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In Search of Lost Time: Firm Vintage and Macroeconomic Dynamics

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In search of lost time: firm vintage and macroeconomic dynamics*

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Abstract

This paper attempts to reproduce the past landscape of the economy with the help of evidence and structural models. For that purpose, we built a theoretical model consisting of endogenous firm entry and firm selection. Given the distribution of firm age and firm sales that we see today, we simulated age-specific technologies and fixed costs for operation. With these simulated parameters, we then reestablished the macroeconomic dynamics of each historical firm. With Japanese data from over 126 years, despite the massive presence of firms created after the Second World War until the oil crisis in the 1970s, we found that these historical firms show relatively low productivity. Old historical firms are subject to high fixed costs and high productivity. Finally, we demonstrated that our counterfactual fixed costs dramatically change the landscape of historical firms, as well as their characteristics.

Keywords: Heterogeneity, fixed cost, business cycles.
JEL classification: D24, E23, E32, L11, L60.

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And suddenly the memory revealed itself. by Proust, "A la recherche du temps perdu"

1 Introduction

What does the past look like? Given the economic landscape that we see today, is there any way to trace back history, not only for the entire economy but also for individual firms? If the crumbs of a madeleine are enough to reveal one's childhood memories, as Proust wrote, then other pieces of evidence may reestablish history in every tiny detail. In search of lost time, we attempt to build a macroeconomic model with vintage firms and attempt to reveal the history of each firm with the help of limited data.

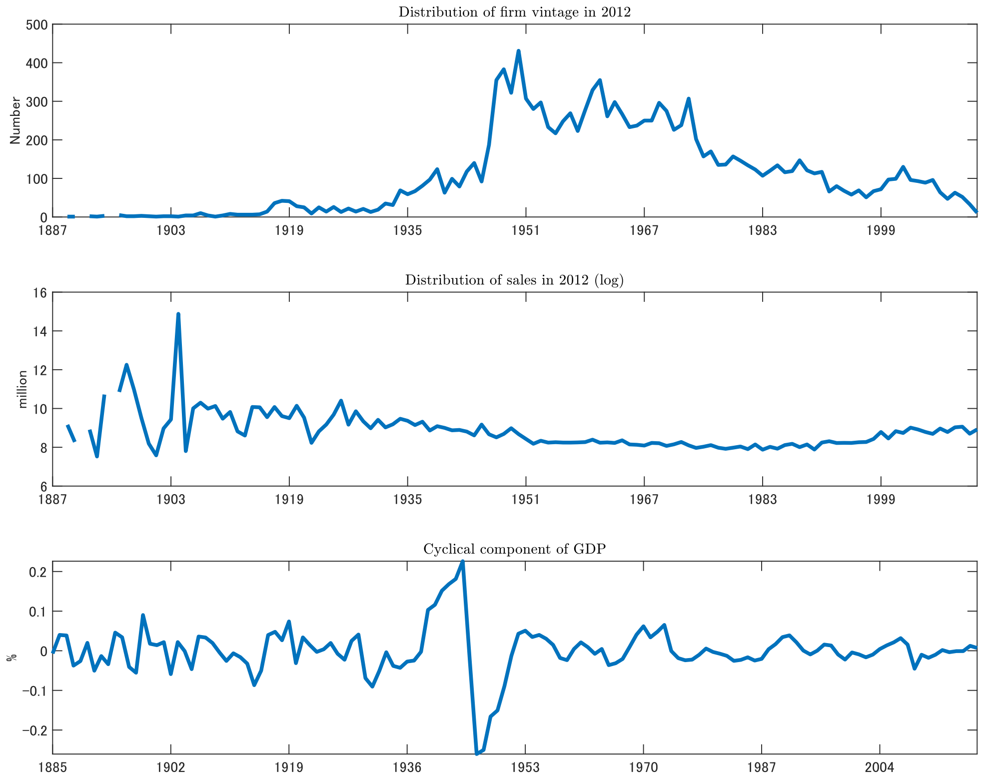
The first two panels in Figure 1 provide the distribution of vintage Japanese firms and their sales, as reported in a 2013 survey. We define "vintage" as the firm's age since its foundation. For the distribution of vintage firm shares and their relative sales, we use the Basic Survey of Japanese Business Structure and Activities (BSJBSA), as provided by the Ministry of Economy, Trade and Industry of Japan (METI). The data covers firms from 1887 to 2012.[1] It is noticeable that the share of firms created in the middle ranges of the study period spanning 126 years is relatively high, while these firms show lower sales compared to their counterparts. Sales tended to be higher for old vintage firms in the initial time periods, which lasted until approximately the time of the 1929 Great Depression, i.e., roughly the time corresponding to the Meiji (1868-1912) and Taisho (1912-1926) era. We intentionally employ the word "vintage" rather than "age" because vintage refers to conditions that are specific to birth years and crucial for the later performance of firm.

We use the distribution of vintage firms and their sales, as well as the business cycle of real GDP (shown in the third panel in the figure), as pieces of evidence with which we reestablish the history of each vintage firm.[2] In the theoretical model, there is an interaction between the vintage of firms and the macroeconomic aggregate. Each vintage firm constitutes aggregate dynamics in the economy, while the aggregate outcome

[1]See Appendix A for the description of the data.

[2]The historical Japanese real GDP data is taken from Maddison: https://www.rug.nl/ggdc/historicaldevelopment/maddison/?lang=en

Figure 1: Distribution of vintage firms and their sales in the 2013 survey



The first panel shows the distribution of vintage firms in the 2013 survey. The second panel shows the distribution of the sales of these vintage firms in the 2013 survey. The third panel shows the cyclical component of the real GDP for Japan. To detrend the real GDP, we use an HP filter with the smoothing parameter $\lambda = 100$.

influences the sales, production, and employment of each vintage firm. The theoretical model allows us to explore the history of each vintage firm. Given the cyclical component of the historical GDP and the landscape of today's economy, namely, the distribution of vintage firms and their sales, as shown in Figure 1, we simulate two important structural parameters, namely, vintage-specific technologies and fixed operational costs. Once we obtain the value of these structural parameters, we are able to reestablish other vintage-specific distributions, such as productivity and employment, as well as the dynamics for each vintage firm.

Our simulated distribution of the productivity and employment of vintage firms shows remarkably similar patterns to those based on estimation and data. Our simulation results are summarized as follows. First, old vintage firms, i.e., firms created in the early part of the study time period up until the approximate time of the 1929 Great Depression, i.e., roughly the time period corresponding to the Meiji and Taisho era, are subject to higher fixed costs yet are more productive compared to other vintage firms. Second, vintage firms created near the onset of the Second World War up until approximately the time of the Plaza Accord in 1985 (this cohort has the largest share in the distribution of vintage firms in the 2013 survey) have low productivity and low employment, although they benefitted from low fixed costs when they were founded. Third, vintage firms born in the most recent time period, i.e., after circa 1985, show low productivity and low employments, and they have slightly higher specific fixed costs compared to the average.

Next, to see the history of vintage firms in a compact way, we provide "snapshots" at particular moments in history. These snapshots are the result of our simulation given the abovementioned aggregates, as well as the dynamics of each vintage firm. In particular, we discuss a snapshot for 1923 and 1996. In our snapshot of 1923, which corresponds to the boom period after the First World War, the share of vintage producers from 1914 and 1919 is found to be high. However, the sales, productivity, and employment of these firms are not particularly high. Importantly, our simulated snapshots provide similar landscapes that enable comparisons with the actual snapshots taken at these historical moments.

Finally, we perform a counterfactual analysis. With a counterfactual distribution of vintage-specific fixed costs that shows the opposite pattern compared to that in our simulation, we show the share of recent vintage firms has increased significantly, while the number of vintage firms created in the post war boom, 1950 to 1980, was reduced. At the same time, the sales, productivity and employment of these postwar vintage firms are substantially high. Our counterfactual fixed costs thus dramatically change the landscape of vintage firms, as well as their characteristics.

Our paper is related to the literature that discusses firm entry and exit in a real business cycle model, such as Ghironi and Melitz (2005), Bilbiie et al. (2012), Hamano and Zanetti (2017). Different from these preceding papers, our theoretical model explicitly examines vintage firms and shows how each vintage firm constitutes aggregate dynamics. Many previous studies have argued the presence of link between firm size distribution and firm age in the context of firm growth theory. Cabral and Mata (2003) found that the skewness of the distribution comes from financial constraints, which are conditional on firm age. Arkolakis (2016) and Arkolakis et al. (2018)) and Luttemer (2007, 2011) explained the size and age distribution using firm growth theory. In a recent study, Pugsley et al. (2018) emphasized ex-ante firm heterogeneity in the birth period to characterize the firm's size distribution and age profile in a theoretical model based on Hopenhayn (1992), Hopenhayn and Rogerson (1993) and Melitz (2003). As in these papers, our theoretical model embeds heterogeneous firms. Different from them, however, we place more emphasis on vintage-specific characteristics rather than those characteristics that are specific to individual firms that may or may not evolve overtime. In our model, vintage-specific technologies and fixed costs allow us to reestablish firm size distribution and age distribution both in the past and in the current time period. Finally, Cacciatore and Fiori (2016), Bilbiie et al. (2019), Hamano and Vermeulen (2019) argued the important role played by fixed costs and induced market regulation to shape the equilibrium outcome as ours.

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 discusses our benchmark calibration and estimation. Section 4 simulates the theoretical model with Japanese data and provides the simulated vintage-specific technologies and fixed costs. Based on these parameters, we then reestablish the macroeconomic dynamics of each vintage firm and perform a counterfactual analysis. Section 5 concludes the paper.

2 The Model

In this section, we present the theoretical model using vintage firms. The model embeds endogenous firm entry and selection based on heterogeneous firms. Further, we explicitly model vintage firms and their products. Consumption at time t is composed from differentiated product varieties produced by vintage firms created in previous time periods, $v < t$. Entrants incur a sunk cost to enter the market and upon entry, they draw vintage-specific technology φ_v from vintage-specific distribution $G(\varphi_v)$. Firms are also required to pay vintage-specific operational fixed costs f_v to engage in production, which may start from the next time period of entry. This operational cost is assumed to be specific to each vintage firm. The aggregate dynamics in the current time period are reestablished by aggregating those at each vintage level.

2.1 Households

During each time period t, the representative household maximizes the following expected utility:

$$E_t \sum\nolimits_{i=t}^{\infty} \beta^{i-t} \left(\ln C_t - \chi \frac{L_t^{1+\frac{1}{\psi}}}{1+\frac{1}{\psi}} \right), \tag{1}$$

where C_t is consumption, L_t is labor supply, $0 < \beta < 1$ is the discount factor, $\chi > 0$ is the degree of disutility in supplying labor and ψ is the Frisch elasticity of the labor supply.

Consumption at time t is composed from different "vintage" of baskets as follows:

$$C_t = \left(\sum_{v=0}^{t-1} C_{v,t}^{1-\frac{1}{\sigma}} \right)^{\frac{1}{1-\frac{1}{\sigma}}}$$

where $C_{v,t}$ stands for the consumption of a vintage product produced by firms created at time v. Furthermore, product varieties within a particular vintage v are differentiated as follows:

$$C_{v,t} = \left(\int_{\omega \in \Omega_v} c_{v,t}(\omega)^{1-\frac{1}{\sigma}} d\omega \right)^{\frac{1}{1-\frac{1}{\sigma}}},$$

where $c_{v,t}(\omega)$ represents the demand for each product variety ω of a vintage v; $\sigma > 1$ is the elasticity of substitution among product varieties. We keep the model as simple as possible by assuming the same elasticity of substitution across vintage firms and within the product varieties.

The optimal demand for each product variety ω of a vintage v at time t is found to be as follows:

$$c_{v,t}(\omega) = \left(\frac{p_{v,t}(\omega)}{P_{v,t}}\right)^{-\sigma} C_{v,t}, \tag{2}$$

where $p_{v,t}(\omega)$ denotes the price of the product variety ω of a vintage v. The price index of a basket of vintage v at time t is as follows:

$$P_{v,t} = \left(\int_{\omega \in \Omega_t} \left(p_{v,t}(\omega)\right)^{1-\sigma} d\omega\right)^{\frac{1}{1-\sigma}},$$

The optimal demand for a basket of a certain vintage v is found to be as follows:

$$C_{v,t} = \left(\frac{P_{v,t}}{P_t}\right)^{-\sigma} C_t \tag{3}$$

where P_t is the price index of aggregate basket C_t. Finally, the aggregate price index P_t which we choose as numeraire is found to be as follows:

$$P_t = \left(\sum_{v=0}^{t-1} P_{v,t}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

2.2 Production, Pricing and Producing Decision

Upon entry, each entrant draws a productivity level, φ_v, from a cumulative distribution, $G(\varphi_v)$, with support on $[\varphi_{\min}, \infty)$. Production requires labor as input. It also requires a fixed operational cost of f_v/Z_t in effective labor units, where Z_t stands for the aggregate productivity level. We assume that f_v is specific to each vintage firm. The total labor demand at time t for a vintage firm with productivity level φ_v is thus given by the following:

$$l_{v,t}(\varphi_v) = \frac{y_{v,t}(\varphi_v)}{Z_t \varphi_v} + \frac{f_v}{Z_t}, \tag{4}$$

where $y_{v,t}(\varphi_v)$ stands for the production scale of a vintage firm with productivity level φ_v.

The demand addressed to a vintage firm with productivity level φ_v is characterized by equation (2). Profit maximization yields the following optimal price of a vintage firm with productivity level φ_v at time t:

$$\rho_{v,t}\left(\varphi_v\right) = \frac{\sigma}{\sigma - 1}\frac{w_t}{Z_t \varphi_v}, \tag{5}$$

where w_t is the real wage.

Depending on the level of firm-vintage-specific productivity, φ_v, firms may or may not produce. Thus, using equation (4), (5) and (3), if production materializes, the following real operational profits are generated as follows:

$$d_{v,t}\left(\varphi_v\right) = \frac{1}{\sigma}\rho_{v,t}\left(\varphi_v\right)^{1-\sigma} C_t - w_t \frac{f_v}{Z_t}. \tag{6}$$

Only vintage firms with $d_{v,t}\left(\varphi_v\right) > 0$ produce at time t by covering the operational fixed cost. We thus determine the cutoff productivity level for a particular vintage v at time t, $\varphi_{v,t}$, with the following:

$$d_{v,t}\left(\varphi_{v,t}\right) = 0.$$

2.3 Average within Vintage

Given the distribution of the productivity level, $G_v\left(\varphi_v\right)$, the mass of firms, $N_{v,t}$, is defined over the productivity levels $[z_{\min},\ \infty)$. Among these firms, a subset of firms engage in production. The number of vintage producers is determined by $S_{v,t} = \left[1 - G_v\left(\varphi_{v,t}\right)\right] N_{v,t}$. Following Melitz (2003) and Ghironi and Melitz (2005), we refer to the average with $\sim$ and define the average productivity of vintage producers $\tilde{\varphi}_{v,t}$ as follows:

$$\tilde{\varphi}_{v,t} \equiv \left[\frac{1}{1 - G_v\left(\varphi_{v,t}\right)} \int_{\varphi_{v,t}}^{\infty} \varphi_v^{\sigma-1} dG_v\left(\varphi_v\right)\right]^{\frac{1}{\sigma-1}}. \tag{7}$$

The term, $\tilde{\varphi}_{v,t}$ thus contains all the information about the distribution of productivity. By aggregating across productivity levels and substituting equation (7) into equation (5), the average real price of vintage producers is found to be as follows:

$$\rho_{v,t}\left(\tilde{\varphi}_{v,t}\right) = \frac{\sigma}{\sigma - 1}\frac{w_t}{Z_t \tilde{\varphi}_{v,t}}.$$

Similarly, by plugging in the optimal demands, the average real profits of vintage producers can be expressed as follows:

$$d_{v,t}\left(\tilde{\varphi}_{v,t}\right)=\frac{1}{\sigma}\rho_{v,t}\left(\tilde{\varphi}_{v,t}\right)^{1-\sigma}C_t-w_t\frac{f_v}{Z_t}.$$

2.4 Average across Firms in different Vintages

Furthermore, it is convenient to define the average across firms in different vintages at time t. By notation, we represent "the average of averages" of different vintage firms with $X_{\tilde{v},t}$. There is N_t number of firms at time t that are composed of all vintage products, while only a subset number of S_t firms produce and are operating. Note that, by construction, the N_t number of firms at time t that are composed of all vintage products is defined as $N_t = \sum_{v=0}^{t-1} N_{v,t} = tN_{\tilde{v},t}$ and a subset number of S_t producers are aggregated from $S_t = \sum_{v=0}^{t-1} S_{v,t} = tS_{\tilde{v},t}$. The average number of producers across different vintage firms is given by $S_{\tilde{v},t} = \left[1-G\left(\varphi_{\tilde{v},t}\right)\right] N_{\tilde{v},t}$ or equivalently by $S_t = \left[1-G\left(\varphi_{\tilde{v},t}\right)\right] N_t$, where $\varphi_{\tilde{v},t}$ stands for the average cutoff level of productivity across different vintage firms. This cutoff level $\varphi_{\tilde{v},t}$ is determined with the following ZCP condition: $d_{\tilde{v},t}\left(\varphi_{\tilde{v},t}\right)=0$. Given this cutoff level, we define the average productivity of producers across different vintages as follows:

$$\tilde{\varphi}_{\tilde{v},t}\equiv\left[\frac{1}{1-G\left(\varphi_{\tilde{v},t}\right)}\int_{\varphi_{\tilde{v},t}}^{\infty}\varphi_v^{\sigma-1}dG\left(\varphi_v\right)\right]^{\frac{1}{\sigma-1}}.$$

Based on the above cutoff level, the average real price of producers at time t is expressed as follows:

$$\rho_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)=\frac{\sigma}{\sigma-1}\frac{w_t}{Z_t\tilde{\varphi}_{\tilde{v},t}},$$

The average real price is also expressed as shown in the footnote.[3]

$$\rho_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)=S_t^{\frac{1}{\sigma-1}}.$$

Given the above average real price, the average dividends of producing firms at time t are expressed as follows:

[3] $\rho_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)=\frac{p_{\tilde{v},t}(\tilde{\varphi}_{\tilde{v},t})}{P_t}=\frac{p_{\tilde{v},t}(\tilde{\varphi}_{\tilde{v},t})}{\left(\sum_{v=0}^{t-1}P_{v,t}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}=\frac{p_{\tilde{v},t}(\tilde{\varphi}_{\tilde{v},t})}{p_{\tilde{v},t}(\tilde{\varphi}_{\tilde{v},t})\left(\sum_{v=0}^{t-1}S_{\tilde{v},t}\right)^{\frac{1}{1-\sigma}}}=S_t^{\frac{1}{\sigma-1}}$

$$d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)=\frac{1}{\sigma}\frac{C_t}{S_t}-w_t\frac{f}{Z_t}.$$

where f represents the amount of effective labor that vintage firms employ on average.

Finally, we define the average dividends of all firms at time t as follows:

$$d_t\equiv\frac{S_t}{N_t}d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right).$$

Note that d_t is equivalent to the sum of the dividends of all existing vintage firms as $d_t=\sum_{v=0}^{t-1}\frac{S_{v,t}}{N_{v,t}}d_{v,t}\left(\tilde{\varphi}_{v,t}\right)$.

2.5 Firm Entry and Exit

In each period, $N_{E,t}$ number of entrants enters the market. Prior to entry, these new firms are identical and face a sunk entry cost of f_E in effective labor units. The entry cost is therefore equal to $w_t f_E$ units of consumption goods, where w_t stands for the real wage. We assume that firms that enter at time t only start producing at time $t+1$. The value of a firm is expressed with a stream of their expected profits $\{d_i\}_{i=t+1}^{\infty}$. Using the stochastic discount factor of households adjusted by exogenous exit-inducing shock δ, we obtain the following:

$$v_t=E_t\sum_{i=t+1}^{\infty}\left[\beta\left(1-\delta\right)\right]^{i-t}\left(\frac{C_i}{C_t}\right)^{-1}d_i. \tag{8}$$

Firm entry occurs until the expected product value (8) is equal to the entry cost, which leads to the following free entry condition:

$$v_t=w_t\frac{f_E}{Z_t}.$$

The timing of entry and production implies that the number of products evolves according to the law of motion:

$$N_t=\left(1-\delta\right)\left(N_{t-1}+N_{E,t-1}\right).$$

Finally, given the above motion of firms the number of firms of a particular vintage is as follows:

$$N_{v,t}=\left(1-\delta\right)^{t-v}N_{E,v}. \tag{9}$$

2.6 Parametrization of Productivity Draw

To solve the model, we must assume a distribution of productivity levels, φ_v. Thus, we assume the following vintage-specific Pareto distribution:

$$G_v(\varphi_{v,t}) = 1 - \left(\frac{\varphi_{\min}}{\varphi_v}\right)^{\kappa_v},$$

where $\varphi_{\min}$ is the minimum productivity level and κ_v determines the shape of the distribution at vintage v. The parameter κ_v indexes the dispersion of productivity across the products of a particular vintage v. The dispersion decreases as κ_v increases and is skewed towards the lower bound $\varphi_{\min}$. When $\kappa_v = \infty$, all products are located at $\varphi_{\min}$, and the products become homogeneous within vintage. To ensure the variance of the productivity distribution is finite, we assume that $\kappa_v > \sigma - 1$. With the above Pareto distribution, we can express the average productivity of producers $\tilde{\varphi}_{v,t}$ in equation (7) as follows:

$$\tilde{\varphi}_{v,t} = \varphi_{v,t}\left[\frac{\kappa_v}{\kappa_v - (\sigma - 1)}\right]^{\frac{1}{\sigma-1}}, \tag{10}$$

and the number of vintage producers is given by the following:

$$\frac{S_{v,t}}{N_{v,t}} = \varphi_{\min}^{\kappa_v}\left[\frac{\kappa_v}{\kappa_v - (\sigma - 1)}\right]^{\frac{\kappa_v}{\sigma-1}} \tilde{\varphi}_{v,t}^{-\kappa_v}. \tag{11}$$

In addition, substituting equation (10) into the product's real profits (6) yields an equation that determines the cutoff productivity level:[4]

$$d_{v,t}(\tilde{\varphi}_{v,t}) = \frac{\sigma - 1}{\kappa_v - (\sigma - 1)} \frac{w_t f_v}{Z_t}$$

Similarly, at the average across vintages, we get the following:

$$\tilde{\varphi}_{\tilde{v},t} = \varphi_{\tilde{v},t}\left[\frac{\kappa}{\kappa - (\sigma - 1)}\right]^{\frac{1}{\sigma-1}}, \quad \frac{S_t}{N_t} = \varphi_{\min}^{\kappa}\left[\frac{\kappa}{\kappa - (\sigma - 1)}\right]^{\frac{\kappa_{\tilde{v}}}{\sigma-1}} \tilde{\varphi}_{\tilde{v},t}^{-\kappa},$$

[4] $d_{v,t}(\tilde{\varphi}_{v,t}) = \frac{1}{\sigma}\rho_{v,t}(\tilde{\varphi}_{v,t})^{1-\sigma} C_t - w_t \frac{f_v}{Z_t}$, $d_{v,t}(\varphi_{v,t}) = \frac{1}{\sigma}\rho_{v,t}(\varphi_{v,t})^{1-\sigma} C_t - w_t \frac{f_v}{Z_t} = 0$ and with pricing equations, we have $d_{v,t}(\tilde{\varphi}_{v,t}) = \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{w_t}{Z_t \tilde{\varphi}_{\tilde{v},t}}\right)^{1-\sigma} C_t - w_t \frac{f_v}{Z_t}$ and $d_{v,t}(\varphi_{v,t}) = \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{w_t}{Z_t \varphi_{v,t}}\right)^{1-\sigma} C_t - w_t \frac{f_v}{Z_t} = 0$. Combining these two equations, we get $d_{v,t}(\tilde{\varphi}_{v,t}) = \left[\left(\frac{\varphi_{v,t}}{\tilde{\varphi}_{\tilde{v},t}}\right)^{1-\sigma} - 1\right] w_t \frac{f_v}{Z_t}$. With $\tilde{\varphi}_{\tilde{v},t} = \varphi_{\tilde{v},t}\left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{1}{\sigma-1}}$, we get (16).

and

$$d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)=\frac{\sigma-1}{\kappa-(\sigma-1)}\frac{w_t f}{Z_t}.$$

In the above average expressions, κ stands for the parameter that shapes the Pareto distribution for all the vintage firms.

2.7 Household Budget Constraint and Intertemporal Problems

The household budget constraint is given by the following:

$$C_t+x_{t+1}v_t\left(N_t+N_{E,t}\right)=L_t w_t+x_t N_t\left(v_t+d_t\right). \tag{12}$$

During each period t, the representative household chooses its consumption, C_t, shareholding, x_{t+1}, and labor supply, L_t, to maximize the expected utility function (1) subject to the budget constraint (12). The first-order conditions with respect to consumption and labor supply yield the standard labor supply equation as follows:

$$\chi\left(L_t\right)^{\frac{1}{\psi}}=w_t C_t^{-1}.$$

The first-order condition with respect to shareholdings yields the following:

$$v_t=\beta\left(1-\delta\right)E_t\left(\frac{C_{t+1}}{C_t}\right)^{-1}\left(v_{t+1}+d_{t+1}\right),$$

which, once iterated forward, shows the share price as (8).

2.8 Model Equilibrium and Solution

In equilibrium, the aggregate labor supply, L_t, is employed in either the production of consumption goods (intensive margins, i.e., the production scale) or the creation of new firms (extensive margins):[5]

$$L_t=S_t l_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)+N_{E,t}\frac{v_t}{w_t},$$

[5]Using the notation of vintages, this is equivalent to $L_t=\sum_{v=0}^{t-1}S_{v,t}l_{v,t}\left(\tilde{\varphi}_{v,t}\right)+N_{E,t}\frac{v_t}{w_t}$.

where $l_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right) = (\sigma - 1)\frac{d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)}{w_t} + \sigma\frac{f}{Z_t}$, which represents the labor demand required for the production on average.

As auxiliary variables, we also define real GDP Y_t and real average sales $y_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)$ with $Y_t \equiv L_t w_t + S_t d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)$ and $d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right) = \frac{\rho_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)}{\sigma} y_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right) - \frac{w_t f}{Z_t}$, respectively. Finally, we assume that the aggregate productivity follows an AR(1) process as $\ln(Z_t) = \rho\ln(Z_{t-1}) + \varepsilon_t$, where ε_t is a normally distributed innovation with a zero mean and a variance equal to s_Z^2. The model at the aggregate average level consists of 14 equations and 14 endogenous variables. Table 1 summarizes the system of equations.

Table 1: Summary of the benchmark model

Average pricing	$\rho_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right) = \frac{\sigma}{\sigma-1}\frac{w_t}{Z_t\tilde{\varphi}_{\tilde{v},t}}$
Real price	$\rho_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right) = S_t^{\frac{1}{\sigma-1}}$
Average profits	$d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right) = \frac{1}{\sigma}\rho_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)^{1-\sigma} C_t - w_t\frac{f}{Z_t}$
Average sales	$y_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right) = \frac{\sigma}{\rho_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)}\left(d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right) + w_t\frac{f}{Z_t}\right)$
Average profits	$d_t = \frac{S_t}{N_t} d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)$
ZCP	$d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right) = \frac{\sigma-1}{\kappa-(\sigma-1)}\frac{w_t f}{Z_t}$
Surviving rate	$\frac{S_t}{N_t} = \varphi_{\min}^{\kappa}\left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{\kappa}{\sigma-1}}\tilde{\varphi}_{\tilde{v},t}^{-\kappa}$
Free entry condition	$v_t = \frac{w_t f_{E,t}}{A_t}$
Motion of products	$N_{t+1} = (1-\delta)\left(N_t + N_{E,t}\right)$
Euler equation	$v_t = \beta(1-\delta) E_t\left(\frac{C_{t+1}}{C_t}\right)^{-1}\left(v_{t+1} + d_{t+1}\right)$
Optimal labor supply	$\chi\left(L_t\right)^{\frac{1}{\psi}} = w_t C_t^{-1}$
Labor market clearing	$L_t = S_t l_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right) + N_{E,t}\frac{v_t}{w_t}$
Average employment	$l_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right) = (\sigma-1)\frac{d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)}{w_t} + \sigma\frac{f}{Z_t}$
Real GDP	$Y_t \equiv L_t w_t + S_t d_{\tilde{v},t}\left(\tilde{\varphi}_{\tilde{v},t}\right)$
Productivity process	$\ln(Z_t) = \rho\ln(Z_{t-1}) + \varepsilon_t$

The variables for each vintage firm are characterized by the system of equations presented in Table 2. Given the number of new entrants in each period $N_{E,v}$, the aggregated consumption C_t, the wages w_t and the productivity level Z_t, the vintage-specific variables are derived from these equations. The equilibrium conditions do not have an analytical

Table 2: Summary of the benchmark model (for a vintage)

Average pricing	$\rho_{v,t}\left(\tilde{\varphi}_{v,t}\right)=\frac{\sigma}{\sigma-1}\frac{w_t}{Z_t\tilde{\varphi}_{v,t}}$
Average survivor's profits	$d_{v,t}\left(\tilde{\varphi}_{v,t}\right)=\frac{1}{\sigma}\rho_{v,t}\left(\tilde{\varphi}_{v,t}\right)^{1-\sigma}C_t-w_t\frac{f_v}{Z_t}$
Average sales	$y_{v,t}\left(\tilde{\varphi}_{v,t}\right)=\frac{\sigma}{\rho_{v,t}(\tilde{\varphi}_{v,t})}\left(d_{v,t}\left(\tilde{\varphi}_{v,t}\right)+\frac{w_t f_v}{Z_t}\right)$
Average employment	$l_{v,t}\left(\tilde{\varphi}_{v,t}\right)=\left(\sigma-1\right)\frac{d_{v,t}(\tilde{\varphi}_{v,t})}{w_t}+\sigma\frac{f_v}{Z_t}$
ZCP	$d_{v,t}\left(\tilde{\varphi}_{v,t}\right)=\frac{\sigma-1}{\kappa_v-(\sigma-1)}\frac{w_t f_v}{Z_t}$
Surviving rate	$\frac{S_{v,t}}{N_{v,t}}=\varphi_{\min}^{\kappa_v}\left[\frac{\kappa_v}{\kappa_v-(\sigma-1)}\right]^{\frac{\kappa_v}{\sigma-1}}\tilde{\varphi}_{v,t}^{-\kappa_v}$
	$N_{v,t}=\left(1-\delta\right)^{t-v}N_{E,v}$

solution. Consequently, we approximate the system with the perturbation method around the stationary steady state.

3 Benchmark Calibration and Estimation

We calibrate the theoretical model with benchmark values of the parameters, as shown in Table 3. The annual discount factor is set to 0.96, under which the steady state real interest rate is 4 %. The value of the Frish elasticity of labor supply ψ is 2.15, which is taken from Sugo and Ueda (2008), who estimate the elasticity using Japanese data from the postwar period. The elasticity of substitution among varieties and the parameter that shapes the Pareto distribution across vintages are set to 3.8 and 3.4, respectively, following Ghironi and Melitz (2005). With $\sigma=3.8$, this gives a markup of 35 %. Note that the latter value satisfies the restriction on these parameters such that $\kappa>\sigma-1$. The value of firm deprecation rate δ and fixed operational cost $f_{\tilde{v}}$ are chosen following Hamano and Oikawa (2021); thus, these values match the average firm creation and operation rate in Japan, as observed in the current production survey. Specifically, we set $\delta=0.0223$ and $f=0.013855$, under which the steady state firm entry N_E/N and operation rate S/N are 0.00571 and 0.987, respectively.[6] The minimum idiosyncratic productivity level $\varphi_{\min}$ and

[6]The data covers from 2001Q to 2017Q. Note at the steady state, $N=(1-\delta)(N+N_E)$. Then, we have $\delta=(N_E/N)/(1+N_E/N)$.

fixed entry cost f_E are set to unity in the steady state. The parameter that determines the disutility of labor supply χ is given so that the value gives the steady state labor supply of $L = 1$.

Table 3: Calibration of the model

β	Discount factor	0.96
ψ	Frisch elasticity of labor supply	2.15
χ	Disutility of supplying labor	0.86091
σ	Elasticity of substitution among varieties	3.8
κ	Distribution parameter	3.4
δ	Depreciation rate	0.0223
f	Fixed operational costs	0.013855
$\varphi_{\min}$	Minimum idiosyncratic productivity level	1
f_E	Fixed entry costs	1
ρ	Persistence of aggregate productivity	0.68049
s_Z	Standard deviation of productivity shocks	0.014089

For the productivity process, we estimate the standard deviation σ_Z and persistence ρ using historical real GDP data for Japan (1885 to 2018, taken from Maddison Historical Statistics) by maximizing the likelihood. For the estimation, we consider an empirically consistent measure of the theoretical GDP as $Y_{R,t} \equiv Y_t / S_t^{\frac{1}{\sigma-1}}$ following Ghironi and Melitz (2005). The idea is to capture imperfect fluctuations in the number of product varieties in the official statistics. Additionally, we define empirically consistent consumption $C_{R,t} \equiv C_t / S_t^{\frac{1}{\sigma-1}}$ and investment $v_{R,t} N_{E,t} \equiv v_t N_{E,t} / S_t^{\frac{1}{\sigma-1}}$ accordingly.[7][8]

[7]To detrend the GDP data, we use an HP filter with a smoothing parameter of $\lambda = 100$. Ravn and Uhlig (2002) suggests $\lambda = 6.25$ for annual data. We find that $\lambda = 100$ is sufficiently good to capture the business cycle over 126 years, while $\lambda = 6.25$ picks up a higher-frequency business cycle. However, the simulation result is qualitatively the same with respect to trend of real GDP.

[8]In estimation, we introduce the measurement error. The estimation is also performed with the Bayesian method using established prior information from the literature. The result is isomorphic to the benchmark estimation with uniform prior, however. The estimation, as well as the approximation of the

4 Simulation

4.1 Vintage-specific Technologies and Fixed Costs

To reveal the history of each vintage firm, we simulate the vintage-specific fixed cost f_v and the specific technology that is captured by κ_v. Our simulation strategy is as follows. First, we simulate the theoretical model 100,000 times over 126 years with the calibrated parameters and the estimated productivity process, as shown in Table 3. Second, given the current distribution of vintage firms and their sales in the 2013 survey, as shown in Figure 1, and taking the simulated number of new entrants in each period $N_{E,v}$, the final date values of the simulated consumption C_t, the wages w_t and the productivity level Z_t, we determine the vintage-specific technology κ_v and the vintage-specific fixed cost f_v. Third, among these simulations, we select the one that gives us the closest dynamics of actual real GDP, and we choose the corresponding distribution of vintage-specific technology κ_v and fixed cost f_v as our estimate.[9]

Figure 2 shows the results of our simulation. Given the end-of-period value of the aggregate consumption, wage, and technology level, as well as the end-of-period distribution

system of nonlinear equations with the perturbation, are conducted with the RISE toolbox developed by Junior Maih.

[9]In the simulation, we match the share of a particular vintage firm in the total number of vintage firms in the 2013 survey with the theoretical counterpart, $S_{v,126}/S_{126}$. The data reports manufacturing firms that have more than 50 employees and those with more than 30 million yen in capital assets. The total number of manufacturing firms as of the 2013 survey was 13,426, according to the BSJBSA data. For the same year, according to the Census of Manufacture by the Ministry of Economy, Trade and Industry ("Kogyo Tokei", in Japanese) and the converter (KogyoTokei Konbata) prepared by RIETI to sum up from plant level to firm level, there were 184,485 firms, based on the census of plants that had more than four employees. Another data source, the Establishment and Enterprise Census of Japan (Ministry of Internal Affairs and Communications), reported the existence of approximately 650,000 published establishments without any restriction regarding the number of employees and any organization. Given that the average reply rate of the BSJBSA survey is approximately 85% and that there are other vintage firms that are not captured in the BSJBSA data, the total number of manufacturing firm would be 50 times higher, at most, than the number reported in the 2013 BSJBSA survey. However, our simulation results are robust with respect to scaling in matching the share.

of the relative number of vintage firms and their relative vintage sales (the first and the second panel in the figure), we simulate the distribution of vintage-specific technologies κ_v and their fixed costs f_v (the third and the fourth panel), as well as the implied distribution of vintage-specific relative productivity $\tilde{\varphi}_{v,t}$ and relative employment $l_{v,t}$ (the fifth and the sixth panel).

Vintage-specific technologies κ_v tend to be high for the initial sample periods and from the late 1960s until the beginning of the 1990s. It is noticed the distribution of vintage-specific fixed costs f_v gives an asymmetric wedge-shaped pattern.[10] In addition, the distribution of vintage productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}\,(\tilde{\varphi}_{v,t})$ show a similar wedge-shaped pattern.[11]

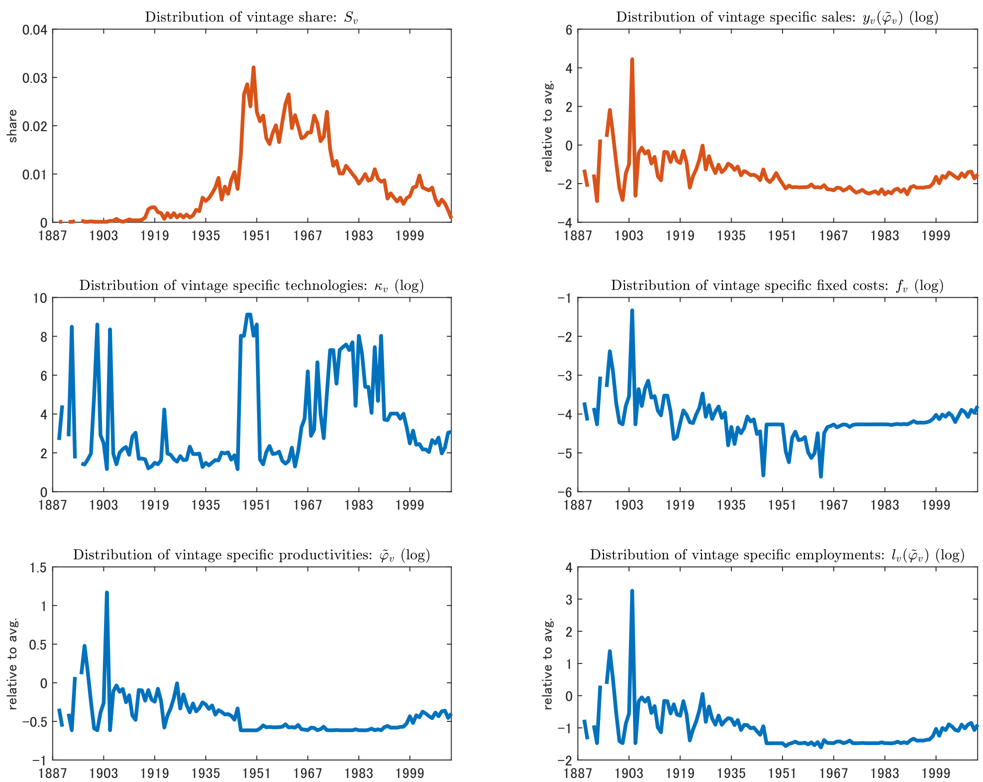
From the simulation, the following result emerges. First, old vintage firms (the least popular cohort in the distribution of firm vintage), i.e., firms created in the initial time periods up until the approximate time of the 1929 Great Depression, which is roughly the time corresponding to the Meiji (1868-1912) and Taisho (1912-1926) era, are subject to higher fixed costs f_v, yet they are currently more productive compared to other vintage firms. Second, vintage firms created near the beginning of the Second World War up until the approximate time of the Plaza Accord in 1985 (the most popular cohort in the distribution of vintage firms) show low average productivity $\tilde{\varphi}_{v,t}$ and low average employment $l_{v,t}\,(\tilde{\varphi}_{v,t})$, although they benefit from low fixed costs f_v. Third, vintage firms created in the most recent time period after approximately 1985 (the secondly popular cohort in the distribution of vintage firms) show low average productivity $\tilde{\varphi}_{v,t}$ and low average employments $l_{v,t}\,(\tilde{\varphi}_{v,t})$ and have slightly higher specific fixed costs f_v than the average.

Noting that vintage-specific fixed costs f_v and technologies κ_v encompass various types

[10]The theoretical model cannot compute the vintage-specific technology κ_v and the fixed cost f_v for 1888, 1891 and 1895 because of missing data.

[11]Cabral and Mata (2003) argue that time varies the firm size dispersion of firms and found that the distribution becomes skewed to the right for young vintage firms. Our results echo their result by simulating vintage-specific technologies κ_v that shape the productivity dispersion of firms. Specifically, our paper replicates a similar pattern of the skewness depending on the sample time period.

Figure 2: Simulation of vintage-specific technologies and fixed costs



The first and second panel in the first row show the distribution of vintage firms and the distribution of their sales in the 2013 survey, respectively. The first and the second panel in the second row show the simulated distribution of vintage-specific technologies κ_v and their fixed costs f_v at the end of periods, respectively. The first and the second panel in the third row show the simulated distribution of productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ at the end of the periods, respectively.

in the real world, our results seem consistent with the industrial policies present in postwar Japan. After the Second World War, the Ministry of International Trade and Industry implemented several industrial policies (Ito et al., 1988; Komiya et al., 1984). The policy scheme consisted of subsidies for specific industries, tax exemptions, R&D policies, and export promotion policies. The targeted sectors were first the steel and iron industries, followed by heavy industries, and then shifted to machinery sectors and high-tech industries. Government banks also had several lending programs that specialized in infrastructure investment, the development of rural areas, investments for the environment, and energy-saving technology (e.g., DBJ, 2002, JASME, 2003). The Japan Development Bank (JDB), which is a government bank housed under the Ministry of Finance, had special lending programs that offered lower interest rates to large companies and major industries. In contrast to the JDB scheme, the Japan Finance Corporation for Small and Medium Enterprise (JASME) (Chusho Kigyo Kinyu Koko) (1953–2008), which was also a government bank, specialized in helping SMEs. The central strategy for several lending programs consisted of lowering interest rates for investments. [12]

To see how our results are comparable with the data, we use the distribution of the number of regular employees and the estimated total factor productivity.[13] It is striking to see that our simulated distribution of employment and productivity provides a similar pattern as that of the distribution of TFP and employment, as shown in Figure 3. The correlation between the estimated TFP and our simulated productivity amounts to 0.7040, while the correlation between the employments in data and our simulated employments is 0.8618.

Finally, we provide the simulation for other sectors in Appendix B. The data for the light manufacturing, service, public utilities, telecommunication, and transportation and construction sectors are available from the same source, i.e., BSJBSA. While we see substantial variation across the sectors, it is noticed the share of the firms created in the middle range of the time period spanning 126 years is relatively high, while these firms show lower sales across all sectors. Accordingly, we confirm a similar pattern for the simulated fixed costs, which produces an asymmetric wedge-shaped pattern, as is the case for the manufacturing sector.

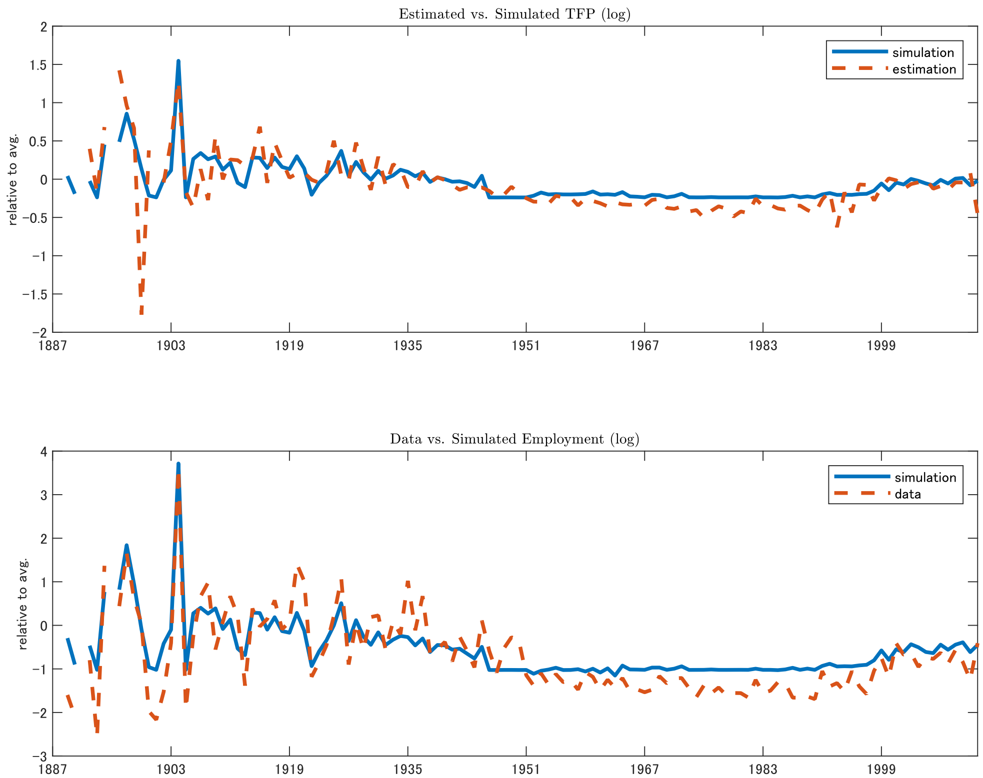
4.2 Macroeconomic Dynamics of Vintages and Snapshots

Figure 4 shows the macroeconomic dynamics for the major aggregate variables that are directly required to compute the pass of each vintage firm. The simulated pass of real GDP captures well the business cycles in the data. Overall, the cyclical properties of other aggregate variables, including firm entry and exit, are similar to the ones discussed

[12] Elliott and Okubo (2016) found that these special lending programs offered lower interest rates than the market rates, which promoted abatement investment in Japan.

[13] The total factor productivity is estimated following Olley and Pakes (1996). In the calculation of tangible capital, we use the data of book-to-market value ratio by Hosono et al. (2017).

Figure 3: Comparison with estimated TFP and employment data



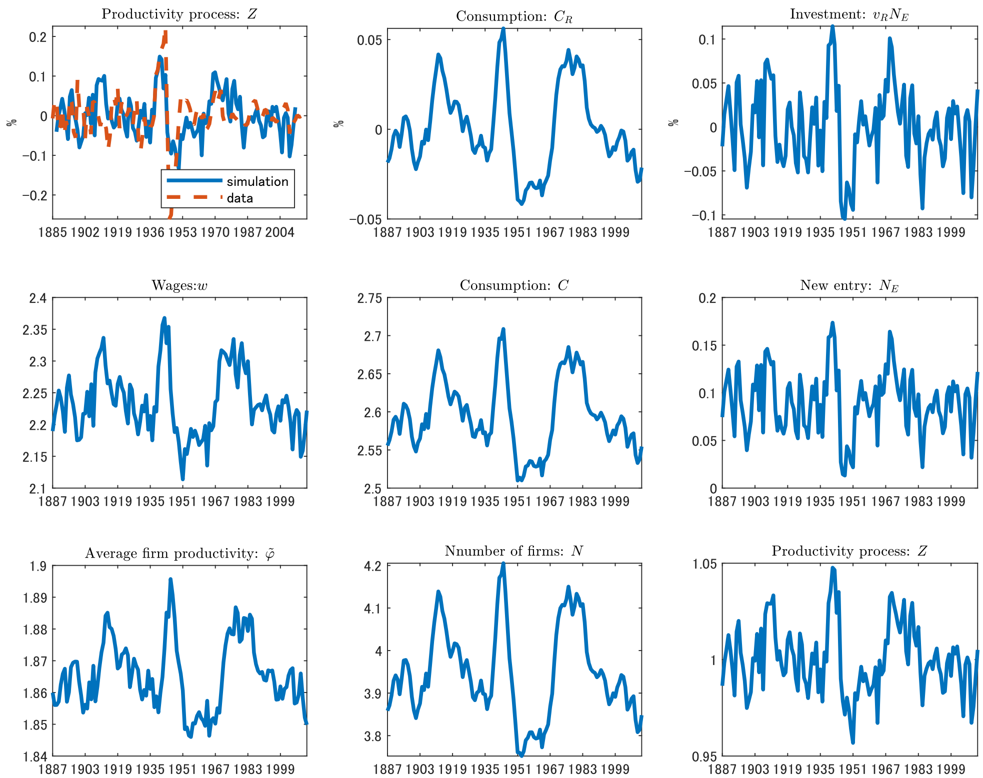
The first panel shows the simulated distribution of vintage productivity $\tilde{\varphi}_{v,t}$ (solid line) and the distribution of estimated vintage TFP (dashed line) at the end of the periods. The second panel shows the simulated distribution of vintage employment $l_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ (solid line) and the distribution of vintage employment in the data (dashed line) at the end of the periods, respectively.

in Hamano and Zanetti (2017) and are in line with those discussed in the literature of real business cycle models.[14] Specifically, procyclical investment is a key to generating a higher number of entrants ($N_{E,v}$), which translates into a proportionally higher number of vintage firms $N_{v,t}$, as the equation (9) indicates.

With the simulated distribution of vintage-specific technologies κ_v and fixed costs f_v, together with the abovementioned aggregate macroeconomic dynamics in hand, we can

[14]The standard deviation of GDP in the simulated model is 0.0555, while that in the data is 0.0596. The simulated consumption is less volatile than GDP (its standard deviation with respect to GDP is 0.4185), while the simulated investments are equally as volatile as GDP (the standard deviation with respect to GDP is 0.9014).

Figure 4: Simulation for aggregate variables

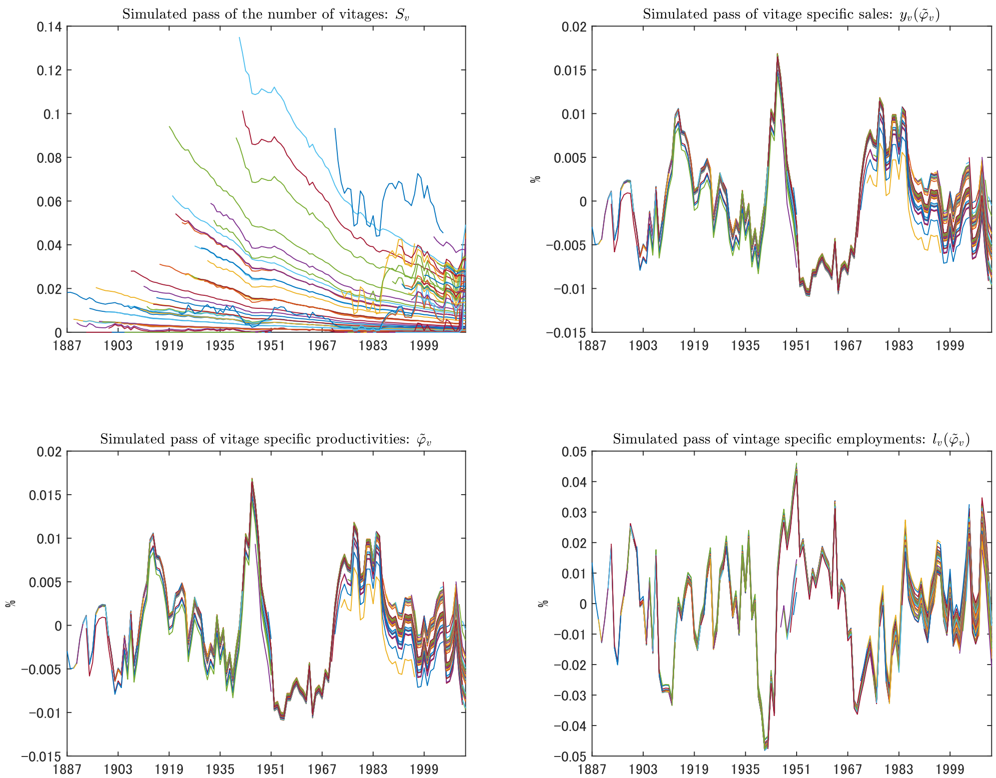


Each entry in the first row shows the percentage-point response in the simulated economy over 126 years. Each entry in the second and third row shows the simulated values expressed in levels over 126 years.

reestablish the history of each vintage firm. Figure 5 provides the simulated number of producers $S_{v,t}$, the percent deviation of the average sales $y_{v,t}(\tilde{\varphi}_{v,t})$, the average productivity $\tilde{\varphi}_{v,t}$ and the average employment $l_{v,t}(\tilde{\varphi}_{v,t})$ for vintage firms from 1887 to 2012.[15] We observe considerable heterogeneity across vintage firms. The number of producers $S_{v,t}$ tends to be high for the periods that correspond to the boom. It is also noticed the levels of sales $y_{v,t}(\tilde{\varphi}_{v,t})$, productivity $\tilde{\varphi}_{v,t}$ and employments $l_{v,t}(\tilde{\varphi}_{v,t})$ fluctuate in a synchronized

[15] The simulated values of vintage-specific costs κ_v show substantial heterogeneity across vintage firms (with the highest value of 9159 in 1949 and the smallest value of 3.185 in 1945). While there is no required restriction per se for its upper end, we find that an unusually high value of κ_v generates unstable dynamics at vintage levels, thereby violating the surviving condition such that $S_{v,t}/N_{v,t} > 1$. In generating Figure 5, we exclude the vintage firms that show unstable dynamics.

Figure 5: Simulated pass of vintages



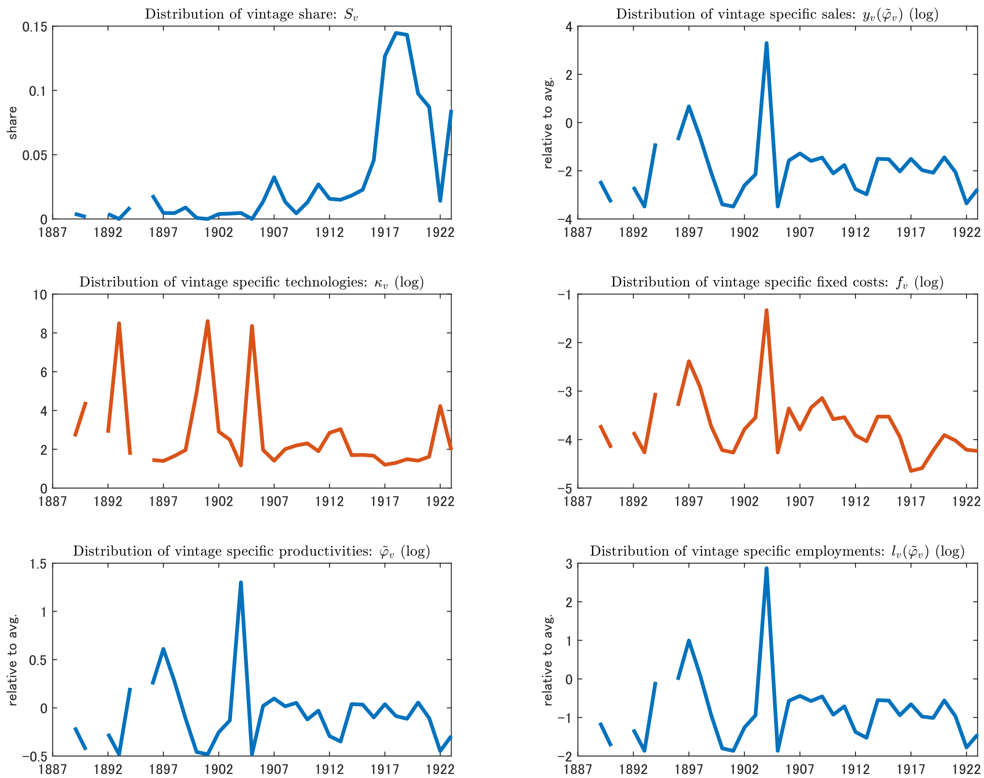
Each entry shows the simulated dynamics of the number of producers $S_{v,t}$, sales $y_{v,t}\left(\tilde{\varphi}_{v,t}\right)$, productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ for vintage firms over 126 years.

way with each other and with the aggregate dynamics, as shown in Figure 4.

To see the history of vintage firms in a compact way, we provide "snapshots" at particular moments in history. These snapshots are the result of our simulation given the abovementioned aggregates, as well as vintage-specific dynamics.[16] Figure 6 provides a snapshot for 1923. Because of the economic boom during the First World War ("Taisen-keiki" in Japanese), the share of vintage producers from 1914 and 1919 is high (first panel in the figure). At the moment of 1923, these firms are relatively new vintage firms. The sales, productivity, and employment of these firms born during the war period are not particularly high. We observe a low entry in 1922 and a rebound in 1923 when the great Kanto earthquake hit in September.

[16]Other snapshots (1914, 1931, 1945, 1960, 1985 and 2009) are given in Appendix C.

Figure 6: Snapshot: 1923

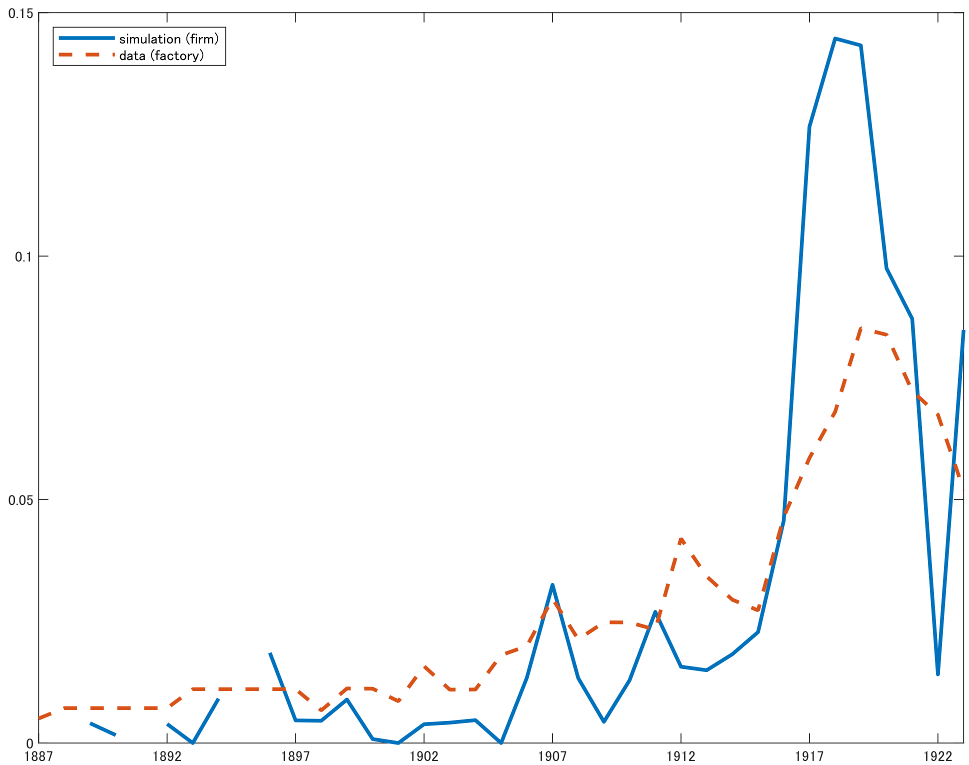


The first and the second panel in the first row show the simulated distribution of vintage firms $S_{v,t}$ and the distribution of their sales $y_{v,t}(\tilde{\varphi}_{v,t})$ in 1923, respectively. The first and the second panel in the second row show the estimated distribution of vintage-specific technologies κ_v and their fixed costs f_v in 1923, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}(\tilde{\varphi}_{v,t})$ in 1923, respectively.

To check the relevance of our simulation, we compare our snapshot of the distribution of vintage firms with the Census of Manufacture by the Ministry of Commerce and Agriculture ("Kojyo Tokei Hyo", in Japanese). The Census of Manufactures in the prewar period records the number of firms in terms of their founding year. The red dotted line in Figure 7 shows the distribution of "factory" vintage firms in 1923. It gives a similar pattern as our simulated distribution of vintage firms in 1923, which is shown by the solid blue line in the figure. The correlation of these two distributions is 0.8406.

Figure 8 gives a snapshot for 1996 based on our simulated vintage-specific technologies and fixed costs. It is particularly interesting to have a snapshot for this year since the

Figure 7: Distribution of factories and vintage firms in 1923



The figure shows the simulated distribution of vintage firms $S_{v,t}$ and the distribution of factory vintage firms in the data (dashed line) in 1923.

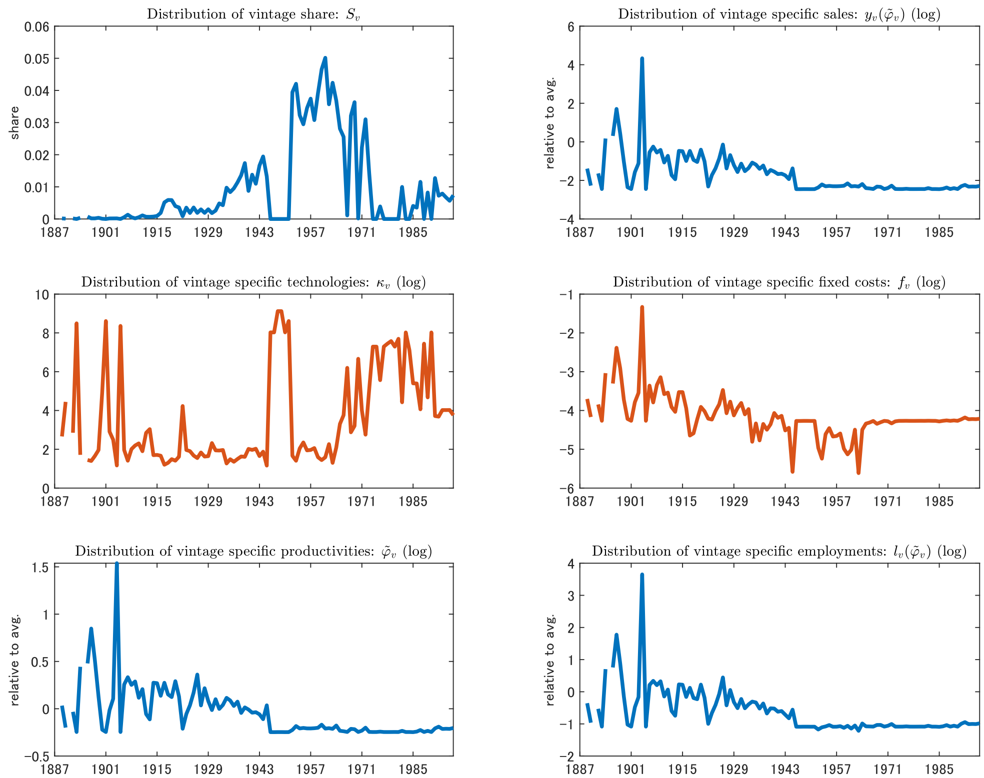
Census of Manufacture provided by the Ministry of Economy, Trade and Industry also has a snapshot for 1996. While the census covers medium-sized firms (all plants with more than four employees), our snapshot and the census snapshot provide a similar landscape.[17]

4.3 Counterfactual Analysis

As the last exercise, we explore the consequence of a counterfactual distribution of vintage-specific fixed costs f_v. We consider a counterfactual pass of fixed costs f_v given the simulated distribution of vintage-specific technologies κ_v. Although it is highly stylized in the theoretical model, the fixed cost for operation ranges from physical costs to legal

[17]The correlation between these two snapshots for the distribution of vintage firms, their sales, their productivity and their employment rates are 0.2995, 0.3847, 0.2384 and 0.3349, respectively.

Figure 8: Snapshot: 1996

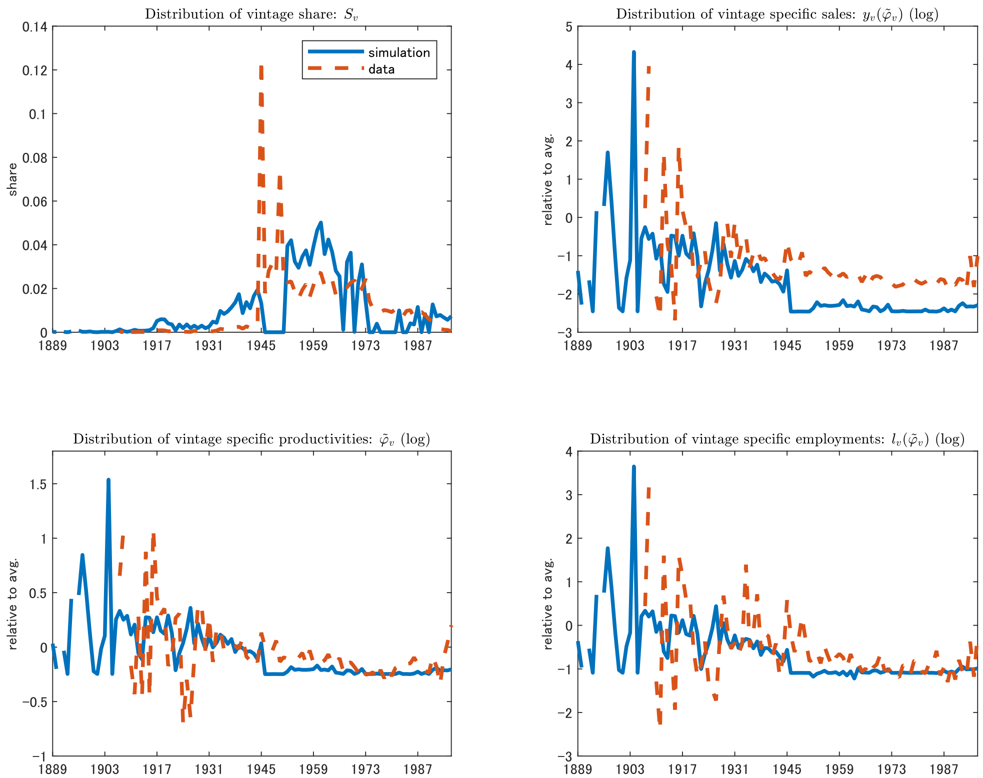


The first and second panel in the first row show the simulated distribution of vintage firms $S_{v,t}$ and the distribution of their sales $y_{v,t}(\tilde{\varphi}_{v,t})$ in 1996, respectively. The first and the second panel in the second row show the estimated distribution of vintage-specific technologies κ_v and their fixed costs f_v in 1996, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}(\tilde{\varphi}_{v,t})$ in 1996, respectively.

procedures in the real world. Importantly, we believe that a part of these costs would be a subject of industrial policy instruments, as mentioned before. This is the reason why we consider a counterfactual distribution of fixed costs f_v rather than a counterfactual distribution of technologies κ_v which seems likely to be limited by the condition of the time.

Our counterfactual distribution of vintage-specific fixed costs f_v is shown by the dotted line in Figure 10. To obtain this, we first approximate the simulated distribution of vintage-specific fixed costs f_v with a quadratic function (shown by the smoothed line). The counterfactual is computed as a flipped symmetric distribution against the horizontal

Figure 9: Simulated vs. Census Snapshots in 1996

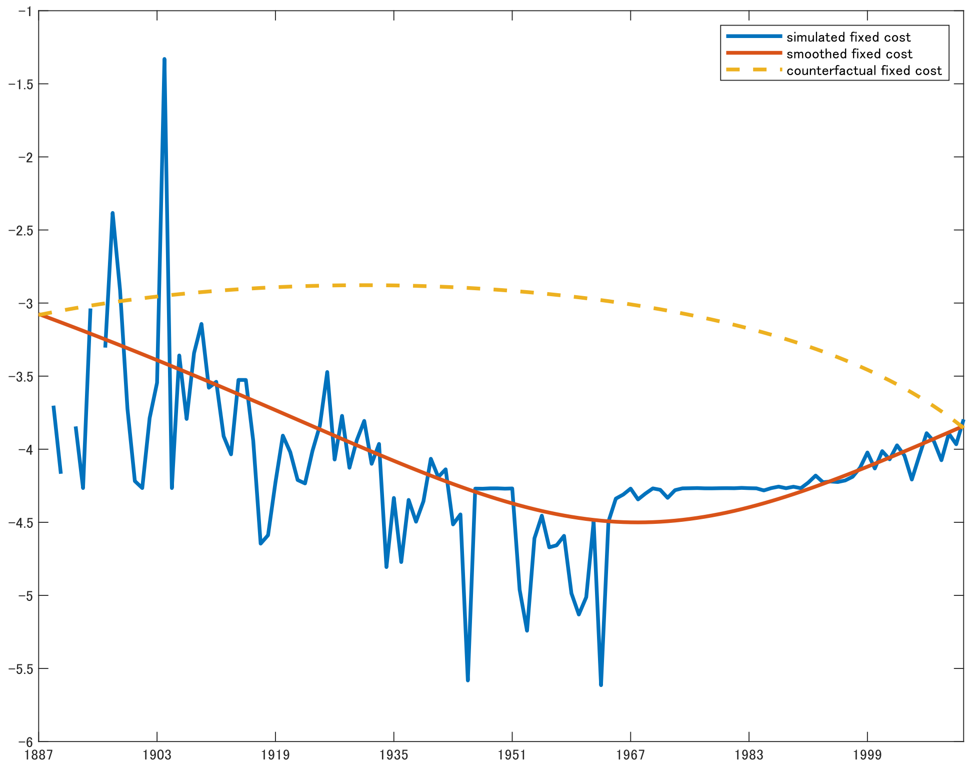


The solid lines in the figure show the simulated distribution of vintage firms $S_{v,t}$, the distribution of their sales $y_{v,t}(\tilde{\varphi}_{v,t})$, the distribution of their productivity $\tilde{\varphi}_{v,t}$ and the distribution of their employment $l_{v,t}(\tilde{\varphi}_{v,t})$ in 1996, respectively. The dashed lines in the figure show these distributions in actual data collected in 1996.

axis of the smoothed quadratic distribution. We also set the initial and end values of the smoothed distribution to coincide with those of the counterfactual distribution. Our counterfactual distribution shows the opposite pattern as the simulated distribution of the fixed costs. Specifically, it increases steadily, peaks at approximately 1920, and then decreases.

The result of our counterfactual simulation is shown in Figure 11. With the counterfactual distribution, it is striking to see that the share of recent vintage firms increases significantly while dramatically reducing the number of vintage firms created in the postwar boom (the first panel in the figure). At the same time, the sales $y_{v,t}(\tilde{\varphi}_{v,t})$, productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}(\tilde{\varphi}_{v,t})$ of these postwar vintage firms become substantially high.

Figure 10: Counterfactual fixed-cost distribution (log)



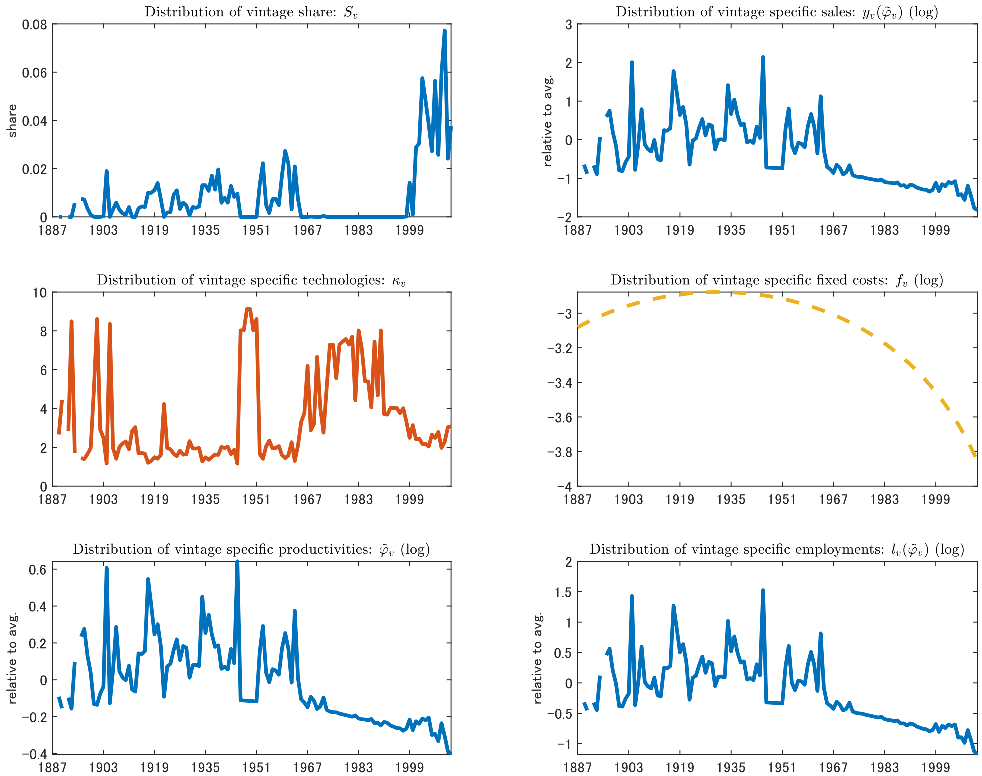
The solid blue line shows the simulated vintage-specific fixed costs f_v . The smoothed red line shows the trend of f_v estimated with the quadratic function. The dashed line shows the counterfactual vintage-specific fixed costs f_v .

Our counterfactual fixed costs thus dramatically change the landscape of vintage firms, as well as their characteristics. Our results indirectly point out how powerful the industrial policies were in supporting these firms in the postwar period.

5 Conclusion

This paper reestablishes the past dynamics of each vintage firm. For that purpose, we built a theoretical model based on the entry and selection of these firms. Given the distribution of vintage firms and the distribution of their sales as we see them today, we simulate vintage-specific technologies and fixed costs required for operation. With these simulated parameters and the cyclical component of GDP over 126 years, we reproduce

Figure 11: Simulation based on the counterfactual fixed costs



The first and the second panel in the first row show the simulated distribution of vintage firms $S_{v,t}$ and the distribution of their sales $y_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ at the end of periods based on the counterfactual vintage-specific fixed costs f_v , respectively. The first and the second panel in the second row show the estimated distribution of vintage-specific technologies κ_v and the counterfactual fixed costs f_v at the end of periods, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ at the end of periods, respectively.

the macroeconomic dynamics of each vintage firm. Using Japanese data, the distribution of vintage-specific fixed costs gives an asymmetric wedge-shaped pattern. While the share of firms created after the Second World War until the oil crisis in the 1970s in the distribution of vintage firms is high in the 2013 survey, these vintage firms have low productivity and low employments. On the other hand, old vintage firms in the Meiji and Taisho era have high productivity despite their high fixed costs. Vintage firms created in the recent time periods after approximately 1985 manifest low productivity and low employments. Furthermore, given the simulated distribution of vintage-specific technologies and fixed costs, we reestablish the macroeconomic dynamics of each vintage firm and provide snapshots of vintage firm distribution at particular moments in time. Finally, we demonstrate that our counterfactual fixed costs dramatically change the landscape of vintage firms, as well as their characteristics.

While we choose to keep the theoretical model as parsimonious as possible, for future research, it would be interesting to incorporate other characteristics of firms, such as capital accumulation within the firm, multiproducts, and economic growth at the firm and/or aggregate level. In addition, detailing the demand side of the economy by introducing a more elaborated preference may be explored. Finally, our exercise can be useful to shape policy debate on a desired allocation of resources and firm dynamics.

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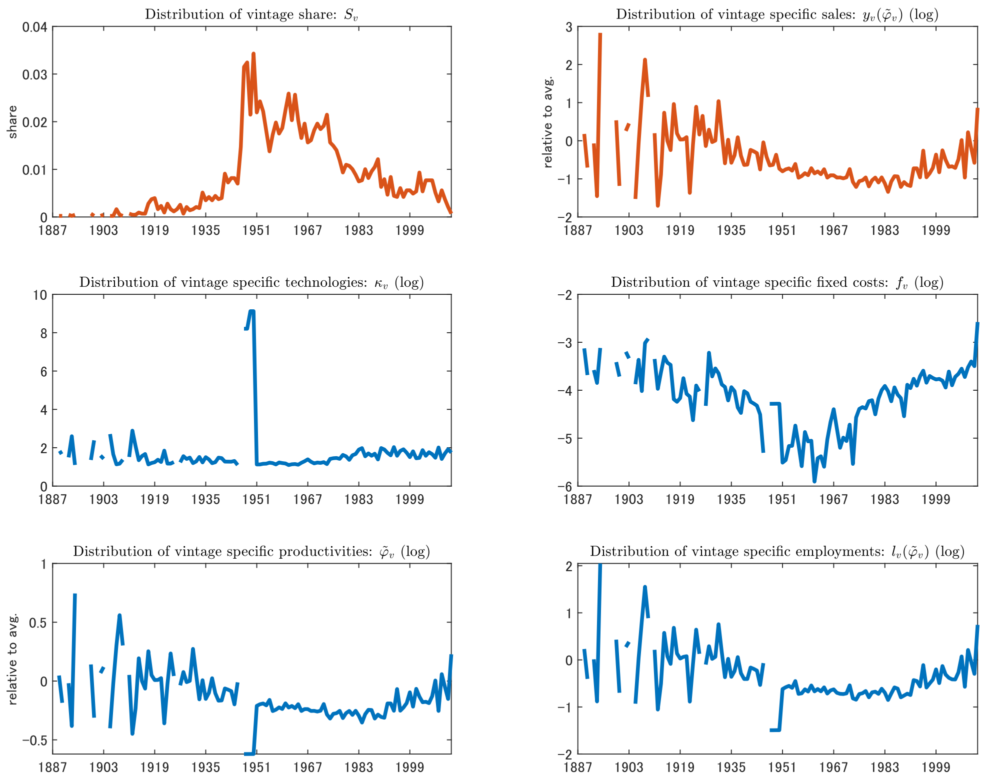
A Data

This paper uses Japanese firm-level data from the Basic Survey of Japanese Business Structure and Activities (BSJBSA), provided by the Ministry of Economy, Trade and Industry of Japan (METI). The data contain a wide variety of firm-level variables such as founding year, number of employees, sales, profit, and tangible capital. The survey covers all firms with more than 50 employees and with more than 30 million yen of capital asset and has an approximate 85% reply rate. The survey was conducted in 2013.

In addition, the paper uses Japanese plant-level data from the Census of Manufacture ("Kogyo Tokei" in Japanese), provided by the Ministry of Economy, Trade and Industry. The data covers all plants with more than 4 employees.

Figure 12: Simulation of vintage-specific technologies and fixed costs: light manufacturing



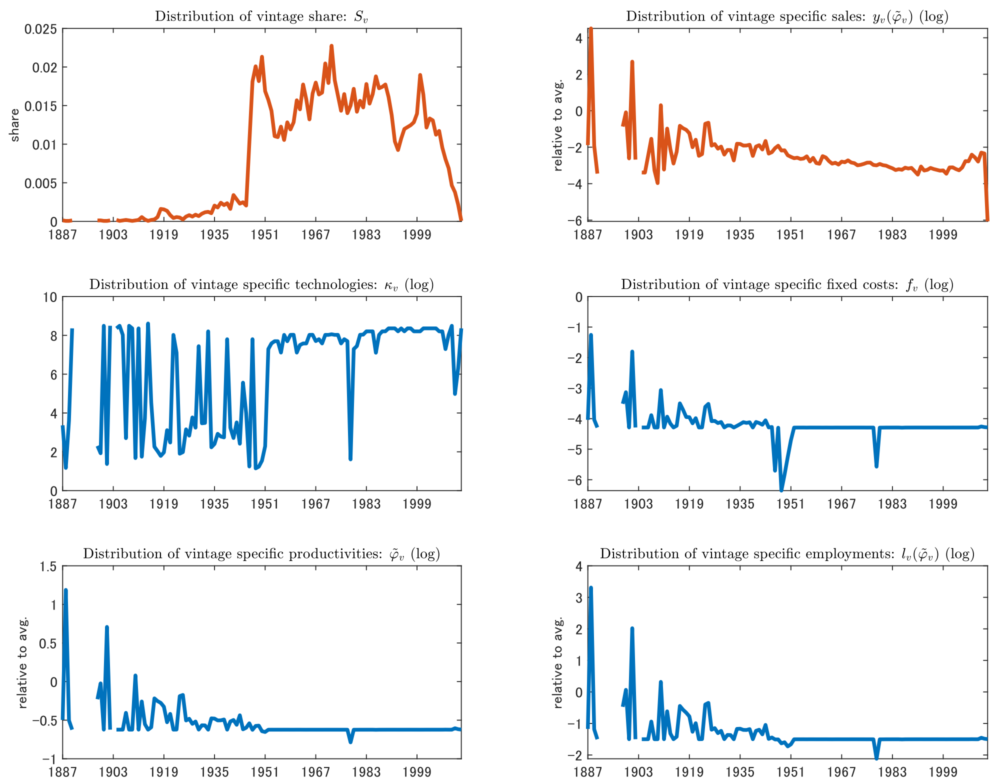
The first and the second panel in the first row show the distribution of vintage firms and the distribution of their sales in the 2013 survey, respectively. The first and the second panel in the second row show the simulated distribution of vintage-specific technologies κ_v and fixed costs f_v at the end of periods, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}(\tilde{\varphi}_{v,t})$ at the end of the periods, respectively. Light manufacturing includes food, beverage, fertilizer, textile, printing, paper and pulp, furniture, pottery, fur skins and glass.

B Sectors

Figures provide simulation results for the light manufacturing, service, public utilities, telecommunication and transportation and construction sectors. The figures are obtained using the same procedure as the case of the manufacturing sector.

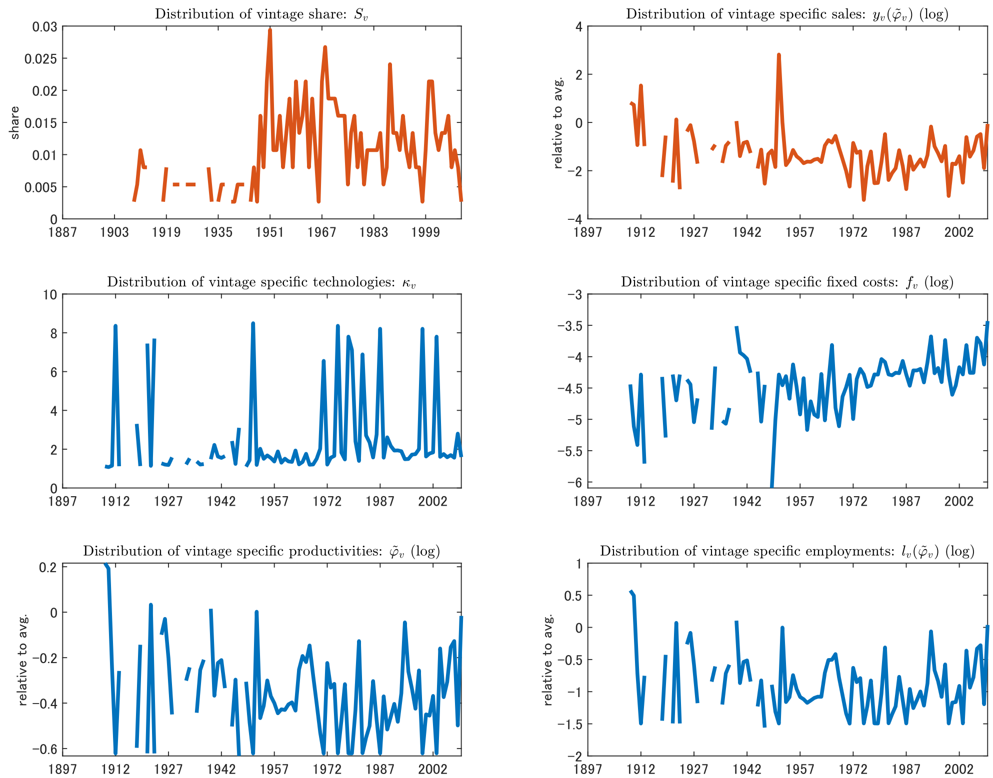
C Snapshots

Figure 13: Simulation of vintage-specific technologies and fixed costs: service



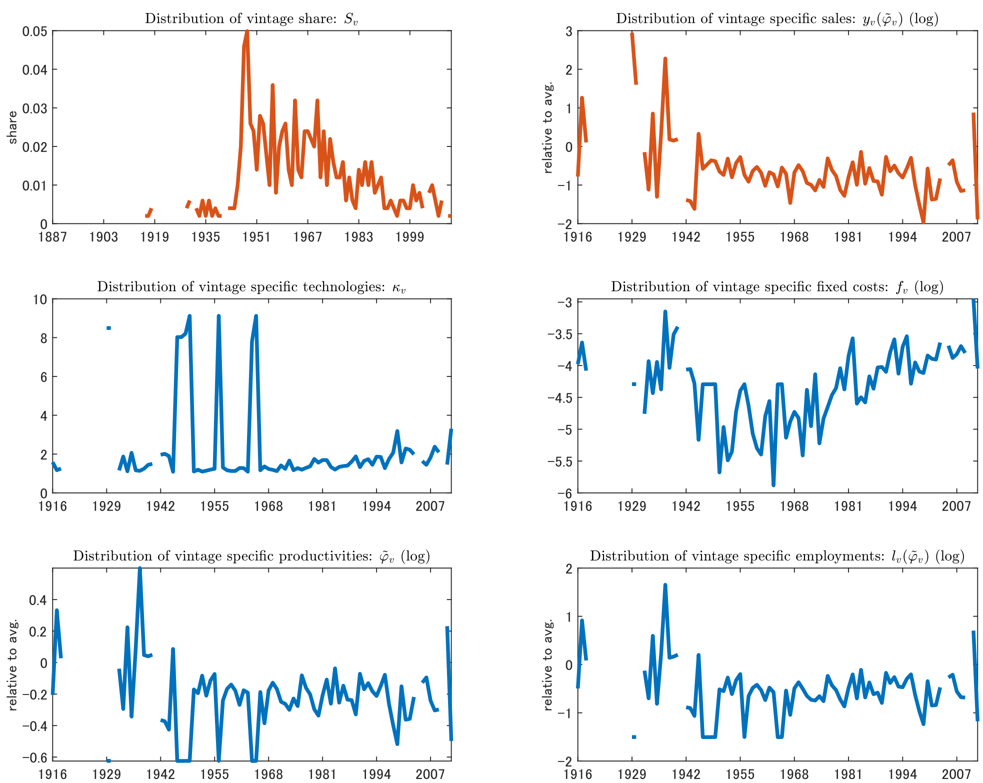
The first and the second panel in the first row show the distribution of vintage firms and the distribution of their sales in the 2013 survey, respectively. The first and the second panel in the second row show the simulated distribution of vintage-specific technologies κ_v and fixed costs f_v at the end of periods, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}(\tilde{\varphi}_{v,t})$ at the end of the periods, respectively. Service includes wholesales, retail, restaurant and general services except public service, IT, telecommunication, transportation, insurance finance.

Figure 14: Simulation of vintage-specific technologies and fixed costs: public utilities, telecommunication and transportation



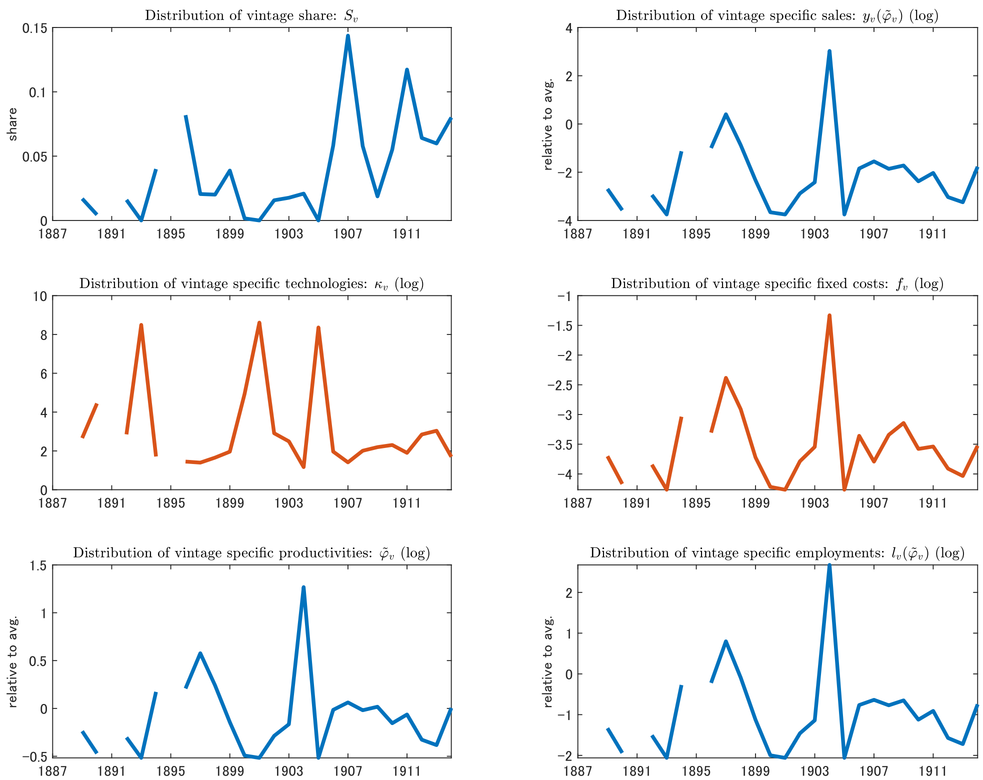
The first and the second panel in the first row show the distribution of vintage firms and their sales in the 2013 survey, respectively. The first and the second panel in the second row show the simulated distribution of vintage-specific technologies κ_v and fixed costs f_v at the end of periods, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ at the end of the periods, respectively.

Figure 15: Simulation of vintage-specific technologies and fixed costs: construction



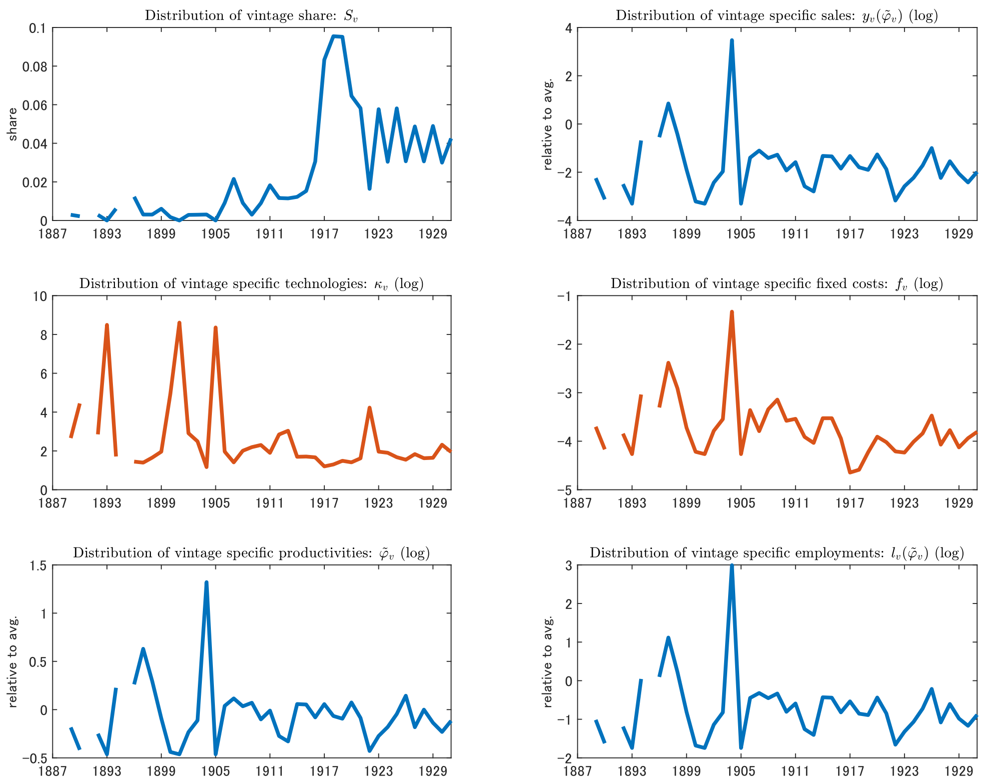
The first and the second panel in the first row show the distribution of vintage firms and the distribution of their sales in the 2013 survey, respectively. The first and the second panel in the second row show the simulated distribution of vintage-specific technologies κ_v and fixed costs f_v at the end of periods, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ at the end of the periods, respectively.

Figure 16: Snapshot: 1914



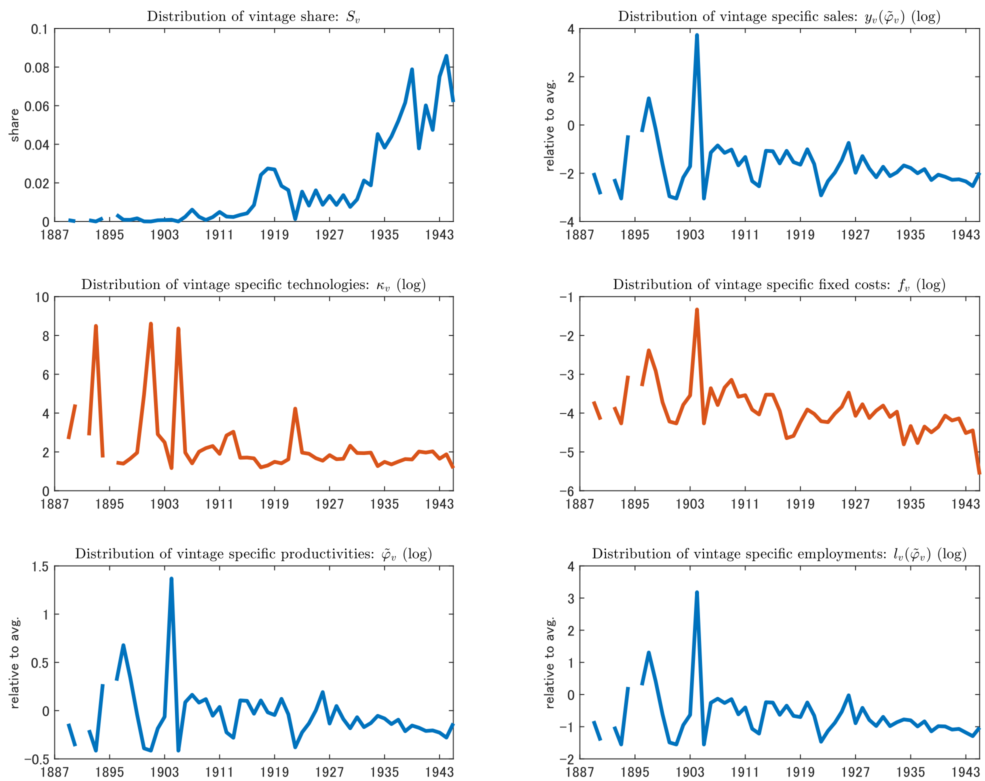
The first and the second panel in the first row show the simulated distribution of firm vintage $S_{v,t}$ and the distribution of their sales $y_{v,t}(\tilde{\varphi}_{v,t})$ in 1914, respectively. The first and the second panel in the second row show the estimated distribution of vintage-specific technologies κ_v and fixed costs f_v in 1914, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}(\tilde{\varphi}_{v,t})$ in 1914, respectively.

Figure 17: Snapshot: 1931



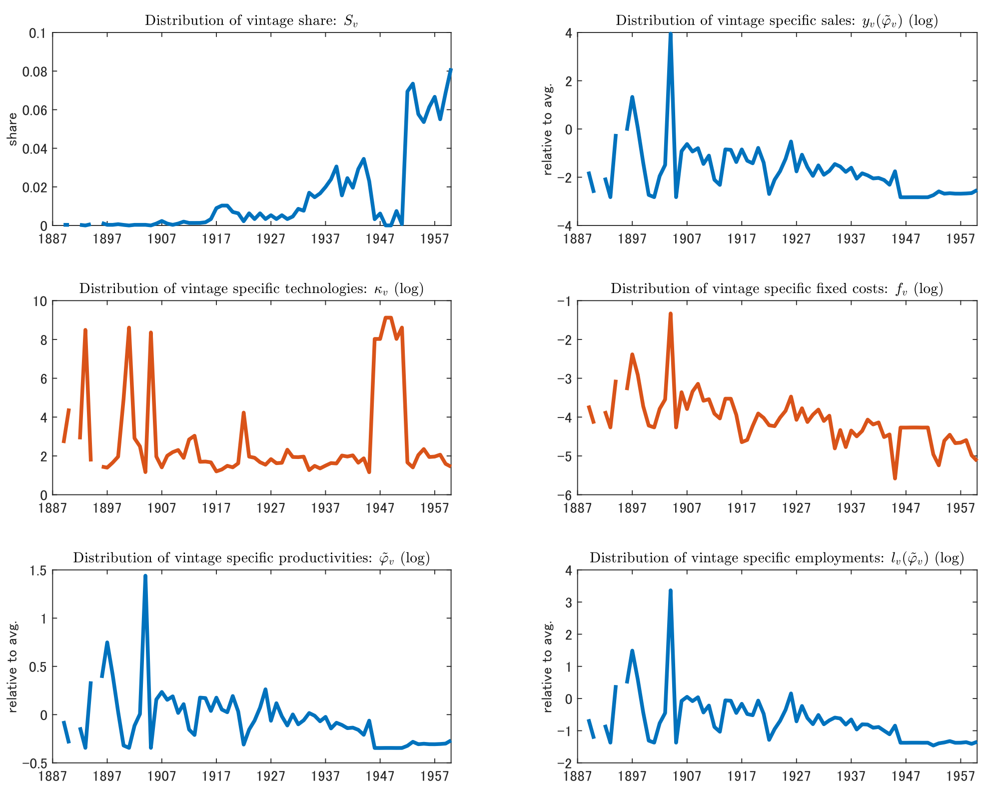
The first and the second panel in the first row show the simulated distribution of firm vintage $S_{v,t}$ and the distribution of their sales $y_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ in 1931, respectively. The first and the second panel in the second row show the estimated distribution of vintage-specific technologies κ_v and fixed costs f_v in 1931, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ in 1931, respectively.

Figure 18: Snapshot: 1945



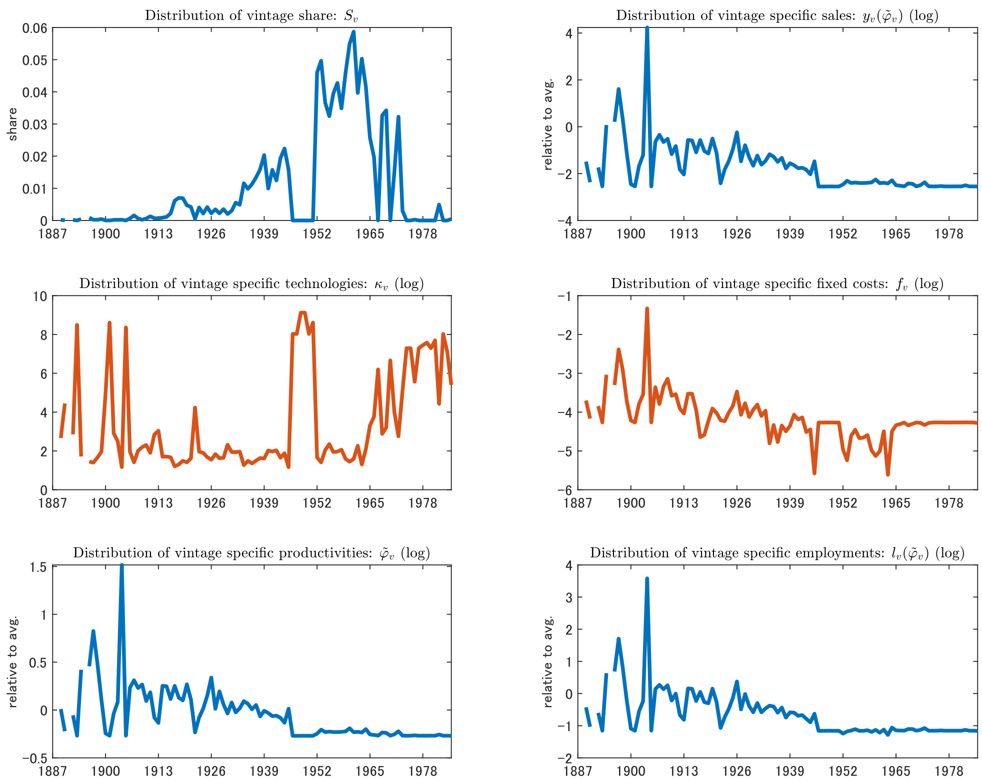
The first and the second panel in the first row show the simulated distribution of firm vintage $S_{v,t}$ and the distribution of their sales $y_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ in 1945, respectively. The first and the second panel in the second row show the estimated distribution of vintage-specific technologies κ_v and fixed costs f_v in 1945, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ in 1945, respectively.

Figure 19: Snapshot: 1960



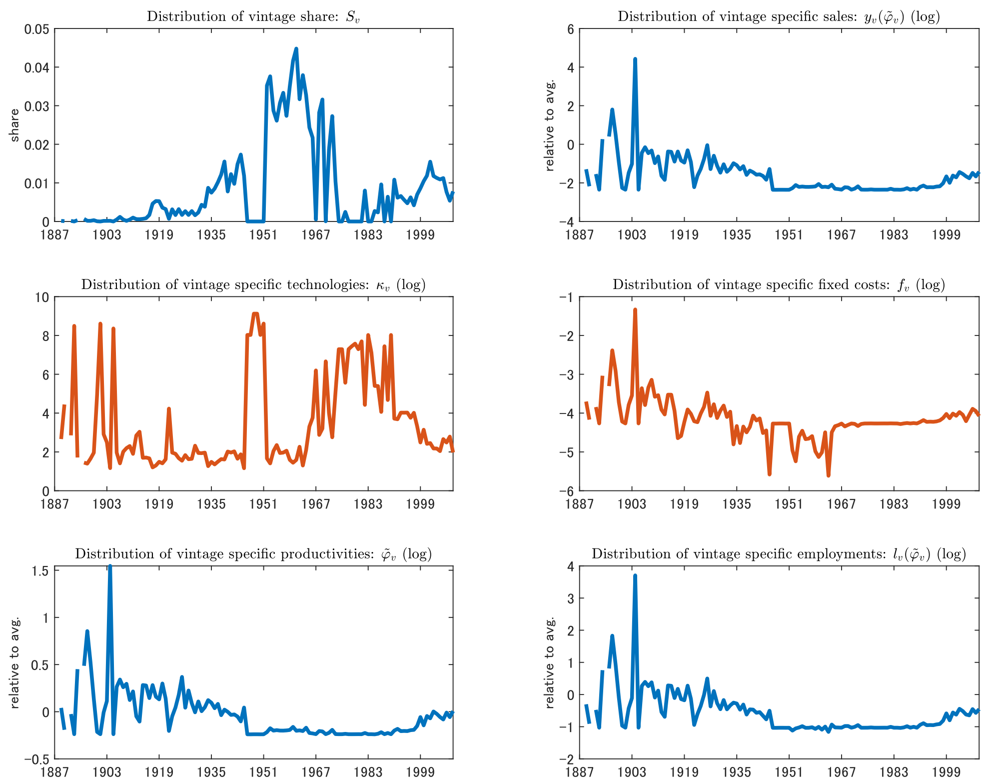
The first and the second panel in the first row show the simulated distribution of firm vintage $S_{v,t}$ and the distribution of their sales $y_{v,t}(\tilde{\varphi}_{v,t})$ in 1960, respectively. The first and the second panel in the second row show the estimated distribution of vintage-specific technologies κ_v and fixed costs f_v in 1960, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}(\tilde{\varphi}_{v,t})$ in 1960, respectively.

Figure 20: Snapshot: 1985



The first and the second panel in the first row show the simulated distribution of firm vintage $S_{v,t}$ and the distribution of their sales $y_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ in 1985, respectively. The first and the second panel in the second row show the estimated distribution of vintage-specific technologies κ_v and fixed costs f_v in 1985, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}\left(\tilde{\varphi}_{v,t}\right)$ in 1985, respectively.

Figure 21: Snapshot: 2009



The first and the second panel in the first row show the simulated distribution of firm vintage $S_{v,t}$ and the distribution of their sales $y_{v,t}(\tilde{\varphi}_{v,t})$ in 2009, respectively. The first and the second panel in the second row show the estimated distribution of vintage-specific technologies κ_v and fixed costs f_v in 2009, respectively. The first and the second panel in the third row show the simulated distribution of vintage firm productivity $\tilde{\varphi}_{v,t}$ and employment $l_{v,t}(\tilde{\varphi}_{v,t})$ in 2009, respectively.