From Smithian Growth to Schumpeterian Development: An Inquiry into the Development of the Kiryu Weaving District in the Early 20th Century Japan

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Abstract

This study finds that the process of evolutionary development of the Kiryu weaving district in Japan from 1895 to 1930 can be divided 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 among others, thereby contributing to the steady growth in production. Newly emerged joint stock firms played a role of genuine entrepreneurs by realizing significant scale economies and transforming the traditional weaving district into a cluster of large modern factories.

Keywords: industrial district, Smithian growth, Schumpeterian development, weaving industry, 20th century Japan

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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, 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

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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).[1]

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.

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

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[1] 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.

process of Kiryu weaving district in the early 20th century.   Kiryu was one of the most

advanced silk weaving districts in 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* 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

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 adopted power looms and successfully

sought the scale economies, thereby "destroying" the out-weaving system and

"constructing" factory system.   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 leading

to the destruction of out-weaver systems and the creation of factory systems.   We also

inquire into the causes of the success and failure of the three types of weaving firms.

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 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, WMCs, 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 the adoption of power looms which are considered as the keys to the growth of Kiryu. Through the observation of structural changes, we will identify the two distinct phases of growth in Kiryu in the early 20th century.

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 at around 10 millions yen 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 the level between 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 in 1904.   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, 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 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 rate in labor productivity was 0.92% from 1904 to 1915 and 9.95% from 1916 to 1927.

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

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[2] The data in 1904 and 1905 are not available.　*Statistical Survey of Gunma Prefecture* where Kiryu was located defines four types of production organizations with two criteria, i.e. the numbers 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 characteristics 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.　For details, see Hashino (2007a, p. 34, footnote 2).

town, increased rapidly from the 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. This division of labor happened not only in weaving

process but also in many other processes carried out by specialized subcontractors

(Hashino and Kurosawa 2011).[3]

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 processes but

gradually out-sourced many processes, such as throwing, dying, designing, weaving,

and finishing. For example, dyeing process was one of the key preparatory processes

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[3] 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).

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.[4]

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 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 Kiryu was 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

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[4] 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).

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 of Yamada county already in 1921. Therefore, we can assume that the introduction of power looms in urban area proceeded at much faster rate than that in rural villages, probably even in the 1910s. New technology needed new production organizations, because the use of power looms confers scale advantages. Previous studies report that the introduction of power loom was accompanied by the adoption of factory system in Japan (Hashino 2007a; Hunter 2003; Minami and Makino 1983; Saito and Abe 1988). It is therefore likely that factories with power looms located in the center of the district 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.[5]

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[5] Although we do not analyze in this study, firms which adopted power looms made a number of improvements in the product designs in order to produce traditional products by power looms.

To sum up, it seems legitimate to call the first trend of output growth Smithian

growth and the second one Schumpeterian development. Smithian growth is chiefly

caused by the increase in the division of labor which must have been created by

reduction in the transaction cost associated with the improved assignment of tasks and

enforcement of property right and production responsibilities (Mokyr 1990). On the

other hand, Schumpeterian development is derived from the major increase in

production efficiency by innovations. Such innovations encompass new production

technology and organizational changes that enable innovative firms either production of

a given output with much smaller amount of resources or the production of much better

or large quantity of new products with the same resources, or both (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 of Gunma prefectural government and *Factory Survey*.[6] These firms

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[6] The data source in 1915 and 1918 is *Factory Survey*, which was conducted by Gunma prefectural government in order to report to the central government. Compared with *Statistical Survey* data used for 1906 and 1910, individual data in 1915 and 1918 contain much more detailed information about production of each firm.

were termed factories. Although there are four production organizations (i.e.,

out-weavers, factories with more than 10 workers, cottages with less than 10 workers,

and MWCs), it is possible that the increase in the number of workers converted the

cottages and MWCs 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 new large firms was not necessarily the

major reason. Recall that aside from out-weavers, there are three types of sample

weaving firms in Kiryu; (1) large firms which attempted 'vertical integration',[7] (2)

traditional firms including WMCs whose number of workers increased to more than 10,

and (3) newly-established joint stock firms which equipped power looms and adopted

factory system in the late 1910s.

Large firms with the employment of nearly 100 workers seem to have appeared

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[7] 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 processes in the case of WMCs as is shown in Figure 3. It is partly 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.

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, it seems that 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, it can be considered that 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).[8]

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

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

continued to decline to 23.2 in 1906 (see column of 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.

It is likely that the stagnant production from the mid-1900s to the mid-1910s observed

in Figure 1 was the result of the reduction in production by large firms and offsetting

increase in production by growing WMCs.

In the 1910s, new entries can be recognized from both increase in the number

of firms and the rise of 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 average

number of firms and the number of workers 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 which 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 cost 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 is larger.

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.

Organized by WMCs, traditional products for domestic market were produced by

utilizing complicated and specialized division of labor within the district, as was

illustrated by Figure 3.　In contrast, the large firms established in the late 19th century

attempted to sell product at export markets without depending on any 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.[9]　Data

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[9] We estimate the export- and domestic market-orientation from the main product reported by the
survey.

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 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, however, other firms outside Kiryu town were likely to be WMCs,

because, although smaller, their sales revenue was not low in 1915, if we consider the

smaller number of employed workers.   The number of export-oriented firms increased

from 1906 to 1910 and then declined, whereas the number of other firms in both Kiryu

town and outside 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 firms with more

moderate scale 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

other firms in Kiryu town because they are likely to be leading WMCs type firms, in which the relatively larger number of male workers played an important role in the preparatory processes, delivery of raw materials, and collection of finished products. Percent of firms using traditional water wheels was also high among other firms in Kiryu town because they were used for preparatory processes (Hashino 2007c). Only some export-oriented firms introduced motive-powers in 1906 and 1910, which was steam engine. In 1915, however, some of other 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. It must be also pointed out that the number of workers of the export-oriented firms far exceeded the number of looms in 1906, which indicates that many workers were engaged in a variety of production activities other than weaving within the large factories.

Until the late 1900s, hand looms were used in almost all firms in Kiryu except for a 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

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fixed inputs.   In fact, such large-scale firms disappeared and were replaced by smaller firms with the employment of much less than 50 workers, which were likely to be successful WMC-type firms whose advantage lay in the use of the division of labor with out-weavers and other supporting firms.   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 (1915-1918).   Responding to the increasing demand for the 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 used power looms to save labor by using electricity.

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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 number of looms because there were both hand and power looms. In the case of joint stock firms, female workers operated primarily power looms, whereas in other export-oriented firms female workers used both hand and power 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), which 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 far different from the large 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, factory production, and electricity.*

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 formers were likely to be large WCMs employing relatively many male workers without much internal production. In the case of a leading WCM, 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 out-weavers. Its strategy was low volume production of a wide variety of products for domestic market by enjoying the advantage of agglomeration economies.[10] In addition, holding of

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[10] For the flexibility of production, Nakabayashi (2007) also admits that putting-out system using hand looms had advantage in Kiryu until the 1910s.

registered trademarks in Meiji Era indicates that other firms in Kiryu town were old

leading firms[11].   They also began the introduction of power looms, but percentage of

power looms were the lowest among the four groups in Table 3.   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.   Therefore, we advance the following hypothesis

regarding WCMs:

Hypothesis 3: WCMs became laggards in the era of the Schumpeterian innovation.

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, loom/worker ratio, proportion of power loom,

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, so that the panel data analysis cannot be

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[11]   According to Arai (year unknown), around 100 trademarks were registered by firms, which are
considered mainly as WMCs, from the 1890s to the 1900s.

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:

$Y_{it} = \alpha_{0t} + \alpha_{1t}$(Edo period dummy)$_i$ + α_{2t}(Operation years in Meiji era)$_{it}$ +

α_{3t}(Export firm dummy)$_{it}$ + α_{4t}(Domestic firm dummy)$_{it}$ + α_{5t}(Join stock

firm dummy)$_{it}$ + α_{6t}(Power use dummy)$_{it}$+ α_{7t}(Wheel use dummy)$_{it}$+

α_{8t}(Trademark dummy)$_i$+ ε_{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 (most likely WMCs):

"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; "Domestic firm dummy"

means domestic market-oriented firms located outside Kiryu town;[12] and "Join stock

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

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 to capture the behavior of the leading WMCs.[13]

Problematic as explanatory variables are export firm, domestic firm, and joint stock 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. Another caveat is that while we apply the ordinary least squares regression when depended variables are continuous, 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 (α_3) is

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[13] We use 'trademarks registered by firms in the Meiji 30s (from the late 1890s to the mid-1900s)' shown in Arai (year unknown).

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 (α_5) 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 all three firm dummies in the proportion of power loom function to be

positve, as WMCs were inactive in the introduction of power looms according to

Hypothesis 3.

4-2. Estimation Results

Table 4 shows the estimation results for 1906, 1910, and 1915. Several

important observations 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.[14]   These coefficients are not significant, either, for 1918 to be shown in

Table 5.   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

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[14]   The results remain qualitatively unchanged, even if we excluded the operation years in the Meiji
era.

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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-contractor. On the other hand, its impact on female worker ratio is 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 in 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 and even negative and significant effect on sales revenue per workers in 1915. Such results are substantially different from the case of joint stock companies to be examined from Table 5. 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. Since the magnitudes of coefficients of power use dummy in the regression of the numbers of workers are similar among the three years, it is doubtful that the replacement of steam by electricity brought about large changes in the employment practice immediately. Fourth, dummy for domestic market-oriented 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 5 exhibits the estimation results of regression functions in 1918. Interestingly, joint stock firm dummy is positively correlated with the number of

workers, number of looms, and sale revenue, as well as female worker ratio and worker-loom ratio.   Moreover, the coefficients in the regression functions for the number of workers, number of looms, and sales revenue are comparatively large, which strongly indicates that newly established large joint stock firms sought the scale economies.   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 latte by 16 times, whereas the number of workers is 12.5 times and the number of hand-loom equivalent looms 13.4 times,[15] indicating the strong scale advantages of the former over the latter.[16]   These results support Hypothesis 2.

Somewhat unexpectedly, the effect of joint stock firm on the power loom ratio is insignificant.   This is because all the joint stock firms used powers and, hence, their use of power looms is captured by the power use dummy. Although the difference is not statistically significant, it is noteworthy that coefficient of joint stock firm dummy is smaller that that of non-joint stock firm dummy in the loom/worker ratio regression. This is likely because joint stock firms served as sub-contractors for other firms by carrying out preparatory and finishing processes, which did not use looms.   This may

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[15]   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.
[16]   Note that these firms did not contract out sub-processes, so that the revenue was generated by own production activities.

result 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.

The effects of non-joint stock firm dummy are similar to those of joint stock firms except for the size effects on the number of workers and looms, and sales revenue. Moreover, the magnitudes of its coefficients in the female worker ratio, loom/worker ratio, and sales per worker regressions in Table 5 are similar to those in Table 4. It appears that non-joint stock firms are not significantly different from the export-oriented firms analyzed in Table 4.

The results examined so far imply that WMCs employed smaller number of workers, used fewer looms, particularly power looms (Table 3), and lower sales revenue than joint stock firms but attained much higher revenue per worker due to the subcontracts with out-weavers and other specialized sub-contractors. WMCs in Kiryu town, however, were different from domestic market-oriented firms outside Kiryu town: WMCs in Kiryu town employed relatively more labor and less power loom (Table 5).

This is consistent with Hypothesis 3 that WMCs were less active in the introduction of power looms, mostly likely because of their established and at least formerly successful subcontract-based production systems

As may be expected, power use dummy is particularly significant in the power loom ratio 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 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).

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, the pursuit of scale economies by export-oriented firms, and the importance of electricity to facilitate successful adoption of power-looms and factory systems. 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 two 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 were 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. Historically, they were engaged not only in manufacturing but also in marketing, designing, quality control, and making trial samples (Uchida 2002). In other words, WMCs played the role of traders, who are essential for linking producers with markets. Although they were not so keen about breakthroughs, they effectively utilized existing resources in local community, e.g., cheap rural labor, based on mutual trust (Hayami and Godo 2005). When the trust was insufficient in mobilizing collective action, support of local trade association or local government became crucial for strengthening agglomeration economies (Hashino and Kurosawa 2011). 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

Another 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). Establishment of joint stock firms and utilization of division of labor also fall under the organizational innovation. 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.

Acknowledgement

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Figure 1. Changes in real value of production, employment, and labor productivity in Kiryu, 1895-1930 in semi-log scale (Index, 1895=100)
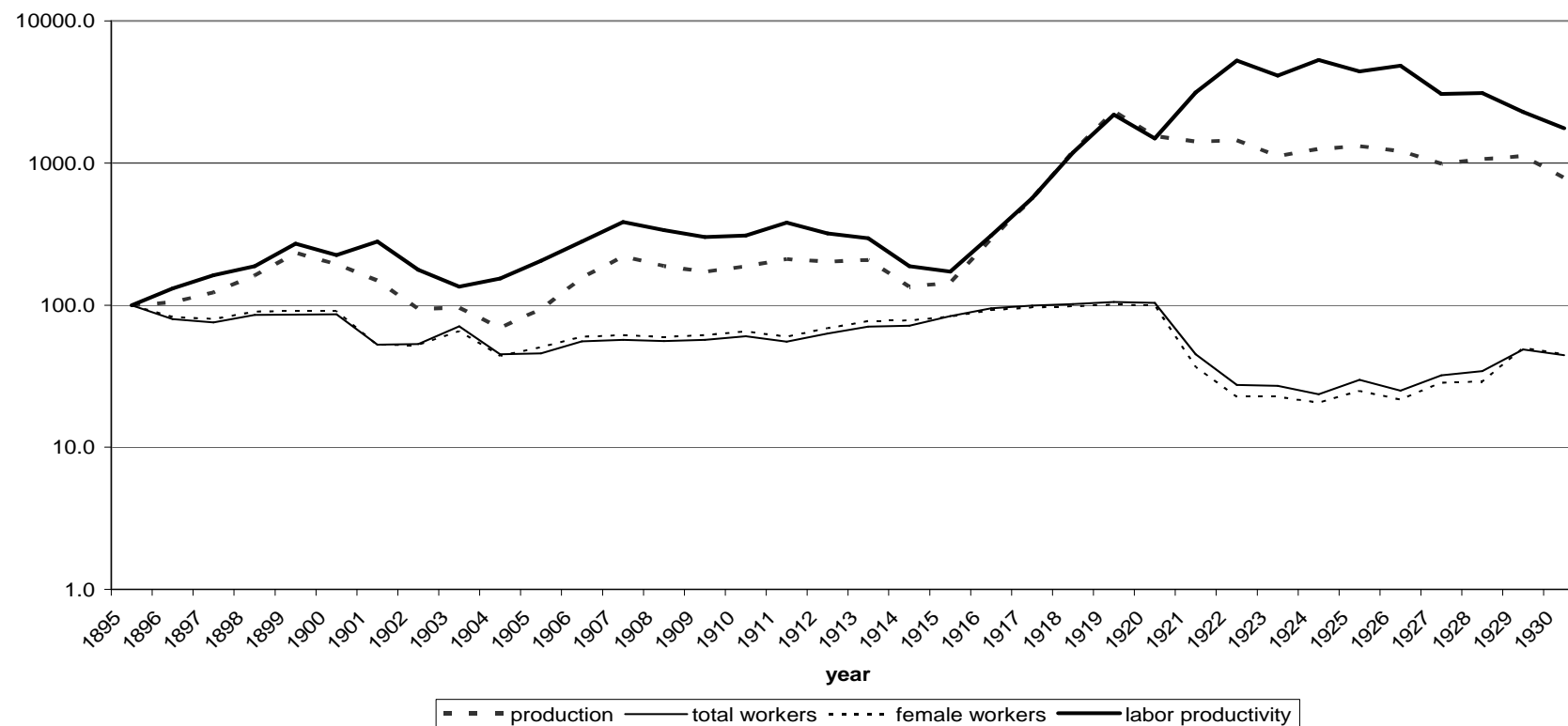
Source: *History of Weaving Industry in Gunma Prefecture [Gunmaken Orimono Enkaku Chosasho]* (1895-1901); *Statistical Survey of Gunma Prefecture [Gunmaken Tokeisho]* (after 1902).

Note: For realized value, we used price index for textile products in Ohkawa, K. *et al. Estimates of Long-term Economic Statistics on Japan since 1868 (LTES) : Price* (Tokyo: Toyo Keizai Shiposha), p.192.

Figure 2. Changes in the number of out-weavers and other production organizations in Kiryu, 1901-20
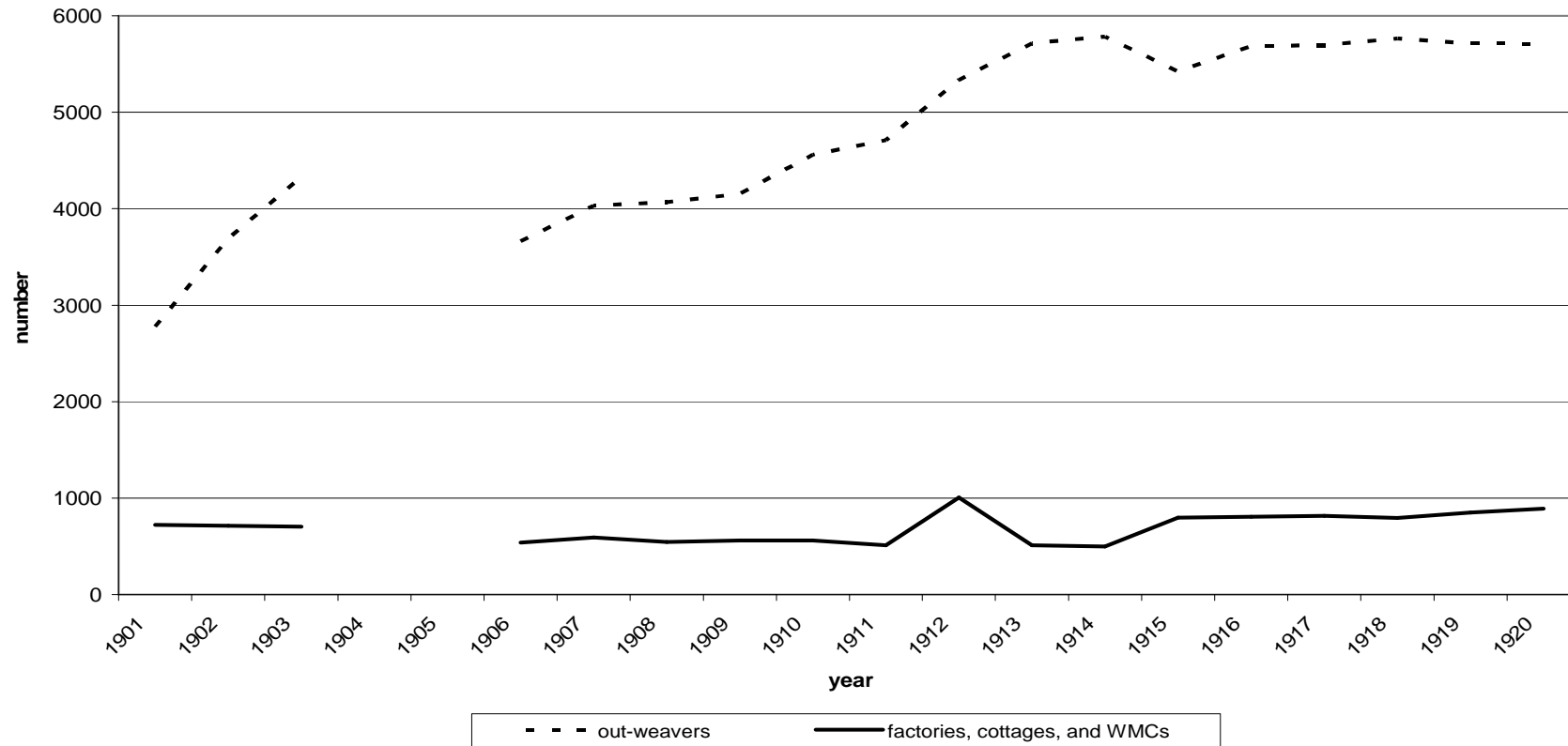
Source: *Yearbook of Promoting Industry in Gunma Prefecture [Gunmaken Kangyo Nenpo]* (1901-02); *Statistical Survey of Gunma Prefecture* (1906-20).

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.

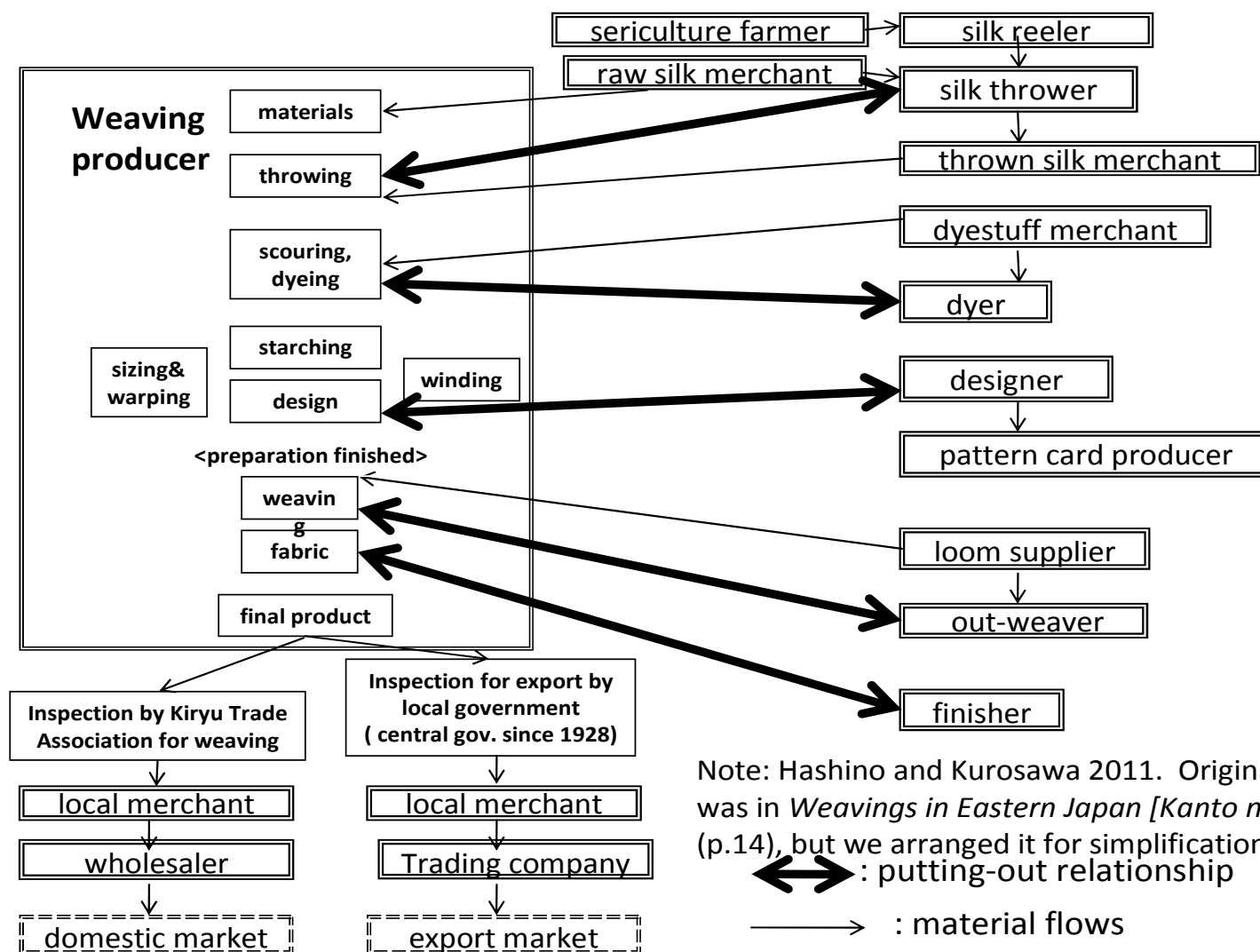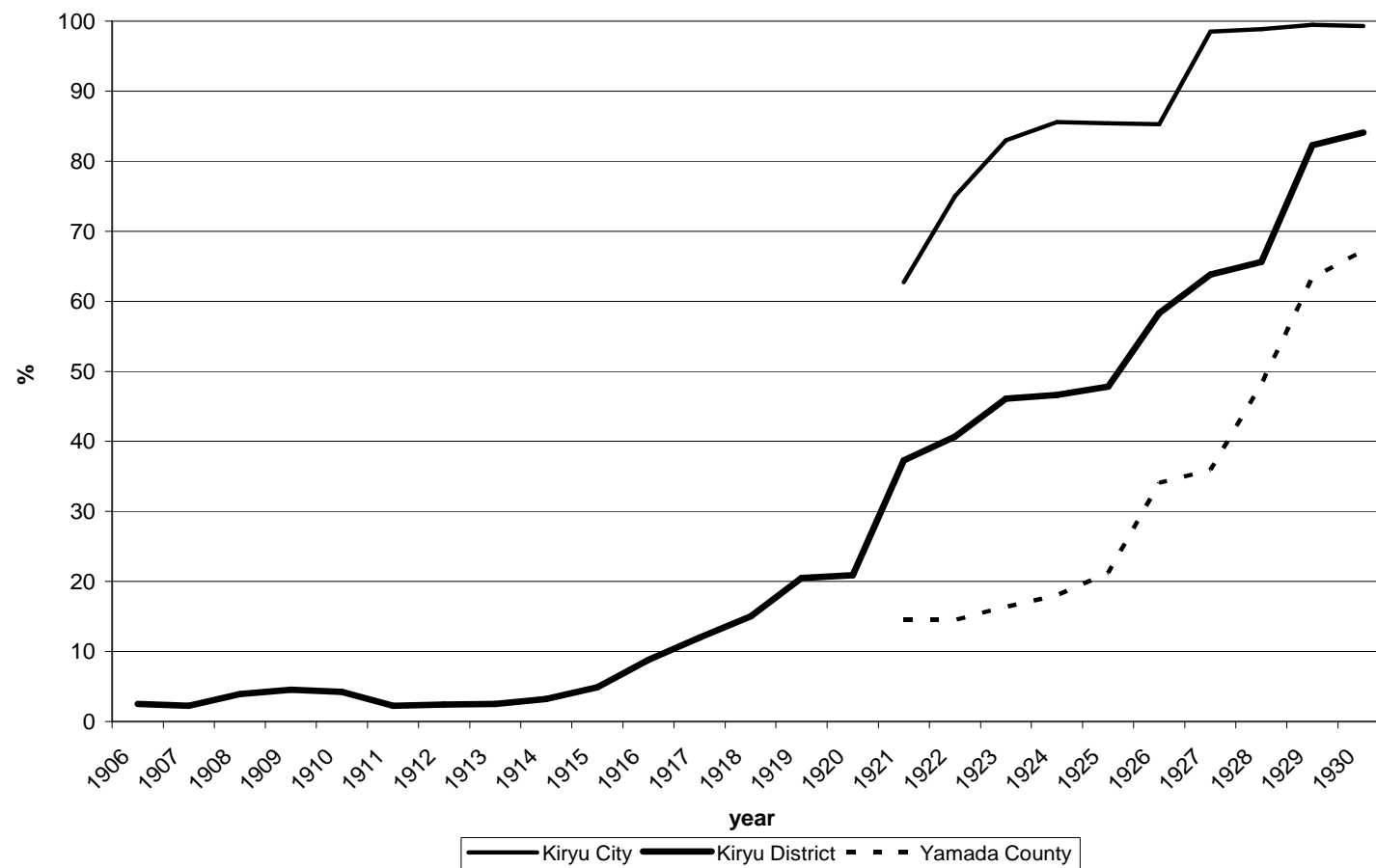⬌ : putting-out relationship

→ : material flows

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

Source: *Statistical Survey of Gunma Prefecture*, various years.

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[c]	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: *Yearbook of Promoting Industry in Gunma Prefecture* (1895,1899, and 1903), *Statistical Survey of Gunnma Prefecture* (1906 and 1910), *and Factory Surveys [Kojo Tokeisho]* (individual data, 1915 and 1918).

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 establi-shment	Number of workers	Female worker ratio	Number of hand looms	Sales revenue (1,000yen)	Percent of 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	-	64.9	68.4	21.1
Others in Kiryu town	34	1890[c]	20.8	66.1	-	47.8	41.2	50.0
Others outside	11	1887[c]	15.5	72.0	-	39.1	0.0	27.2

a. Four firms each whose establishment years were unknown were excluded.

b. Five firms each whose establishment years were unknown were excluded.

c. Two firms each whose establishment years were unknown were excluded.

d. Figures in 1915 show the percent of use of electricity.

e. Not available.   Source: *Statistical Survey of Gunnma Prefecture* (1906 and 1910) and *Factory Survey* (1915).

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

	Number of firms	Average year of establish-ment	Number of workers	Female Worker ratio	Number of looms	Percent of power looms[c]	Sales revenue (1,000 yen)	Percent of use of electricity	Percent of holding of trade-mark in Meiji era
Export-oriented firms:	41								
Joint stock firms	5	1914	316.0	78.2	193.2	73.6	816.2	80.0	0.0
Others	36	1891[a]	25.2	84.1	19.8	53.3	50.4	75.0	2.8
Other firms:	47								
In Kiryu town	32	1887	21.2	62.0	12.4	32.9	85.4	62.5	34.5
Others	15	1891[b]	19.3	73.0	17.6	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 excludes.

c. In the case of firms which do not own any loom, we assume that percent of power looms is zero. There are 1 such firm among
   export-oriented non-joint stock firms, 13 among other firms in Kiryu town, and 2 among the last category.

Source: *Factory Survey* (1918).

Table 4. 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	.12	-3.00	-.00	-23.90	.04	-11.34	-.04	-18.41	312.89
	(-0.62)	(1.52)	(-0.50)	(-0.02)	(-1.21)	(.49)	(-.60)	(-.46)	(-.54)	(.66)
Operation years in Meiji era[g]	.05	.00	.06	.00	-.74	.00	-.23	.00	-.54	9.25
	(.75)	(.29)	(1.45)	(1.68)	(-1.18)	(.84)	(-.48)	(.08)	(-.20)	(.75)
Export dummy	16.17**	.153*	19.65**	.38*	17.49	.29**	23.70	.22**	11.27	-1326.00**
	(2.28)	(2.30)	(3.59)	(3.88)	(.96)	(4.71)	(1.71)	(3.75)	(.45)	(-3.81)
Domestic outside dummy					9.59	.03	5.18	.08	10.37	345.48
					(.45)	(.40)	(.28)	(1.05)	(.32)	(.76)
Power use dummy	41.44**	0.06	29.28**	.10	30.48*	-.10	24.58	.01	52.74*	658.93*
	(3.54)	(.06)	(3.45)	(.64)	(1.94)	(-1.56)	(1.71)	(.17)	(2.04)	(1.83)
Wheel use dummy	13.89*	.06	14.61**	.24*	2.62	-.00	1.99	-.08	7.41	35.55
	(2.19)	(.18)	(2.99)	(2.70)	(.16)	(-.07)	(.14)	(-1.39)	(.02)	(.10)
Intercept	5.51	.66	-9.00	.09	26.41	.55	14.99	.64	33.31	1986.18
R²	.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

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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 5. 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 looms[d]	Power loom ratio[d,e]	Loom/worker ratio[d]	Sales revenue[b, e]	Sales per worker[b, f]
Edo period	5.48	-.02	4.91	.09	.01	12.80	-643.32
dummy	(.17)	(-.37)	(.22)	(.41)	(.07)	(.13)	(-.77)
Operation years in	.52	-.00	.51	.01	.00	1.72	-18.49
Meiji era[g]	(.67)	(-.18)	(.97)	(1.68)	(.61)	(.73)	(-.94)
Joint stock	295.57**	.19*	192.86**	.40	.38**	737.00**	-3258.42**
dummy	(6.26)	(2.10)	(6.12)	(1.49)	(2.48)	(5.16)	(-2.71)
Non-joint stock	-.69	.26**	21.14	.16	.43**	-23.08	-2190.37**
export dummy	(-.03)	(5.62)	(1.23)	(.99)	(5.21)	(-.31)	(-3.52)
Domestic-oriented	5.02	.16**	25.12	.63**	.17	12.22	-662.58
dummy	(.16)	(2.70)	(1.17)	(2.54)	(1.69)	(.13)	(-.85)
Power use	14.16	.15**	32.47*	1.59**	-.12	38.06	-986.49
dummy	(.60)	(3.34)	(1.99)	(6.04)	(-1.51)	(.54)	(-1.65)
Wheel use	-16.57	.06	8.02	-.445	.25**	-62.92	-1448.19*
dummy	(-.60)	(1.14)	(0.42)	(-1.91)	(2.73)	(-.76)	(-2.07)
Trademark	-7.70	-.08	-20.55	-.35	-.07	-13.90	1179.26
dummy	(-.24)	(-1.26)	(-.89)	(-1.42)	(-.61)	(-.14)	(1.42)
Intercept	0.23	.54	35.78	-1.20	-0.2	46.85	6254.28
R²	.394	.455				.313	.257
Log-likelihood			-405.64	-48.36	-22.71		
ratio							

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.