Aging and Declining Trends in the Real Interest Rate and Inflation: The Role of Aging

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Motivation

- Japan's labor force is rapidly aging.
  - The *average age* of its workforce has risen roughly by three years.
  - The *level* of the labor force has been falling.
- The Japanese economy has experienced a prolonged slowdown in growth.
  - The real interest rate and the inflation rate have also followed gradual declining trends.
- Timing of the start of deflation and the declining working age population coincides.
  - Is this causal or mere coincidence?
  - We explore a causal link between the labor force aging and the low-frequency declining trends in important macroeconomic variables over the last three and half decades.

Model

- Declining fertility (or participation) rate is the only exogenous driver of dynamics.
- A search/matching framework that incorporates heterogeneities in the worker's age and skill:
  1. the empirical regularity that older workers are more productive than young workers.
     - A worker enters the labor force as a young worker with no experience.
     - Experienced workers enjoy higher productivity.
  2. the unique feature of the Japanese labor market: the importance of the firm specific skill.
     - The (old) worker's skill associated with his experience in the labor market tends to be firm specific.
     - When an old worker indeed loses his experience premium, he needs to look for a job in the market where young (inexperienced) workers also look for their entry-level jobs.

Related Literature

- New Keynesian Search/Match: Krause et al. (2008); Trigari (2009); Esteban-Pretel and Fraglia (2010)
  - Search/Match with Demographics: Esteban-Pretel and Fujimoto (2012); Cheron et al. (2013)
- There are several studies which relate aging and the declining real interest rates or economic growth.
  - Saving for retirement: Eggertsson and Mehrotra (2014); Ferrero and Carvalho (2014); Fujiwara and Teranishi (2008)
  - Demographic Change and Labor Market Reallocation: Katagiri (2012)
  - Political Economy through FTPL: Katagiri, Konishi and Ueda (2014)
  - Financial Frictions: Ikeda and Saito (2014)
  - Empirical Studies: Yoon, Kim and Lee (2014); Juiselius and Takats (2015); Feyer (2007)

Saving for Retirement

- Eggertsson and Mehrotra (2014): the secular stagnation hypothesis posits that a decline in the birth rate eventually leads to the oversupply of saving and decrease in aggregate demand, resulting in the lower real interest rate.
- Ferrero and Carvalho (2014): persistent deflation in Japan is related to aging of the economy through consumption/saving heterogeneity under a longer life expectancy (saving for the retirement).
- Fujiwara and Teranishi (2008): real interest rates decline as more older people in the economy in the new Keynesian OLG model.

- We deliberately abstract the consumption/saving heterogeneity.
  - all sources of incomes are pooled and consumed equally.
  - to highlight the key mechanism of our paper: skill (productivity) heterogeneity in the workforce.
  - to avoid modeling social security, which is indispensable in evaluating saving for retirement.

Empirical Studies

- Yoon, Kim and Lee (2014): higher population growth leads to higher inflation.
- Juiselius and Takats (2015): a negative correlation between the share of working age population and the inflation rate.
- Feyer (2007) provides the strong empirical evidence, supporting the main idea of this paper.
  - Strong correlation between the age structure of the workforce and aggregate productivity growth with cross-country panel regression.
    - Poterba (2004): no significant relationship between demographic variables and real rate of return in the US.
  - "While emphasizing the importance of demographics, this paper is agnostic as to the mechanisms through which demographic change and productivity are related."

Bean (2004): Aging and Monetary Policy

1. Demographic developments represent a macroeconomic shock, which may lead to abrupt movements in asset prices and sharp movements in saving behavior.
2. The natural rate of interest falls both along the transition path and in the steady state.
3. The natural rate of unemployment may also be affected through the matching mechanism.
4. The wealth channel is likely to become a more important transmission channel of monetary policy than intertemporal substitution.
5. The Phillips curve is flatter due to immigration and the increased participation of retired workers whose supply of labor is considered to be relatively elastic.
6. The constituency for keeping inflation low will be larger thanks to higher average wealth accumulation.
7. Diversification and risk-shifting with a securitized market is more induced than bank-intermediated finance, which has implications for financial stability.

Main Conclusion

- Evolution of the demographic structure leads to the changes in the aggregate skill mix of the workforce.
  - The changes in the demographic structure induce significant low-frequency movements in per-capita consumption growth and the real interest rate.
- The model suggests that aging of the labor force accounts for roughly 40% of the declines in the real interest rate observed between 1980s and 2000s in Japan.
- It also leads to similar movements in the inflation rate when the monetary policy rule follows the standard Taylor rule, failing to recognize the time-varying nature of the natural rate of interest.
  - “Inflation is always and everywhere a monetary phenomenon.”

Structure of Presentation

- Introduction
- Facts
- Model
- Calibration
- Quantitative Exercises
- Conclusion

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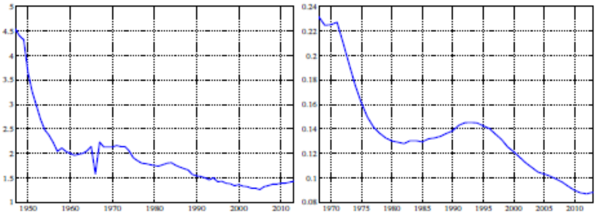
Labor Force Entry in Japan

Figure 1: Labor Force Entry in Japan

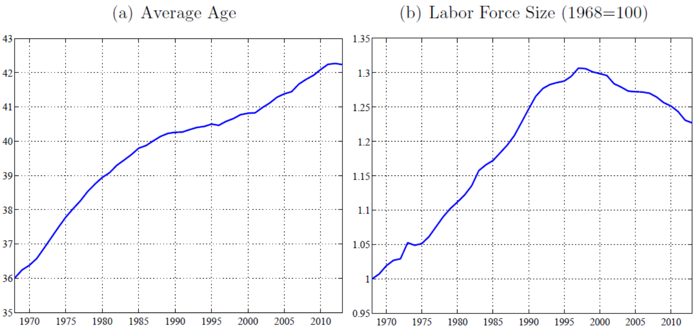
(a) Birth Rate (b) Entry into the Labor Force



Notes: The birth rate equals "the total fertility rate" which gives the number of children that are born to each woman in her childbearing years (15-49 years old). Panel (b) plots the share of workers between 15 and 24 in the total labor force (workers between 15 and 64).

Average Age and Labor Force Size

Figure 2: The Average Age and Labor Force Size



Nominal Variables

Figure 3: Wages in Japan (1996=100)

(a) Nominal Hourly Wage (b) Real Hourly Wage

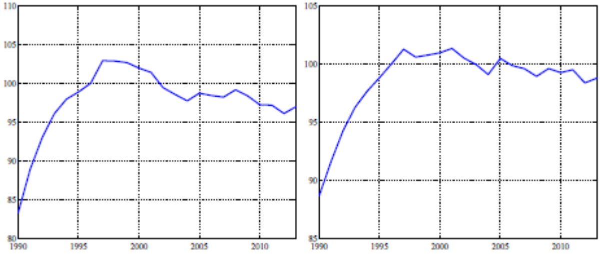
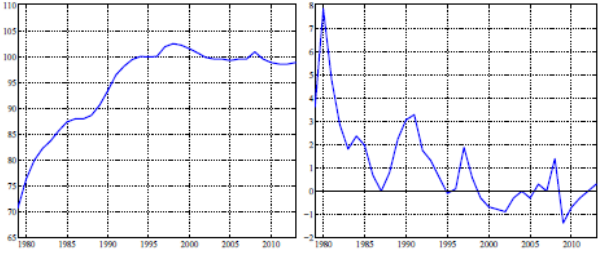


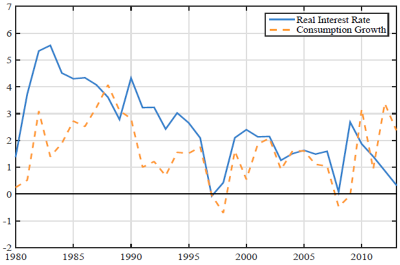
Figure 4: Price Level and Inflation Rate in Japan

(a) Price Level (CPI; 1996=100) (b) Inflation Rate



Real Interest Rate and Consumption Growth

Figure 5: Real Interest Rate and Consumption Growth



Notes: Real interest: The Treasury bill rate minus the realized inflation rate measured by the CPI. The Treasury bill rate is taken from International Financial Statistics by the IMF.

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Overview

- The economy consists of three types of agents: households, firms, and a monetary authority.
  - Firms produce and sell differentiated goods to the household.
    - The goods market is characterized by monopolistic competition and price stickiness as in the standard new Keynesian models.
    - Labor is the only input for production and there are three types of workers.
    - Hiring is subject to search frictions.
  - Households smooth aggregate consumption.
  - The central bank determines the policy interest rate following the Taylor-type rule.

Heterogeneous Workers

- There are three types of workers in the model: (i) young and inexperienced workers, (ii) old and experienced workers, and (iii) old and inexperienced workers.
  - A mass of ϕ young workers are born and enter the labor market as jobless.
  - Young workers become old with probability μ and also "experienced," having higher labor productivity by a factor of $1+\gamma$.
  - Old workers will survive with probability $1-d$.
  - Jobs are subject to exogenous job destruction probabilities s^e and s^i and with probability $1-\delta$, the worker remains experienced and can be hired as an experienced worker retaining the productivity premium.

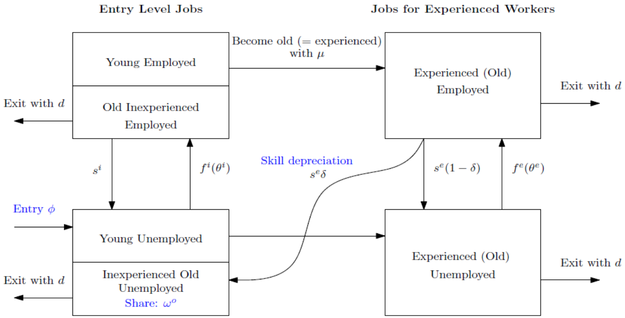
Matching Market

- The matching markets are divided by the skill level:
  1. "E-matching market": jobs that require previous experience thus suitable only for experienced workers.
  2. "I-matching market.": entry-level jobs for any workers.
- Each jobless worker finds a job with probability, either $f^e(\theta_t^e)$ or $f^i(\theta_t^i)$, that are a function of labor market tightness in the respective matching market (θ_t^e and θ_t^i).

Timing of Events

1. Demographic transitions occur.
2. Job destruction occurs. If the worker is old, the worker may lose their skill with probability δ at this point.
   - Workers who lost their job here can possibly find a new job in the same period.
3. Job search takes place if the worker is jobless; whether the worker finds a job or not is then determined.
4. Production takes place.

Labor Market Transitions



$$
\begin{aligned}
n_{y,t} &= (1-\mu)[1-s^i+s^i f^i(\theta^i_t)]n_{y,t-1}+f^i(\theta^i_t)(1-\mu)u_{y,t-1},\\
u_{y,t} &= \left[1-f^i(\theta^i_t)\right](1-\mu)u_{y,t-1}\\
&\quad +s^i\left[1-f^i(\theta^i_t)\right](1-\mu)n_{y,t-1}+\phi h_{y,t-1},\\
n^e_{o,t} &= (1-d)[1-s^e+(1-\delta)s^e f^e(\theta^e_t)]n^e_{o,t-1}\\
&\quad +[1-s^e+s^e f^e(\theta^e_t)]\mu n_{y,t-1}\\
&\quad +f^e(\theta^e_t)\left[\mu u_{y,t-1}+(1-d)u^e_{o,t-1}\right],\\
u^e_{o,t} &= (1-d)\left[1-f^e(\theta^e_t)\right]u^e_{o,t-1}\\
&\quad +\left[1-f^e(\theta^e_t)\right]\mu\left(s^e n_{y,t-1}+u_{y,t-1}\right)\\
&\quad +(1-d)s^e(1-\delta)\left[1-f^e(\theta^e_t)\right]n^e_{o,t-1},\\
n^i_{o,t} &= (1-d)[1-s^i+s^i f^i(\theta^i_t)]n^i_{o,t-1}\\
&\quad +(1-d)f^i(\theta^i_t)\left(s^e\delta n^e_{o,t-1}+u^i_{o,t-1}\right),\\
u^i_{o,t} &= (1-d)\left[1-f^i(\theta^i_t)\right]\left(u^i_{o,t-1}+s^i n^i_{o,t-1}+s^e\delta n^e_{o,t-1}\right),
\end{aligned}
$$

Job Seekers

- The number of job seekers in the two matching markets are not equal to *u*s, because those who are separated at the beginning of each period can start looking for a job within the period.

$$
\begin{aligned}
\bar{u}_t^i &= (1-\mu)\left(s^i n_{y,t-1} + u_{y,t-1}\right) \\
&\quad + (1-d)\left(\delta s^e n_{o,t-1}^e + s^i n_{o,t-1}^i + u_{o,t-1}^i\right), \\
\bar{u}_t^e &= \mu\left(s^e n_{y,t-1} + u_{y,t-1}\right) \\
&\quad + (1-d)[(1-\delta)s^e n_{o,t-1}^e + u_{o,t-1}^e], \\
\omega_{o,t} &\equiv \frac{\bar{u}_{o,t}^i}{\bar{u}_t^i} = \frac{(1-d)\left(\delta s^e n_{o,t-1}^e + s^i n_{o,t-1}^i + u_{o,t-1}^i\right)}{\bar{u}_t^i}.
\end{aligned}
$$

Population

$$
\begin{aligned}
h_{y,t} &= (1-\mu)h_{y,t-1} + \phi h_{y,t-1}, \\
h_{o,t} &= (1-d)h_{o,t-1} + \mu h_{y,t-1}, \\
h_t &= h_{t-1} + \phi h_{y,t-1} - d h_{o,t-1}.
\end{aligned}
$$

- In the simulation, nonstationary variables are de-trended by the total population.

Matching Function

$$
\begin{aligned}
m_t^i &= \overline{m}^i \left(\bar{u}_t^i\right)^{\alpha} \left(v_t^i\right)^{1-\alpha}, \\
m_t^e &= \overline{m}^e \left(\bar{u}_t^e\right)^{\alpha} \left(v_t^e\right)^{1-\alpha}, \\
\theta_t^i &\equiv v_t^i / \bar{u}_t^i, \\
\theta_t^e &\equiv v_t^e / \bar{u}_t^e, \\
f^i(\theta_t^i) &\equiv m_t^i / \bar{u}_t^i = \overline{m}^i \left(\theta_t^i\right)^{1-\alpha}, \\
f^e(\theta_t^e) &\equiv m_t^e / \bar{u}_t^e = \overline{m}^e \left(\theta_t^e\right)^{1-\alpha}, \\
q^i(\theta_t^i) &\equiv m_t^i / v_t^i = \overline{m}^i \left(\theta_t^i\right)^{-\alpha}, \\
q^e(\theta_t^e) &\equiv m_t^e / v_t^e = \overline{m}^e \left(\theta_t^e\right)^{-\alpha},
\end{aligned}
$$

Firm

The firm maximizes its value:

$$
\begin{aligned}
& \Pi\left[\mathbf{s}_t^f(j)\right] \\
= \quad & \max \left[\frac{p_t(j)}{P_t}\right]^{1-\epsilon} y_t(j) \\
& - w_{y,t}(j) n_{y,t}(j) - w_{o,t}^i(j) n_{o,t}^i(j) - w_{o,t}^e(j) n_{o,t}^e(j) \\
& - \kappa^i v_t^i(j) - \kappa^e v_t^e(j) - \frac{\chi}{2}\left[\frac{p_t(j)}{p_{t-1}(j)} - 1\right]^2 Y_t - T_t \\
& + \hat{\beta}_{t,t+1} \Pi\left[\mathbf{s}_{t+1}^f(j)\right],
\end{aligned}
$$

subject to

$$y_t(j) = \left[\frac{p_t(j)}{P_t}\right]^{-\epsilon} Y_t,$$

$$y_t(j) = n_{y,t}(j) + n^i_{o,t}(j) + (1+\gamma)n^e_{o,t}(j),$$

$$n_{y,t}(j) = (1-\mu)(1-s^i)n_{y,t-1}(j) + (1-\omega_{o,t})q^i(\theta^i_t)v^i_t(j),$$

$$n^i_{o,t}(j) = (1-d)(1-s^i)n^i_{o,t-1}(j) + \omega_{o,t}q^i(\theta^i_t)v^i_t(j),$$

$$n^e_{o,t}(j) = (1-d)(1-s^e)n^e_{o,t-1}(j) + (1-s^e)\mu n_{y,t-1}(j) + q^e(\theta^e_t)v^e_t(j).$$

Marginal Gain to Firm

- The marginal gain to the firm from adding each type of labor by one unit $J_{y,t}$, $J^i_{o,t}$ and $J^e_{o,t}$ are the Lagrange multipliers associated with

$$
\begin{aligned}
n_{y,t}(j) &= (1-\mu)(1-s^i)n_{y,t-1}(j) \\
&\quad + (1-\omega_{o,t})q^i(\theta^i_t)v^i_t(j), \\
n^i_{o,t}(j) &= (1-d)(1-s^i)n^i_{o,t-1}(j) + \omega_{o,t}q^i(\theta^i_t)v^i_t(j), \\
n^e_{o,t}(j) &= (1-d)(1-s^e)n^e_{o,t-1}(j) + (1-s^e)\mu n_{y,t-1}(j) \\
&\quad + q^e(\theta^e_t)v^e_t(j).
\end{aligned}
$$

- The multiplier on the production function defines the real marginal costs.

Household

- The household maximizes the following value function $V(.)$:

$$V(\mathbf{s}_t^h) = \max h_t u(c_t) + \beta V(\mathbf{s}_{t+1}^h),$$

subject to the budget constraint:

$$\begin{aligned} h_t c_t + \frac{B_{t+1} h_t}{P_t} &= (1 + i_{t-1}) \frac{B_t h_{t-1}}{P_t} \\ &+ w_{y,t} n_{y,t} + w_{o,t}^e n_{o,t}^e + w_{o,t}^i n_{o,t}^i \\ &+ b_y u_{y,t} + b_o^e u_{o,t}^e + b_o^i u_{o,t}^i + d_t. \end{aligned}$$

Note on Preference

- Our preference is

$$V(\mathbf{s}_t^h) = \max h_t u(c_t) + \beta V(\mathbf{s}_{t+1}^h),$$

which results in no population variable in the Euler equation:

$$u'(c_t) = \beta R_{t+1} u'(c_{t+1}).$$

- When the preference is

$$V(\mathbf{s}_t^h) = \max u(c_t h_t) + \beta V(\mathbf{s}_{t+1}^h),$$

with log preference, it becomes

$$\frac{1}{c_t} = \beta R_{t+1} \frac{h_{t+1}}{h_t} \frac{1}{c_{t+1}}.$$

Marginal Benefit to Household

- The marginal value of each type of employment is defined respectively as

$$
\begin{aligned}
M_{y,t} &\equiv \frac{\partial V\left(\mathbf{s}_t^h\right)}{\partial n_{y,t-1}}, \; M_{o,t}^e \equiv \frac{\partial V\left(\mathbf{s}_t^h\right)}{\partial n_{o,t-1}^i}, \\
M_{o,t}^i &\equiv \frac{\partial V\left(\mathbf{s}_t^h\right)}{\partial n_{o,t-1}^i}, \; D_t \equiv \frac{\partial V\left(\mathbf{s}_t^h\right)}{\partial h_{o,t-1}^e}.
\end{aligned}
$$

- They are all derived from the household utility maximization subject to

$$\begin{aligned}
n_{y,t} &= (1-\mu)[1 - s^i + s^i f^i(\theta^i_t)]n_{y,t-1} \\
&\quad + f^i(\theta^i_t)(1-\mu)(h_{y,t} - n_{y,t-1}), \\
n^e_{o,t} &= (1-d)[1 - s^e + (1-\delta)s^e f^e(\theta^e_t)]n^e_{o,t-1} \\
&\quad + [1 - s^e + s^e f^e(\theta^e_t)]\mu n_{y,t-1} \\
&\quad + f^e(\theta^e_t)\left[\begin{array}{c} \mu(h_{y,t-1} - n_{y,t-1}) \\ +(1-d)(h^e_{o,t-1} - n^e_{o,t-1}) \end{array}\right], \\
n^i_{o,t} &= (1-d)[(1 - s^i + s^i f^i(\theta^i_t))n^i_{o,t-1} \\
&\quad + f^i(\theta^i_t)(s^e \delta n^e_{o,t-1} + h_{o,t-1} - h^e_{o,t-1} - n^i_{o,t-1})], \\
h^e_{o,t} &= (1-d)(h^e_{o,t-1} - s^e \delta n^e_{o,t-1}) + \mu_{t-1} h_{y,t-1}.
\end{aligned}$$

Wage Bargaining

- Each type of worker and the firm engage in Nash bargaining individually:

$$S_t = J_t + \frac{1}{u'(c_t)} M_t$$

- This surplus is split between the worker and the firm according to the worker bargaining power η and the firm bargaining power $1 - \eta$:

$$(1-\eta) S_t = J_t,$$
$$\eta S_t = \frac{1}{u'(c_t)} M_t.$$

- Thus,

$$\eta J_t = (1-\eta) \frac{1}{u'(c_t)} M_t.$$

- Then, real wages are determined as

$$
\begin{aligned}
w_{y,t} &= \eta\tau_t + (1-\eta)b_y \\
&\quad + \eta\hat{\beta}_{t,t+1}\left[\begin{array}{c}(1-\mu)(1-s^i)f^i(\theta^i_{t+1})J_{y,t+1} \\ +\mu(1-s^e)f^e(\theta^e_{t+1})J^e_{o,t+1}\end{array}\right], \\
w^i_{o,t} &= \eta\tau_t + (1-\eta)b^i_o \\
&\quad + (1-d)(1-s^i)\eta\hat{\beta}_{t,t+1}f^i(\theta^i_{t+1})J^i_{o,t+1}, \\
w^e_{o,t} &= \eta(1+\gamma)\tau_t + (1-\eta)b^e_o \\
&\quad + (1-d)\hat{\beta}_{t,t+1}\left\{\begin{array}{c}(1-s^e)f^e(\theta^e_{t+1})\eta J^e_{o,t+1} \\ +\delta s^e\left[\begin{array}{c}f^e(\theta^e_{t+1})\eta J^e_{o,t+1} \\ -f^i(\theta^i_{t+1})\eta J^i_{o,t+1} \\ +\frac{D_{t+1}}{u'(c_{t+1})}\end{array}\right]\end{array}\right.
\end{aligned}
$$

Aggregate Conditions

- From the budget constraint together with the financial market clearing condition and the government budget constraint:

$$b_y u_{y,t} + b_o^e u_{o,t}^e + b_o^i u_{o,t}^i = T_t,$$

  one can obtain the following resource constraint:

$$Y_t = h_t c_t + \kappa^i v_t^i + \kappa^e v_t^e + \frac{\chi}{2}(\pi_t - 1)^2 Y_t.$$

- Monetary policy is characterized by a standard Taylor-type rule:

$$1 + i_t = \frac{1}{\beta} + \psi_\pi(\pi_t - 1).$$

  - When we simulate real model, monetary policy becomes

$$\pi_t = 1.$$

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Basic Calibration

- The calibration intends to replicate the Japanese economy at the start of the aging process, assuming that the economy is in the steady state at that point.
- In the quantitative exercises below, we consider the effects of decreasing fertility rate ϕ.
  - This is the only driver of the dynamics.
- One period in the model corresponds to one quarter in the actual economy.

Demographic Transition

- Each worker spends on average 20 years as a "young" worker and 25 years as an "old" worker: $\mu = 1/80 = 0.0125$, and $d = 0.01$.
- The total fertility rate, which was above 4 at the peak in 1948, needs to be translated into the entry rate ϕ.
  - If childbearing years correspond to the 20-year period as a young worker, this implies that each young worker reproduces 2 young workers over this 20-year period, corresponding to $\phi = 0.025 (= 2/80)$.
  - Since our young worker's definition is somewhat narrower than the actual childbearing years, we set $\phi = 0.02$.
  - ϕ falls to 0.011 roughly over the following 10-year period.

Labor Market Transition

- Lin and Miyamoto (2012): the monthly aggregate job separation rate into unemployment averaged roughly around 0.4% over the period between 1980 and 2010.
- Esteban-Pretel and Fujimoro (2012): the young worker's separation rate is roughly twice as high that of the old worker is plausible.
- s^i and s^e are targeted at 1.5% and 0.75% (per quarter).
- The steady state job finding rates is set to be consistent with Lin and Miyamoto (2012):

$$f^i(\theta^i) = f^e(\theta^e) = 0.35.$$

- In the steady state, $q^i(\theta^i) = f^i(\theta^i)$ and $q^e(\theta^e) = f^e(\theta^e)$.

- By setting $\alpha = 0.5$, these assumptions leads to $\overline{m}^i = \overline{m}^e = 0.35$.
- The probability of losing the human capital δ is set at 0.8 in the benchmark calibration but with robustness check with lower δ.
- The experience premium is set to be consistent with the observed wage premium of 40%.

Others

Subjective Discount Factor	β	0.99
CRRA	σ	2
Bargaining Power	η	0.5
Experience Premium	γ	0.6
Unemployment Benefit for Young	b_y	0.6
Unemployment Benefit for Old	$b_o^e = b_o^i$	0.96
Vacancy Posting Cost for I-Market	κ_i	0.251
Vacancy Posting Cost for E-Market	κ_e	0.337
Elasticity of Substitution	ϵ	6
Price Adjustment Cost	χ	77
Policy Reaction to Inflation	ψ_π	1.5

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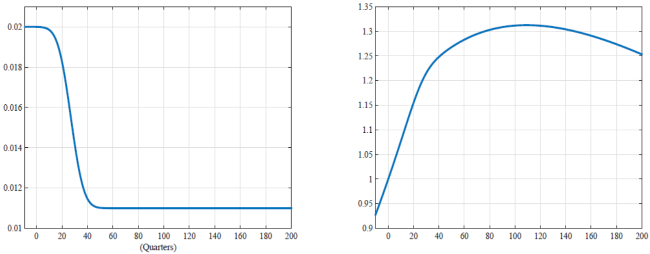
Exogenous Driver of Dynamics

Figure 6: The Entry Rate and Labor Force

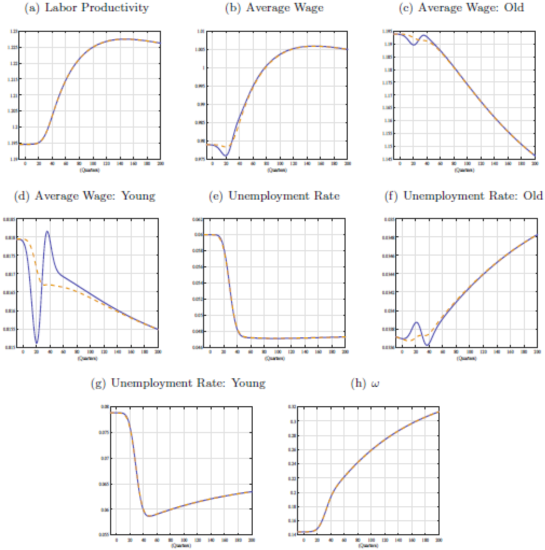
(a) Assumed Entry Rate Path (b) Implied Path of the Labor Force



Notes: The labor force is normalized to 1 in period 0.

Labor Market Responses to Aging

Figure 7: Perfect Foresight Equilibrium Paths (I)

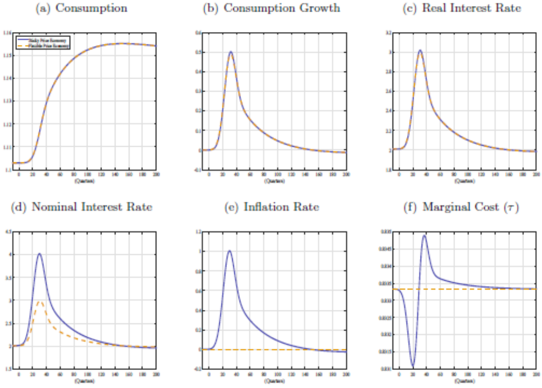


- Labor productivity increases in the initial phase of the aging process.
  - More young workers are gaining experience, thus becoming more productive.
- After this initial phase is over, labor productivity growth slows down, and eventually turns negative.
  - There are fewer young workers (whose future productivity is higher), which implies less room to grow further.
  - As the workforce gets older, there are more workers that are subject to the risk of job destruction that is accompanied by the loss of the firm-specific skill.
- The behavior of average wage is similar to that of labor productivity.

- Average wage of old workers steadily fall over time.
  - The share of inexperienced workers (within old workers) increases, thereby putting a downward pressure on average wage of old workers.
  - Although wages of two types workers within the old are affected by changing market tightness in each matching market, these effects turn out to be quantitatively small.
    - Bean (2004) notes that "But whether these effects are quantitatively significant is another matter altogether."
- Average wage of young workers falls over time.
  - More old inexperienced workers in the I-matching market lowers job creation in this market, because their wage is higher than that of young workers, and hence, a higher ω translates into a lower return to posting vacancies in that market.

Real Interest Rate and Inflation Responses

Figure 8: Perfect Foresight Equilibrium Paths (II)



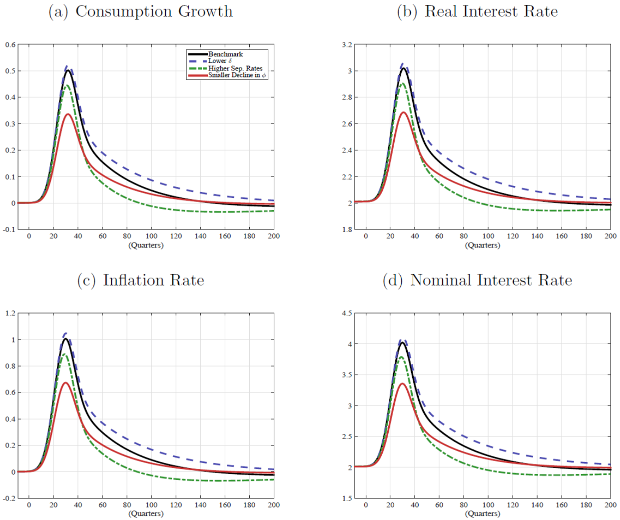
Notes: Consumption growth, real interest rate, nominal interest rate, and inflation are expressed as annualized percent.

- The hump-shaped pattern in the level of per-capita consumption comes from the same mechanism discussed with respect to the hump-shaped pattern in labor productivity.
- Consumption growth increases roughly 0.5 percentage point at its peak and then gradually comes down. Given the value of CRRA parameter of 2, the real interest rate rises 1 percentage points and follows a similar gradual declining path.
  - Consumption growth and the real interest rate fell 1.3 percentage points and 2.3 percentage points, respectively, between the 1980s and 2000s.
  - Aging of the labor force accounts for roughly 40% of these declines. Below we will consider how these numbers change under the alternative calibrations.
- The negative growth occurs only in the economy with high δ as in our benchmark calibration.
  - More old workers are (re-)employed only in the entry-level job.

- The nominal interest rate is set by a standard Taylor rule which does not fully reflect the changing natural rate of interest.
- Under this assumption, the inflation rate, after initially increasing roughly 1 percentage point, follows a gradual declining trend over the following decades. In particular, the inflation rate turns negative (deflation) around 150th quarter, which roughly corresponds to mid 2000s.

Alternative Calibrations

1. Low Human Capital Specificity
   - δ is set to a lower value 0.4 instead of 0.8.
   - This case reduces the effect of specificity of human capital and thus is useful in highlighting the importance of human capital specificity in generating our results.
2. Higher Separation Rates
   - s_o and s_y are doubled to 0.015 instead of 0.03.
   - The aggregate job separation rate has increased significantly since the mid 1990s, raising the unemployment rate in Japan.
3. Smaller Decline in Entry Rate
   - ϕ drops to 0.014 instead of 0.011 from 0.02.
   - Population keeps growing and the path of the labor force roughly mimics the observed path of the U.S. labor force.


(a) Consumption Growth
(b) Real Interest Rate
(c) Inflation Rate
(d) Nominal Interest Rate
Benchmark
Lower δ
Higher Sep. Rates
Smaller Decline in ϕ
(Quarters)

Low Human Capital Specificity

- The deceleration of consumption growth occurs more gradually.
  - The source of the decline in the consumption level in the benchmark case is a high value of the specificity parameter.
  - Consumption growth and inflation never turn negative.
  - The labor market institution (represented by a high degree of skill specificity in this paper) carries important implications for low frequency movements in interest rates and inflation.

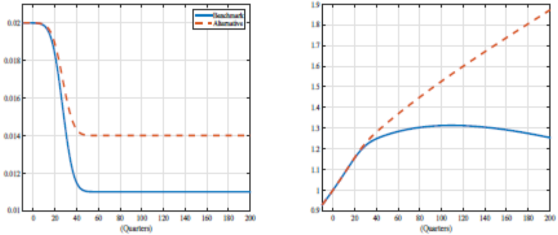
Higher Separation Rates

- The higher separation rate for the experienced worker s^e implies a higher risk of skill loss, and thus puts a downward pressure on labor productivity, aggregate wage, and consumption, when aging of the labor force reaches its later stage.
  - The timing of negative consumption growth comes much earlier, and the pace of decline becomes faster than in the benchmark calibration.
  - The economy experiences larger deflation, and deflation itself occurs much earlier.
- When the separation rate increases (which indeed occurred throughout the 1990s), it puts a downward pressure on real wages, interest rates, and thus inflation.
  - The results under the benchmark calibration may be viewed as an underestimate of the impacts of the labor force aging.

Smaller Decline in Entry Rate

Figure 10: The Entry Rate and Labor Force

(a) Alternative Entry Rate Path (b) Implied Path of the Labor Force



Notes: The labor force is normalized to 1 in the initial period.

- Contrary to the benchmark case, labor force continues to be positive even after the economy reaches the new steady state.
- This seemingly innocuous change makes significant differences in the subsequent behavior of the economy.
  - Different labor force growth implies a different age compositions along the economy's transition path.
  - A smaller decline in ϕ implies a smaller initial increase in consumption growth and, accordingly, the deceleration in consumption growth is less pronounced and occurs more smoothly.
  - The economy experiences a smaller low-frequency swing because the workforce composition does not change as much as in the benchmark calibration.
- The changing demographics composition is an important element in understanding the low-frequency movement of the economy.

Summary

Table 4: Changes in Real Interest Rate and Consumption Growth

	Real Interest Rate (%)	Consumption Growth (%)
Data	−2.27	−1.26
Benchmark	−1.02	−0.51
Lower δ	−1.00	−0.50
Higher separation rate	−0.96	−0.48
Smaller decline in ϕ	−0.67	−0.33

Notes: Data refers to the difference between the average levels in 1980s and 2000s. See Table 1. The decline in the two variables in the model is computed as the difference between the peak level and the level at 160th quarter (40 years later) after the start of the decline in the entry rate.

Conclusion

- The collapse in labor force entry in the 1970s (associated with the end of the baby boom roughly 20 years before) could be an important driver of low frequency movements in consumption growth and the real interest rate as well as important labor market variables such as labor productivity and real wage.
  - Aging of the labor force accounts for roughly 40% of the declines in consumption growth and the real interest rate in the last three decades in Japan.
- If the monetary authority follows a simple standard Taylor rule that fails to react to the time-varying nature of the natural rate of interest, the economy experiences a sizable low-frequency movement in the inflation rate results.
  - Under our benchmark calibration, the decline in the labor force entry in the 1970s leads to deflation 35 years later.