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Market Access, Technology, and Plant Lifecycles:
A Natural Experiment from Japan's Opening to Trade in 1859*

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Abstract

This paper examines how trade regime change has affected the lifecycle of manufacturing plants. For this purpose, we exploited the historical event of Japan's opening to trade in 1859 as a natural experiment. Based on plant-level data for 1902 and 1919, we explore how lifecycles of plants differ between the periods before and after 1859. It was found that lifecycles of plants were indeed different between these two periods: (1) a plant grew much faster as it aged after 1859 than before 1859; (2) this effect is larger for plants in exporting industries and plants located in metropolitan areas; (3) plant size at entry was larger for plants that entered after 1859 compared to those that entered before 1859. The difference in plant lifecycles between the periods before and after 1859 was confirmed by long-term time series data covering both periods. Based on these findings, we argue that access to markets and advanced technologies affected the lifecycle of plants.

Keywords: Plant lifecycle, Market access, Trade reform, Natural experiment, Economic History, Japan.
JEL Classification Number: D22, L25, O14, O43, N65.

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1 Introduction

Plant lifecycle dynamics are heterogeneous across countries, in particular, between developed and developing countries, and these differences have substantial implications for efficiency of the economy. Hsieh and Klenow (2014) compared the age-size profiles of plants in the United States, Mexico, and India, and found that in the latter two countries, plants grow more slowly as they age compared to in the United States. They further found that plant life cycles in India and Mexico are associated with 25% lower aggregate total factor productivity (TFP) according to results from general equilibrium modeling.

Thus, the question that arises is why do these differences in plant life cycles exist across countries? Hsieh and Klenow (2009, 2014) suggest barriers facing larger plants in India and Mexico, such as financial frictions, higher tax burdens on larger firms, contractual frictions in hiring nonfamily labor, especially skilled managers and costs of shipping to distant markets.[1] Meanwhile, Poschke (2017) reveals that average firm size across all sectors of the economy increases with per capita income both across countries and in terms of historical experience in the United States over 1890–2006. Bento and Restuccia (2017) also show that average firm size in the manufacturing sector also increases with GDP per capita. There is no systematic relationship between average firm size and population size. De Mel, McKenzie, and Woodruff (2008) show that credit constraints affect smaller and young firms, reducing their growth opportunities. Bloom et al. (2013) and McKenzie and Woodruff (2013) find that low-qualified managers, insufficient firm-level capabilities, and inadequate training all hinder the growth of firms and plants. Akcigit, Alp, and Peters (2017) theoretically investigate how managerial delegation inefficiencies can limit firm growth and apply this model to compare the effects of delegation efficiency on the lifecycles of Indian and US firms. Finally, Jensen and Miller (2016) explain the slow growth of firms and plants in developing economies by the limit of market.[2]

This paper attempts to identify mechanisms and channels that hinder plant growth in developing economies, using data from Japan in the nineteenth and early twentieth centuries.

[1] Financial barriers, informational barriers, and lack of competitive institutions cause misallocation of input resources and these distortion channels hinder productive investments in terms of firms' entry and growth (Bento and Restuccia, 2017; Hsieh and Klenow, 2009, 2014; Restuccia and Rogerson, 2008, 2017).

[2] Foster, Haltiwanger, and Syverson (2016) also show that the demand accumulation process through building customer capital causes slow growth of plants even in commodity-like product markets in the United States. This result implies that firms' or plants' age is a proxy for accumulating demand. Haltiwanger, Jarmin, and Miranda (2013) investigate the role of age (i.e., firm births) in explaining the growth of plants by exploring job creation and destruction at establishment in the United States. They show that firm births and younger firms contribute to both gross and net job creation. Their result testifies to the importance of accounting for business start-ups to understand job creation and aggregate employment growth. In addition, Foster, Haltiwanger, and Syverson (2008) unpack the contribution of young producers to aggregate productivity growth based on the observation that these young producers charge lower prices than incumbent firms.

The case of Japan in this period is highly valuable in the context of the foregoing literature, because plants in Japan experienced growth in two essentially different environments, namely autarchy via the seclusion policy of the Tokugawa government and the open economy through partial treaties with Western countries enacted in 1859. This exogenous trade regime change in 1859 provides an important opportunity for a natural experiment, which Bernhofen and Brown (2004) exploit for a direct test of the Heckscher-Ohlin Theorem. We use this opportunity to identify the mechanisms which explain the plant life cycle heterogeneities revealed by Hsieh and Klenow (2014) between developing and developed countries.

To accomplish our objective, we use two sets of data. The first consists of plan-level data of manufacturing censuses for 1902 and 1919, which provide information on entry year, employment location, and industry for each manufacturing plant. Although many plants entered after 1859, there were plants that entered before that as well. The latter group of plants operated under two different trade regimes. Using these data, we test whether 1-year experience of operation under the open economy had a larger effect on plant growth than that under the autarchy. Second, we also use long-term time series data for two individual plants covering the period before and after the opening of trade. It is known that in Japan, there are many companies with long histories dating back to the pre-modern period. For two of those companies, we found long-term data on production and employment. Through this, we examine whether the pattern of plant growth indeed changed after the opening of trade. Narrative materials on those plants are also examined to identify the sources of the different patterns of plant growth.

The rest of the paper is organized as follows. Section 2 describes the background, context, and theoretical framework of this paper. Section 3 describes and explains the data and methodology before estimation results are presented Section 4. In Section 5, we explore relevant historical evidence. Finally, Section 6 concludes.

2 Background: Japan's opening to trade in 1859

In the early seventeenth century, the central government of Japan, that is, Tokugawa *Bakufu*, closed the country through a series of acts. By 1639, trade and other international relationships of Japan were limited to those with The Netherlands, China, Korea, and Ryukyu and were strictly controlled by *Bakufu* (Tashiro 1988; Maehira 1991). It is not easy to evaluate the impact of the seclusion policy directly by the volume of trade, but Bernhofen and Brown (2004) estimate that imports per capita were 0.6 cents in the last year of seclusion, whereas the counterpart of China was 9 cents just before it was forced to open up in the 1840s.

The end of the seclusion policy has its roots in 1853, when Matthew C. Perry, a general of the U.S. Navy, came to Japan with his fleet, to request opening up to *Bakufu*. Under the threat of the fleet, *Bakufu* concluded the Treaty of Kanagawa in 1854, which established a diplomatic relationship between Japan and the United States. Similar treaties were concluded with Britain, Russia, and The Netherlands in 1854, 1855, and 1856, respectively.

Based on these diplomatic relationships, *Bakufu* then concluded trade treaties with the United States, Britain, Russia, The Netherlands, and France in 1858, which prescribed opening of five ports (Kanagawa, Nagasaki, Hakodate, Niigata, and Hyogo) and two markets (Edo and Osaka). The ports of Kanagawa, Nagasaki, and Hakodate were opened in 1859. Because of criticism and objections from powerful feudal lords, the opening of other ports was postponed, but to secure foreign approval for this postponement, *Bakufu* conceded to a low conventional tariff rate of 5%. In this sense, Japan's opening up was not only the start of trade but also a transition to a free trade regime.

The impact and magnitude of this trade regime change can be illustrated by changes in prices. Shinbo (1978) compares changes in prices between domestic goods, export goods, and import goods using a 5-year moving average of price data, whereas Bernhofen and Brown (2004) study the relationship between net exports in 1869 and price changes from 1851–53 to 1869. Here to focus on the impact of the regime change in 1859, we utilize annual prices of raw silk (export good), rice (domestic good), and cotton fabric (import good). It is clear that the price of raw silk started to rise sharply in 1859, whereas the prices of rice and cotton fabric were stable (Figure 1).

==== Figure 1 here ====

3 Data, descriptive statistics, and empirical strategy

3.1 Data and descriptive statistics

The Ministry of Agriculture and Commerce conducted censuses on manufacturing factories with 10 or more workers from the 1890s, and individual plant-level data were published under the title of *Kojo Tsuran* (Handbook of Factories) from 1902 (Matsuda, Sato and Kimura 1990). *Kojo Tsuran* is available for 1902, 1904, 1907, 1909, 1918, and 1919[3] containing information for all private manufacturing plants in Japan with 10 or more workers in terms of plant name, industry, product, location, owner, year and month of foundation, number of employees by

[3] After that *Kojo Tsuran* was not published for several years; publication recommenced under the name of *Zenkoku Kojo Tsuran* from 1931 (1929 issue), but did not provide the information on the number of employees.

gender, and number and horse power of engines by power source. Herein, we use data from the 1902 (the oldest) and 1919 (the most recent) issues of *Kojo Tsuran*. The industries we study are shown in Table 1.

==== Table 1 here ====

Descriptive statistics are summarized in Tables 2 and 3. The total number of manufacturing plants in 1902 and 1919 are 7628 and 24,034, respectively. The increase in manufacturing plants from 1902 to 1919 reflects rapid growth of the economy during World War I. The size distribution of plants did not change substantially in this period, however. That is, the mean number of plant employees increased slightly, and the median declined. It is suggested that although existing plants grew, many small plants also entered. On the other hand, the composition of industries changed substantially. Namely, the proportion of plants representing heavy and chemical industries increased such as machinery, metal instruments, ship building, and automotive vehicles, whereas that of silk reeling declined sharply

==== Table 2 and Table 3 here ====

An important feature of this data set in the context of this paper is that the observations include a substantial number of plants that were founded before 1859. Table 4 reports the number of plants by time of foundation. Of the 7,628 and 24,034 total plants in 1902 and 1919, 338 and 718 plants were founded before 1859, respectively. These plants were therefore operational before and after the opening of Japan to international trade. Figure 2 illustrates the employment shares of younger and older plants in 1902 and 1919: younger plants are more likely to have a larger employment share than older plants in these 2 years.

==== Table 4 and Figure 2 here ====

3.2 Empirical strategy

The key question of this paper is how the lifecycle of plants was affected by a trade regime change, the opening of Japan to international trade in 1859. The lifecycle of plants is characterized by the relationship between age (years after entry) and size of plant, that is age-size profile. Figure 5 shows the relationship between age and average plant size without controlling for other plant-level characteristics; average plant size is an increasing function of operational years until the age 40–44.

==== Figure 5 here ====

To determine the nature and scope of the effect of the trade regime change, we exploit a natural experiment provided by Japan's opening to trade in 1859. More specifically, we divide years after plant entry into two periods: the years before and after the opening of trade. We assume that years before the opening of trade is a proxy for exposure to a traditional environment in terms of market and technology. Meanwhile, we assume that the years after the opening of trade are a proxy for exposure to a modern environment in terms of market and technology. Given these assumptions, we regress plant size (number of workers) on years of exposure to the traditional and modern environments. That is, we estimate the following linear equation as the baseline model.

$$y_{ijpt} = \beta_1(\text{Years after entry})_{ijpt} + \beta_x(\text{other controls})_{ijpt} + u_{ijpt}, \tag{1}$$

$$= \beta_1 \underbrace{(\text{Years } \textbf{before} \text{ opening})_{ijpt}}_{\text{Autarky period}} + \beta_2 \underbrace{(\text{Years } \textbf{after} \text{ opening})_{ijpt}}_{\text{Trade period}} + \beta_x(\text{other controls})_{ijpt} + u_{ijpt}, \tag{2}$$

where y_{ijpt} is log of size of plant i belonging to industry j, located in prefecture p at time t (t=1902 or 1919). The explanatory variable "Years before opening" is the number of years between the time of plant entry and the year of Japan's opening to trade, 1859. The variable "Years after opening" is the number of years between 1859 and time t. "Other controls" is a set of further explanatory variables including a plant-level steam power dummy, an export industry dummy, a metro prefectures dummy (Tokyo, Kanagawa, Aichi, Osaka, Hyogo, and others), an urban country dummy, the county-level population, and a year dummy. We estimate this equation by Ordinary Least Squares. A key identifying assumption here is that the opening of trade was determined exogenously to each plant.

4 Results

4.1 Baseline regression

Table 5 presents the baseline estimation results. Column (1) reports the results of an estimation that does not distinguish the years before and after the opening of trade nor the plants that entered before and after the opening of trade. The coefficient on years after entry, i.e., plant age, is positive and significant at the 1 percent level. The magnitude of the coefficient 0.001

indicates that a plant grew 0.1 percentage points larger as it aged by 1 year. Column (2) shows the results of the regression that distinguishes between plants that entered before and after 1859. This specification still does not distinguish between the years before and after 1859, but it allows for a shift in the plant scale at entry (age 0) because of the opening to trade, which is captured by the entry after opening dummy. The coefficient of that variable, 0.392, indicates that, on average, the plant scale at entry was 48.0% (=exp(0.392)-1) larger for those plants that entered after 1859 compared to those that entered before 1859, other things being equal.

Finally, Column (3) is the case where we distinguish the years before and after 1859. Interestingly, the coefficient on years after opening is two times larger than that on years before opening. The change in environment because of the opening of trade doubles the age effect on plant size. In this case, the coefficient on the entry after opening dummy is still positive and significant. In other words, the opening of trade in 1859 had a positive impact on the slope and intercept of the age-size profile. In this sense, trade opening substantially changed the plant lifecycle.

==== Table 5 here ====

4.2 Mechanisms

In the previous subsection, we revealed that operational experience after the opening of trade had a different effect on plant growth compared to the pre-opening, traditional period. Then, the next question is through what channels did the opening of trade affect the plant lifecycle? As we have already discussed, one hypothesis is that plants grew faster because they accessed larger markets after the opening of trade. We can test this hypothesis by exploiting the variation of industries and locations of plants. That is, if improved access to larger markets after 1859 is the salient channel here, the coefficient of the entry after opening dummy as well as the difference between the years before opening and years after opening coefficients will be larger for plants in export industries compared to those in non-export industries. For the same reason, plants located in metropolitan prefectures (Tokyo, Kanagawa, Aichi, Osaka, and Hyogo), which were close to large sea ports, would enjoy a larger positive impact of trade opening.

Table 6 reports regression results for the model which distinguishes between export industries and metropolitan prefectures. Exporting industries here refer to silk reeling, cotton making, cotton spinning, weaving, knitting, stitch work, floss silk, and twining. Columns (3) and (6) show a sharp contrast vis-à-vis the impact of opening to trade on the age effect between the export and the non-export industries. For the export industries, there is a large difference in age effects between the years before and after 1859. For the exporting industries, the coefficient on years after opening is more than 10 times larger than the coefficient on years before opening, and furthermore, the latter coefficient is not statistically significant. On the other hand, for the non-exporting industries, the coefficient on years after opening is negative and marginally statistically significant. In other words, for the export industries, the opening of trade had a positive impact on the slope of the age-size profile, whereas for the non-exporting industries, it had a negative impact. The results are similar concerning the impact on the intercept of the age-size profile. That is, the coefficient on entry after opening for the exporting industries is more than five times larger than that for the non-exporting industries.

Table 7 reports regression results for a specification that distinguishes between plants in metropolitan and non-metropolitan prefectures. These results also show a clear contrast in the impact of the opening of trade on the age-size profile of plants. For plants in metropolitan prefectures, the coefficient on years after opening is significantly positive and three times larger than that on years before opening. Although, for plants in non-metropolitan prefectures, the coefficient on years after opening is the same as that on years before opening. Furthermore, the coefficient on entry after opening for metropolitan prefectures is much larger than that for the non-metropolitan prefectures.

==== Table 6 and Table 7 here ====

The impact of the opening of trade was not limited to improved market access. After the opening of trade, firms in Japan came to be able to adopt advanced Western technologies, and the Meiji government supported and promoted technology adoption in line with its "rich country and strong army" (*fukoku kyohei*) slogan. Thus, we can hypothesize that improved access to Western technologies is another channel by which the opening up affected plant lifecycle. To examine this hypothesis, we exploit the variation of modern technology intensity across industries.

Table 8 shows adoption rates of modern technologies by industry. The adoption rate of modern technology here refers to the ratio of plants that used steam power to electric power. The average adoption rate across all plants in 1902 and 1919 was 0.59. Based on this, we regard the 28 industries with an adoption rate higher than 0.60 as the industries that intensively used modern technologies (modern technology intensive industries), whereas we regard the other 25 industries as the industries that did not used modern technologies intensively (on-modern technology intensive industries).

Table 9 presents regression results for a model that distinguishes these two groups of industries. These two groups of industries show a clear contrast in the impact of the opening of trade on the age-size profile of plants. For plants in the modern technology intensive industries, the coefficient on years after opening is significantly positive and six times larger than that on years before opening (see Column 3). On the other hand, for plants in the non-intensive use industries, the coefficient on years after opening is negative and statistically significant (see Column 6). Furthermore, the coefficient on entry after opening for the modern technology intensive industries is much larger than that for the non-modern technology intensive industries.

==== Table 8 and Table 9 here ====

5 Historical evidence

In Section 4, we estimated the age-size profile of plants, observing changes thereof after the opening of Japan to international trade, using data for plants that had survived until at least 1902 and 1919. Fortunately, we can directly explore what happened before and after the opening of trade in 1859, for two specific plants to test our hypotheses, because long-term data on plant size from the Tokugawa Period to the Meiji Period are available for them.

The first case is a copper mining and refining plant at Besshi in Ehime Prefecture. Besshi Mine was a major pillar of Sumitomo *Zaibatsu*, the third largest business group in prewar Japan, whose origin dates back to the sixteenth century (Sakudo 1982). Sumitomo was given a license to mine copper ores at Besshi from *Bakufu* in 1691 (ibid). Sumitomo mined copper ore and smelted it to crude copper at Besshi, before sending this crude copper to Osaka to be refined (Sumitomo Metal Mining Co., 1991). Figure 3 displays the long-term time series of crude copper production at Besshi. It is remarkable that after a decline in the early eighteenth century, production was very stable at around 500 tons for about 150 years until the 1860s, and after that, it soared to exceed 4000 tons. In the context of this paper, until the 1860s, the Besshi Mine did not grow as it aged, whereas it grew sharply as it aged from the 1870s. Referring to the history of Besshi Mine, we can understand the reasons for this distinctive pattern of plant growth.

==== Figure 3 here ====

The first reason is a technological constraint and the subsequent resolution of that constraint. In Tokugawa Period, Besshi Mine faced problems of transportation and drainage, as headways became longer and deeper, because both transportation and drainage depended upon human power. They were fundamental problems common to all mines in this period (Sumitomo Metal Mining Co., 1991). The opening up of Japan provided a chance to resolve these problems, and Sumitomo exploited the chance to do so. In 1869, directly following the Meiji Restoration, the manager of Besshi Mine, Saihei Hirose, traveled to Ikuno Mine, which was operated by the government. At Ikuno, Hirose learned Western mining technology from a French engineer employed by the government. After returning to Besshi, Hirose invited a mining engineer, Bruno L. Larroque, from France to come and work at Besshi. Based on the advice of Larroque, Sumitomo updated the Besshi Mine introducing Western technologies, including steam engines and machine drills (Ibid), which re-solved the problems that Besshi faced in the Tokugawa Period.

The second reason is a market constraint and its resolution. In the Tokugawa Period, the copper produced in Japan was mainly exported to China and The Netherlands, but it was strictly controlled by *Bakufu* (Sakudo 1982; Imai 2015). In 1871, the Meiji government liberalized domestic trade and exports of copper, and as a result, copper became a major export good in the 1870s (Takeda 1987). Sumitomo swiftly responded to this policy change, and established a branch in Kobe to sell copper to foreign trading houses there in 1871 (Sakudo 1982). The case of Besshi indicates that access to Western technologies and Western markets enabled the plant to grow, whereas it had not been able to grow as it aged prior to this under limited access to such technologies and markets.

The other case is from the soy sauce industry. Yamasa is a major soy sauce and food company in present Japan, and its origin dates back to early eighteenth century. The founder Gihei Hamaguchi came to Choshi in Chiba Prefecture and found a soy sauce plant in that period (Hayashi 1990). Yamasa established itself as a soy sauce producer by increasing its sales in the Edo (Tokyo) market in the late seventeenth and early nineteenth century. As the years progressed following the early nineteenth century, Yamasa's sales in Edo declined, due to the effects of control by the soy sauce merchant guild (*kabu nakama*) in Edo. Yamasa compensated for this decline in sales in Edo through sales in the local market, but nevertheless total sales stagnated from the early nineteenth century (Shinoda 1987). The movement of sales is reflected in that of employment (Figure 3). Although the number of employee at the Yamasa plant increased steadily from around 10 to around 20 until the 1810s, it stagnated after that. Then, in the 1870s, it started to grow again registering more than 40 employees in the 1880s. The company history of Yamasa writes: there was an old saying that the upper limit of plant growth was 3500 koku (=631 kl), but under the new economic regime after the Meiji Restoration a new trend of capitalist mass production came, and our company got on the trend. Furthermore, our company shifted sales to the Tokyo market with the largest population. Although the proportion of sales to the Tokyo market and the local market were 50/50, respectively until 1871, they became 90% and 10%, respectively in 1887. This was indeed a drastic change (Yamasa Soy Sauce Co. ed. 1977, p.139).

The case of Yamasa clearly indicates that restricted access to the Tokyo (Edo) market curbed the growth of the plant, and that the removal of this restriction enabled the plant to grow.

==== Figure 4 here ====

6 Concluding remarks

Differences in plant age-size profiles represent one of the most remarkable distinctions between the advanced and developing economies (Hsieh and Klenow 2009, 2014). This paper empirically explores how and why this difference emerges and is maintained, using historical data from Japan. Japan experienced a drastic political and economic regime change in the 1850s and 1860s, that is, the opening of trade and Meiji Restoration. We exploit this event as a natural experiment against which to investigate plant age-size profiles.

The main findings of this paper are as follows. First, the speed of plant growth was much higher after the opening of trade compared to the pre-opening, traditional period. In other words, the age-size profile of plants is steeper after the opening of trade. Second, the difference in speeds of plant growth between before and after the opening of trade is larger for exporting industries and for the plants located in metro regions. This finding suggests that one of the reasons for the above change in the age-size profile of plants was market access improvements. Third, where a plant newly entered after the opening of trade, it was larger when it entered, compared with a plant entering before the opening of trade. In other words, before the opening of trade, plants were born small and stayed small, whereas after the opening up, plants were born large and grew faster.

The historical cases explored herein are consistent with the findings from regression analyses. That is, long-term time series data of plant size covering the period before and after the opening of trade show that plant size was stagnant before the opening of trade and that it started to grow fast after the opening. In addition, the historical cases indicate the source of the difference in the age-size profile. As stated above, regression analyses suggest the importance of market access. This is indeed corroborated by the historical cases. Bessshi Mine started to grow in the 1870s based on access to export markets for copper, whereas Yamasa plant started to grow in the same period based on access to the Tokyo market. Meanwhile, market access was not the only source of growth. The case of Besshi indicates that access to Western technologies was also important. In summary, constraints on market access and barriers to adopting Western technologies brought about the flatter age-size profile of plants before the opening of trade, and the removal of those constraints made the age-size profile steeper.

Comparing our results with those in Hsieh and Klenow (2009, 2014), we find that characteristics of the age-size profile of plants after the opening of trade are similar to those of the present United States, whereas the characteristics of the age-size profile of plants before the opening are similar to contemporary India and Mexico. It is suggested that differences in access to markets and technologies are possible and plausible sources of the differences in age-size profiles between plants in advanced and developing countries.

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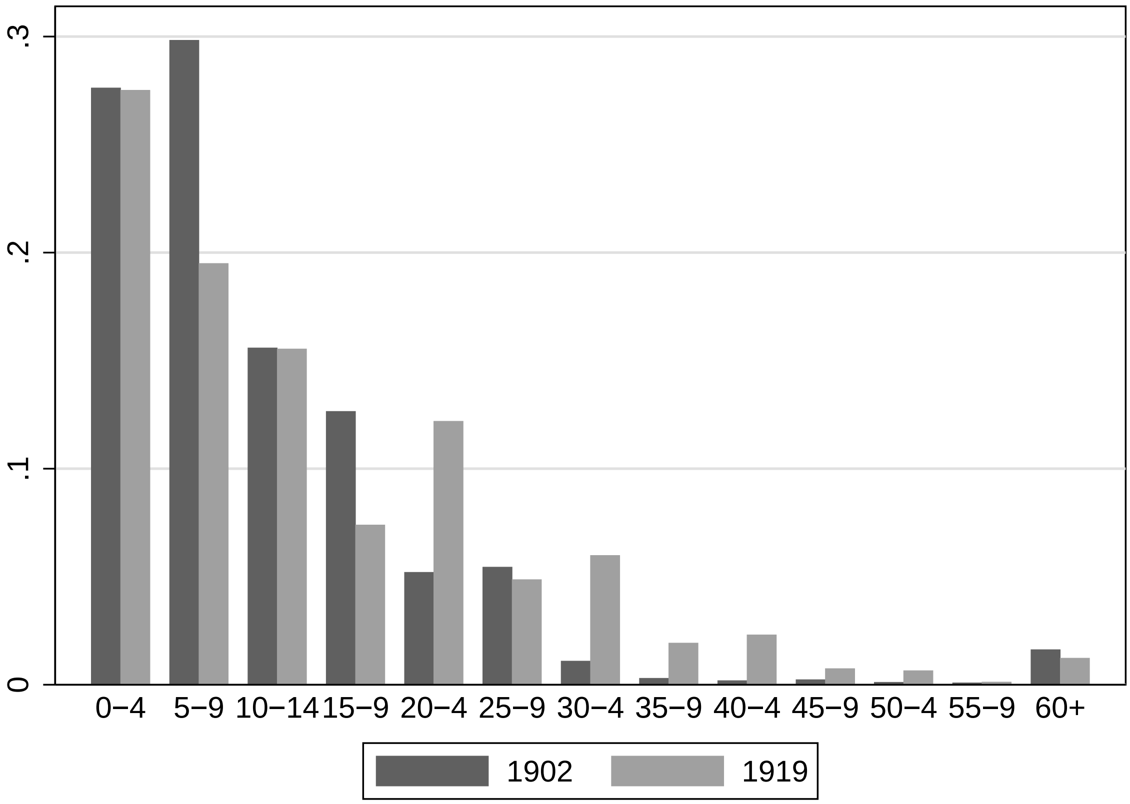
Figures and tables

Figure 1: Relative prices (1858=100) of cotton fabric, raw silk, and rice in Japan following opening up to trade in 1859

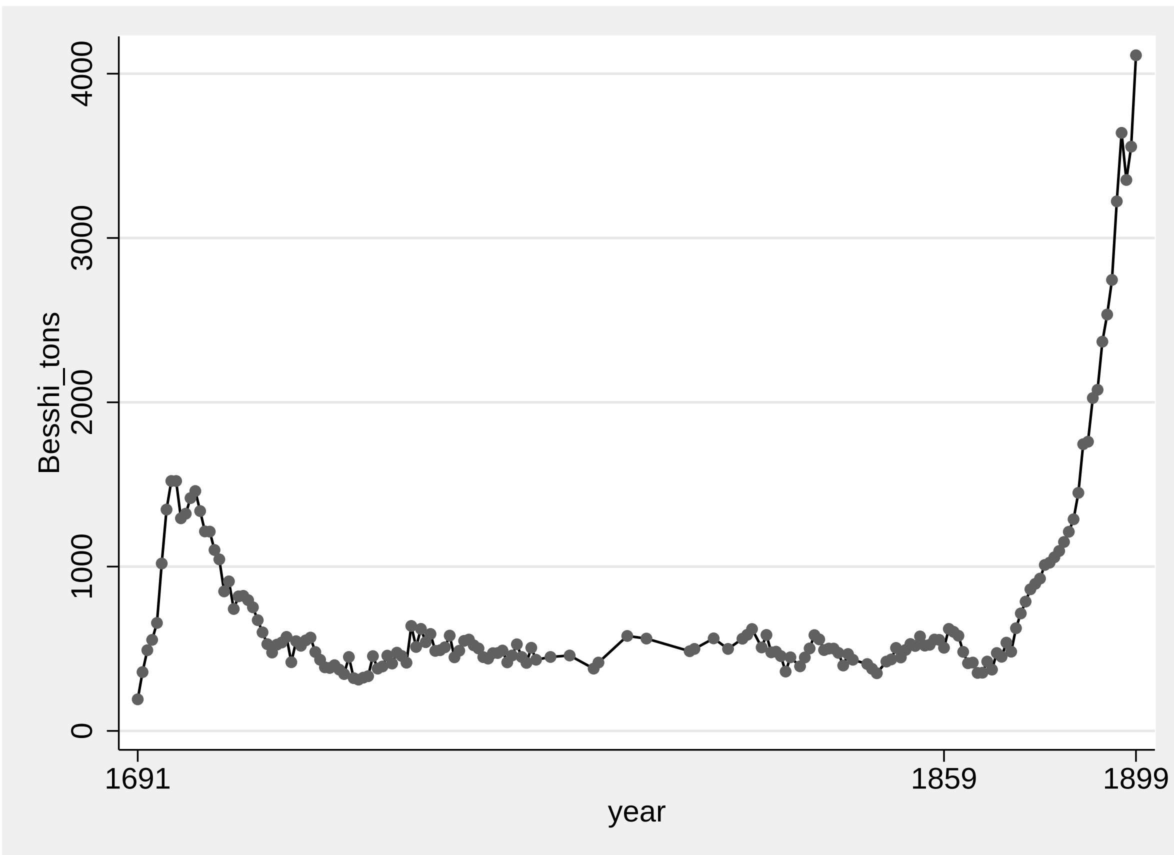
Source: Source: *Kin'yu Kenkyukai* (1937), pp.13-15, 89-90 and 103-104.

Figure 2: Employment share by age of plants in 1902 and 1919



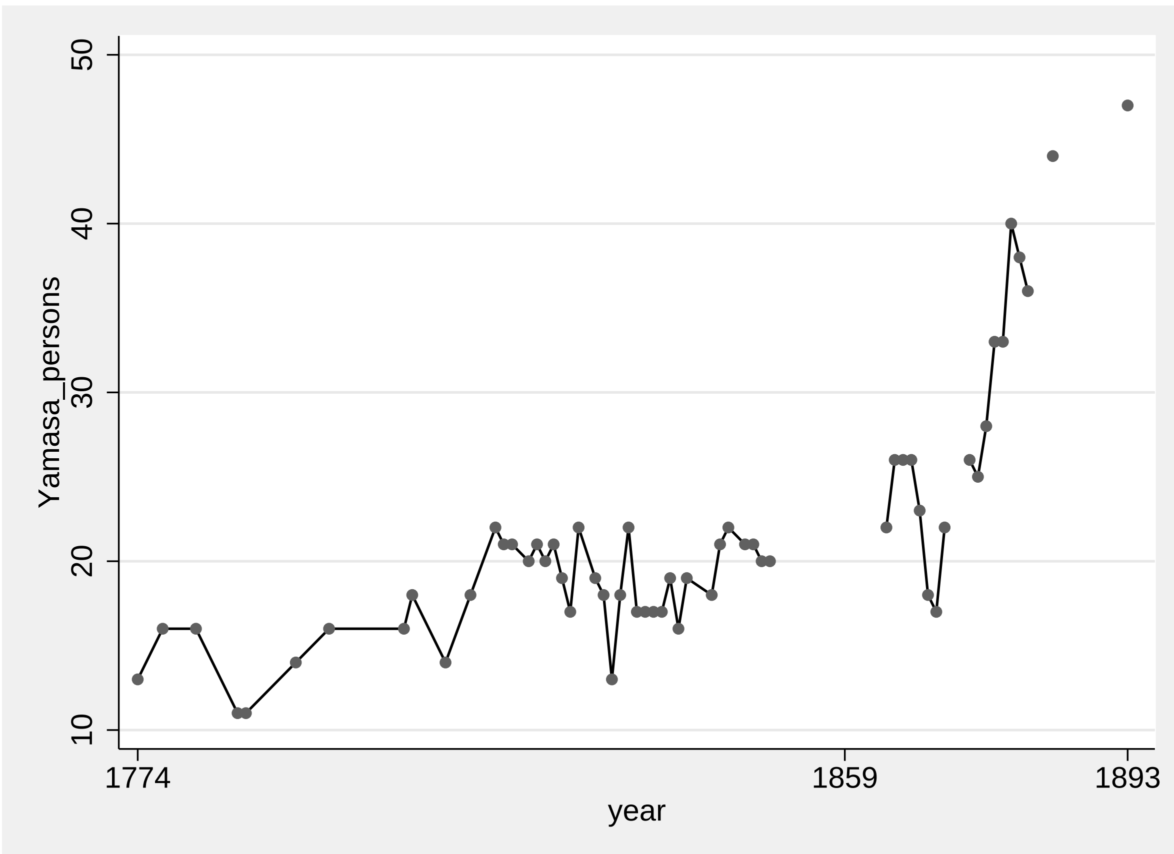
Source: Manufacturing Census, 1902 and 1919.

Figure 3: Production of copper at Sumitomo Besshi Mine (Unit: Tons), 1691–1899



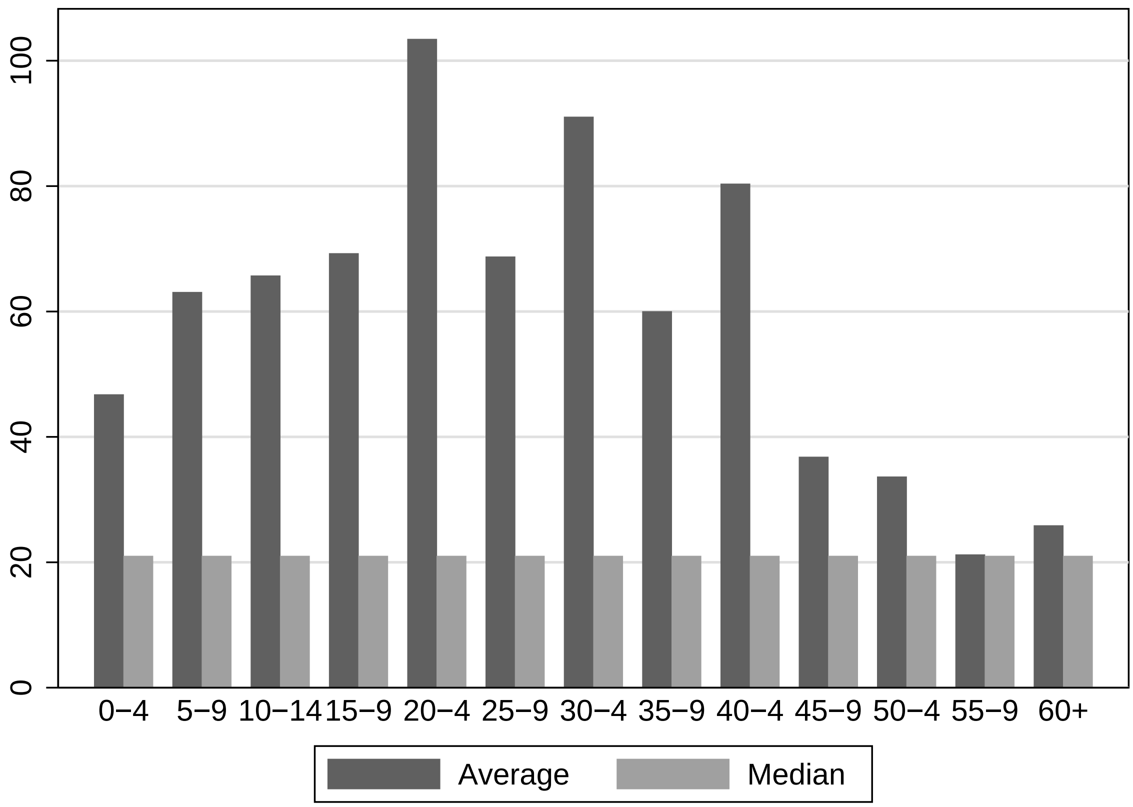
Source: Sumitomo Metal Mining Co. ed. *Sumitomo Besshi Kozan-shi*, appendix volume, 1991.

Figure 4: Number of employees at Yamasa Soy Sauce (Unit: Persons), 1774–1893



Source: Suzuki(1990), pp.146-7. Those workers who were not employed in an entire year, are converted into the workers employed in an entire year by multiplying it by (days of employment/360).

Figure 5: Mean and median plant size by plant age



Source: Manufacturing Census, 1902 and 1919.

Table 1: Sample industries

Year	1902			1919		
Rank	Industry name	N	Ratio	Industry name	N	Ratio
1	Silk Reeling	2,470	32.38%	Weaving	6,184	25.73%
2	Weaving	1,588	20.82%	Silk Reeling	3,089	12.85%
3	Ceramic	421	5.52%	Brewing	1,731	7.20%
4	Tobacco	354	4.64%	Ceramic	1,412	5.88%
5	Brewing	333	4.37%	Wood/Bamboo	1,179	4.91%
6	Printing	213	2.79%	Machinery	1,107	4.61%
7	Cotton Spinning	207	2.71%	Metal Instrument	956	3.98%
8	Ignitable substance	206	2.70%	Misc	706	2.94%
9	Mining	190	2.49%	Printing	700	2.91%
10	Wood/Bamboo	184	2.41%	Dyeing	625	2.60%
11	Tatami/Bakkan	141	1.85%	Ship/Vehicle	495	2.06%
12	Dyeing	139	1.82%	Knitting	475	1.98%
13	Machinery	134	1.76%	Twining	449	1.87%
14	Instrument	109	1.43%	Paper	444	1.85%
15	Food Misc	106	1.39%	Instrument	426	1.77%
16	Metal Instrument	94	1.23%	Flour	333	1.39%
17	Paper	81	1.06%	Pharmacy	301	1.25%
18	Flour	80	1.05%	Cotton Spinning	287	1.19%
19	Metal Refining	76	1.00%	Sea Foods	197	0.82%
20	Misc	75	0.98%	Paper Products	193	0.80%
21	Ship/Vehicle	73	0.96%	Rush/Straw	186	0.77%
22	Knitting	58	0.76%	Metal Refining	185	0.77%
23	Pharmaceutical	56	0.73%	Ignitable substance	180	0.75%
24	Paper Products	37	0.49%	Cotton Making	175	0.73%
25	Chemical Misc	24	0.31%	Tea	163	0.68%
26	Oil	20	0.26%	Stone	161	0.67%
27	Stone	18	0.24%	Sweets	157	0.65%
28	Sweets	18	0.24%	Canned/Bottled Food	154	0.64%
29	Feather	17	0.22%	Rubber	138	0.57%
30	Canned/Bottled Food	16	0.21%	Coloring	136	0.57%
31	Electricity	14	0.18%	Oil/Wax	130	0.54%
32	Tannery	14	0.18%	Chemical Misc	121	0.50%
33	Tea	14	0.18%	Food Misc	115	0.48%
34	Leather	12	0.16%	Electricity	101	0.42%
35	Lacquer	10	0.13%	Feather	88	0.37%
36	Soda/Ice	8	0.10%	Soda/Ice	86	0.36%
37	Fertilizer	7	0.09%	Textile Misc	73	0.30%
38	Gas	4	0.05%	Soap/Candle	69	0.29%
39	Stitch-work	4	0.05%	Fertilizer	66	0.27%
40	Sugar	3	0.04%	Leather	46	0.19%
41	Coloring	0	0.00%	Gas	44	0.18%
42	Cosmetic	0	0.00%	Tannery	43	0.18%
43	Cotton Making	0	0.00%	Stitch-work	38	0.16%
44	Dairy Products	0	0.00%	Sugar	31	0.13%
45	Floss Silk	0	0.00%	Lacquer	19	0.08%
46	Oil/Wax	0	0.00%	Dairy Products	17	0.07%
47	Pharmaceutical	0	0.00%	Cosmetic	16	0.07%
48	Rubber	0	0.00%	Floss Silk	7	0.03%
49	Rush/Straw	0	0.00%	Tobacco	0	0.00%
50	Sea Foods	0	0.00%	Mining	0	0.00%
51	Soap/Candle	0	0.00%	Tatami/Bakkan	0	0.00%
52	Textile Misc	0	0.00%	Pharmaceutical	0	0.00%
53	Twining	0	0.00%	Oil	0	0.00%
	Total	7,628	100%	Total	24,034	100%

Source: Manufacturing Census, 1902 and 1919.

Table 2: Number of plants and employment shares by plant size

Year	1902			1919		
Plant size	N	(Share)	Emp Share	N	(Share)	Emp Share
5000 or more	2	(0.0003)	0.0272	9	(0.0004)	0.0455
2000-4999	8	(0.0011)	0.1059	52	(0.0022)	0.1059
1000-1999	31	(0.0041)	0.1032	108	(0.0045)	0.1022
500-999	65	(0.0086)	0.1031	207	(0.0087)	0.0981
100-499	621	(0.0821)	0.2651	1969	(0.0823)	0.2624
50-99	1036	(0.1370)	0.1571	2571	(0.1075)	0.1206
20-49	2893	(0.3826)	0.1999	7612	(0.3183)	0.1589
10-19	2905	(0.3842)	0.0911	11390	(0.4762)	0.1065
Min	10			10		
Max	7224			15344		
Mean	58.398			60.931		
Median	24			20		
N	7561			23918		

Source: Manufacturing Census, 1902 and 1919.

Table 3: Summary statistics

Variable	Mean	Std. Dev.	Min	Max
Entry before opening (N=1056)				
Number of employees	25.475	35.092	4	810
Number of non-steam power	0.537	2.782	0	80
Years before opening	70.761	84.982	1	973
Years after opening	54.559	7.934	43	60
1902 year dummy	0.320	0.467	0	1
Metro region	0.410	0.492	0	1
Exporting industry	0.065	0.247	0	1
Entry after opening (N=30594)				
Number of employees	61.330	234.522	2	15344
Number of non-steam power	1.367	10.157	0	563
Years before opening	0.000	0.000	0	0
Years after opening	11.282	11.249	0	60
1902 year dummy	0.238	0.426	0	1
Metro region	0.382	0.486	0	1
Exporting industry	0.489	0.500	0	1

Source: Manufacturing Census, 1902 and 1919.

Table 4: Number of plants, average size of plants, and employment shares by the year of entry

Year	1902			1919		
Year of entry	N	Size	Share	N	Size	Share
before 1859	338	27.38	0.02	718	24.58	0.01
1860–64	40	27.55	0.00	99	22.07	0.00
1865–69	106	28.01	0.01	270	35.35	0.01
1870–74	171	45.92	0.02	283	38.58	0.01
1875–79	368	82.76	0.07	400	84.27	0.02
1880–84	378	70.13	0.06	438	64.35	0.02
1885–89	897	84.52	0.17	855	102.17	0.06
1890–94	1410	59.39	0.19	1095	64.88	0.05
1895–99	2338	56.54	0.30	1554	114.55	0.12
1900–1904	1582	46.71	0.17	1669	64.68	0.07
1905–1909				3490	65.00	0.16
1910–1914				4473	63.63	0.19
1915+				8690	46.21	0.28
Total	7628	58.17		24034	60.73	

Source: Manufacturing Census, 1902 and 1919.

Table 5: Baseline results: Full sample

	(1)	(2)	(3)
Larger as they age?			
Years after entry	0.001***	0.003***	
	(0.000)	(0.000)	
Years before opening			0.002***
			(0.000)
Years after opening			0.004***
			(0.000)
Are new entrants larger?			
Entry after opening (dummy)		0.392***	0.356***
		(0.036)	(0.034)
Other controls			
Use steam power (dummy)	0.836***	0.830***	0.831***
	(0.024)	(0.024)	(0.024)
Use nonsteam power (dummy)	0.413***	0.411***	0.412***
	(0.011)	(0.011)	(0.011)
Exporting industry (dummy)	0.231***	0.226***	0.227***
	(0.011)	(0.011)	(0.011)
Metro prefectures (dummy)	-0.003	0.000	0.001
	(0.012)	(0.012)	(0.012)
Urban county (dummy)	-0.047***	-0.054***	-0.054***
	(0.013)	(0.013)	(0.013)
ln of county population	0.037***	0.036***	0.036***
	(0.006)	(0.006)	(0.006)
1902 data (dummy)	0.045***	0.057***	0.058***
	(0.012)	(0.012)	(0.012)
Constant	2.464***	2.064***	2.093***
	(0.071)	(0.081)	(0.080)
Observations	31,638	31,638	31,638
R-squared	0.100	0.102	0.102

Source: Manufacturing Census, 1902 and 1919.

Table 6: Mechanisms: Exporting vs. Non-exporting industries

	(1)	(2)	(3)	(4)	(5)	(6)
Sample		Exporting			Non-exporting	
Larger as they age?						
Years after entry	0.012***	0.013***		-0.001***	0.000	
	(0.001)	(0.001)		(0.000)	(0.000)	
Years before opening			0.007			0.002***
			(0.005)			(0.000)
Years after opening			0.011***			-0.001*
			(0.001)			(0.001)
Are new entrants larger?						
Entry after opening (dummy)		0.910***	0.944***		0.162***	0.181***
		(0.110)	(0.134)		(0.037)	(0.036)
Other controls						
Use steam power (dummy)	1.003***	0.998***	0.997***	0.637***	0.633***	0.630***
	(0.029)	(0.029)	(0.029)	(0.041)	(0.041)	(0.041)
Use nonsteam power (dummy)	0.446***	0.441***	0.442***	0.369***	0.370***	0.367***
	(0.016)	(0.016)	(0.016)	(0.014)	(0.014)	(0.014)
Metro (dummy)	-0.098***	-0.096***	-0.095***	0.108***	0.109***	0.108***
	(0.018)	(0.018)	(0.018)	(0.016)	(0.016)	(0.017)
Urban (dummy)	-0.042*	-0.043*	-0.042*	-0.027*	-0.031*	-0.030*
	(0.022)	(0.022)	(0.022)	(0.016)	(0.016)	(0.016)
ln of county population	0.077***	0.079***	0.078***	0.003	0.003	0.003
	(0.013)	(0.013)	(0.013)	(0.007)	(0.007)	(0.007)
1902 data (dummy)	-0.057***	-0.051***	-0.050***	0.163***	0.171***	0.167***
	(0.017)	(0.017)	(0.017)	(0.018)	(0.018)	(0.018)
Constant	2.153***	1.218***	1.196***	2.848***	2.678***	2.677***
	(0.153)	(0.195)	(0.209)	(0.084)	(0.094)	(0.093)
Observations	15,027	15,027	15,027	16,611	16,611	16,611
R-squared	0.120	0.122	0.122	0.069	0.070	0.071

Source: Manufacturing Census, 1902 and 1919.

Table 7: Mechanisms: Metro vs. Non-metro prefectures

	(1)	(2)	(3)	(4)	(5)	(6)
Sample		Metro			Non-metro	
Larger as they age?						
Years after entry	0.003***	0.006***		0.001*	0.002***	
	(0.001)	(0.001)		(0.000)	(0.000)	
Years before opening			0.002**			0.002***
			(0.001)			(0.001)
Years after opening			0.006***			0.002***
			(0.001)			(0.001)
Are new entrants larger?						
Entry after opening (dummy)		0.555***	0.491***		0.300***	0.288***
		(0.063)	(0.062)		(0.044)	(0.043)
Other controls						
Use steam power (dummy)	0.931***	0.924***	0.923***	0.793***	0.789***	0.789***
	(0.047)	(0.047)	(0.047)	(0.027)	(0.027)	(0.027)
Use nonsteam power (dummy)	0.383***	0.385***	0.385***	0.429***	0.428***	0.428***
	(0.019)	(0.019)	(0.019)	(0.013)	(0.013)	(0.013)
Exporting industry (dummy)	0.120***	0.116***	0.117***	0.279***	0.274***	0.275***
	(0.022)	(0.022)	(0.022)	(0.013)	(0.013)	(0.013)
Urban (dummy)	0.024	0.012	0.011	-0.074***	-0.077***	-0.077***
	(0.027)	(0.027)	(0.027)	(0.016)	(0.016)	(0.016)
ln of county population	0.001	-0.001	-0.000	0.035***	0.036***	0.037***
	(0.011)	(0.011)	(0.011)	(0.010)	(0.010)	(0.010)
1902 data (dummy)	-0.008	0.009	0.011	0.058***	0.067***	0.067***
	(0.022)	(0.022)	(0.022)	(0.015)	(0.015)	(0.015)
Constant	2.922***	2.359***	2.418***	2.460***	2.133***	2.145***
	(0.132)	(0.150)	(0.147)	(0.112)	(0.123)	(0.123)
Observations	12,135	12,135	12,135	19,503	19,503	19,503
R-squared	0.074	0.078	0.078	0.123	0.125	0.125

Source: Manufacturing Census, 1902 and 1919.

Table 8: Intensive-use vs. non-intensive use of power

Intensive use		Non-intensive use	
Industry name	Ratio	Industry name	Ratio
Gas	1	Cosmetic	0.563
Cotton making	0.977	Feather	0.552
Machinery	0.939	Sweets	0.549
Electricity	0.887	Tea	0.542
Soda and ice	0.883	Weaving	0.533
Twining	0.862	Wood and bamboo	0.514
Flour	0.860	Dyeing	0.499
Metal refining	0.858	Stone	0.497
Metal instrument	0.857	Paper products	0.487
Oil	0.850	Leather	0.483
Rubber	0.841	Pharmaceutical	0.482
Soap and candle	0.841	Misc	0.469
Printing	0.819	Tobacco	0.438
Cotton spinning	0.802	Floss silk	0.429
Fertilizer	0.795	Food misc	0.425
Oil and wax	0.785	Canned and bottled	0.406
Textile misc	0.781	Ceramic	0.385
Instrument	0.768	Rush and straw	0.371
Tannery	0.754	Brewing	0.360
Chemical misc	0.738	Ignitable substance	0.350
Ship and vehicle	0.720	Sea foods	0.284
Knitting	0.707	Dairy products	0.235
Sugar	0.706	Lacquer	0.138
Silk reeling	0.670	Stitch-work	0.024
Mining	0.663	Tatami and bakkan	0
Pharmaceutical	0.645		
Coloring	0.632		
Oaper	0.629		

Source: Manufacturing Census, 1902 and 1919.

Table 9: Mechanisms: Intensive-use vs. Non-intensive use of power

	(1)	(2)	(3)	(4)	(5)	(6)
Sample		Intensive-use			Non-intensive	
Larger as they age?						
Years after entry	0.006***	0.011***		-0.002***	-0.002***	
	(0.001)	(0.001)		(0.000)	(0.000)	
Years before opening			0.002**			0.003***
			(0.001)			(0.001)
Years after opening			0.013***			-0.002***
			(0.001)			(0.000)
Are new entrants larger?						
Entry after opening (dummy)		1.181***	0.805***		0.021	0.107***
		(0.098)	(0.087)		(0.036)	(0.038)
Other controls						
Use steam power (dummy)	0.826***	0.818***	0.822***	0.607***	0.606***	0.605***
	(0.031)	(0.031)	(0.031)	(0.051)	(0.051)	(0.051)
Use steam power (dummy)	0.392***	0.389***	0.389***	0.378***	0.378***	0.378***
	(0.019)	(0.019)	(0.019)	(0.012)	(0.012)	(0.012)
Exporting industry (dummy)	0.477***	0.457***	0.457***	0.016	0.016	0.012
	(0.021)	(0.021)	(0.021)	(0.013)	(0.013)	(0.013)
Metro (dummy)	-0.076***	-0.067***	-0.065***	0.076***	0.076***	0.075***
	(0.023)	(0.023)	(0.023)	(0.013)	(0.013)	(0.013)
Urban county (dummy)	-0.139***	-0.155***	-0.158***	0.031**	0.030**	0.031**
	(0.022)	(0.022)	(0.022)	(0.015)	(0.015)	(0.015)
ln of county population	0.050***	0.046***	0.046***	0.022***	0.022***	0.021***
	(0.010)	(0.010)	(0.010)	(0.007)	(0.007)	(0.007)
1902 data (dummy)	-0.218***	-0.199***	-0.196***	0.166***	0.167***	0.163***
	(0.022)	(0.022)	(0.022)	(0.014)	(0.014)	(0.014)
Constant	2.406***	1.245***	1.597***	2.615***	2.592***	2.522***
	(0.119)	(0.154)	(0.145)	(0.084)	(0.094)	(0.093)
Observations	14,331	14,331	14,331	17,307	17,307	17,307
R-squared	0.115	0.121	0.123	0.073	0.073	0.074

Source: Manufacturing Census, 1902 and 1919.