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Hand Looms, Power Looms, and Changing Production Organizations: The Case of the Kiryu Weaving District in the Early 20th Century Japan

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Abstract

This study finds that the development process of the Kiryu silk weaving district in Japan from 1895 to 1930 can be divided at least into the two phases, i.e., Smithian growth based on the inter-firm division of labor using hand looms and Schumpeterian development based on factory system using power looms. Weaving manufacturers-cum-contractors led Smithian growth by organizing sub-contracts with out-weavers in rural villages and grew faster than factory production systems. Newly emerged joint stock firms played a role of genuine entrepreneurs by realizing significant scale economies. During this new phase, weaving manufacturers-cum-contractors survived and also introduced new production system.

Keywords: industrial district, production organizations, weaving industry, 20th century Japan, economic development

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1. Introduction

Pioneering studies on industrial districts or clusters in business and economic history by Piore and Sabel (1984) and Sabel and Zeitlin (1997) have contributed to clear understanding of their important roles in the development of national economy in Western countries. The investigation of industrial districts per se was not new; their studies were new because they tried to explain major advantages of industrial districts by using the concept of 'externalities' which Alfred Marshal introduced almost one century ago (Marshall, 1920). In fact, by analyzing industrial districts through the lens of such externalities, the nature of competition and source of competitive advantage have been more clearly identified (Porter 1998).

By reviewing the burgeoning literature on industrial districts or clusters in many countries, regions, and industries, Zeitlin (2008) concludes his article by highlighting three major remaining research questions; (1) the relationship between the district and the wider world, (2) the changing morphology of the districts and relationships among different sizes and types of firms within them,[1] and (3) governance and coordination mechanisms within the districts. In the case of Japan, recent studies on industrial districts focus mainly on the last point (Abe, 1992, 1999; Fujita, 1998; Hashino and Kurosawa, 2011; Tolliday and Yonemitsu, 2007). Above all, collective institutions and organizations within the district played an important role in the introduction and diffusion of new technologies, as they entailed technology spillovers among firms and created the problem of inferior quality products, which damaged the reputation of the district (Sawai, 1999; Hashino, forthcoming).[2]

In contemporary developing world, cluster-based industrial development is widely observed. Sonobe and Otsuka (2006, 2011) primarily analyze the determinants of the quality improvement of products and the possibility of exports from the clusters in Asia and sub-Saharan Africa, which correspond to the first problem identified by Zeitlin. Nadvi (1999) and Shumitz (1995) discuss the governance and coordination mechanism of the cluster, which lead to what they call collective efficiency in the context of South Asia and Latin America. Their studies squarely address the third issue of Zeitlin. While the importance of industrial clusters for economic development has been well analyzed by them, the historical or long-term perspectives are limited in their studies.

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[1] Scranton (1983) explores the reasons for the coexistence of textile firms of different sizes in Philadelphia, such as small shops, middle-size firms each of which engages in one specialized process, and relatively large integrated mills.

[2] Hashino (2007b, 2010) explores Zeitlin's first and second points. The former study analyzes the relationship between small-scale firms within the district and large-scale ones located outside. The latter study attempts to clarify how newly-developing weaving districts solved the problem of inferior quality products, which reduced the districts' reputation at the international markets. Arimoto et al. (2011) attempts to compare the improvement of productivity between the firms within a cluster and those outside regarding a cluster in silk reeling industry in the prewar Japan.

The aim of this study is to explore how and why the different sizes and types of firms within the district appeared, grew and collapsed in the long-term development process of Kiryu silk weaving district in the early 20th century. Kiryu is located 200 km north of Tokyo and has been one of the most advanced silk weaving districts since the Tokugawa period (1603-1868). It was a pioneer in export of silk products in the 1870s as well as the leading producer of traditional Japanese *kimono* and *obi* (sash belt) for domestic markets. In this study, we will demonstrate that three different types of players attempted to lead the growth of Kiryu. The first is relatively large firms established in the late 19th century which introduced the vertically integrated production system for mass production of export products. The second is merchant-manufactures, or domestic market-oriented weaving manufacturers-cum-contractors [WMCs henceforth], who promoted division and specialization of labor with village-based out-weavers and other specialized small firms. Putting-out system for weaving, dyeing, and preparatory and finishing processes prospered in the early 20th century. The third is joint stock firms established in the early 1910s which newly adopted power looms and successfully sought the scale economies. Following Parker (1984) and Mokyr (1990) who study the historical patterns of economic change in the Western world, we would like to demonstrate that Kiryu experienced Smithian growth based on the expanded division of labor among a large number of firms, followed by Schumpeterian development based on vertically integrated production systems. We also inquire into the causes of the success and failure of the three types of weaving firms. In particular, we show that WMCs remained a significant player even in the phase of Schumpeterian development in Kiryu by introducing new production system.

The rest of the paper is organized as follows. The next section describes an overview of the development of Kiryu with indicators of changes in production, labor force, structure of firms, and technology. Section 3 examines the characteristic of firms with the employment of more than 10 workers in selected years from 1895 to 1918, whose production record was collected by various statistical surveys. Three hypotheses regarding the dominant firms are presented through the comparison among export-oriented large firms, domestic market-oriented firms, and newly emerged joint stock firms. Section 4 presents the methodology of regression analysis and examines the results. The last section concludes by summarizing the main findings of the study and drawing implications for future research.

2. An Overview of the Development of the Kiryu Weaving District

This section examines the production growth in Kiryu since the late 19th century and investigates the changes in the extent of the inter-firm division of labor and adoption of power looms which are considered as the keys to the growth of Kiryu. Through the observation of structural changes, we will identify three distinct phases of growth in early 20th century Kiryu.

2-1 Production growth in the early 20th century in Kiryu

Figure 1 illustrates the changes in real value of production, employment, and labor productivity in Kiryu, using index (1895 = 100). In the early 1900s, the real value of production shows upward trend: It was 3.5 million yen in 1904 but increased to roughly 10 million yen in 1907. Since then, it had been stagnant or declining until 1914. In contrast, it experienced rapid growth around the boom period of the First World War from 1914 to 1919, which was 17 times increase during the mere 5-year period. Even though it is well known that the 1920s was the era of repeated recessions or depressions in Japanese economy, surprisingly real value of production in Kiryu was maintained subsequently at around 60 to 70 millions yen until 1929.

In Figure 1, solid and broken curves show the indices of the total number of workers and female workers, respectively. Since the female workers account for 70 to 80 percent of labor force, the two curves look alike. From the late 1890s to 1900s, the total number of workers decreased and dropped to around 7,000. It continues to stagnate through the late 1900s but begins to increase toward the end of the 1910s. It was around 9,000 in 1910 and rose to 13,500 in 1920. It suddenly dropped to less than half in 1921 due to depression. In the late 1920s, it finally began the recovery process. It can be confirmed that the total labor force increased faster than female labor force in the 1910s, implying that male employment grew faster than female employment. It is also clear that the increase in production was not caused primarily by the increased input of workers.

2-2 Smithian growth and Schumpeterian development

If we turn to the changes in labor productivity (bold curve), it is apparent that it was improvement of labor productivity that contributed to boosting the real value of production. More importantly, it can be recognized that there are three distinct phases of increase in labor productivity; (1) gradual growth in the 1900s, (2) stagnation or setback from the end of the 1900s to the mid-1910s, and (3) drastically rapid growth from the mid-1910s to the mid-1920s. Average annual growth rates in labor productivity were 2.9% from 1900 to 1910, -11.0% from 1910 to 1915, and 38.3% from 1915 to 1925.

Figure 2 examines the changes in the number of out-weavers and other production organizations including factories, cottages, and WMCs in Kiryu.[3] The number of out-weavers, who are primarily based in surrounding villages around Kiryu town, increased rapidly from the

[3] The data in 1904 and 1905 are not available. *Statistical Survey* by Gunma prefectural government (various years) in which Kiryu was located, defines four types of production organizations with two criteria, i.e., the number of workers and ownership of raw materials. Factory is defined as a workshop with more than ten workers and cottage as one with less than ten workers. On the other hand, the defining characteristic of the weaving manufacturer-cum-contractor is to put out raw materials to out-weavers. Out-weavers are those who are engaged in weaving for contractors. Because out-weavers do not operate a business on their own account, they are differentiated from other three production organizations. For details, see Hashino (2007a, p. 34, footnote 2).

mid-1900s to the 1910s. It was approximately 3,700 in 1906 but rose to 5,800 in 1914. Note that the average number of workers per out-weaver workshop had been stable at about 1.5. In contrast, the number of other production organizations continued to stagnate at around 500 until it shows increasing trend from the mid-1910s. These observations clearly indicate the increase in the number of out-weavers per other production organization. Indeed, it almost doubled from 6.8 in 1906 to 11.6 in 1914. This indicates the expansion of division of labor, which was organized by WMCs. Note that the division of labor happened not only in weaving process but also in many other processes carried out by specialized subcontractors (Hashino and Kurosawa, 2011).[4]

Figure 3 illustrates the coordination activities of WMCs (left) and specialized processes carried out by subcontractors (right) in Kiryu around 1910. It is apparent that many processes were carried out by specialized subcontractors. It must be noted, however, that WMCs were originally engaged in the whole production process but gradually out-sourced many sub-processes, such as throwing, dyeing, designing, weaving, and finishing. For example, dyeing process was one of the key preparatory processes carried by WMCs in the earlier period. Since the introduction of synthetic dyes in the 1880s, whose proper use required scientific knowledge, WMCs gave up dyeing and began to put out the process to specialized subcontractors, who have acquired such knowledge. Henceforth, division and specialization of labor were gradually and widely diffused. Such an evolutionary process can be termed as Smithian growth.[5] In addition to organizing specialized subcontractors, WMCs engaged in marketing, designing, quality control, and making trial samples (Uchida, 2002). In other words, they played a crucial role as traders who linked a variety of producers with market.

It is extremely important to note that despite Smithian growth from the late 1900s to the mid-1910s indicated by the increasing number of out-weavers (Figure 2), neither total production nor total employment increased significantly in this period (Figure 1). As will be discussed in the next section, we attribute this puzzling observation to the failure of large export-oriented firms and offsetting rise of WMCs in the early 20th century. The former aggressively mechanized since the late 19th century to create added value for exported products through improved designs, textures, and luster, but failed to expand the production (Hashino and Kurosawa, 2011).

Undoubtedly the most important single innovation in the early 20th century in Kiryu was

[4] Specialized subcontractors are generally small and located in Kiryu town. Whether their activities were recorded in statistics is not known in earlier period. Responding to a significant increase in the number of dyers, the prefectural government included the dyeing industry in its annual statistical survey after 1915 (Hashino and Kurosawa, 2011).

[5] Interesting statistical data collected by Kiryu Trade Association for Weaving indicates how widely outsourcing diffused in Kiryu. According to their report in 1900, there were 853 weaving producers, 37 fabric merchants, 16 scouring and finishing producers, 62 raw silk merchants, 18 dyers, 14 dyestuff merchants, 6 cotton-yarn merchants, 12 designers for jacquard machines, 25 reed producers, 115 warping producers, and 6,725 out-weavers within the district (Hashino and Kurosawa, 2011).

the introduction of power looms, whose dissemination can be traced by the changing proportion of power looms in this period. As is shown in Figure 4, the adoption of power looms in the Kiryu district as a whole (bold curve) started to increase from the mid-1910s and grew rapidly toward the 1920s. The average adoption rate was only 4.9% in 1915 but drastically increased to 84.1% in 1930.

Solid and broken curves in the same figure show the proportion of power looms in Kiryu city (former Kiryu town) and Yamada county (surrounding rural villages) within the Kiryu weaving district, respectively. It is interesting to observe that the proportion of power looms in Kiryu city was much higher than that in Yamada county already in 1921. Therefore, we can assume that the introduction of power looms in urban area proceeded at much faster pace than that in rural villages, probably even in the 1910s. New technology needed new production organizations, because the use of power looms confers clear scale advantages in this period. Previous studies report that the introduction of power loom was accompanied by the adoption of factory systems in Japan (Hashino, 2007a; Hunter, 2003; Minami and Makino, 1983; Saito and Abe, 1988). It is therefore likely that factories with power looms played an important role in promoting Schumpeterian development since the late 1910s in Kiryu. No less important might be the establishment of joint stock firms which contributed to financing large investments in factory buildings and machineries.[6]

To sum up, both Smithian growth and Schumpeterian development were associated with distinct growth patterns in Kiryu. The former is chiefly caused by the increase in the division of labor which must have been supported by reduction in the transaction cost associated with the improved assignment of tasks and enforcement of property right and production responsibilities (Mokyr, 1990). The latter development is derived from the major increase in production efficiency by innovations. Such innovations encompass the adoption of new production technology and production organizations (Mokyr, 1990).

3. Changing Characteristics of Sample Firms and Hypotheses

3-1 Characteristics of sample firms

Based on the above discussions, we attempt to investigate the behaviors of weaving firms in Kiryu with the employment of more than 10 workers covered by *Statistical Survey* and *Factory Survey* of Gunma prefectural government.[7] These firms with more than 10 workers are called

[6] Although we do not analyze in this study, firms which adopted power looms made a number of improvements in the production systems including the introduction of new raw materials to produce traditional products by power looms.

[7] The data source in 1915 and 1918 is *Factory Survey*, which was conducted by Gunma prefectural government (1916, 1919) in order to report to the central government. Compared with *Statistical Survey*

'factories' in these surveys. Although there are four production organizations (i.e., out-weavers, factories with more than 10 workers, cottages with less than 10 workers, and WMCs), it is possible that the increase in the number of workers converted the cottages and WMCs to factories.

Table 1 exhibits the average characteristics of weaving firms in selected years from 1895 to 1918. A glance establishes that the number of firms was only ten in the late 19th century but tripled in the 1900s. Furthermore, the number more than doubled in the early 1910s and reached 88 in 1918. Why did the number of firms with the employment of more than 10 workers increase appreciably? The average year of establishment of firms indicates that the entry of newly established large firms was not necessarily the major reason. There are three types of sample weaving firms in Kiryu; (1) large firms which attempted 'vertical integration,'[8] (2) traditional firms including WMCs whose number of workers increased to more than 10, and (3) newly-established joint stock firms in the late 1910s which equipped power looms and adopted factory system.

Large firms with the employment of nearly 100 workers seem to have appeared in the late 19th century. The average year of establishment was 1851 in 1895 and 1876 in 1899, respectively, which are much different. In 1895, old firms were dominant, even though there were a few newly-established firms which just started their operation. Judging from the rising average year of establishment in 1899, newly-established firms became dominant. The latter firms attempted large-scale vertical integration with extraordinarily large western machines mainly for preparatory and finishing processes. These firms did not depend on the division of labor with other small firms, unlike WMCs, which means that they did not enjoy agglomeration economies arising from inter-firm transactions. They used hand looms except for Nihon Orimono Corporation, which tried to produce exportable products but faced difficulties in operating large-scale factory (Kameda, 2011; Tasugi, 1943).[9]

Interestingly, from 1899 to 1903 not only the average number of workers sharply declined from 91.5 to 33.1 but also the average year of establishment changed from 1876 to 1867. On the other hand, the number of firms became tripled between the two years. Thus, it is clear that major players promoting the growth drastically changed in this period. In other words, while the large-scale firms failed their business, relatively old WMCs became dominant in the 1900s. The average number of workers continued to decline to 23.2 in 1906 (see column of

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data used for 1906 and 1910, individual data in 1915 and 1918 contain much more detailed information about production of each firm.

[8] In our study, vertical integration refers to the production system in which preparatory, weaving and finishing processes are carried out within a firm. Some of them were typically out-sourced in the case of WMCs as is shown in Figure 3. It is somewhat similar to that discussed by Jones (1987), i.e., the backward integration system in British silk industry in the 1820s and 1830s, in which throwing and weaving process were carried out internally.

[9] According to Kameda (2011), this company installed imported power looms.

1906[b] in Table 1, which excludes Nihon Orimono Cooperaton, as it is outlier). Female worker ratios in 1903 and 1906 were also lower than those in the 1890s, which strongly indicates that the relatively large number of male workers who were engaged in preparatory processes and delivery of yarns to out-weavers increased. Loom/worker ratio was far less than unity in 1906, which means that not all workers in the weaving firms were engaged in the weaving process. From the above discussions, it seems clear that some WMCs grew to be medium-scale firms and promoted the growth of Kiryu by expanding division of labor.

In the 1910s, new entries can be recognized from both increase in the number of firms and the rise in the average year of establishment. While the average number of workers slightly increased compared with the 1900s, female worker ratio continued to decline. WMCs would have been still dominant in this period but newly entering firms gradually expanded their scale of operation. From 1915 to 1918, the number of firms and the average number of workers per firm rapidly increased with concomitant rise in the average year of establishment, which indicate increase in the number of newly-established large firms. At the same time, the proportion of power loom reached 80%. Such newly established large firms which appeared in the 1910s can be considered as the new major players who promoted Schumpeterian development. It is worth pointing out that with the advent of such firms, the average sale revenue per firm increased six times from 1915 to 1918. Note that since the costs of putting-out contracts and out-sourcing are not included in the sales revenue, it becomes larger as the extent of the division of labor increases.

3-2. Comparison of Export-Oriented Firms with Other Firms

What kind of products did our sample firms produce? Some of their products were shipped for domestic markets but others were for export markets. The production of traditional products for domestic market organized by WMCs were highly differentiated and produced by vertically specialized firms within the district, as is illustrated by Figure 3. This is reminiscent of the highly specialized production system of the Lancashire cotton industry described by Broadberry and Marrison (2002). In contrast, the large firms established in the late 19th century attempted to sell standardized product at export markets without depending on any inter-firm division of labor.

In order to compare the firms with different market orientations and locations, Table 2 undertakes the comparison of export-oriented firms with other domestic market-oriented firms in Kiryu town and outside in 1906, 1910, and 1915.[10] Data source and sample size are the same as in Table 1. The reason why we regard location as important is that leading WMCs tended to

[10] We estimate the export- and domestic market-orientation from the main product reported by the survey. We chose 1906 because this was the first year in which the data on the numbers of looms were available and 1915 because this was the first year in which the data on sales revenue were available. Year 1910 was chosen because this is almost the mid-year between 1906 and 1915.

be located in Kiryu town partly because this is most convenient for them to organize putting-out contracts in various processes and partly because access to railways and electricity was also favorable in town. According to Table 2, most other firms outside Kiryu town were also likely to be WMCs, because, although smaller than that in Kiryu town, their average sales revenue was not so low in 1915, if we consider the smaller number of their employed workers. The number of export-oriented firms increased from 1906 to 1910 and then declined, whereas the number of domestic market-oriented firms continued to increase and became dominant in 1915. This suggests that the second players, large WMCs, supported Smithian growth.

In terms of the number of workers, export-oriented firms were largest in all years but their employment size declined from 71.8 workers in 1906 to 45.4 workers in 1910. Judging from the facts that the number of export-oriented firms doubled from 1906 to 1910 and that average year of establishment in 1910 is 6 years younger than that in 1906, large firms disappeared and the newly established, moderate scale firms became dominant.

Female worker ratio tends to decline over time but it is much lower in other firms in Kiryu town. The relatively large number of male workers was employed by these firms in Kiryu town because the relatively larger number of male workers played an important role in the preparatory processes, delivery of raw materials, and collection of finished products. Proportion of firms using traditional water wheels was also high among relatively large firms in Kiryu town because they were used for preparatory processes of materials to be put out to out-weavers (Hashino, 2007c). Only some export-oriented firms introduced motive-powers in 1906 and 1910, which was steam engine. In 1915, however, some domestic market-oriented firms in Kiryu town also equipped powers, even though their adoption rate was lower than that of export-oriented firms. This is likely because electric powers were supplied by the Watarase Water Power Electricity Company, which was established in 1906 and started operation in 1908 (Kiryu Orimonoshi Hensankai, 1940). Prior to supply of electricity, export-oriented firms had to equip motive-powers such as steam engines on their own account.

Until the late 1900s, hand looms were used in almost all firms in Kiryu except for a very few (Kiryu Orimonoshi Hensankai, 1940). It is therefore doubtful whether the large-scale export-oriented firms could enjoy scale advantage in the absence of large fixed inputs. Therefore, we advance the following hypothesis:

Hypothesis 1: Although more than several large firms with the employment of more than 50 workers and the use of hand looms were founded in the late 19th century, they soon collapsed due, at least partly, to the lack of scale advantages. In contrast, WMCs thrived based on the out-weaving system in the beginning of 20th century in Kiryu.

3-3 Comparison of Newly Emerging Large Firms with Other Firms

Our sample firms in 1918 benefitted from the economic boom during the First World War (1914-1918). Responding to the increasing demand for their products in Kiryu, the number of large firms increased. Wage rates also increased sharply in Japan, surpassing the Lewisian turning point according to Fei and Ranis (1963). In fact, in local labor markets in the neighborhood of Kiryu, wage rates of female workers in weaving, silk-reeling, and farming sharply increased in this period (Hashino, 2007a). Hence many weaving firms in Kiryu started production using power looms to save labor by using electricity. Establishment of new factories and workshops as well as the installation of power looms would have required large investment funds, which seems to have led to the establishment of joint stock firms, as will be shown shortly.

Table 3 analyzes the characteristics of 88 firms in 1918 from the perspective of market orientation and location. Joint stock firms were export-oriented and established around the war boom period. They were particularly large with the employment of more than 300 workers, which clearly indicates that they sought the scale advantages. There are many differences between joint stock firms and other firms within the category of export-oriented firms. Caution is needed in interpreting the *average* number of hand and power looms, and power loom ratio because some of the firms in each category equipped no hand looms or no power looms.[11] For example, in the case of joint stock firms, three firms equipped power looms only, whereas two firms owned both looms. In other export-oriented firms, there were three types of firms regarding the ownership of looms; hand looms only, power looms only, and both looms.

It must be emphasized that most joint stock firms were subcontractors for smaller weaving firms and received fees of undertaking preparatory and finishing activities from other firms within the districts. Such behavior is consistent with the theory of the division of labor formulated by Stigler (1951), who argues that one of the main sources of the division of labor is the different optimum scales of production in different sub-production processes. In this respect they are different from the large vertically-integrated export-oriented firms established a few decades earlier. Based on the above discussion, therefore, we postulate the following hypothesis regarding the large firms which emerged in the mid-1910s:

Hypothesis 2: Several large joint stock firms founded in the mid-1910s were Schumpeterian innovators, who transformed Kiryu weaving district by realizing the scale advantages associated with the introduction of power looms and factory production systems.

Let us turn to the characteristics of domestic market-oriented firms. Remarkable differences between 32 firms in Kiryu town and 15 others can be observed in female worker ratio, the number of looms, use of electricity, and holding of registered trademarks in the 1900s. The

[11] Note that the power loom ratio, defined as the proportion of the number of power looms in the total number of looms, is assumed to be zero, if the firm did not own any looms.

formers were likely to be large WMCs employing relatively many male workers without much internal production. In the case of a leading WMC, called Goto Firm, about which Hashino (2007a) explores the relation between adoption of new production organization and technology choice, increase in male workers in the mid-1910s was associated with the expansion of subcontracts with out-weavers. Its strategy was low volume production of a wide variety of products for domestic market by enjoying the advantage of agglomeration economies.[12] In addition, holding of registered trademarks in Meiji Era indicates that domestic market-oriented firms in Kiryu town were old leading firms (see Table 3).[13] They also began the introduction of power looms, and the ratio of the average number of power looms to that of hand looms (i.e., 10.8/1.5) was highest among the four groups shown in Table 3. This is because some domestic market-oriented firms expanded production by using a large number of power looms, whereas others equipped no looms or a small number of hand looms. Out of 32 firms in Kiryu town, 13 equipped no looms and 7 owned less than 5 hand looms, which are heavily dependent on the production by out-weavers, while 9 firms started factory production using only power looms. It is worth noting that there was one domestic market-oriented firm which equipped as many as 200 power looms for production of relatively low-quality traditional *kimono*. If we take simple average of power loom ratios, it is only 32.9% for firms in Kiryu town. It is likely that some WMCs immediately followed Schumpeterian innovators.

3-4 Estimated Total Number of Workers by Group of Firms

Assuming that domestic market-oriented firms are all WMCs[14] and using the official statistical data from 1906 to 1918, we estimated the total number of workers by group of firms, i.e., export-oriented joint stock firms, other export-oriented firms, WMCs in Kiryu town, and WMCs outside the town (see Table 4). Several important observations can be made. First, the total number of workers at the joint stock firms sharply declined from 1909 to 1912-13, confirming that the large factory production system failed in this period. Second, the total number of workers at WMCs, as well as that of out-weavers, sharply increased approximately in the same period, supporting our earlier conjecture that WMCs prospered during the period in which the total production in the Kiryu district stagnated or decreased (see Figure 1). Third, the total number of workers at the joint stock firms increased dramatically from 1915 to 1918, indicating the emergence and entry of new large firms. Finally, the total number of workers at WMCs in Kiryu town increased in 1918. This indicates that the Schumpeterian development associated with the emergence of new joint stock firms did not immediately destroy the old system. On the contrary, WMCs seem to have survived and introduced power looms and

[12] For the flexibility of production, Nakabayashi (2007) also admits that putting-out system using hand looms had advantage in Kiryu until the 1910s.
[13] According to Arai (year unknown), around 100 trademarks were registered by firms, which are considered mainly as WMCs, from the 1890s to the 1900s.
[14] There are, however, several relatively large domestic market-oriented firms, which employed roughly equal number of workers and looms. Such firms are unlikely to be WMCs.

factory systems, while reducing the reliance on the out-weaving systems since the late 1910s (Hashino, 2007a).[15] Therefore, we advance the following hypothesis regarding WMCs:

Hypothesis 3: While some WMCs tended to be laggards in the introduction of power looms, others quickly introduced power looms, thereby catching up with Schumpeterian innovators.

4. Econometric Analyses

In order to test the validity of the hypotheses postulated in previous section, in this section we estimate the regression functions explaining the number of workers, female worker ratio, the number of looms, power loom ratio, loom/worker ratio, sales revenue, and sales/worker ratio in 1906, 1910, 1915, and 1918. Note that not all the data of dependent variables are available in every year except in 1918. Sample firms are also different from year to year and explanatory variables are essentially time-invariant, so that the panel data analysis cannot be applied. Thus, we estimated the regression functions separately in each year.

4-1. Specification of Regression Functions

Denoting the dependent variables mentioned above by *Y*, the estimated regression function is specified as follows:

$$Y_{it} = \alpha_t + \beta_t(\text{Edo period dummy})_i + \gamma_t(\text{Operation years in Meiji era})_{it} + \delta_t(\text{Export firm dummy})_{it} + \varepsilon_t(\text{Dummy for other firms outside Kiryu town})_{it} + \zeta_t(\text{Join stock firm dummy})_{it} + \eta_t(\text{Power use dummy})_{it} + \theta_t(\text{Wheel use dummy})_{it} + \iota_t(\text{Trademark dummy})_i + \varepsilon_{it}$$

where subscripts *i* and *t* refer to i-th firm and t-th year, respectively; α_s are regression parameters; and ε is an error term. Edo period establishment dummy and the number of operation years in the Meiji era for those firms established in the Meiji period are used to examine if the experience of weaving business affects the scale of operation and productivity. We use three mutually exclusive firm dummies, in which the base of comparison is domestic market-oriented firms in Kiryu town: "Export firm dummy" refers to export-oriented firms in 1906, 1910, and 1915 and to export-oriented firms other than joint stock firms in 1918; "Dummy for other firms outside Kiryu town" is self-explanatory;[16] and "Join stock firm dummy" was used only for 1918 regression because they were too few in previous years. The dummy for trademarks registered in 1897-1907 period, which was used only in 1918 regression, is expected

[15] For example, the introduction of power looms in the above mentioned Goto Firm was delayed and occurred from the late 1910s to 1920s. This accompanied adoption of factory production system and giving up of producing a wide variety of products unsuited for mechanized mass production.

[16] Since there was only one such firm in 1906, it was combined with domestic market-oriented firms in Kiryu town in the regression analysis.

to capture the behavior of the leading WMCs.[17] Since this variable is likely to be endogenous and closely related with WMCs in Kiryu town, we show the estimation results without this variable in Appendix Table A.[18]

Problematic as explanatory variables are the three firm dummies, and power use and water wheel use dummies, as they are likely to be endogenous. Due to the paucity of exogenous variables, however, we are forced to use them as explanatory variables. To the extent that they are positively correlated with unobservable factors included in the error term, such as managerial abilities, their estimated coefficients tend to be over-estimated. Thus, we can hardly assert the causality from the estimated coefficients of these variables. What can be conjectured is association or the correlation of the variables of our interest. We apply the ordinary least squares regression when depended variables are continuous, whereas we apply the tobit estimation method when dependent variables are truncated, such as the number of looms and loom/worker ratio, which include zeros.

Since export orientation is expected to be positively associated with the scale of operation, particularly in early years, the coefficient of export firm dummy (is expected to be positive and significant in 1906 but becomes insignificant or less significant in the regression equations dealing with the scale of operation in later years, if Hypothesis 1 is correct. On the other hand, we expect the coefficient of joint stock firm dummy ( ) to be positive and significant in the employment, the number of looms, and revenue functions in 1918, if Hypothesis 2 is correct. Finally we expect the coefficients of export firm and joint stock firm dummies in the function explaining the power loom ratio in 1918 to be positive but maybe insignificant, as some WMCs were active in the introduction of power looms according to Hypothesis 3.

4-2 Estimation Results

Table 5 shows the estimation results for 1906, 1910, and 1915, from which several important findings can be made. First, neither coefficients of Edo period dummy nor those of the operation years in the Meiji era are significant in any regression equations.[19] These coefficients are not significant, either, for 1918 to be shown in Table 6. These findings indicate that the mere production experience did not affect the performance of weaving firms. Second, export firm dummy is significant in all the four regression functions in 1906, it becomes insignificant in the regression of the number of workers in 1910 and 1915, and its coefficient is negative and significant in the sales per worker regression in 1915. The last result strongly suggests that sales revenue per worker was significantly larger for WMCs, because they use out-weavers and other sub-contractors. On the other hand, its impact on female worker ratio is

[17] We use 'trademarks registered by firms in the Meiji 30s (from the late 1890s to the mid-1900s)' shown in Arai (year unknown).
[18] The qualitative results are largely the same.
[19] The results remain qualitatively unchanged, even if we excluded the operation years in the Meiji era.

significantly positive in all three years, suggesting that female workers were employed to operate large lots for producing export products. Note that the magnitude of the coefficients of export dummy in the regression of the number of workers are not so different among 1906, 1910, and 1915, even though those in 1910 and 1915 are insignificant, which indicates the larger variations of employment size among the export-oriented firms in these latter two years. Thus, it seems clear that the export-oriented firms chose large-scale factory production system initially, while employing relatively large number of female workers, but they failed to realize and maintain scale advantages, as is reflected in its insignificant effect on labor employment and sales revenue in 1915. Such results are substantially different from the case of joint stock firms to be examined from Table 6. The other side of the same coin is that leading WMCs prospered in this period. These results are consistent with Hypothesis 1.

Third, power use dummy has significantly positive effects on the number of workers in all three years, the number of looms in 1906, and sales revenue in 1915. Note that the source of the power was steam in 1906 and 1910, but it was almost completely replaced by electricity in 1915 (see Table 2). Also note that since only large export-oriented firms used the steam power in 1906 and 1910, the combined effects of export-orientation and the use of steam power were extremely large. Thus, it appears that large export-oriented firms attempted to enjoy scale economies by adopting the vertically integrated production system with the installation of large steam-power generators. Fourth, dummy for other firms outside Kiryu town is insignificant, which indicates that the behaviors of WMCs in Kiryu town and outside were not substantially different in 1915. Finally, it must be pointed out that three of the coefficients of water wheel use dummy are positive and significant in 1906, suggesting that in the absence of electricity, water wheel was used to expand the scale of operation and adopt the capital-intensive production method not for weaving but for other production processes.

Table 6 exhibits the estimation results of regression functions in 1918. Interestingly, joint stock firm dummy is positively correlated with the number of workers, the number of both hand and power looms, and sales revenue, as well as female worker ratio. Moreover, the coefficients in the regression functions for the number of workers, the number of looms, and sales revenue are comparatively large, which strongly indicates that newly established large joint stock firms sought the scale economies. The effects of non-joint stock firm dummy are significantly different from those of joint stock firm dummy in the number of workers, the number of both hand and power looms and sales revenue, presumably because non-joint stock firms did not seek scale economies.[20] In fact, if we compare joint stock firms and other export-oriented firms shown in Table 3, revenue of the former, on average, exceeded the latter by 16 times, whereas

[20] Moreover, the magnitudes of its coefficients in the female worker ratio, hand loom, and sales per worker regression in the Table 6 are similar to those of the export dummy reported in Table 5. It appears that non-joint stock firms in 1918 are not significantly different from the export-oriented firms in 1906, 1910, and 1915.

the number of workers is 12.5 times and the number of hand-loom equivalent looms 13.4 times,[21] indicating the strong scale advantages of the former over the latter.[22] These results support Hypothesis 2.

Somewhat unexpectedly, the coefficient of joint stock firm dummy is negative and larger in absolute value that that of non-joint stock firm dummy in the sales revenue/worker ratio regression. This is likely because joint stock firms served as sub-contractors for other firms by carrying out unmechanized preparatory and finishing processes, thereby resulting in the negative and larger coefficient of joint stock firm dummy in the sales per worker regression. This negative coefficient as well as the negative and significant coefficient of non-joint stock export-oriented firm dummy in the sales per worker regression indicates that WMCs in Kiryu town achieved significantly large sales revenue per *own* worker due to the outsourcing to out-weavers and specialized subcontractors.

Interesting findings of Table 6 are the presence of significant effect of non-joint stock export dummy in the hand loom function and its absence in the power loom function, which implies that domestic market-oriented firms in Kiryu used, on average, a larger number of power looms relative to hand looms. Domestic market-oriented firms outside Kiryu town seem slightly more active in the use of power looms and significantly so in the employment of female workers than those in Kiryu town. Most interesting finding is that neither joint stock firm dummy nor non-joint stock firm dummy is significant in the power loom ratio function. Thus, although WMCs did not attempt to expand the size of their production immediately, they were not intoxicated by success in the past but keen in the introduction of the new technology, even though this technology is not suitable for the production of complicated traditional Japanese products without some adaptations. These findings clearly support Hypothesis 3 that some WMCs successfully attempted to catch up with the joint stock firms in the introduction of power looms.

As may be expected, power use dummy is particularly significant in the power loom use function. As Minami (1977) emphasizes, the electrification promoted the use of motor-driven machines in Japan, which led to rapid decentralized industrialization in the early 20th century Japan. Although this study does not analyze the development of this weaving district in the subsequent periods, it is known that many WMCs actually followed the factory production system introduced by the joint stock firms and used power looms, which meant the demise of the out-weaving systems in favor of factory systems in this weaving district (Hashino, 2007a).

[21] For conversion, we used the price ratio of hand loom to power loom. According to Hashino (2007c), price of power loom was around 300 yen, whereas that of hand loom was 2 yen to 5 yen. Thus, the price ratio was 60 to 150.

[22] Note that these firms did not contract out sub-processes, so that the revenue was generated by own production activities.

5. Conclusion

In this study, we focused on the performances of three types of firms which contributed to the weaving production in Kiryu in the early 20th century. Changing phases of production were characterized by the concepts of Smithian growth and Schumpeterian development. Expansion and sophistication of division of labor supported Smithian growth, in which domestic market-oriented WMCs played a major role. Introduction of power looms and factory system were the major drivers of Schumpeterian development, which was promoted by large, export-oriented joint-stock firms. Three hypotheses regarding the performance of the three types of firms were tested by regression analyses, which reveal strategies of WMCs to utilize sub-contracts, and the pursuit of scale economies by large export-oriented firms. Although the rise of wage rates in the 1910s would have affected the introduction of power looms and relative advantage of factory systems, our study cannot identify its effect due to the cross-section nature of our data sets.

We would like to conclude this study by identifying three major remaining issues for further research. The first one is concerned with the importance of Smithian growth. Of course, division of labor in various industrial clusters is widely observed in developing economies, particularly in the early stage of cluster development (Sonobe and Otsuka 2006, 2011), but its role has not been highlighted. In the case of Kiryu, WMCs are worthy of being called entrepreneurs promoting Smithian growth by organizing specialized production systems. Although they were not so keen about breakthroughs, they continued utilizing division of labor in the processes other than weaving, even after they built power-loom factories. It seems worth exploring the extent to which Smithian growth lays foundation for the development of industrial districts in its early stage of the development and at the same time, the extent of the survival and demise of firms organizing the division of labor in the subsequent phases of cluster development.

The second issue is to explore how Schumpeterian development emerges or what types of entrepreneurs play a role of Schumpeterian innovators. Three types of innovations were observed in our study site; process innovation (e.g., introduction of power looms), product innovation (e.g., introduction of new products for export), and organizational innovation (e.g., introduction of factory systems). Since the introduction of power looms and suitable products for mechanized production, the adoption of factory systems, and the emergence of joint stock firms are so closely interrelated with each other that they took place simultaneously. Thus, successful innovations seem to require managerial capacity to carry out a variety of component innovations. What type of human capital is needed for such innovations must be clarified through further historical research and research on the contemporary development of industrial clusters in developing countries.

Finally, it must be pointed out that the role of traders to connect the weaving district with outside markets needs to be analyzed. According to Broadberry and Marrison (2002), one of the competitive advantages of Lancashire cotton industry rested in the strong network of traders. What role traders played and how they were related with WMCs in Kiryu are of particular importance, as WMCs themselves were engaged in market-oriented activities including procurement of raw materials, designing, quality control, and sales to local and urban traders.

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Table 1. Average Characteristics of Weaving Firms with the Employment of More Than 10 Workers in Selected Years from 1895 to 1918

	1895	1899	1903	1906[a]	1906[b]	1910	1915	1918
No. of firms	10	10	31	28	27	68	64	88
Year of establishment	1851	1876	1867	1869	1868	1879	1876	1881
No. of workers	98.5	91.5	33.1	47.2	23.2	29.5	28.4	39.2
Female worker ratio (%)[d]	81.2	84.5	77.4	77.5	77.3	69.7	68.3	68.6
No. of looms	--[e]	--	--	17.5	12.5	--	--	26.5[f]
Loom/worker ratio	--	--	--	.46	.47	--	--	.24
Sales revenue (1,000 yen)	--	--	--	--	--	--	52.3	358.3
Sales revenue per worker (1,000 yen)	--	--	--	--	--	--	1.8	9.1

a. Sample size of the original data is 28, including one large firm whose number of workers is 697.
b. Computed while excluding a large firm with 697 workers
c. Computed while excluding those firms whose establishment years were unknown: two firms were excluded in 1903, 1915, and 1918; three firms in 1895; four firms in 1906; and five firms in 1910. The excluded firms are likely to be very old.
d. Ratio of the number of female workers to the total number of workers.
e. Not available.
f. The proportion of power loom is 78.4%.

Source: For the data of 1895, 1899, 1903, Gunma Prefectural Government (1896,1900, and 1904) *Gunmaken Kangyo Nenpo*; for 1906, Gunma Prefectural Government (1907) *Gunmaken Tokeisho*; for 1910, Gunma Prefectural Government (1910) *Gunmaken Tokeisho*; for 1915, Gunma Prefectural Government (1916) *Taisho 5 nen Kojohyo*; for 1918, Gunma Prefectural Government (1919) *Taisho 8 nen Kojohyo*.

Table 2. Comparison of Export-Oriented Firms with Other Firms in Kiryu Town and Outside in 1906, 1910, and 1915

	Number of firms	Average year of establishment	Number Of workers	Female worker ratio	Number of hand looms	Sales revenue (in 1000 ¥)	% use of steam powers[d]	Percent of use of water wheels
1906 Export-oriented firms	16	1889[a]	71.8	83.1	26.9	-[e]	12.5	25.0
Others in Kiryu town	11	1874	14.5	67.9	4.6	-	0.0	54.5
Others outside	1	1600	15.0	86.7	9.0	-	0.0	0.0
1910: Export-oriented firms	31	1895[b]	45.4	78.4	-	-	12.9	22.6
Others in Kiryu town	24	1881	17.0	63.0	-	-	0.0	41.7
Others outside	13	1873[b]	15.2	70.0	-	-	0.0	0.0
1915 Export-oriented firms	19	1893[c]	48.5	73.6	-	72.1	68.4	21.1
Others in Kiryu town	34	1890[c]	20.8	66.1	-	53.8	41.2	50.0
Others outside	11	1887[c]	15.5	72.0	-	39.1	0.0	27.2

Five firms each whose

a. Four firms each whose establishment years were unknown were excluded.
b. Two firms each whose establishment years were unknown were excluded.
c. Figures in 1915 show the percent of use of electricity.
d. Not available.

Source: Same as Table 1.

Table 3. Comparison of Joint Stock Firms, Other Export-Oriented Firms, and Domestic Market-Oriented firms in Kiryu Town and Outside in 1918

	Number of firms	Average year of establishment	Number of workers	Female worker ratio	Number of hand looms	Number of power looms	Power loom ratio[c]	Sales revenue (1000 yen)	Percent use of electricity	Percent of holding trade-mark
Export-oriented firms:	41									
Joint stock firms										
Others	5	1914	316.0	78.2	38.0	155.2	73.6	816.2	80.0	0.0
	36	1891[a]	25.2	84.1	6.1	13.6	53.3	50.4	75.0	2.8
Domestic	47									
market-oriented firms:										
In Kiryu town	32	1887	21.2	62.0	1.5	10.8	32.9	85.4	62.5	34.5
Others	15	1891[b]	19.3	73.0	3.0	14.6	39.1	74.3	33.3	6.7

a. Two firms whose establishment years were unknown were excluded.
b. Three firms whose establishment years were unknown were excluded.
c. Power looms ratio is assumed to be zero, if the firm does not own any looms.
Source: Same as Table 1.

Table 4: The Estimated Total Number of Workers by Group of Firms, 1906-1918[a]

	Joint-stock firms	Other export-oriented firms	WMCs in Kiryu town	WMCs outside Kiryu town	Out-weavers
1906	697	452	159	15	5219
1907	583	375	165	23	5825
1908	812	577	134	59	5774
1909	925	868	462	112	5726
1910	596	810	418	187	6216
1911	406	859	463	90	6308
1912	233	801	469	168	7481
1913	247	661	465	224	8608
1914	301	643	668	269	8770
1915	326	613	699	150	8169
1916	--[b]	--	--	--	8854
1917[c]	932	894	433	228	8826
1918	1556	932	761	221	8771

a. We categorized all the firms with more than 10 workers which appeared in the official statistics into four types of firms, judging from the main products. If the main products were 'textiles' or 'silk textiles', we regarded such firms as WMCs.
b. Not available.
c. The original data for this year contains a list of firms with less than 10 workers. Therefore, we excluded them from the computation..

Source: For out-weavers, *Gunmaken Tokeisho* (various years). For other firms, *Gunmaken Tokeisho* (data for 1906-1914), *Taisho 5 nen Houkoku Kojohyo* and *Taisho 8 ne Houkoku Kojohyo* (for 1915 and 1918), *Gunmakenshi Shiryohen 23* (for 1917).

Table 5: Estimation Results of Regression Functions Explaining the Number of Workers, Female Worker Ratio, and Other Performance Indicators at the Firm Level in 1906, 1910, and 1915[a]

	1906				1910		1915			
	No. of workers[b]	**Female worker ratio[b, c]**	**No.of looms[d]**	**Loom/worker ratio[d]**	**No. of workers[b]**	**Female worker ratio[b, c]**	**No. of workers[b]**	**Female worker ratio[b, c]**	**Sales revenue[b, e]**	**Sales per worker[b, f]**
Edo period dummy	-5.18 (-0.62)	.12 (1.52)	-3.00 (-0.50)	-.00 (-0.02)	-23.90 (-1.21)	.04 (.49)	-11.34 (-.60)	-.04 (-.46)	-18.41 (-.54)	312.89 (.66)
Operation years in Meiji era[g]	.05 (.75)	.00 (.29)	.06 (1.45)	.00 (1.87)	-.74 (-1.18)	.00 (.84)	-.23 (-.48)	.00 (.08)	-.20 (-.23)	9.25 (.75)
Export dummy	16.17** (2.28)	153* (2.30)	19.66** (3.59)	.38** (3.88)	17.48 (1.13)	.29** (4.71)	23.70 (1.71)	.22** (3.75)	11.27 (.45)	-1326.00** (-3.81)
Dummy for other firms outside Kiryu town					9.59 (.45)	03 (.40)	5.18 (.28)	.08 (1.05)	10.37 (.32)	345.48 (.76)
Power use dummy	41.44** (3.54)	0.06 (.06)	29.28** (3.45)	.10 (.64)	30.48* (1.94)	-.10 (-1.56)	24.58 (1.71)	.01 (.17)	52.74* (2.04)	658.93* (1.83)
Wheel use dummy	13.89* (2.19)	.01 (.18)	14.61** (2.99)	.24* (2.70)	2.62 (.16)	-.00 (-.07)	1.99 (.14)	-.08 (-1.39)	.41 (.02)	35.55 (.10)
Intercept	5.51 (.84)	.66 (10.72)	-9.00 (-1.67)	.09 (.09)	26.41 (1.32)	.55 (6.85)	15.00 (.14)	.64 (8.64)	33.31 (1.05)	1986.18 (4.50)
R^2	.540	.378			.166	.302	.148	.278	.110	.265
Log-likelihood ratio			-89.48	.071						
Sample size	27	27	27	27	68	68	64	64	64	64

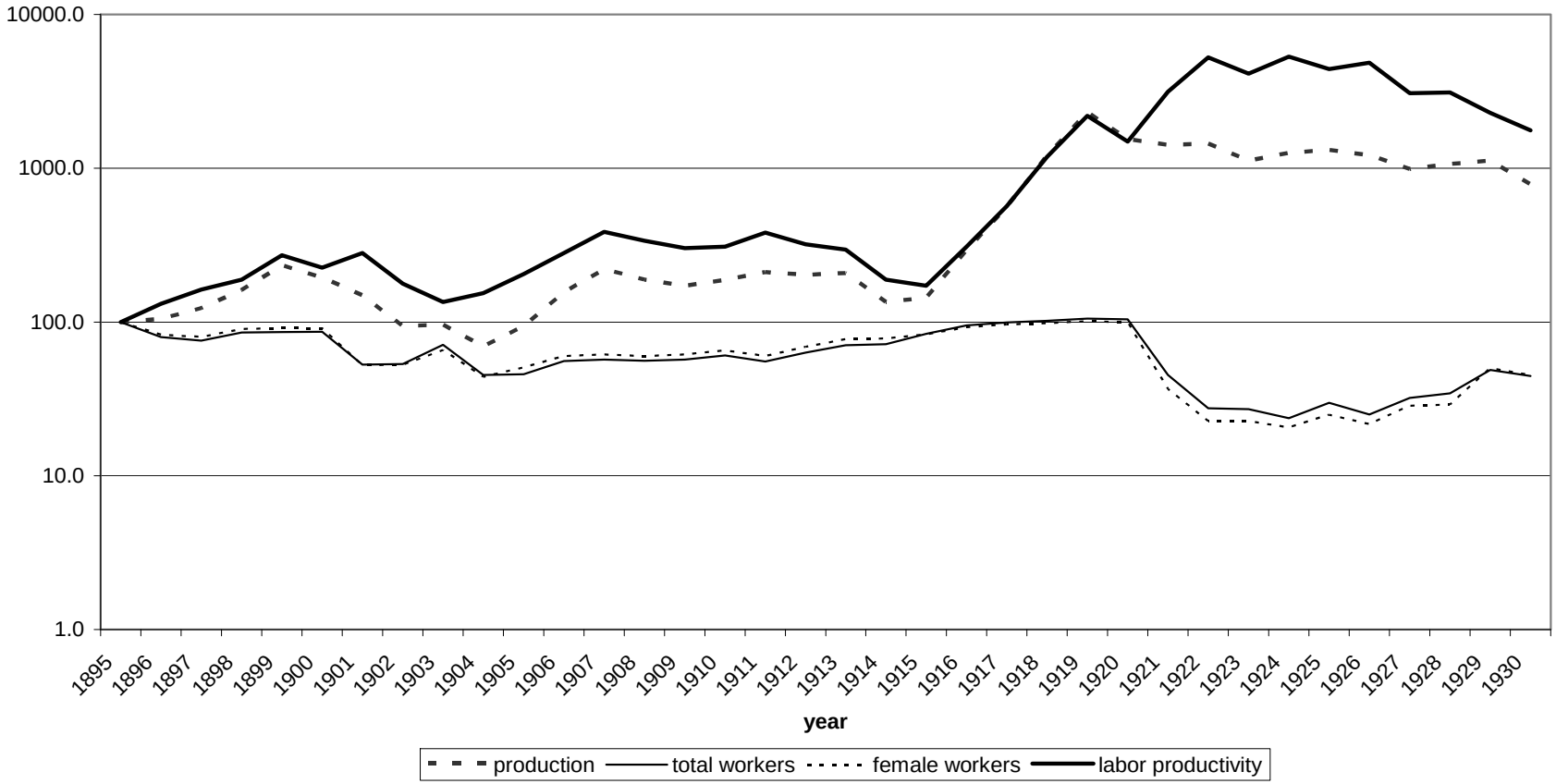
a. Numbers in parentheses are *t*-statistics. ** and * indicate significance at 1% and 5% level, respectively, according to one-tailed test.
b. OLS regression.
c. Ratio of the number of female workers to the total number of workers.
d. Tobit regression.
e. Unit is 1,000 yen.
f. Unit is yen.
g. Operation years of firms established after the Meiji Restoration in 1867

Table 6: Estimation Results of Regression Functions Explaining the Number of Workers, Female Worker Ratio, and Other Performance Indicators at the Firm Level in 1918[a]

	Number of workers[b]	Female worker ratio[b,c]	Number of hund looms[d]	Number of power looms[d]	Power loom ratio[d]	Sales revenue[b, e]	Sales per worker[b, f]
Edo period dummy	5.48 (.17)	-.02 (-.37)	-.56 (-.06)	12.21 (.34)	.09 (.41)	12.80 (.13)	-643.32 (-.77)
Operation years in Meiji era[g]	.52 (.67)	-.00 (-.18)	-.07 (-.32)	1.33 (1.50)	.01 (1.68)	1.72 (.73)	-18.49 (-.94)
Joint stock dummy	295.57** (6.26)	.19* (2.10)	54.93** (4.48)	177.12** (4.23)	.40 (1.49)	737.00** (5.16)	-3258.42** (-2.71)
Non-joint stock export dummy	-.69 (-.03)	.26** (5.62)	21.57** (2.83)	7.23 (.29)	.16 (.99)	-23.08 (-.31)	-2190.37** (-3.52)
Dummy for other firms outside Kiryu town	5.02 (.16)	.16** (2.70)	5.24 (.61)	58.37 (1.49)	.63** (2.54)	12.22 (.13)	-662.58 (-.85)
Power use dummy	14.16 (0.60)	.15** (3.34)	-8.72 (-1.40)	172.16** (3.85)	1.59** (6.04)	38.06 (.54)	-986.49 (-1.65)
Wheel use dummy	-16.57 (-.60)	.06 (1.14)	20.67** (2.96)	-55.76 (-1.48)	-.445 (-1.91)	-62.92 (-.76)	-1448.19* (-2.07)
Trademark dummy	-7.70 (-.24)	-.08 (-1.26)	2.41 (.26)	-44.41 (-1.13)	-.35 (-1.42)	-13.90 (-.14)	1179.26 (1.42)
Intercept	7.51 (-.24)	.45 (7.47)	-17.41 (-1.87)	-188.25 (-3.58)	-1.20	46.85 (.48)	6254.28 (7.61)
R^2	.394	.455				.313	.257
Log-likelihood			-194.48	-273.14	-48.36		

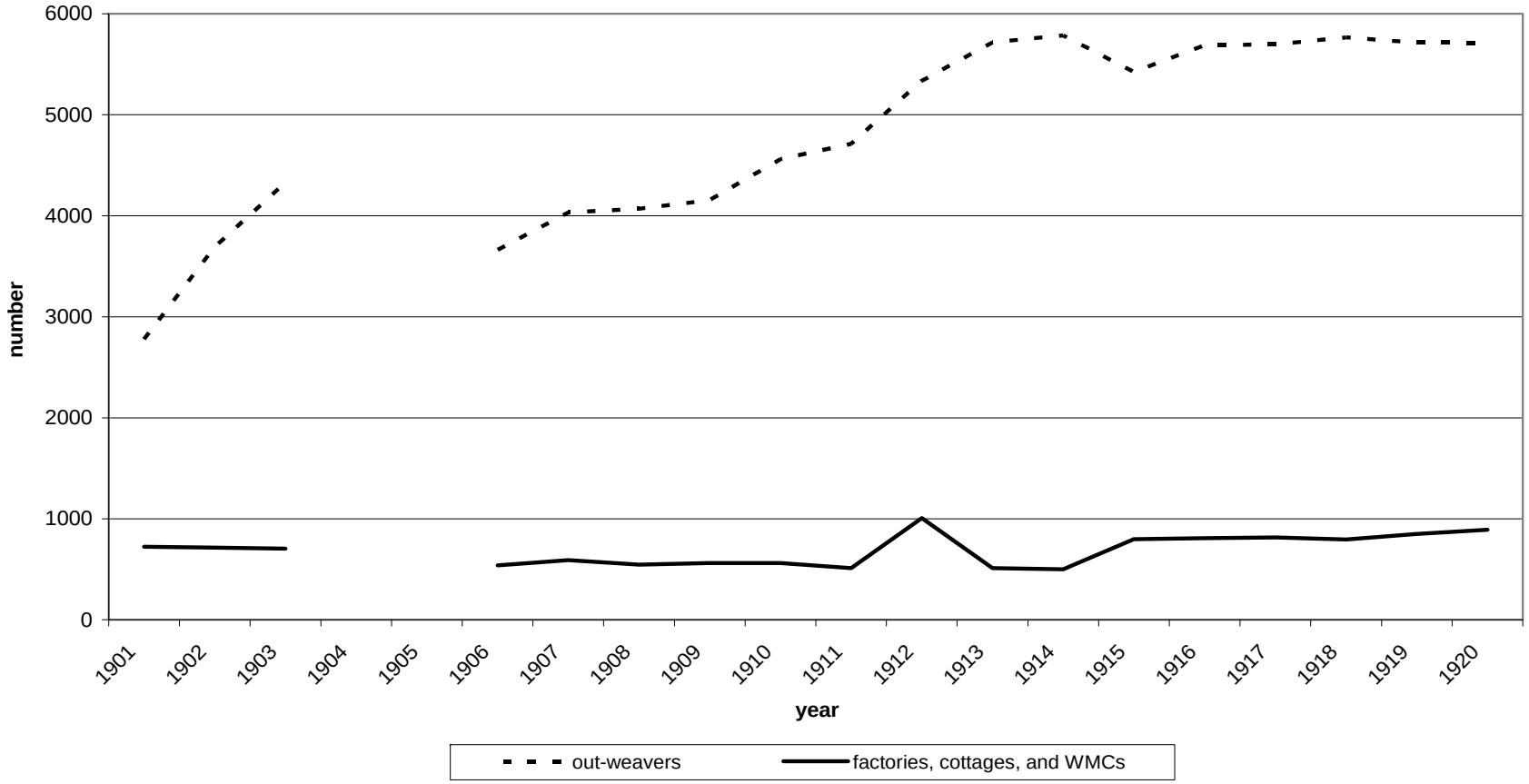
a. Numbers in parentheses are *t*-statistics. ** and * indicate significance at 1% and 5% level, respectively, according to one-tailed test. Sample size is 88.
b. OLS regression.
c. Ratio of the number of female workers to the total number of workers.
d. Tobit regression.
e. Ratio of the number of power loom to the total number of looms including hand looms.
f. Unit is 1,000 yen.
g. Unit is yen.
h. Operation years of firms established after the Meiji Restoration in 1867.

Figure 1. Changes in real value of production, employment, and labor productivity in Kiryu, 1895-1930 in semi-log scale (Index, 1895=100)



Source: Gunma Prefectural Government (1904) for the data from 1895 to 1901; Gunma Prefectural Government (1903-1931) *Gunmaken Tokeisho*, for the data from 1902 to 1930.
Note: For realized value, we used price index for textile products in Ohkawa et al., p.192.

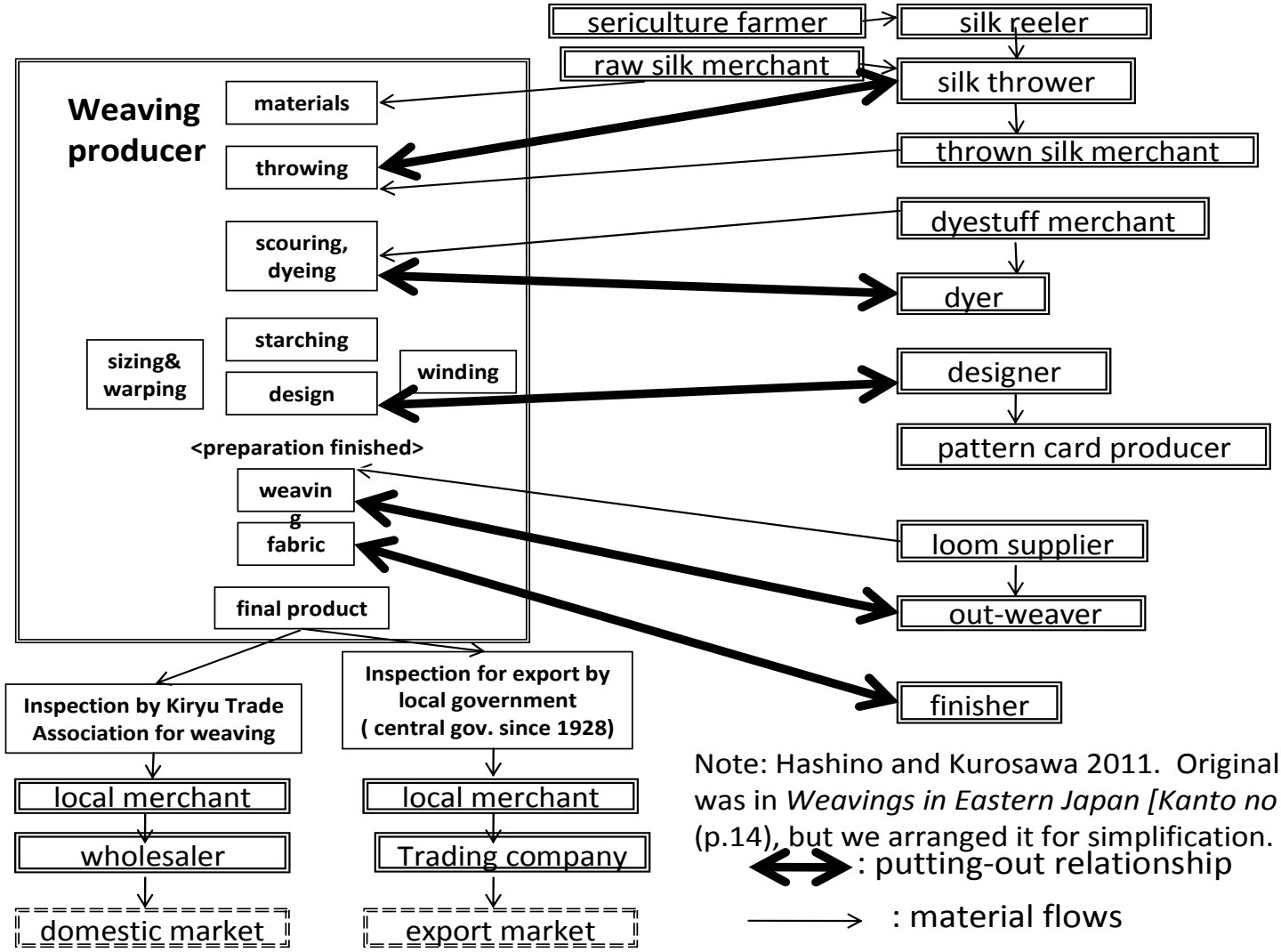
Figure 2. Changes in the number of out-weavers and other production organizations in Kiryu, 1901-20



Source: Hashino and Kurosawa (2011), Figure 3.

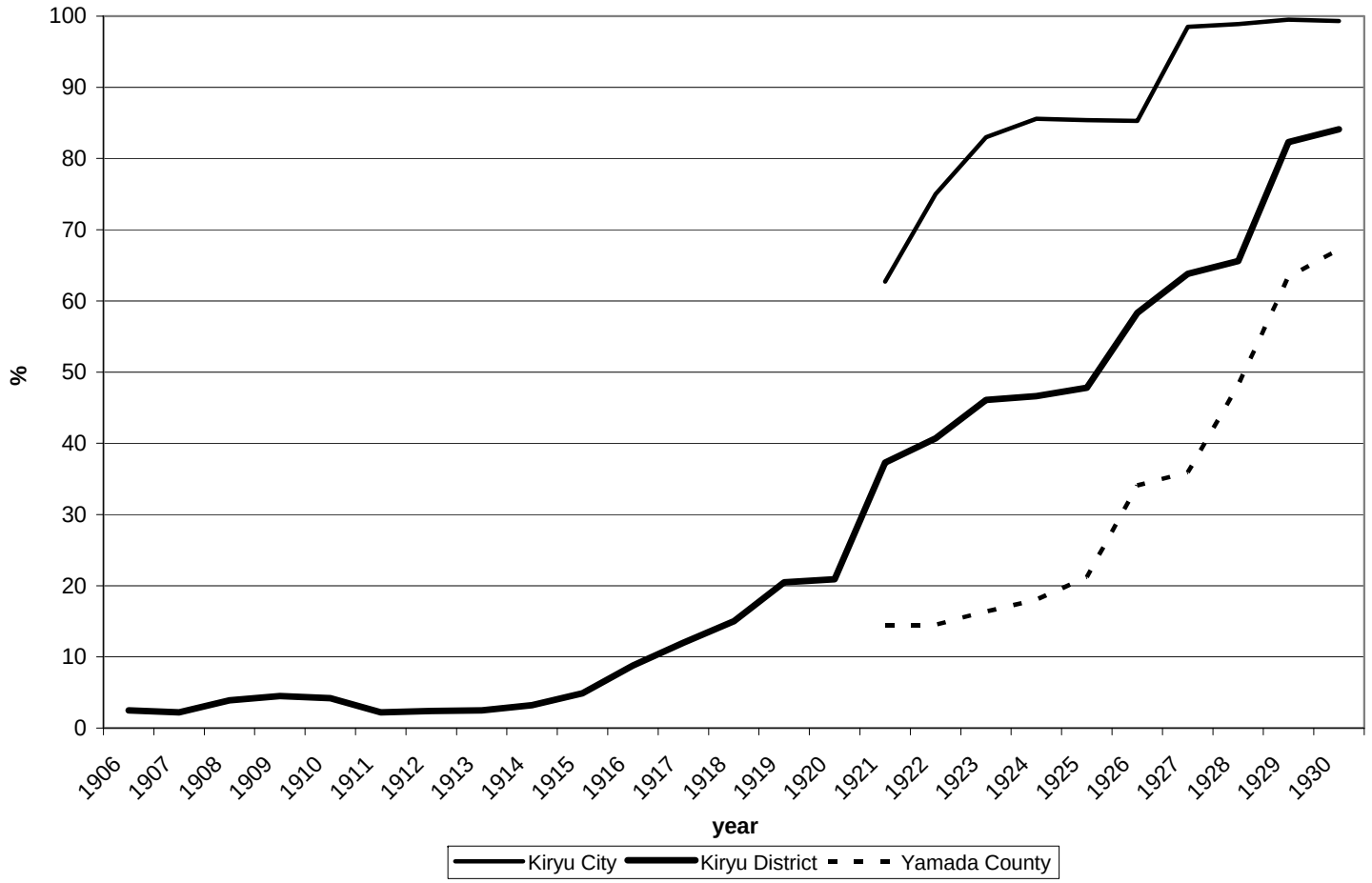
Note: No data is available in 1903 and 1904.

Figure 3. Process of producing silk fabric (left) and specialization organizing by WMCs (right) in Kiryu around 1910



Note: Hashino and Kurosawa 2011. Original figure was in *Weavings in Eastern Japan [Kanto no Kigyo]*, (p.14), but we arranged it for simplification.

Figure 4. Changes in the proportion of power looms in Kiryu, 1906-1930



Source: Hashino (2007a), Figure 2.2.

Appendix Table A. Estimation Results of Regression Functions Explaining the Number of Workers, Female Worker Ratio, and Other Performance Indicators at the Firm Level in 1918 without Using Trademark Variable[a]

	Number of workers[b]	Female worker ratio[b,c]	Number of hand looms[d]	Number of power looms[d]	Power loom ratio[d]	Sales revenue[b, e]	Sales per worker[b, f]
Edo period dummy	2.74 (.09)	-.06 (-.86)	.00 (.00)	-4.43 (-.13)	-.04 (-.20)	7.85 (.08)	-223.72 (-.28)
Operation years in Meiji era[g]	.473 (.63)	-.00 (-.51)	-.06 (-.29)	.88 (1.11)	.01 (1.17)	1.64 (.73)	-11.46 (-.60)
Joint stock dummy	297.18** (6.39)	.20* (2.29)	54.13** (4.58)	184.07** (4.40)	.47 (1.70)	739.91** (5.27)	-3504.65** (-2.93)
Non-joint stock export dummy	1.07 (.05)	.28** (6.27)	20.81** (2.98)	17.72 (.74)	.25 (1.59)	-19.91 (-.28)	-2459.07** (-4.12)
Dummy for WMCs outside Kiryu town	7.07 (.24)	.18** (3.17)	4.42 (.55)	74.72* (2.01)	.76** (3.18)	15.92 (.18)	-979.76 (-1.29)
Power use dummy	13.15 (.57)	.14** (3.15)	-8.44 (-1.38)	168.85** (3.72)	1.58** (5.82)	36.24 (.52)	-832.31 (-1.41)
Wheel use dummy	-17.82 (-.66)	.05 (.91)	20.99** (3.05)	-62.43 (-1.67)	-.51* (-2.15)	-65.18 (-.80)	-1256.76 (-1.82)
Intercept	7.34 (.23)	.45 (7.42)	-16.99 (-1.86)	-188.74 (-3.53)	-1.23 (-3.76)	46.55 (.48)	6279.95 (7.59)
R^2	.394	.444				.313	.238
Log-likelihood ratio			-194.52	-273.78	-49.38		

a. Numbers in parentheses are *t*-statistics. ** and * indicate significance at 1% and 5% level, respectively, according to one-tailed test. Sample size is 88.
b. OLS regression.
c. Ratio of the number of female workers to the total number of workers.
d. Tobit regression.
e. Ratio of the number of power loom to the total number of looms including hand looms.
f. Unit is 1,000 yen.
g. Unit is yen.
h. Operation years of firms established after the Meiji Restoration in 1867.

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