts for infertility treatment, a portion of the associated costs is subsidized or insured by the government. The specifics of this arrangement are elaborated in Section 3. The out-of-pocket cost is given by:

$$\Delta_j = \iota \cdot \lambda_j \cdot \Omega \tag{9}$$

where ι is an indicator taking the value of 1 if infertility treatment is pursued and 0 otherwise. The term λ_j represents the age-specific copay rate for infertility treatment expenses, and Ω signifies the gross cost of the treatment. Δ_j denotes the total out-of-pocket expenditure for the household.

2.8 Recursive Formulation

There are 3 stages of life in this economy. The first stage is "young fecund" period. In this period, agents decide their level of consumption and employment status (if female), as well as make marriage decision (if single) and make an intention for having a child and for using infertility treatment (if married). The value of single female, single male, and married couple in this period are denoted as $S^f_{\mathcal{F}}$, $S^m_{\mathcal{F}}$, and $M_{\mathcal{F}}$, respectively.

The second stage is "young but not fecund" period. In this period, although they work, they no longer can get married nor have a child. The value of single female, single male, and married couple in this period are given as $S^f_{\mathcal{N}}$, $S^m_{\mathcal{N}}$, and $M_{\mathcal{N}}$, respectively.

The last stage is "retired" period. In this period, agents only determine their consumption level, i.e., the asset level next period. The value of single female, single male, and married couple in this period are given as $S^f_{\mathcal{R}}$, $S^m_{\mathcal{R}}$, and $M_{\mathcal{R}}$, respectively.

The expectation in the value function is on the attributes of the potential spouse if single, and on the shocks to fertility and children if married.

Young Fecund Single Female: A state vector of young fecund single female is given as $(j, s_f, a, \phi, e_{-1})$ where j denotes age, s_f skill, a asset, ϕ human capital, and e_{-1} previous employment state.

$$S^f_{\mathcal{F}}(j, s_f, a, \phi, e_{-1}) = \max_{c,a',e,m} \{u^S(c, l_f) + \beta[(1-m)ES^f_{\mathcal{F}}(j+1, s_f, a', \phi', e)$$
$$mEM_{\mathcal{F}}(j+1, s_m, s_f, a' + \tilde{a}', \phi', e, \xi, h, \chi', \nu)]\}$$

subject to

$$(1+\tau_c)c + a' = Ra + y_f - \tau^l_S(y_f)$$
$$a' \geq 0$$

Young Fecund Single Male: A state vector of young fecund male is given as (j, s_m, a) that represent age, skill, and asset, respectively. The expectation is for the expected value of joy shock on marriage after the next period and states of a potential spouse.

$$S^m_{\mathcal{F}}(j, s_m, a) = \max_{c,a',m}\{u^S(c, l_m) + \beta[(1-m)S^m_{\mathcal{F}}(j+1, s_m, a')$$
$$mEM_{\mathcal{F}}(j+1, s_m, s_f, a' + \tilde{a}', \phi', e, , \xi, h, \chi', \nu)]\}$$

subject to

$$(1+\tau_c)c + a' = Ra + y_m - \tau_S^l(y_m)$$
$$a' \geq 0$$

Young Fecund Married Couple: A state vector of young fecund couple is given as $(j, s_m, s_f, a, \phi, e_{-1}, \xi, h, \chi)$. ξ denotes the indicator of fertility and it takes 1 if she is fertile and 0 otherwise. h represents the history of childbirth, with the maximum 3. χ is an indicator which takes 1 if there is a small child in the household and 0 if not. ξ becomes to 0 with stochastic shock given their age. $h_{t+1} = h_t + 1$ given their states and intention of having a child stochastically. ν denotes the realized shock in the period.

$$\begin{aligned} M_{\mathcal{F}}(j, s_m, s_f, a, \phi, e_{-1}, \xi, h, \chi, \nu) = \max_{c, a', e, i, \iota} \{ & u^m(c, l_m, l_f, b, \nu) \\ & + \beta[(1 - b(i,j)) E M_{\mathcal{F}}(j+1, s_m, s_f, a', \phi', e, \xi, h, \chi', \nu') \\ & + b(i,j) E M_{\mathcal{F}}(j+1, s_m, s_f, a', \phi', e, \xi, h+1, \chi', \nu')]\} \end{aligned}$$

subject to

$$(1+\tau_c)c + a' + \Delta(\iota) = Ra + \sum_g y_g - \tau_M^l(y_m, y_f)$$
$$a' \geq 0$$

Young but Not Fecund Single Female: A state vector of young but not fecund female is given as $(j, s_f, a, \phi, e_{-1})$.

$$S_{\mathcal{N}}^f(j, s_f, a, \phi, e_{-1}) = \max_{c, a', e} \{ u^S(c, l_f) + \beta S_{\mathcal{N}}^f(j+1, s_f, a', \phi', e) \}$$

subject to

$$(1+\tau_c)c + a' = Ra + y_f - \tau_S^l(y_f)$$
$$a' \geq 0$$

Young but Not Fecund Single Male: A state vector of young but not fecund male is given as (j, s_f, a).

$$S_{\mathcal{N}}^m(j, s_f, a) = \max_{c, a'} \{ u^S(c, l_m) + \beta S_{\mathcal{N}}^m(j+1, s_f, a') \}$$

subject to

$$(1+\tau_c)c + a' = Ra + y_m - \tau_S^l(y_m)$$
$$a' \geq 0$$

Young but Not Fecund Married Couple: A state vector of young but not fecund married couple is given as $(j, s_m, s_f, a, \phi, e_{-1}, \chi)$.

$$M_{\mathcal{N}}(j, s_m, s_f, a, \phi, e_{-1}, \chi) = \max_{c,a',e}\{u^m_{\mathcal{N}}(c, l_m, l_f) + \beta M_{\mathcal{N}}(j+1, s_m, s_f, a', \phi', e, \chi')\}$$

subject to

$$(1+\tau_c)c + a' = Ra + \sum_g y_g - \tau^l_M(y_m, y_f)$$
$$a' \geq 0$$

Retired Single Female and Male: For gender $g \in \{M, S\}$, a state vector of single retiree is given as (j, a).

$$S^g_{\mathcal{R}}(j, a) = \max_{c,a'}\{u^S_{\mathcal{N}}(c, l_g) + \beta S^g_{\mathcal{R}}(j+1, a')\}$$

subject to

$$(1+\tau_c)c + a' = Ra + p_g$$
$$a' \geq 0$$

Retired Married Couple A state vector of retired married couple is given as (j, a).

$$M_{\mathcal{R}}(j, a) = \max_{c,a'}\{u^M_{\mathcal{N}}(c, l_m, l_f) + \beta M_{\mathcal{R}}(j+1, a')\}$$

subject to

$$(1+\tau_c)c + a' = Ra + \sum_g p_g$$
$$a' \geq 0$$

Note that since there is no stochastic death and agents marry someone of the same age, one member of a couple does not die before the other, and they both end their lives together in the final period.

3 Calibration/Estimation

The model is specifically calibrated to reflect the Japanese economy. Within this model, each period corresponds to one calendar year. The calibration process utilizes Japanese data, primarily sourced from the JPSC panel data. The cohorts selected for calibration include cohort 1960 and cohort 1985.[3] These cohorts are modeled to enter the economy at age 25 ($j = 1$), remain fertile until age 50 ($j^f = 26$), retire at age 65 ($j^R = 41$), and have a maximum lifespan of 85 years ($J = 61$).

3.1 Demographics

In this model, the maximum number of childbirths per household is capped at 3, hence $h \in \{0, 1, 2, 3\}$. The transition probabilities of an existing child leaving the household in the subsequent period (o_j) are calibrated to align with the observed data on married couples, both with and without dependent children (aged 0 to 5), as per the JPSC data. This calibration ensures the model accurately reflects the demographic patterns observed in Japan.

3.2 Human Capital

Male earnings, denoted as y_m, are modeled to follow a deterministic process that depends on their education and age.

For women, earnings are influenced by skill level, employment type, and accumulated human capital up to the current period, and are represented as $\phi' = \mathcal{H}(\phi, s, e)$. The JPSC data is employed to estimate this process, adhering to the methodology outlined by Guner et al. (2020). The functional form is given by:

$$\phi' = \mathcal{H}(\phi, s, e) = \exp[\ln(\phi) + \alpha_{j,e,s} I_e - \delta_s (1 - I_e)] \tag{10}$$

The initial value of female human capital is adjusted to align with the observed wage gender gap at the initial age of $j = 1$. The parameters $\alpha_{j,e,s}$ are selected to ensure that the wage profile of a skilled female in a specific employment type ($e = R$ or $e = C$) mirrors the wage profile of a male across all periods for regular and contingent type job for each.[4] The skill-specific depreciation rate δ_s is calibrated to replicate the change in the gender wage gap.

3.3 Preferences

The household equivalence scales, η, are based on the OECD's modified equivalence scale. The scale assigns a value of 1.0 for the first adult, an additional 0.5 for the second adult,

[3]"In the JPSC study, Cohort A consists of individuals born between 1959 and 1969, while Cohort E comprises those born between 1985 and 1989. Henceforth, these will be referred to as 'cohort 1960' and 'cohort 1985,' respectively.

[4]Although males in this model do not choose an employment type and their wages are deterministically determined for each skill and age, we utilize data from both JPSC and BSWS to obtain skill and employment-specific wage profiles for males.

and 0.3 for each subsequent child. The subjective discount factor, β, is set at 0.98. The parameters for risk aversion, σ, and the weight parameter, ω, are established at 3.0 and 0.5, respectively, aligning with ranges commonly utilized in the literature.[5]

An individual's total available time is normalized to 1.0. Parameters associated with the disutility of working are calibrated to match the observed profiles of female life-cycle employment status. These parameters include the participation cost by employment type and marital status $\varpi_{q,e}$, where q denotes marital status $q \in \{S, M\}$. Additionally, the model incorporates the extra participation cost associated with the presence of a young child aged between 0 to 5 years, denoted as ψ, and the cost of switching employment types, $\kappa_{e_{-1},e}$. Following the methodology outlined in Kitao and Mikoshiba (2022), disutility from switching employment types is only realized in cases of upward transitions: moving from contingent to regular employment or from NILF to either contingent or regular employment. There are eight parameters in total related to the disutility of work. These parameters are calibrated by minimizing the sum of the differences between model predictions and empirical data regarding employment rates among single and married females, aged 25 to 49, in both regular and contingent employment. As the experiments encompass two cohorts, the total number of parameters for modeling disutility is doubled.

Joy Shock on Marriage: The shock on marriage is age dependent and is drawn from 3. Thus, there are 52 parameters to be calibrated. These parameters are calibrated to match the marriage rate at each age from Census data. The results and the calibration strategy is in Appendix A.

Joy Shock on a Child: The shock on child depends on age and the history of childbirth. They are jointly estimated so that the model matches to data in terms of fertility at each age and the fraction of child's kinship and the results are on the tables in Appendix B.

3.4 Fecundity

Parameters for fecundity include medical probability for conception q and subjective overestimation φ.

Medical Fecundity: We calibrate the probability to get pregnant each age q_j using empirical results from Konishi et al. (2018). The paper examines the cumulative probability to get pregnant after after discontinuing contraception for certain period for several age groups. The exact probability for each age is summarized in Table 13 of Appendix D.

Subjective Fecundity: Given medical probability of conception, the degree of over-

[5]See Borella et al. (2022) and De Nardi et al. (2016) for risk aversion and Nardi et al. (2020) and French (2005) for weight parameter, for example.

estimation, denoted by φ_j for their own fecundity at each age is calculated. We use survey by HGPI as a proxy for subjective fecundity. We use the result of total respondents, consist of a half with female and another with male, as the decision would naturally made within a couple, not either of composite.[6] The highest response rate to the question item, "Until what age can a woman conceive through natural intercourse, after which it becomes rapidly more difficult," was 35.3% at age 35, with the next highest response rate at age 40 at 32.3%. We use these two ages, and assume that agents maximize utility under the belief where they can have a child until that age with a hundred percent, and the probability decreases linearly drop which reaches to 0 at the age of 49. Exact parameter values are described in Table 14 of Appendix D.

3.5 Infertility Treatment

The probability with which an agent becomes infertile is calibrated referring Trussell and Wilson (1985). The success rate of infertility treatment, specifically in the context of in vitro fertilization and embryo transfer, is derived from the detailed 2021 report by the Japan Society of Obstetrics and Gynecology, which provides extensive data on clinical outcomes in these areas.[7]

According to NPO Fine (2021) and the final report by Ministry of Health, Labour, and Welfare, the median of the cost of infertility treatment each year is about 500,000 yen and we use this value as a proxy for gross cost for infertility treatment each period.[8]

3.6 Government

The government related parameters are include taxes, public pension, and infertility treatment subsidy/insurance and they are calibrated as follow.

Taxes: There was no consumption tax until 1998, raised to 3% in 1989, 5% in 1997, 8% in 2014, and 10% in 2020. We assume that the current tax rate continues onwards. The capital tax rate is set to 35%.[9]

As mentioned in Section 2, the income tax is progressive and the function of marital status and each individual's income. For tax rate, the rate is the summation of the national tax whose range is 5% to 45% and local tax whose tax rate is constant 10%.

[6] For the research of intention on having child within a couple, see Doepke and Kindermann (2019).

[7] Japan Society of Obstetrics and Gynecology. "Clinical Performance of In Vitro Fertilization and Embryo Transfer in 2021." 2021. [Online]. Available: `https://www.jsog.or.jp/activity/art/2021_JSOG-ART.pdf`. [Accessed: 30-Nov-2023].

[8] There are various types of infertility treatments, including not only in vitro fertilization and intracytoplasmic sperm injection but also timed intercourse and ovulation induction. In this model, particularly costly procedures such as in vitro fertilization and intracytoplasmic sperm injection, which are forms of ART (Assisted Reproductive Technology), are introduced as choices for infertility treatment.

[9] See Hansen and İmrohoroğlu (2016)

The amount of deduction depends on individual's income and spouse's income. There are certain threshold at which the amount of deduction changes: as of 2022, there is fixed amount of basic deduction with 1.03 million yen, and spousal deduction starts to decline from 1.5 million yen until which they get maximum deduction of 380,000 yen and reaches to 0 at 2.01 million yen.[10]

Public Pension: The government offers public pension for retired agent. The amount of pension is different for male and female. We set $p_g = 80,000$ per month. Note that there is no accidental death, so that there is no case where either member of the couple die earlier than another.

Infertility Treatment Subsidy/Insurance

The subsidy for infertility treatment originally started in 2004, with a subsidy of 100,000 yen per year, an income limit of 6.5 million yen or less for the couple combined, and a payment period of two years. The subsidy was available to "legally married couples who have been diagnosed by a doctor as having no or very little chance of conceiving through treatment methods other than specified infertility treatment.

In 2006, the subsidy period was extended to five years, and in 2007, the subsidy became per treatment instead of per year, and the recipient could receive 100,000 yen per treatment and up to two treatments in one year. In addition, the income limit was raised to 7.3 million yen.

In 2009, the amount was expanded to 150,000 yen per treatment. In 2011, the number of payments was expanded to 3 times per year for the first year, and the total number of payments was increased to 10 times.

In 2015, the amount paid for initial treatment was expanded from 150,000 yen to 300,000 yen.[11] In 2016, an age limit was established, and if the wife is 43 years old or older, she is no longer eligible for the benefit. In addition, if the wife is under 40 years of age, the subsidy is limited to a total of six times, and if the wife is between 40 and 43 years of age, the subsidy is limited to a total of three times.[12] The restrictions on the number of subsidies per year and the total period of subsidies were abolished. The amount was relaxed to less than 9.05 million yen for a married couple combined from 2019.

In April 2022, insurance coverage for infertility treatment has begun, and all people enrolled in the National Health Insurance system, regardless of income, are partially reimbursed by the insurance. Eligible women must be under 43 years of age at the start of treatment. In addition, as for the number of times of coverage, if a woman is under

[10] For detailed discussion about income tax deduction, see Yokoyama and Kodama (2016). Kitao and Mikoshiba (2022) examines the effect on female labour force participation by changing policy of the deduction.

[11] In 2015, infertility treatment for male also became the target of the subsidy.

[12] Reasons for the age limit include the fact that after the age of 43, less than 5% of IVF cases result in births.

40 years of age, she can receive coverage up to a total of six times per child, and if she is between 40 and 43 years of age, she can receive coverage up to a total of three times per child.[13]

Table 2: Parameters of the Model

Parameter	Description	Value/Source
j^f	Last fecund age	26 (50 years old)
j^R	Retirement age	41 (65 years old)
J	Maximum age	61 (85 years old)
$\pi_g(s, s')$	Degree of assortative mating	JPSC data
y_m	Men's earning	JPSC data
β	Subjective discount factor	0.98
σ	Risk aversion parameter	3.0
ω	Leisure/consumption weight	0.5
η	Equivalence scale	OECD
q	Medical fecundity	Konishi et al. (2018)
φ	Subjective fecundity parameter	See text and Appendix D
ρ	Success rate of infertility treatment	See text
Ω	Infertility treatment cost	500,000 yen
$\tau^l_q(y_g)$	Labor income tax	Progressive (see text)
τ^c	Consumption tax rate	3-10%
τ^a	Capital income tax rate	35%
r	Interest rate	2%
λ	Infertility treatment co-payment rate	See text

[13]The transition of subsidy/insurance for infertility treatment is summarized in the 15 of Appendix E

Table 3: Estimated Parameters of the Model

Parameter	Description	Value
1960 cohort		
$\varpi_{q,e}$	Participation cost	$0.382(\varpi_{S,R})$, $0.014(\varpi_{S,C})$
		$0.176(\varpi_{M,R})$, $0.160(\varpi_{M,C})$
ψ	Time cost (a small child)	0.260
$\kappa_{e-1,e}$	Switching cost	$0.291(\kappa_{N,R})$, $0.171(\kappa_{N,C})$, $0.293(\kappa_{C,R})$
δ_s	Human capital depreciation rate	$0.021(\delta_L)$, $0.043(\delta_H)$
1985 cohort		
$\varpi_{q,e}$	Participation cost	$0.293(\varpi_{S,R})$, $0.006(\varpi_{S,C})$
		$0.144(\varpi_{M,R})$, $0.092(\varpi_{M,C})$
ψ	Time cost (a small child)	0.302
$\kappa_{e-1,e}$	Switching cost	$0.252(\kappa_{N,R})$, $0.150(\kappa_{N,C})$, $0.259(\kappa_{C,R})$
δ_s	Human capital depreciation rate	$0.016(\delta_L)$, $0.044(\delta_H)$
a_j	Scale parameters (marriage)	Appendix A
d_j	Location parameters (marriage)	Appendix A
$\varrho_{(j,h)}$	Scale parameters (childbirth)	Appendix B
$\varsigma_{(j,h)}$	Location parameters (childbirth)	Appendix B
$\alpha_{j,e,s}$	Human capital accumulation rate	Appendix C

4 Numerical Analysis

In this section, we discuss the numerical results obtained from our model. We begin by examining the baseline model, with a particular focus on the patterns of female labor force participation and fertility rates. Following this, we conduct three experimental simulations to evaluate their impact on both labor participation and fertility rates. It is noteworthy that the effects observed in the experiments are relatively modest for the 1960 cohort. This shall be attributed to the fact that the decision of cohort 1960 to have a baby at the baseline was already made earlier, so that fewer agents were significantly affected by the change in beliefs and free infertility treatment. Consequently, detailed graphical representations of the changes induced by these experiments for the 1960 cohort are provided in Appendix F.

4.1 Fertility Decisions and Employment in the Baseline Model

Figure 4 displays the cumulative fertility rate in the baseline model alongside data from the IPSS for both the 1960 and 1985 cohorts. As outlined in Sections 3 and Appendix B, the fertility rates are analytically calibrated and precisely aligned, allowing the model to closely match the fertility profiles observed in the data. Figure 4 reveals that the 1960 cohort exhibits higher fertility rates and a greater number of children in the early stages of life.

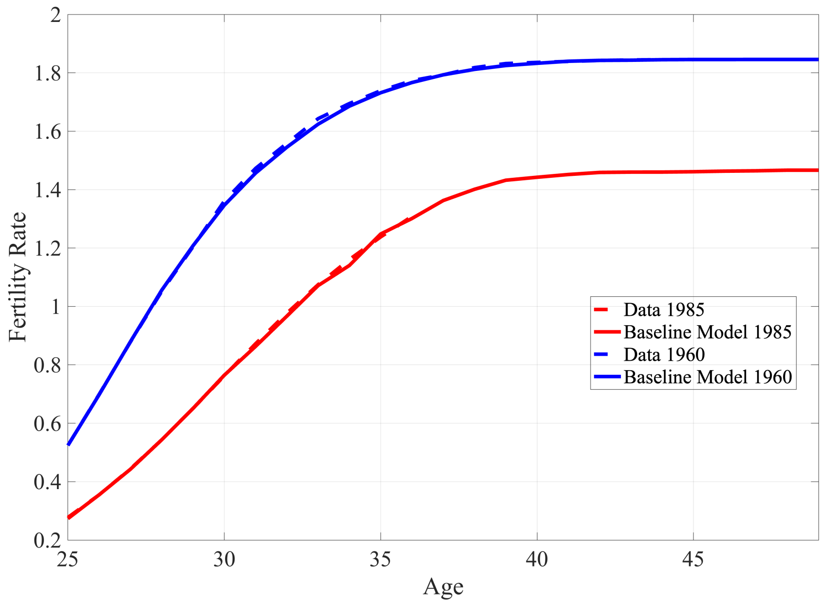


Figure 4: Cumulative Fertility Rate Comparison for 1960 and 1985 Cohorts

Figure 15 illustrates the female labor force participation rates in the baseline model compared with data for the 1960 and 1985 cohorts. Figure 5 provides an overview of the overall employment rates for both cohorts, with the 1985 cohort demonstrating a higher employment rate.

Figure 6(b) presents the employment types for the 1960 cohort in the model and the data. A notable decline in regular employment types is observed between ages 25 to 30, alongside a monotonic increase in contingent job types.

In contrast, the employment patterns for the 1985 cohort differ significantly. Figure 6(a) compares the employment types in the model and data for the 1985 cohort. This cohort maintains a higher rate of regular employment across all ages, with the disparity widening over time.

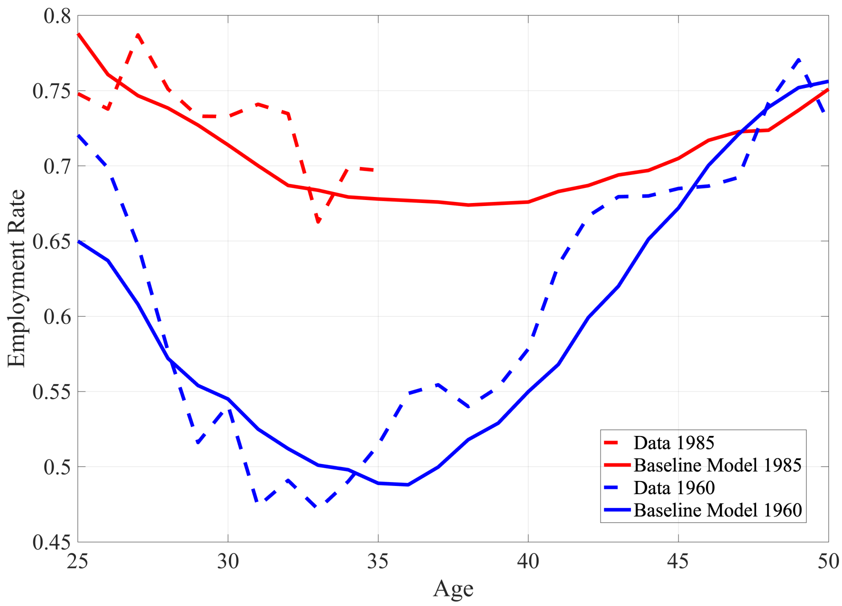
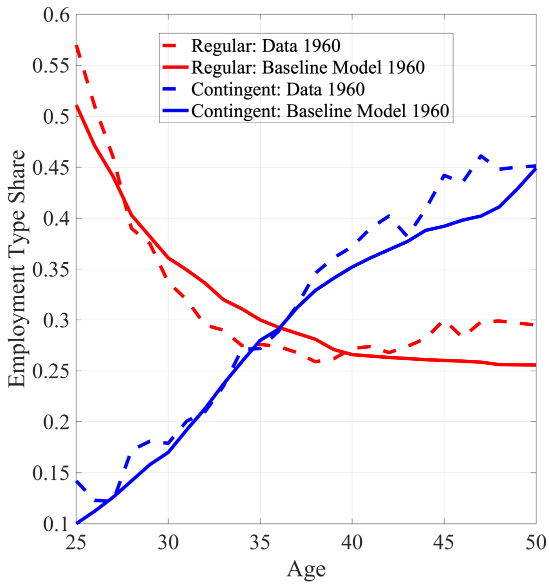
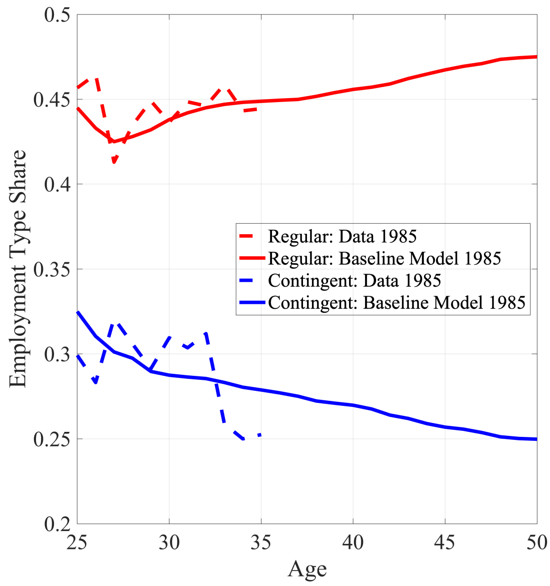


Figure 5: Employment Rate



(a) Employment Share for Cohort 1960



(b) Employment Share for Cohort 1985

Figure 6: Employment Type

4.2 Belief Update: Subjective to Medical Fecundity

The first experiment involves updating subjective fecundity beliefs to align with medical fecundity knowledge, denoted by $\varphi_j = 1, \forall j$, through sex education targeting young individuals. Table 4 illustrates the resultant changes in fertility rate, employment rate, and the distribution of regular and contingent job types.

Following the update, agents no longer harbor optimistic views about their fecundity, recognizing a lower probability of pregnancy in the late life stages. The second column of Table 4 details the fertility rate changes for the 1960 and 1985 cohorts. The fertility rates increased by 0.000(+) and 0.049 for the 1960 and 1985 cohorts, respectively.

Figure 7 depicts fertility rate changes across all ages. Notably, fertility increases in early life stages and decreases in later stages compared to the baseline model. The disparity between the baseline and counterfactual is pronounced until around age 35, after which it diminishes. Overall, the fertility rate experiences a net increase.

The second to fourth columns of Table 4 present the changes in employment status resulting from the experiment. Similar to the fertility rate, the employment profile for the 1960 cohort remains unchanged. However, for the 1985 cohort, a decrease in employment rate and the share of regular job types and an increase in the share contingent job types are observed

Figure 8 shows age-specific changes in employment. Figure 8(a) illustrates the employment rate changes for the 1985 cohort, revealing a uniform downward shift across all ages. This trend is attributed to the updated fecundity beliefs, leading agents to prioritize childbearing in earlier life stages and, consequently, to opt out of the labor force sooner. Figure 8(b) displays the shifts in regular and contingent job types. Both a decrease in regular jobs and an increase in contingent jobs are observed, with these changes paralleling the overall employment rate trend. With the decrease in employment rate, the average income at age 45 decreases by 4.2%.

Table 4: Change in Fertility and Employment Rates with Belief Update

	Fertility	Employment	Regular	Contingent
1960 cohort	0.000(+)	0.000(−)	0.000(−)	0.000(+)
1985 cohort	+0.049	−0.16%	−0.87%	+0.62%

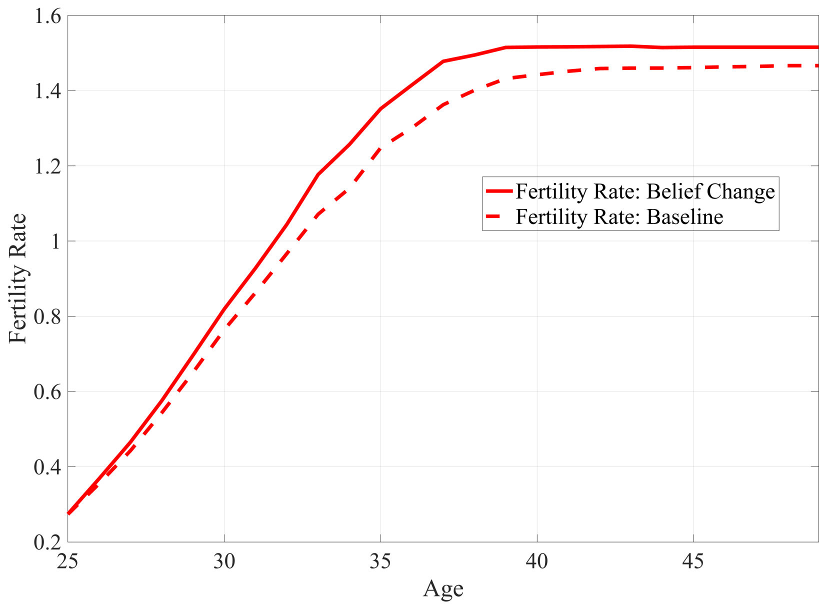
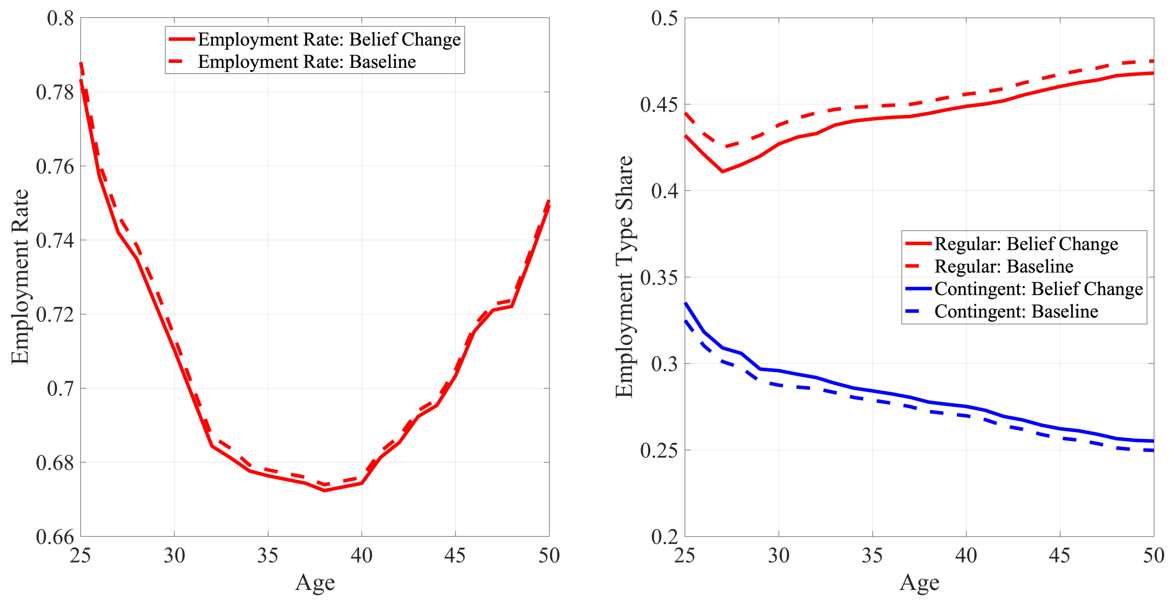


Figure 7: Fertility Rate



(a) Employment Rate

(b) Employment Share

Figure 8: Female's Employment Status with Belief Update

4.3 Policy Experiment: Introduction of Free Infertility Treatment

The second experiment assesses the impact of introducing free infertility treatment. The baseline model's out-of-pocket expenses for infertility treatment are outlined in Equation

9, with $\lambda = 0$ in this experiment. The effects of this policy change are summarized in Table 5.

As the same in the first experiment, the first column of Table 5 shows the fertility rate changes due to the policy: a 0.000(+) and 0.021 change for the 1960 and 1985 cohorts, respectively. The 1960 cohort exhibits a subtle effect on fertility, likely due to their earlier childbearing decisions in the baseline model, which reduces the demand for infertility treatments compared to the 1985 cohort.

For the 1985 cohort, a more effect on fertility rates is observed, with an increase by 0.021. This cohort tends to delay childbirth, increasing the demand for infertility treatments as fecundity decreases with age. Figure 9 illustrates age-specific changes in fertility rates. Unlike the first experiment, where early-stage childbirth decisions increased, this experiment shows an increase in late-stage childbirth. This shift can be attributed to the fact that infertility treatments primarily target older individuals, thus the policy change more significantly impacts them.

Regarding employment-related effects, there are negligible changes for the 1960 cohort. For the 1985 cohort, the employment rate and the share of regular type jobs decreased by 0.08% and 0.72%, respectively, while the share of contingent type jobs increased by 0.31%.

Figure 10 displays the age-specific changes in employment rates. No significant changes are observed in the early life stages, but employment rate and the share of regular type jobs begin to decrease from around age 31. With the decreases 1.1% of decline in the average income at age 45 is observed. The change in income is relatively smaller than that of experiment one, due to that timing of the leave from employment.

Table 5: Changes in Fertility and Employment Rates with Free Infertility Treatment

	Fertility	Employment	Regular	Contingent
1960 cohort	0.000(+)	0.000(−)	0.000(−)	0.000(+)
1985 cohort	+0.021	−0.080%	−0.72%	+0.31%

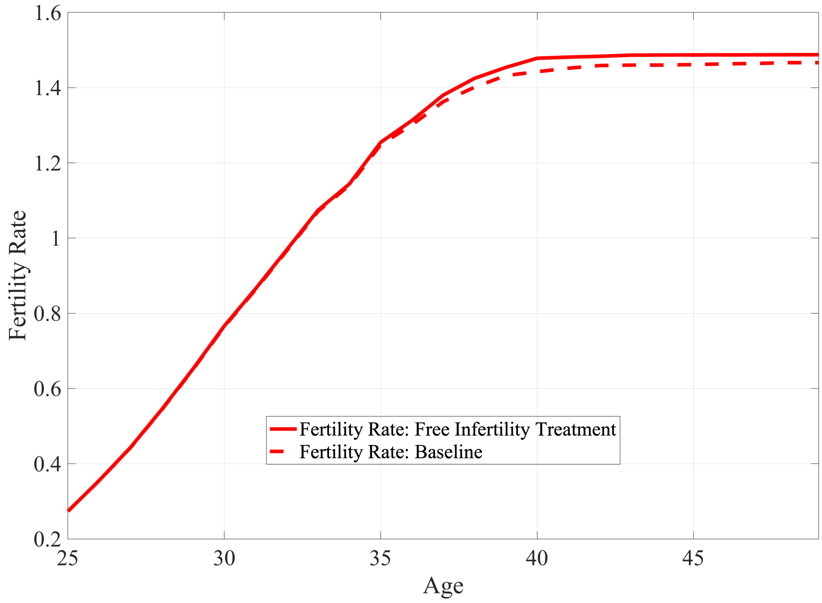
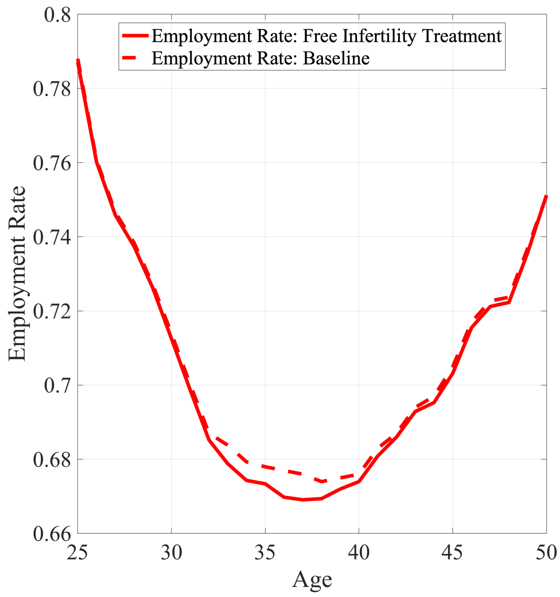
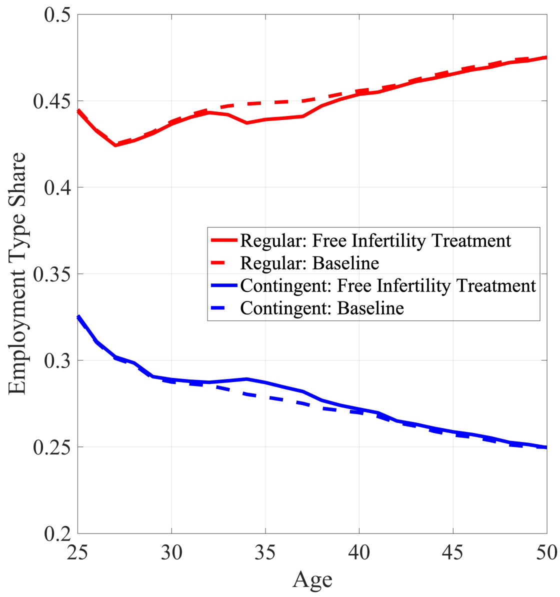


Figure 9: Fertility Rate



(a) Employment Rate



(b) Employment Share

Figure 10: Employment Changes by Age with Free Infertility Treatment

4.4 Combined Belief Update and Free Infertility Treatment

The final experiment integrates the first and second experiments, encompassing both the belief update regarding fecundity and the introduction of free infertility treatment. Table 6 summarizes the combined effects of these experiments.

Similar to the previous experiments, the impact on the 1960 cohort is minimal, with negligible changes in fertility rate, employment rate, and the shares of regular and contingent job types.

In contrast, the 1985 cohort exhibits effects more akin to those observed in the first experiment. The changes in fertility rate, employment rate, share of regular job type, and share of contingent job type are observed.

As can observed in Figure 11 and Figure 12 the degree and the shape of change is quite similar to that of the first experiment, with 0.051 increase in fertility, 0.2% decrease in employment rate, 0.91% decline in the share of regular type job, and 0.78% increase in the share of regular type job. The belief update leads agents to attempt childbearing earlier in life, which in turn diminishes the impact of free infertility treatment. Similar to experiment one, the average income at age 45 decreases by 4.4%.

Table 6: Changes in Fertility and Employment Rates with Combined Belief Update and Free Infertility Treatment

	Fertility	Employment	Regular	Contingent
1960 cohort	0.000(+)	0.000(−)	0.000(−)	0.000(+)
1985 cohort	+0.051	−0.21%	−0.91%	+0.78%

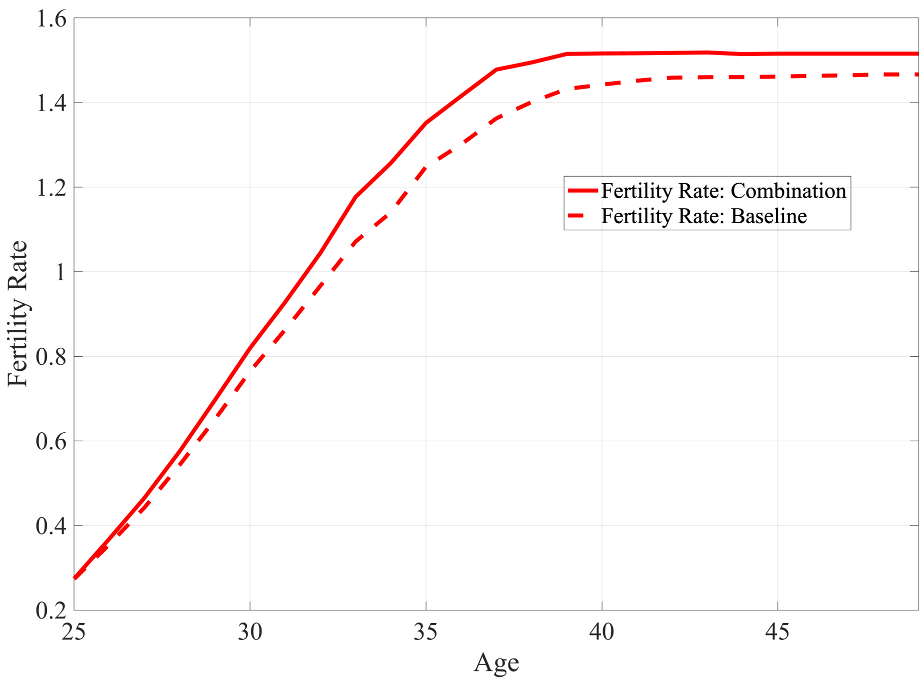
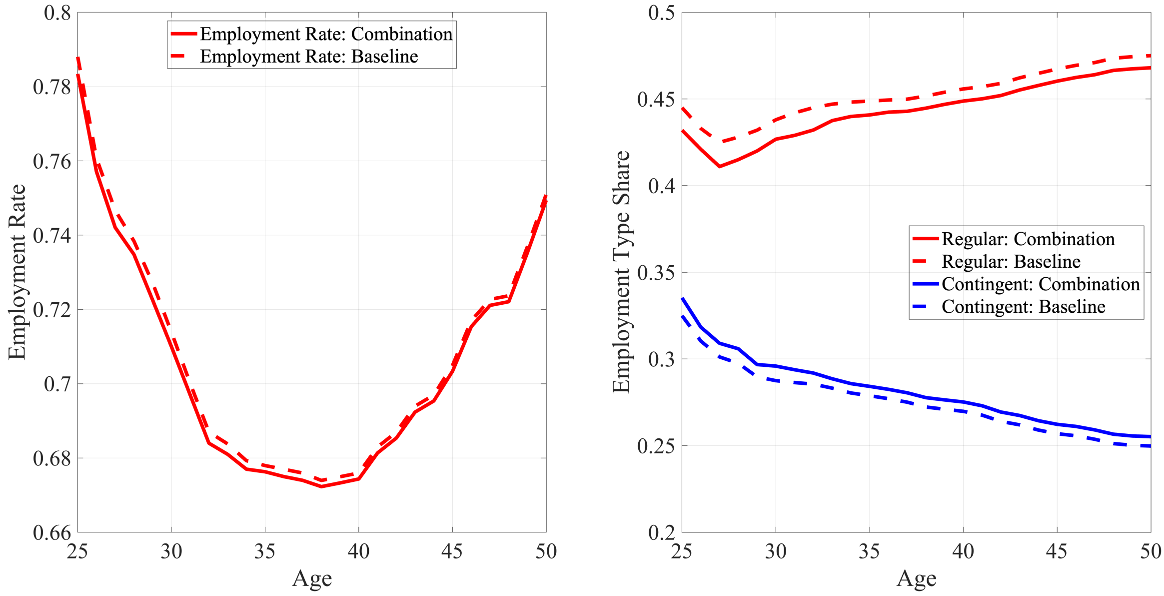


Figure 11: Fertility Rate



(a) Employment Rate

(b) Employment Share

Figure 12: Employment Changes with Combined Experiment

4.5 Welfare

The first experiment aimed at addressing distortions within the model, specifically reconciling the discrepancy between the belief transition matrix and the actual transition matrix. This alignment led to a notable increase in welfare, quantified by a 1.02% rise in consumption equivalence. The improvement suggests that reducing informational or belief-based distortions in the economic model can significantly enhance welfare by aligning expectations more closely with reality.

In the second experiment, while welfare indeed increased, evidenced by a 0.79% rise in consumption equivalence, this experiment highlighted a crucial aspect of the government's fiscal policy. The model assumed that the government's budget constraint was not balanced, implying that the welfare gain was partly due to this fiscal imbalance. It suggests that if new taxes or other fiscal measures were introduced to balance the budget, the welfare outcomes could potentially differ. This nuance underscores the complex relationship between fiscal policy and welfare, indicating that the sustainability of welfare gains may require careful consideration of fiscal balance.

The third experiment synthesized the insights from the first two, exploring the cumulative impact on welfare. Mirroring the fertility and employment outcomes observed in Experiment 1, this comprehensive approach yielded a 1.06% uplift in consumption equivalence. This result highlights the synergistic effects of addressing both informational distortions and fiscal policy interventions on enhancing welfare.

Table 7: Welfare Increases from Counterfactual Experiments

Experiment	Welfare Increase (%)
Experiment 1	+1.02%
Experiment 2	+0.79%
Experiment 3	+1.06%

5 Conclusion

In light of the aging population and delayed childbearing observed in advanced couturiers, with Japan being a primary example, this paper explores the dichotomy between the biologically optimal and socially optimal timings for childbirth. Delays in childbearing are associated with early-life human capital accumulation and potentially higher overall wages.

A quantitative life-cycle model incorporating endogenous childbirth decisions and calibrated for the Japanese economy serves as the foundation of this study. Three experimental scenarios were constructed to assess the impacts on fertility rates and employment choices among individuals born in 1960 and 1985.

The findings suggest that updating young individuals' perceptions of fecundity could potentially elevate fertility rates by 0.049, with a more pronounced effect observed in the 1985 cohort. This cohort-specific variation is attributable to the higher education levels in recent generations, which correlate with later marriages and childbirth.

A significant outcome of this research is the analysis of policy changes in infertility treatment. Under the experimental condition where infertility treatment is fully subsidized by the government, there was an observed increase of 0.021 in the fertility rate for the 1985 cohort, alongside a slight decrease in employment rates.

The final experiment combined elements from the previous two, yielding results akin to the first experiment: an increase in fertility rates and a decrease in employment rates by 0.051 and 0.002, respectively. This suggests that earlier childbearing decisions, influenced by the updated understanding of fertility, could reduce the demand for infertility treatments.

While disseminating information about medical fertility through sex education presents challenges, the consequences of delayed childbearing are significant at both individual and macroeconomic levels.

The implications of subsidizing fertility treatments and the potential externalises they might generate for the nation and its citizens remain unclear. Additionally, the reasons behind reduced childbirth may extend beyond medical factors, such as decreased frequency of sexual intercourse. It is also critical to acknowledge that infertility is not exclusively a female issue but also significantly influenced by male factors. These aspects warrant further investigation in future research.

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Appendix A Marriage Decision

The parameters of Gumbel distribution for the marriage decision is computed analytically. Let $x_1, x_2, \ldots$ be an each state and $\mathbf{x}$ be the set of all possible state for single agent. The value of being single and getting married next period are given by $S(x_i)$ and $M(x_i)$, and the fraction of agent with the state in the economy be $mea(x_i)$. Remember that the value of getting married is iid, and follows gumbel distribution. Then, given the proportion of agents that get married at the age, m_j, we have

$$1 - m_j = exp\left\{-exp\left[-\frac{(\sum_{x_i} mea(x_i)S(x_i) - \sum_{x_i} mea(x_i)M(x_i) - a)}{d}\right]\right\} \tag{11}$$

Then, we compute a and d so that they the model matches to the data for two cohorts. For each age j, let m_j^{1960} and m_j^{1985} be the fraction of getting married. Then we have

$$\frac{ln[-ln(1 - m_{1960})]}{ln[-ln(1 - m_{1985})]} = \frac{\mathbf{S}_{1960} - \mathbf{M}_{1960} - a}{\mathbf{S}_{1965} - \mathbf{M}_{1985} - a}. \tag{12}$$

We now can compute the value for each j and let that be $\hat{a}$. Then, we have

$$d = -\frac{\mathbf{S}_{1960} - \mathbf{M}_{1960} - \hat{a}}{ln(-ln(1 - m_{1960})} \tag{13}$$

and let $\hat{d}$ be that value.

Then, the fraction of those who stay single with a state x_i is given by

$$1 - m(x_i) = exp\left\{-exp\left[-\frac{(S(x_i) - M(x_i) - a)}{d}\right]\right\} \tag{14}$$

As the model is dynamic, unlike (Greenwood, Guner, and Marto 2023), the expectation of the shock is included in the next year's utility so that the model is recursive. The calibration strategy is as follows:

1 With an arbitrary guess for each parameter $\theta_0 = \{a_0, d_0\}$, solve the model by backward induction using them.

2 Compute the decision problems, and obtain the distribution in each state.

3 Calculate the parameters based on the results.

4.1 Check if it coincides with the guess, i.e.,

$$d(\theta_j, \theta_{j+1}) \gtreqless \epsilon$$

where $d()$ is an arbitrary metric function and ϵ denotes the error tolerance parameter. If

$$d(\theta_j, \theta_{j+1}) > \epsilon,$$

update the parameters θ_1 and take the same procedure.

4.2 If

$$d(\theta_j, \theta_{j+1}) < \epsilon,$$

θ_j is represents the pinned down parameter set.

The parameters for each age is described in the following table:

Table 8: Gumbel Distribution Parameters for Joy Shock on Marriage

Age	Scale parameter	Location parameter	Age	Scale parameter	Location parameter
25	6.014	−1.231	38	3.998	−3.795
26	6.494	−0.762	39	3.435	−4.001
27	6.494	−0.417	40	2.988	−4.075
28	6.634	−0.201	41	2.626	−4.230
29	6.707	−0.112	42	2.377	−4.544
30	6.714	−0.151	43	2.207	−5.120
31	6.654	−0.317	44	2.112	−5.712
32	6.527	−0.611	45	2.092	−5.991
33	6.334	−1.033	46	2.142	−6.121
34	6.058	−1.578	47	2.092	−6.313
35	5.684	−2.252	48	2.087	−6.441
36	5.212	−2.918	49	1.998	−6.501
37	4.641	−3.436			

Appendix B Childbirth Decision

The calibration strategy is as the same with the decision of marriage given in Appendix A. The parameters for each age and each childbirth history are given in the following tables.

Table 9: Gumbel Distribution Parameters for Joy Shock on Child $h = 0$

Age	Scale parameter	Location parameter	Age	Scale parameter	Location parameter
25	4.411	−1.07	38	2.689	−2.093
26	4.004	−1.033	39	2.547	−2.341
27	3.675	−0.997	40	2.353	−2.701
28	3.424	−0.964	41	2.131	−3.283
29	3.253	−0.932	42	1.789	−4.181
30	3.154	−0.902	43	1.421	−5.329
31	3.125	−0.875	44	1.067	−6.212
32	3.142	−0.895	45	0.834	−6.765
33	3.068	−1.012	46	0.623	−7.035
34	3.028	−1.219	47	0.526	−7.314
35	2.974	−1.504	48	0.523	−7.638
36	2.920	−1.750	49	0.641	−8.020
37	2.805	−1.939			

Table 10: Gumbel Distribution Parameters for Joy Shock on Child $h = 1$

Age	Scale parameter	Location parameter	Age	Scale parameter	Location parameter
25	3.621	−1.342	38	1.933	−2.091
26	3.487	−1.361	39	1.875	−2.552
27	3.353	−1.388	40	1.805	−3.233
28	3.209	−1.403	41	1.724	−4.106
29	3.065	−1.420	42	1.631	−4.984
30	2.918	−1.456	43	1.526	−5.822
31	2.768	−1.461	44	1.412	−6.618
32	2.615	−1.482	45	1.281	−7.282
33	2.458	−1.513	46	1.141	−7.794
34	2.310	−1.566	47	0.991	−8.161
35	2.184	−1.642	48	0.826	−8.379
36	2.079	−1.735	49	0.651	−8.451
37	1.995	−1.851			

Table 11: Gumbel Distribution Parameters for Joy Shock on Child $h = 2$

Age	Scale parameter	Location parameter
25	2.112	−3.433
26	2.046	−3.666
27	1.975	−3.913
28	1.896	−4.172
29	1.810	−4.445
30	1.716	−4.731
31	1.614	−5.016
32	1.507	−5.221
33	1.405	−5.333
34	1.311	−5.351
35	1.223	−5.299
36	1.143	−5.323
37	1.075	−5.445

Age	Scale parameter	Location parameter
38	1.021	−5.666
39	0.980	−5.986
40	0.954	−6.338
41	0.938	−6.653
42	0.904	−6.932
43	0.850	−7.191
44	0.774	−7.521
45	0.682	−7.935
46	0.601	−8.425
47	0.534	−8.920
48	0.484	−9.408
49	0.450	−9.891

Appendix C Human Capital Accumulation/Depreciation

As mentioned in 3, the annual human capital accumulation process follows that of men based on education and employment type. Initial human capital is calibrated to match the wage of 25 years old for each state, and that is lower than that of men so that we can observe the gender gap in the wages. The data is brought from Basic Survey on Wage Structure (BSWS) conducted by Ministry of Health, Labour, and Welfare.

Table 12: Annual Human Capital Accumulation Rate

High Education		
Age	Regular	Contingent
25 - 29	0.029	0.009
30 - 34	0.028	0.002
35 - 39	0.016	0.012
40 - 44	0.015	−0.013
45 - 49	0.018	0.01
50 - 54	0.017	0.016
55 - 59	−0.021	−0.015
60 - 64	−0.024	−0.018

Low Education		
Age	Regular	Contingent
25 - 29	0.012	0.007
30 - 34	0.016	0.008
35 - 39	0.013	0.007
40 - 44	0.010	0.009
45 - 49	0.046	0.014
50 - 54	0.012	−0.024
55 - 59	−0.03	−0.039
60 - 64	−0.02	−0.012

Appendix D Fecundity Parameter

Medical fecundity, i.e., the probability to get pregnant when they intend to at each age is calibrated using Konishi et al. (2018), and summarized in the following table. The paper examines until age 44, so that we assume that it decreases and reaches to 0 at age of 49 linearly.

Table 13: Probability of conception 12 months after discontinuing contraception by women's age

Age	Probability of conception q_j
25 - 26	0.80
27 - 29	0.69
30 - 32	0.66
33 - 35	0.53
36 - 38	0.48
39 - 44	0.31

Source: Konishi et al. (2018)

The subjective fecundity parameters are calibrated using survey by HGPI.

Table 14: Subjective fecundity parameter by age

Age	Subjective fecundity parameter φ_j
25	1.250
26	1.250
27	1.449
28	1.449
29	1.449
30	1.515
31	1.515
32	1.515
33	1.887
34	1.887
35	1.887
36	1.935
37	1.785

Age	Subjective fecundity parameter φ_j
38	1.638
39	2.303
40	2.305
41	2.302
42	2.304
43	2.306
44	2.303
45	2.306
46	2.301
47	2.306
48	2.258
49	1.000

Source: "The Public Opinion Survey on Child-Rearing in Modern Japan (Final Report)", Health and Global Policy Institute, March 4, 2022.

Appendix E Subsidy/Insurance for Infertility Treatment

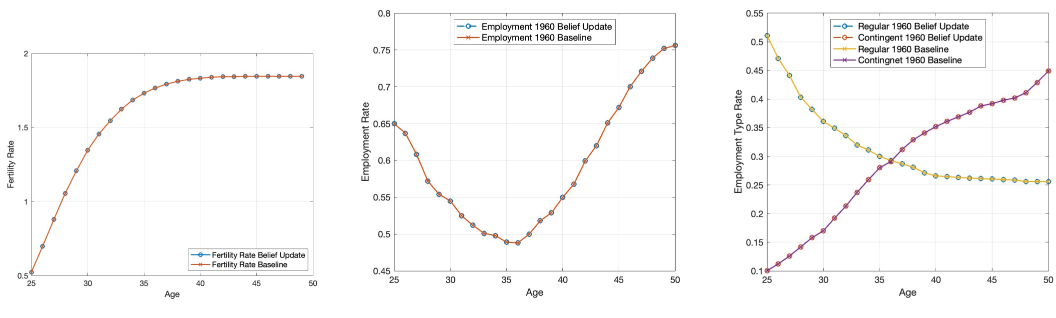
Table 15: Transition subsidy/insurance for infertility treatment in Japan

Year	Limit				Amount
	Income	Age	Number of times per year	In total	
2004	6.5 mil yen	NA	Each year for two years	NA	100,000yen
2006	6.5 mil yen	NA	Each year for five years	NA	100,000yen
2007	7.3 mil yen	NA	2, for five years	NA	100,000yen
2009	7.3 mil yen	NA	2, for five years	NA	150,000yen
2011	7.3 mil yen	NA	3, for the first year	10	150,000yen
			2, for second year onwards		
2015	7.3 mil yen	NA		10	300,000yen (first)
					150,000yen (onwards)
2016	7.3 mil yen	-40	NA	6	
		40-43		3	
2019	9.05 mil yen				
2022	NA		NA		30% of cost

Note: The blank part indicates the same as the last change.

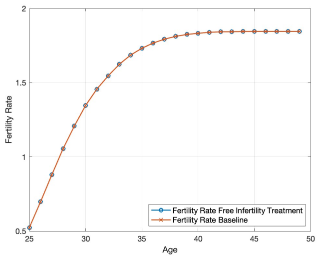
Appendix F Results of 1960 Cohort

The following figures shows the results of the experiments for 1960 cohort. As observed, there is very slight change for fertility rate, employment rate, and employment share.

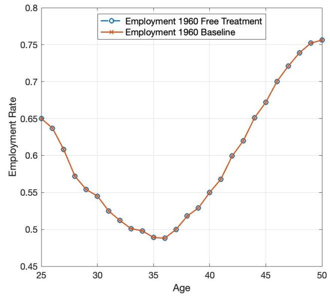


(a) Fertility Rate (b) Employment Rate (c) Employment Share

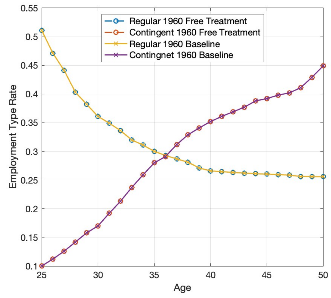
Figure 13: Effect of Belief Update for Cohort 1960



(a) Fertility Rate

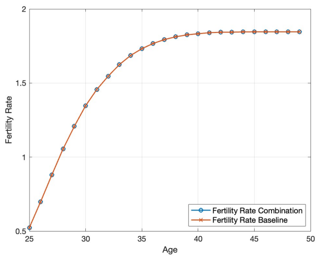


(b) Employment Rate

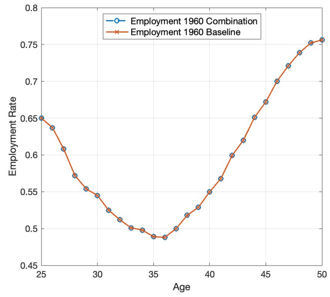


(c) Employment Share

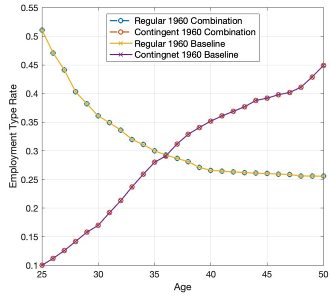
Figure 14: Effect of Free Infertility Treatment for Cohort 1960



(a) Fertility Rate



(b) Employment Rate



(c) Employment Share

Figure 15: Effect of Combined Experiment Cohort 1960