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Abstract

The production of simple silk fabric, called *habutae* or *habutai*, expanded rapidly from 1890 to the end of the 1910s in Fukui prefecture, and it was exported to Europe and the U.S. *Habutae* was initially woven by hand looms in cottage enterprises and, hence, its production was labor intensive. It gradually became capital intensive with the introduction of power looms since around 1905 but its production as well as export declined precipitously since the late 1910s. We attribute such rising and falling production and export to Japan's changing comparative advantage of *habutae* production in international markets associated with changes in production technology from labor-using to

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capital-using direction.

1. Introduction

The issue of the Great Divergence between the West and the East has received increasing attention among economic historians, which has led to a proliferation of studies on Asian economic history with a view to drawing a fuller picture of global economic history (Van der Eng 2004; Broadberry and Van der Eng 2010; Broadberry and Hindle 2011; Brandt, Ma, and Rawski 2014). In spite of this growing body of research, however, the actual catch-up process of the East and changing comparative advantage in industrializing process have not been fully explored presumably because of a lack of long-term micro-level data necessary to investigate how specific industries or regions within Eastern countries learned new technologies from the West, adapted them, and expanded production.

It is well known that the textile industry has played an important role in the early process of industrialization in developed countries as well as in contemporary developing countries based on technology imports from advanced countries. This industry is unique, as it consists of diverse industrial sectors—from the production of yarns to a variety of fabrics—some of which use traditional or indigenous technologies, while others use modern technologies. The cotton spinning industry in the 19th century Japan typified a capital-intensive modern industry characterized by large-scale production with imported

mechanized technologies (see, for example, Otsuka et al. 1988), whereas the weaving industry used a mixture of traditional labor-intensive and modern capital-intensive technologies. According to the literature review conducted by Hashino and Saito (2004), most Japanese economic historians had generally believed until recently that the rise of modern sectors, which directly imported the western technology, contributed to economic growth more than the modernization of traditional sectors. It was Nakamura (1983), who argues that traditional sectors employed a larger share of workers and contributed more significantly to economic growth in Japan from the late 19th through the early 20th century. His argument strongly suggests that the modernization of traditional industries depended on the successful introduction of new technologies from the West. In fact, not only local and central governments but also local entrepreneurs developed various institutions and organizations to introduce and absorb such technologies (Hashino 2012; Hashino and Kurosawa 2013). Yet, quantitative studies on the modernizing process of traditional industries in Japan are scant.

The aim of this study is to explore the development process of the silk weaving district in Fukui prefecture by from 1890 to 1921. The case of Fukui's development offers a good example of a traditional industry which was successful in export-led growth. Saito (2014) argues that Meiji growth was largely export-led by traditional manufacturing sectors in rural areas with some interactions with the emerging modern sectors. Initially almost all *habutae* was produced by hand looms and exported to the

United States and European countries such as France and the United Kingdom, where the demand for silk products increased due to the "democratization" of silk, i.e., changes in the silk products from luxury for the rich to ordinary commodity for mass consumption. Fukui's development can be regarded as a typical case of labor-intensive industrialization consistent with the endowment of cheap labor in Meiji Japan as argued by Sugihara (2007). However, labor-saving technologies, such as power looms, were rapidly introduced in response to the rising wage rate in the first decade of the 20th century. While *habutae* production initially increased with the diffusion of power looms, it became stagnant gradually and finally decreased precipitously from the end of the 1910s. We hypothesize that the silk weaving industry was characterized by high labor intensity until around the turn of the century, so that being labor abundant economy Japan had comparative advantage in this industry and that because of the shift from labor-intensive to capital-intensive production systems, corresponding to change from hand looms to power looms since the late 19th century, particularly in the U.S., Japan lost comparative advantage in this industry.

The rest of the paper is organized as follows. The next section provides an overview of the growth of *habutae* export from Japan and the accompanying development of the Fukui weaving district. In particular, we examine the conditions which facilitated the geographical expansion of *habutae* production from Fukui city to surrounding rural areas, the introduction of power looms, and the fall of *habutae*

production in the Fukui silk weaving district. Section 3 provides an overview of changes in production, the number of firms, firm size in terms of the number of workers per firm, and labor productivity in the Fukui direct. In Section 4, hypotheses that the introduction of power looms boosted *habutae* production significantly in the early phase but such effect was weakened in the later phase are tested. We conclude this paper by summarizing the main findings of the paper and drawing implications for future research in the last section.

2. A Brief History of Rise and Fall of Industrial Development in Fukui

2-1. The rise of *habutae* production in Fukui prefecture

Because of the lack of a major manufacturing sector within Fukui prefecture, the prefectural government made various attempts to promote new industries, particularly for the sake of ex-samurais who found themselves without employment after the Meiji Restoration (1868). For example, the government first tried to stimulate the production of *hosho-tsumugi*, traditional plain silk fabrics for the domestic market, using the modern production techniques. To this end, the prefectural government sent a few people to Kyoto to learn advanced methods of weaving and dyeing. *Hosho-tsumugi* had long been produced mainly in Fukui city; however, it was not such promising industry because demand was limited. Local people wanted to start producing fabrics which had larger market and export potential. A small group of ex-samurais established the weaving

workshop, *'Shokko-gaisha'*, which was equipped with ten hand looms with flying shuttles, to produce silk handkerchiefs and umbrella material for export. This was the first weaving workshop in Fukui prefecture (Fukui Prefecture Silk Fabric Association 1921, pp. 182-189), but its success was by no means guaranteed. The workshop faced a number of problems regarding management and struggled to stay open. Thus, new industries with more promising market opportunities were continually sought by trials and errors.

It was *habutae* production which started in Fukui city in 1887 that seemed to afford the most promise. Local people learned the basic production methods from Naohiro Koriki, an engineer in the Kiryu silk weaving district located 500 km away, who was invited by the Fukui prefectural government to conduct a three-week training session in Fukui city (Harada 2002, pp. 25-26). An estimated 100 people attended.[1] Kiryu had been the first exporter of *habutae*, beginning around 1877, and several prefectures including Fukui had directly introduced Kiryu's *habutae* production methods. The Kiryu district, however, decreased *habutae* production and concentrated on the production of more sophisticated products, such as *kimono*, rather than just simple *habutae* (Hashino and Otsuka 2013).

[1] Unfortunately, the content of the training and participant demographics are not well reported. It is known that prefectural officials and workshop owners decided that each participant had to pay 0.15 yen per person (per hand loom) to Koriki for his training services, and that he received 15 yen in total. This suggests that about 100 people received training (Fukui Prefecture Silk Fabric Association 1921, pp. 188-89). It is interesting to note that the recent development of the garment industry in Bangladesh and Tanzania also started with training program (Mottaleb and Sonobe 2011, Sonobe and Otsuka 2014).

After the introduction of the flying shuttle from Kyoto and following the three-week training program, production of *habutae* grew rapidly in Fukui city. Though *Shokko-gaisha* was not profitable, it played a significant role in diffusion of *habutae* production in Fukui city by providing a series of short-term training programs (Fukui prefecture 199, p. 543)[2]. It is said that in 1892, shortly after foreign merchants from Yokohama opened local branch offices in Fukui city, more than fifty new hand looms entered into operation every day in this city (Mikami and Debuchi 1900, p. 7). Although there is no specific evidence to this effect, it might well be that many foreign merchants identified Fukui as promising new center of *habutae* production in Japan. The production of *habutae* quickly spread from Fukui city to surrounding rural areas through promotion activities both by county governments and local producer groups entrepreneurs (Fukui prefecture 1994, 543). Export of *habutae* produced in Fukui prefecture increased sharply and surpassed Kiryu's *habutae* export in mere several years after production had first commenced.

Figure 1 shows the map of the Fukui weaving district, with its center in Fukui city. *Habutae* production geographically expanded initially from Fukui city to neighboring counties: Ohno county started production in 1886 (Fukuiken Yushutsu Orimono Kensajo 1991, p.7), Imadate county in 1887, Asuwa and Yoshida counties in 1888, Sakai county in 1889, and Nanjo county in 1890 (Fukuiken Yushutsu Orimono

[2] Not only prefectural government but also private sector were keen to diffuse *habutae* production. Many private training centers were established in Fukui city and rural people came there to learn technologies for launching *habutae* production at home (Fukui prefecture 1994, p. 543).

Kensajo 1911, pp. 5-9; Fukui Prefecture 1994, p. 542).[3] As will be shown later, the history of the export-led growth of the Fukui weaving district accompanied the geographic expansion of production.[4]

2-2. Changes in *habutae* export

Figure 2 shows the growth in real value of total *habutae* exports from Japan, *habutae* production in Fukui prefecture and its exports, and exports of *habutae* to Europe and the U.S. The real value of *habutae* exports rose sharply in the 1890s. After stagnant growth in the mid-1900s, export again took off in the 1910s. The share of *habutae* as a fraction of total Japanese exports increased to nearly 12 percent in 1904, which indicates the importance of this commodity at the early stage of Japan's modern economic development. At the same time, *habutae* production in Fukui prefecture occupied a significant place in the Japanese export, especially in the 1890s and 1910s.[5]

As intermediate goods, *habutae* fabrics had to be very light, even, and uniform (Hashino 2010, p. 488). Most of the *habutae* was shipped in its grey state and then printed or dyed in European countries and the U.S. to be used for ladies' dresses, blouses, linings, trimmings, and various ornamental purposes (Crowe 1909, p. 33). Japanese *habutae* that shipped to France was supplied not only to the French domestic market but

[3] Starting year of production in Nyu county is unknown, but production probably began later than in other northern counties.
[4] As the weaving industry did not become popular in the southern part of Fukui prefecture, consisting of Mikata, Oi, Tsuruga, and Onyu counties, we focus only on Fukui city and seven northern counties in this study.
[5] Almost all of the *habutae* produced in Fukui was exported, as is indicated in Figure 2.

also beyond it. Japanese *habutae* became popular throughout Western countries, where demand had increased for cheap silk fabrics worn by the general public, thanks to modern production techniques. This was the so-called great "democratization" of silk (Federico 1997, pp. 43-44). Cheap silk fabrics, in solid colours and piece-dyed prints, became much more fashionable than expensive figured or pre-dyed fabrics. They were thin to save material costs (Tamura 2009, p. 191). The production of such fabrics is highly labor-intensive, and Fukui was suitable for producing them because cheap labor was available for weaving *habutae* on hand looms outfitted with flying shuttles. According to the Silk Association of America (1921, p. 72), in 1913 daily wage of male weavers ranged from $10 to $30 in the U.S., whereas that of female weavers ranged from $0.07 to $0.22 in Japan. In addition, thin raw silk for producing light fabric was available from Yokohama. It appears that the raw silk was too thin to produce *habutae* by power looms in those day.[6]

According to survey data from the Ministry of Agriculture and Commerce (1911, pp. 8-9) in 1895, more than 60 percent of Japanese *habutae* was exported to the U. S., 20 percent to France, and 6 percent to the U.K.[7] *Habutae* export to the U.S., however, decreased beginning in the mid-1890s due to tariffs protecting their nascent silk weaving industry. The number of power looms increased from 5,321 in 1880 to 44,257 in 1900 (Sugiyama 1988, p. 102). The use of power looms and the import of cheap and uniform

[6] Even in the U.S., hand looms were used in the 1880s (Silk Association of America 1920, p. 100).
[7] Ministry of Agriculture and Commerce (1911), pp. 8-9. The figures were reported on a value basis.

Japanese raw silk, rather than *habutae*, enabled American silk weaving industry to grow rapidly. Thus, the European market became more important for Japanese *habutae* in the early 20th century. In 1910, around 30 percent of Japanese *habutae* was exported to France, 20 percent to the U.K, and only 13 percent to the U. S., where the production of broad silk fabrics roughly doubled from 1900 to 1910 (Sugiyama 1988, p. 101).

The above figures do not necessarily mean that Japanese *habutae* was always competitive in the European market. In 1896, a Japanese inspector pointed out that no product could compete with Japanese *habutae* except Chinese pongee in the major silk markets such as Patterson, Manchester, Geneva, Zurich, and Lyons. However, when the same inspector visited the European market again in 1900, he found a number of worthy competitors: pongee, mixed goods with silk and cotton produced in Lyons, American light silk, Chinese pongee, and English satin with silk and cotton (Tamura 2009, p. 192).

In fact, *habutae* export as well as its production in Fukui prefecture drastically declined in the 1920s (see Figure 2). It appears that the silk weaving industry in the U.S. rapidly developed due to the use of power looms to produce thin silk fabrics, as well as mixed fabrics with silk and cotton, which were cheap enough to outcompete Japanese *habutae*. Interestingly, when *habutae* export to the U.S. declined sharply (Figure 2), Japan's raw silk export to the U.S. increased dramatically (Figure 3). Table 1 indicates that the real value of capital as well as consumption of raw silk became almost doubled every ten years in the U.S. Thus, it is clear that silk manufacturing industry rapidly

developed in this country. from the late 19th century to the 1920s[8]. This development accompanied the emergence of large scale silk weaving firms. For example, more than 100 power looms were equipped in 9 firms out of 51 newly-established silk fabric producing firms in 1914 (Silk Association of America 1915, p. 57, p. 60).[9] In contrast, only 10 to 20 power looms were used in factory systems in Fukui.

The Silk Association of America (1915, p. 54) reported that *habutae* was "originally and still largely made in Japan, and now also in the United States." This statement suggests that the U.S. was able to produce thin silk fabrics, such as *habutae*, by using power looms by 1915. Observing the production of silk fabrics in the U.S., Matsui (1930, p. 185) indicated that *habutae* imported from Japan was no longer competitive with the American products. Furthermore, Japan imported power looms for silk fabric production from the U.S. (Silk Association of America 1918, pp. 39-40)[10] It may well be that because of the capital-using (or power loom-using) technological change in the U.S., Japan's comparative advantage in the production of simple silk fabric was lost. This incidence is reminiscent of sharp reduction in output in the labor-intensive cotton spinning industry in India due to the advancement of the capital-intensive cotton spinning industry in the U.K. (Broadberry and Gupta 2009)

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[8] The figures in rayon industry as well as silk manufacturing industry are included in Table 2. It is plausible to assume that these figures pertain almost exclusively to the changes in silk manufacturing industry because it was the middle of the 1920s that rayon industry in the U.S. started developing.

[9] It is also important to consider the significant shift to rayon, which was much cheaper than silk; rayon fabric production soon outpaced that of *habutae* in the late 1920s in Japan.

[10] According to the same article, prominent silk manufactures in the U.S. were keen about export of power looms from the U.S. to Japan, as it may boost *habutae* export from Japan. Such a pessimistic view, however, turned out to be incorrect, as *habutae* export from Japan actually declined.

2-3. Production growth in Fukui prefecture

How did silk fabric production grow in Fukui prefecture, leading it to become the top exporter of *habutae* in Japan soon after the industry first developed? Table 2 shows the real value of *habutae* production, the number of firms, the average number of workers per firm, labor productivity, and the number of hand and power looms in 1905 and 1915 by location. Several important findings can be made. First, Fukui city was by far the most important center of production, accounting for nearly 50 percent of the district's production in 1905. Its production share, however, decreased significantly over time, implying that the *habutae* production subsequently increased in surrounding counties. In this respect, Fukui's development resembles that of the silk fabric industry in Lyons, France, in which production spread from urban to rural areas in the 18th century (Federico 1993). Second, total production in Yoshida and Imadate counties was fairly large in 1905. Taking advantage of their geographic proximity to Fukui city (Figure 1), these counties seem to have begun *habutae* production relatively early on. Third, some counties, such as Sakai and Ohno, caught up with and even surpassed the Yoshida and Imadate counties over time. It appears that the production of *habutae* was technically easy and unskilled labor-intensive, so that the production area expanded smoothly to hitherto underdeveloped rural area. In fact, the labor productivity was comparable among Fukui city, Asuwa, Yoshida, Imadate, and Ohno counties in 1905. In 1915, however,

labor productivity became much higher in Fukui city, because the adoption rate of power looms was higher. Fourth, power looms were not used in 1905 only with a few exceptions, but it dominated over hand looms in 1915. Actually the number of power looms increased from 1905 to the end of the 1910s (Figure 4)[11], which roughly corresponds to the growth of labor productivity. Fifth, according to Figure 4, the number of workers and the number of looms were roughly the same, indicating that typically one worker operated one loom, be it hand or power looms. Sixth, the firm size in terms of the number of workers in 1905 was relatively small; only 5 to 6 workers per firm except in Fukui city, where 15 workers worked per firm. Later on, however, 10 to 20 workers worked per firm in counties where the adoption of power looms was widespread, such as Yoshida, Sakai, and Ohno counties.

It is the purpose of this study to explore why such unique patterns of development emerged in the Fukui silk weaving district by using the available county-level data from 1890 to 1921.[12] We cover this period because reliable data are available during this period.[13]

3. Descriptive Analyses

[11] The number of power loom workers shown in Figure 4 was estimated by subtracting the number of hand looms from the total number of workers, assuming that one hand-loom worker used one hand loom.

[12] Detailed county data are available from statistical survey from 1905 to 1921 by prefectural government. This survey covers firms which produced *habutae* for export.

[13] The large-scale production of rayon fabrics became common in the 1920s (Hashino 2007, pp. 31-32), an analysis of which requires a separate approach focusing on how new products' production techniques were acquired.

3-1. An overview of development

In order to identify the major components of growth in industrial production, we decompose the real value of production (Q) into the number of firms (N), firm size in terms of the number of workers per firm (L/N), and labor productivity (Q/L) according to the following formula:

$$Q = N \times (L/N) \times (Q/L).$$

Taking the logarithm, the above equation can be rewritten as:

$$Ln\,(Q) = Ln\,(N) + Ln\,(L/N) + Ln\,(Q/L).$$

Using this relationship, changes in logarithms of the indices of Q, N, L/N, and Q/L are shown in Figure 5.[14] It should be noted that indices in this figure are set to be unity in 1890 and pertain to the production of only *habutae*.

It is interesting to observe that the development patterns of this industrial district are markedly different in at least three periods. It was primarily an increase in the number of firms and labor productivity growth that brought about a rapid growth in production from 1890 to around 1905. Presumably the number of firms increased due to the entry of imitators and labor productivity grew due to learning effects. Gradually, however, the number of firms stopped growing and began declining after 1910. On the other hand, labor productivity did not increase appreciably from 1900 to 1907, when it began increasing sharply. Labor productivity, however, did not grow or even declined in the

[14] 'Firms' include (1) workshops employing more than 10 workers, (2) workshops employing less than and equal to 9 workers, (3) weaving manufactures-cum-contractors, and (4) out-weavers.

later period of the 1910s. The average firm size in terms of the number of workers increased from 1893 to 1901 but stagnated or decreased thereafter except in the 1910s.

Based on these observations, we may divide the entire study period into three phases: (1) Phase I (1890-1905), in which the increasing number of firms and labor productivity growth were major sources of growth; (2) Phase II (1906-15), in which the number of firms declined but the labor productivity increased; and (3) Phase III (1916-21), in which labor productivity, average firm size, and the number of firms remained largely unchanged or declined. Why such characteristically different phases of development emerged is a major question to be addressed.

3-2. Regional expansion of production

Figure 6 shows changing shares of *habutae* production in Fukui city, neighboring counties, and the remaining counties.[15] It is clear that the production centre shifted from Fukui city to other areas, particularly to neighboring counties in Phase I. Considering that it was an increase in the number of firms and labor productivity growth that were the main sources of production growth in Phase I, and that the decentralization of the production base took place rapidly, it seems reasonable to hypothesize that there were no strong Marshallian agglomeration economies.[16] In fact, if strong agglomeration

[15] In this figure neighboring counties refer to Asuwa and Yoshida counties, whereas remaining counties refer to Sakai, Ohno, Imadate, Nyu, and Nanjo counties (See Figure 1).
[16] We do not totally deny the presence of the agglomeration economies. In fact, it is difficult to explain the rise of the Fukui silk weaving district without considering such economies.

economies are present, production expansion would take place in locations where the total size of production was large from the beginning.[17] Similar arguments can be made for the number of weaving firms. Although we do not have concrete evidence, the most important reason for the industry's geographical expansion was the lower wage rate outside Fukui city, which may correspond to the predictions of the product cycle theory (Vernon 1966).

It also seems sensible to conjecture that scale economies at the workshop or factory level were weak. If they are strong, the firm size tends to increase over time. According to Table 1, however, the firm size expansion was not pronounced only in Yoshida, Sakai, and Ohno counties where power looms were actively adopted. If scale economies were strong in the Fukui district, the initial capital requirement would have been large, which, in turn, may have discouraged the entry of new firms into the silk weaving business outside Fukui city. Actually, hand looms were almost exclusively used until 1909 (see Figure 4) and, roughly speaking, one worker used one hand loom in this period, which indicates that the *habutae* production during this period was very labor intensive.

It is also interesting to observe from Figure 6 that production shares of the remaining counties, located in the far north and east, gradually increased in Phase II and

[17] Usually, industrial districts or clusters are geographically concentrated in small areas. Thus, the case of the Fukui silk weaving district is exceptional. See Sonobe and Otsuka (2006, 2014) and Hashino and Kurosawa (2013) for a discussion of the expansion of industrial clusters and Marshallian agglomeration economies in contemporary East Asia and Africa and modern Japan, respectively.

III. Why this happened is another interesting question. As is shown in Table 2, these counties were characterized by the higher adoption rate of power looms and larger firm size. It is reasonable to conjecture that the comparative advantage of hand-loom based production had been weakened over time.

3-3. Structural transformation of industrial districts

After wage rate began increasing rapidly in the first decade of 20th century, the adoption of power looms has increased sharply, first in Fukui city, followed by the neighbouring counties and subsequently by the remaining counties. Figure 7 confirms this tendency: there was positive correlation between wage rate and adoption rate of power looms, i.e., proportion of power looms in the total number of looms in 1910 and 1916. Furthermore, the average real wage rate of female silk weavers in Fukui city deflated by the consumer price index generally increased from 1910 to 1916 (Figure 7). Real agricultural wage rate in Fukui prefecture also increased in the same period. Consistently wage rate in Japanese economy as a whole began increasing rapidly in the 1910s (Fei and Ranis 1964). Although we cannot claim that high wage rate caused the high adoption of power looms due to possible reverse causation, the evidence shown in Figure 7 is at least consistent with capital-labor substitution induced by increasing wage rate.[18]

The differences in the adoption rate of power looms in Phases II and III are

[18] While the data in 1910 and 1916 are shown in Figure 7, essentially the same tendency is observed in 1913.

largely consistent with changes over time and differences across regions in terms of the number of firms and the average firm size, shown in Table 2; the number of firms tended to be larger in areas where the hand looms were used, while the firm size tended to be larger in areas where the adoption rate of power loom was higher. In fact, the number of firms generally decreased, whereas firm size generally increased during the same period. In Phase II, a structural transformation took place along with the introduction of power looms—first in Fukui city and followed by the neighboring and remaining counties—which destroyed a large number of small firms and increased labor productivity. Even though such changes took place, the number of workers per firm remained small, ranging from ten to twenty in major *habutae* producing counties. Furthermore, the number of power looms operated by one worker was relatively small, slightly more than one on average (Figure 4). Thus, although the *habutae* production became more capital-using over time to the extent that power looms were more expensive than hand looms,[19] highly capital-using, large-scale production organization, as was observed in the U.S., has never emerged in the Fukui weaving district.

4. Hypotheses and Empirical Methodology

4-1. Hypotheses

We have found that the whole development process of the Fukui silk weaving district can

[19] According to Hashino and Otsuka (2013), the price ratio of hand looms to power looms was in the vicinity of ten in the early 20th century.

be divided into three phases: (1) one of geographical expansion (1890-1905); (2) one of structural transformation (1906-15); and (3) one of production stagnation and contraction (1916-21). Although it appears reasonable to hypothesize that the growth in the *habutae* production accompanied the geographic expansion of the industry in Phase I because agglomeration economies were weak, scale economies at the workshop level were weak, and the imitation of existing technology was easy, it is difficult to test this hypothesis statistically essentially because of the difficulty in quantifying the supposed effects. Regarding the latter two periods, we would like to postulate and test the following hypotheses:

Hypothesis 1: The introduction of power looms in Phase II, which would have been induced by increasing wage rates, brought about a structural transformation in which the number of small firms decreased, and the real value of production, firm size, and labor productivity increased in areas where power looms were actively introduced.

Hypothesis 2: Compared with Phase II, the impacts of the use of power looms on production and the structural transformation became weaker, as the production of silk fabric became more capital intensive internationally and consequently Japan lost comparative advantage in the *habutae* production.

4-2. Empirical methodology

In order to test the validity of the above hypotheses, we estimate the following function

by growth phase using the ordinary squared regression method:

$$Z_{it} = \alpha_0 + \Sigma\, \alpha_i PLR_{it} + \Sigma\, \beta_i D_j + \Sigma\, \gamma_t Y_t + \varepsilon\ ,$$

where Z_{it} refers to the logarithm of the value of production, the number of firms, the firm size (or the number of workers per firm), and labor productivity; *PLR* refers to the ratio of the number of power looms to the total number of looms; D_i is a county dummy in which Fukui city is the base of comparison; Y_t is a year dummy; α_s, β_s, and γ_s are regression parameters; and ε is an error term. Although *PLR* is endogenous, the endogenuity bias is expected to be lessened by controlling locational fixed effects by county dummies.[20]

Hypothesis 1 on the structural transformation can be tested by examining whether a positive association exists between the adoption of power looms and the value of production, firm size or labor productivity, and whether a negative relationship exists between the power loom adoption and the number of weaving firms. Testing Hypothesis 2 is a more subtle exercise, because it asserts weak or even insignificant effects of the power loom adoption on the dependent variables.

4-3. Regression results

Now let us examine the results of regression analyses shown in Table 3 for Phase II and in Table 4 for Phase III. It is clear from Table 3 that power loom ratio had significantly

[20] The estimation bias will remain because of the selection effect, e.g., location adopting power looms may have greater potential in the *habutae* production, as well as possible time-varying location specific effects.

positive effects on the value of *habutae* production, firm size, and labor productivity, and significantly negative effect on the number of firms, which are consistent with the Hypothesis 1. That is, the introduction of power looms boosted the *habutae* production by increasing firm size and labor productivity, and by decreasing the number of small firms. It must be also pointed out that almost all county dummies have negative and significant coefficients in all the regression functions, implying that Fukui city was still the center of *habutae* production with the larger number of larger firms, which achieved higher labor productivity. Among the seven counties, the value of production, firm size, and labor productivity are generally higher in Yoshida, Sakai, Ohno, and Imadate counties than Asuwa, Nyu, and Nanjo counties. The former counties adopted power looms faster than the latter counties, according to Table 2, which suggests that swift adoption of power looms promoted the *habutae* production in this phase. Overall, the estimation results in Table 3 confirm significant effects of the adoption of power looms on the firm structure and productivity of *habutae* production.

In sharp contrast to the regression estimates in Phase II, the power loom ratio does not have significant effects on the value to production and labor productivity in Phase III, as is shown in Table 4. It is somewhat surprising to find no significant effect of power loom adoption on labor productivity, because power looms are labor-saving and, hence, labor-productivity enhancing technology. The insignificant effect suggests the sluggish demand for *habutae* produced by power looms. The power loom ratio, however,

continue to have negative and significant effect on the number of firms and positive and significant effect on the number of workers per firm. These findings indicate that the adoption of power looms conferred the advantage of large-scale production, even though it did not increase the total value of *habutae* production and labor productivity in the region as a whole. Thus, it is reasonable to conclude that the Fukui silk weaving district had no longer comparative advantage in the production of *habutae* using power looms, which supports Hypothesis 2. Considering the fact that the silk weaving industry in the U.S. was able to produce thin silk fabrics, this is also consistent with the argument of Ma (2005) that the world silk markets were well integrated across the Pacific in the early 20th century and even before then.

Similar to the results shown in Table 3, coefficients of counties dummies are generally negative and significant in Table 4, indicating the Fukui city was still center of *habutae* production in the Fukui silk weaving district, even though its production share decreased (Figure 6). There are, however, exceptions. The coefficients of Yoshida, Sakai, and Ohno dummies are positive and the former two are significant in the firm size regression, indicating that scale advantages had emerged in these counties. Recall that these are counties where the adoption rate of power looms was high (Table 2). It is also clear from Figure 6 that the production share of these counties sharply increased in Phase III. Thus, the use of power looms in relatively large factories seems to have been relatively efficient within the Fukui silk weaving district. Even if this is the case, however,

the use of power looms failed to prevent the falling production of *habutae* in Phase III.[21]

5. Conclusions

This study attempted to explore the rise and fall of the Fukui silk weaving district, which became the main exporter of *habutae* in Japan shortly after it had introduced production technology from more advanced Japanese weaving districts in the late 1880s. Major factors underlying the successful development of this district were found to be distinctly different in three phases: (1) initially the geographical expansion of the industry took place with an increasing number of firms and a reliance on hand loom technology; (2) subsequently a structural transformation occurred, marked by a declining number of firms, but increased firm size and labor productivity through the introduction of power looms; and (3) finally *habutae* production decreased without accompanying increases in labor productivity.

Before *habutae* was introduced, even though people in Fukui city had attempted to establish a weaving industry, it was not successful and, hence, skilled workers in the weaving industry were quite scarce. Thus, the finding that *habutae* production rapidly expanded from Fukui city to rural area without reducing labor productivity strongly indicates that its production was easy and, hence, unskilled-labor intensive. Since

[21] In contrast to the common view of the day that higher tariff imposed by the U.S. in the early 1920s reduced the export of Japanese *habutae* (Matsui 1930, pp.162-163), our result shows the decline of *habutae* production already in the late 1910s in Fukui. Further research is needed to analyze the structural changes in Fukui silk weaving district after the adoption of power looms from the viewpoint of micro-level factory operations.

unskilled labor was abundantly available, the Fukui silk weaving district must have had a comparative advantage in producing *habutae*.[22] Indeed, the Kyoto and Kiryu silk weaving districts, which had long traditions of producing complicated silk products, such as *kimono*, by using skilled workers, did not undertake *habutae* production on a large scale. Also, power looms were most rapidly introduced to Fukui among the three silk weaving districts (Hashino 2007; Hashino and Otsuka 2013), presumably because machineries could be easily substituted for labor engaged in simple tasks carried out by unskilled workers in the *habutae* production process. Thus, following its comparative advantage seems to be the key to the successful development of this weaving district.

When wage rates increased, however, the comparative advantage of *habutae* production using hand looms and unskilled labor must have weakened. It is also true that the quality of domestically produced power looms improved and their prices declined significantly (Minami and Makino 1983, p. 3; Suzuki 1996, Chapter 9). As a result, power looms were rapidly introduced in the Fukui weaving district beginning in the 20th century. Such shift in technology—from hand looms to power looms—is consistent with the argument of both Broadberry and Guputa (2006; 2009) and Allen (2012), which indicates the significance of factor prices in explaining the large divergence in technology choice and productivity growth between Europe and Asia.

The dominant use of power looms implies that this silk weaving industry was no

[22] Since there were other areas in which there was not a strong weaving tradition, the question of why Fukui particularly developed a silk weaving industry remain puzzling.

longer unskilled-labor intensive by the 1910s; it became more capital-intensive. This suggests that Fukui lost its comparative advantage in producing *habutae*, so far as the basis for its comparative advantage lay in the availability of cheap unskilled labor. The sharp decrease in *habutae* production after the late 1910s is likely be a manifestation of such a fundamental change in the comparative advantage.

In fact, given that the silk weaving industry in the U.S. grew rapidly, Japanese *habutae* production had to compete with its American counterpart by using power looms, some of which were imported from the U.S. Thus, it seems reasonable to conjecture that the development of capital-intensive weaving industry in the U.S. reduced the comparative advantage of *habutae* production in Fukui silk weaving district. Such arguments strongly suggest that the development of export-oriented industries in Asia cannot be analyzed adequately in isolation from that of corresponding industries in the U.S. and Europe.

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Table 1: Changes in the real value of capital in silk manufacturing industry and consumption of raw silk in the U.S. (in 1929 price)

	Real value of capital	Import of raw silk	Material-capital ratio
	in million dollars	in million pounds	in thousand pounds
1889	92	5.8	63.0
1899	171	11.7	68.4
1909	276	22.1	80.1
1919	580	44.3	76.4
1929	926	85.9	92.8

Source: Carter et al. (2006), p. 691, p.694.

Notes: Real value of capital is based on ‘capital’ in silk and rayon industry in Carter et al. (2006) , p. 691. Though capital both in silk and rayon industry is included, it can be considered that the value in rayon industry was negligible except in 1929. For import of raw silk, we used ‘unmanufactured silk imoport for consumption’ in Carter et al. (2006), p. 694. We calculated material-capital ratio by dividing import of raw silk by real value of capital.

Table 2: An overview of production and employment in the Fukui silk weaving district by location

City or County	City or county code	Total *habutae* production in 1000 yen	Number of firms	Average number of workers per firm	Labor producti-vity in yen	Number of hand looms	Number of power looms
1905							
Fukui	Fukui	6317.8	556	14.70	772.8	7,958	5
Asuwa	N-1	939.2	294	4.50	709.4	1,315	0
Yoshida	N-2	2317.8	308	7.64	985.5	2,233	0
Sakai	R-1	1266.8	401	5.94	531.8	2,387	0
Ohno	R-2	900.4	174	5.59	926.4	947	0
Imadate	R-3	2463.2	547	4.85	929.1	2,678	0
Nyu	R-4	303.9	169	3.67	490.1	620	0
Nanjo	R-5	690.8	260	4.77	556.6	1,232	0
1915							
Fukui	Fukui	14943.9	165	14.78	6129.6	193	2,926
Asuwa	N-1	664.2	94	6.94	1018.8	495	159
Yoshida	N-2	3127.0	77	17.74	2289.2	332	1,283
Sakai	R-1	6996.9	89	21.45	3665.2	358	2,295
Ohno	R-2	3479.0	90	12.52	3087.0	36	1,237
Imadate	R-3	5378.8	417	4.22	3054.4	463	1,469
Nyu	R-4	277.5	447	1.55	401.6	559	79
Nanjo	R-5	1826.1	203	2.82	3186.9	178	243

Sources: Fukui Prefecture (1905 and 1915) *Fukuiken tokeisho*.

Notes: A value of production is deflated by the *habutae* price index. For making deflator, we used price index of *habutae* in manufactured goods by commodity (1902=100), Ohkawa et al. (1967), p.199, p. 201.

Table 3: Estimation results of the effect of power-loom adoption on value of production, number of firms, firm size, and labor productivity, 1905-15

	ln (value of production)	ln (no of firms)	ln (firm size)	ln (labor productivity)
powerloom-handloom ratio	0.0360***	-0.00157	0.0153	0.0208*
	(0.00984)	(0.0132)	(0.0110)	(0.0111)
asuwa_d	-2.232***	-0.416**	-0.857***	-0.962***
	(0.128)	(0.171)	(0.143)	(0.145)
yoshida_d	-1.151***	-0.367**	-0.417***	-0.359**
	(0.127)	(0.170)	(0.142)	(0.143)
sakai_d	-1.163***	-0.110	-0.580***	-0.476***
	(0.126)	(0.169)	(0.141)	(0.143)
ohno_d	-1.858***	-1.189***	-0.304**	-0.348**
	(0.131)	(0.175)	(0.146)	(0.148)
imadate_d	-1.052***	0.447**	-1.132***	-0.366**
	(0.127)	(0.170)	(0.142)	(0.144)
nyu_d	-3.048***	-0.137	-1.535***	-1.361***
	(0.128)	(0.171)	(0.143)	(0.145)
nanjo_d	-2.079***	-0.365**	-0.955***	-0.745***
	(0.128)	(0.171)	(0.143)	(0.145)
d_1906	0.214	0.192	-0.0800	0.125
	(0.148)	(0.198)	(0.165)	(0.167)
d_1907	-0.180	0.170	-0.0713	-0.300*
	(0.148)	(0.198)	(0.165)	(0.167)
d_1908	0.192	0.254	-0.0852	0.0122
	(0.148)	(0.198)	(0.165)	(0.167)
d_1909	0.331**	0.368*	-0.127	0.0984
	(0.148)	(0.198)	(0.165)	(0.167)
d_1910	0.364**	0.476**	-0.370**	0.258
	(0.148)	(0.198)	(0.165)	(0.167)
d_1911	0.424***	0.252	-0.315*	0.484***
	(0.148)	(0.198)	(0.165)	(0.167)
d_1912	0.363**	0.0456	-0.354**	0.678***
	(0.148)	(0.198)	(0.165)	(0.167)
d_1913	0.527***	-0.169	-0.232	0.928***
	(0.148)	(0.199)	(0.166)	(0.168)
d_1914	0.229	-0.364*	-0.168	0.747***
	(0.152)	(0.204)	(0.170)	(0.172)
d_1915	0.401**	-0.669***	0.110	0.956***
	(0.168)	(0.225)	(0.188)	(0.190)
Constant	15.65***	6.002***	2.492***	7.152***
	(0.134)	(0.179)	(0.150)	(0.151)
Observations	88	88	88	88
R-squared	0.926	0.707	0.753	0.810

Standard errors in parentheses

***p<0.01, ** p<0.05, *p<0.1

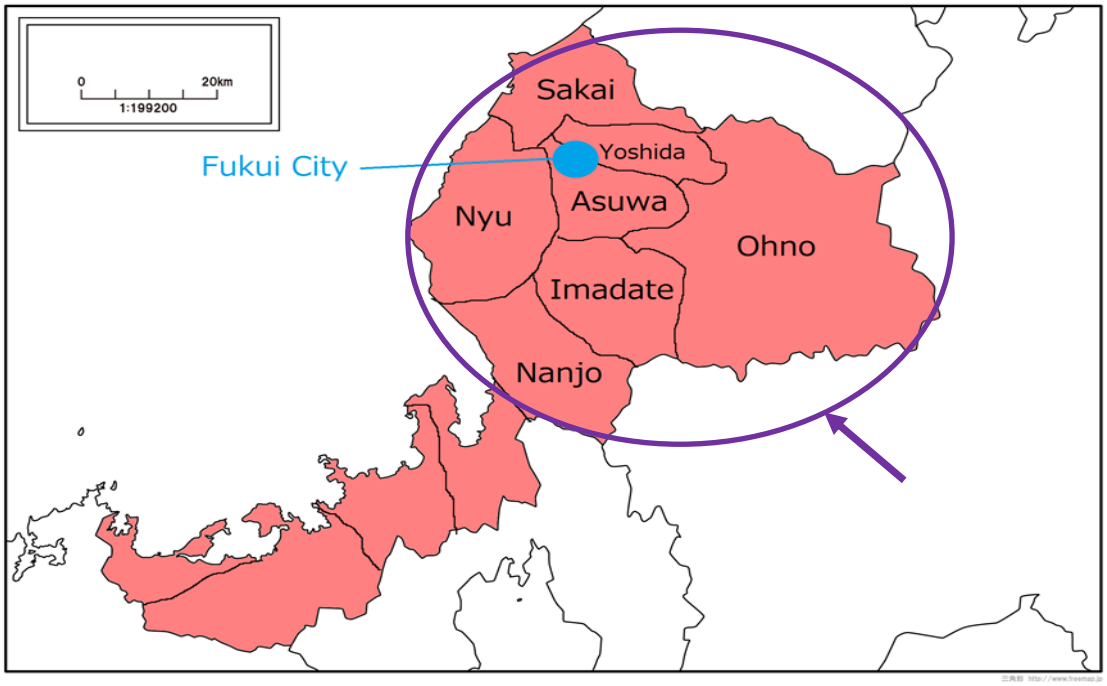
Table 4: Estimation results of the effect of power-loom adoption on value of production, number of firms, firm size, and labor productivity, 1916-21

	ln (value of production)	ln (no of firms)	ln (firm size)	ln (labor productivity)
powerloom-handloom ratio	-0.000374	-0.000563	-0.000437	0.000665
	(0.000486)	(0.000466)	(0.000412)	(0.000528)
asuwa_d	-2.793***	-0.952***	-0.264**	-1.575***
	(0.147)	(0.141)	(0.124)	(0.159)
yoshida_d	-1.601***	-0.951***	0.405***	-1.051***
	(0.146)	(0.140)	(0.124)	(0.159)
sakai_d	-0.693***	-0.973***	0.890***	-0.615***
	(0.158)	(0.152)	(0.134)	(0.172)
ohno_d	-0.625***	-0.311*	0.245*	-0.573***
	(0.166)	(0.159)	(0.141)	(0.180)
imadate_d	-0.310**	0.524***	-0.477***	-0.364**
	(0.147)	(0.141)	(0.124)	(0.159)
nyu_d	-3.122***	0.747***	-1.895***	-1.973***
	(0.147)	(0.141)	(0.124)	(0.159)
nanjo_d	-1.779***	-0.186	-1.274***	-0.324**
	(0.147)	(0.141)	(0.124)	(0.159)
d_1917	0.267**	0.0881	-0.0187	0.165
	(0.127)	(0.122)	(0.108)	(0.138)
d_1918	0.637***	0.234*	-0.0912	0.480***
	(0.127)	(0.122)	(0.108)	(0.138)
d_1919	0.366***	0.472***	-0.128	-0.0159
	(0.129)	(0.123)	(0.109)	(0.139)
d_1920	0.247*	0.282**	-0.131	0.0727
	(0.130)	(0.125)	(0.110)	(0.141)
d_1921	0.0372	0.0960	0.0555	-0.136
	(0.132)	(0.126)	(0.112)	(0.143)
Constant	15.93***	5.250***	2.439***	8.262***
	(0.132)	(0.127)	(0.112)	(0.144)
Observations	48	48	48	48
R-squared	0.963	0.912	0.956	0.894

Standard errors in parentheses

***p<0.01, ** p<0.05, *p<0.1

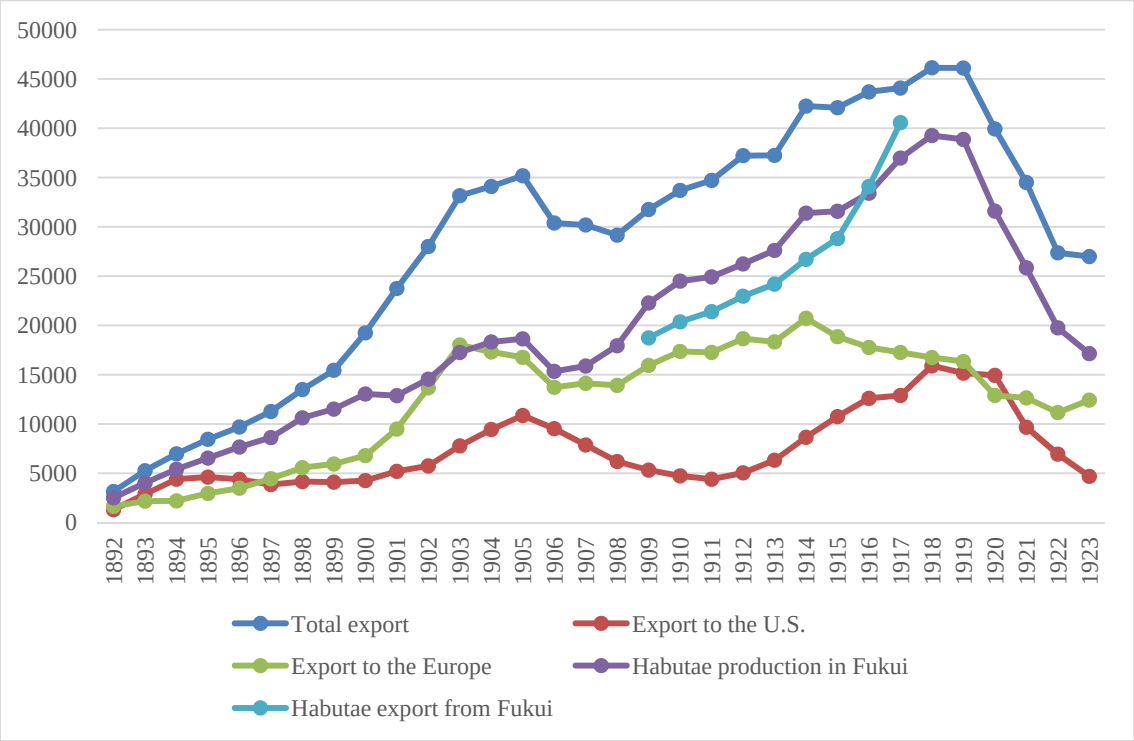
Figure 1: The map of Fukui prefecture and Fukui silk weaving district



Source: http://www.freemap.jp/itemDownload/fukui/fukui/1.png

Notes: The area areas show Fukui Prefecture.

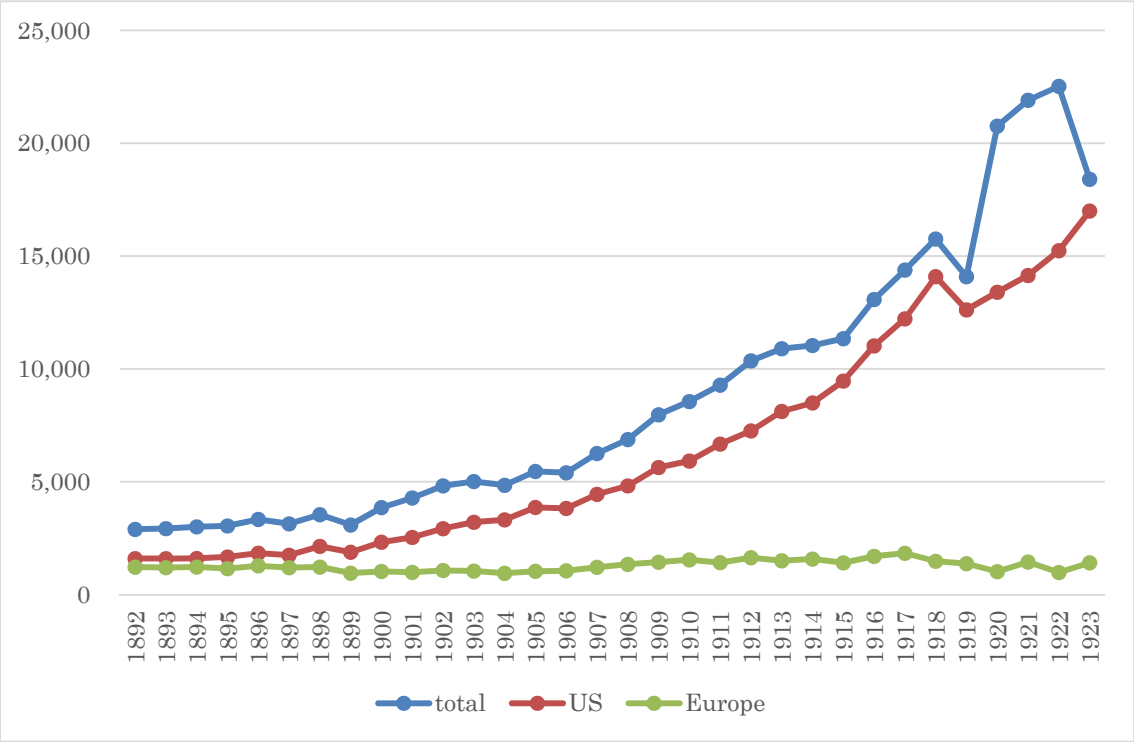
Figure 2: Changes in total *habutae* export from Japan, export to the U.S. and the Europe, *habutae* production in Fukui, and export from Fukui from 1892 to 1923 (three-year moving averages, in thousand yen)



Sources: Data: Yokohamashi (1965), p. 313, for total export, export to the U.S. and the Europe (U.K. and France); The Ministry of Agriculture and Commerce (various years) *Noshomu tokeisho* for *Habutae* production in Fukui; Fukuiken Kinuorimono Dogyo Kumiai (1922), pp. 196-97, for *habutae* export from Fukui.

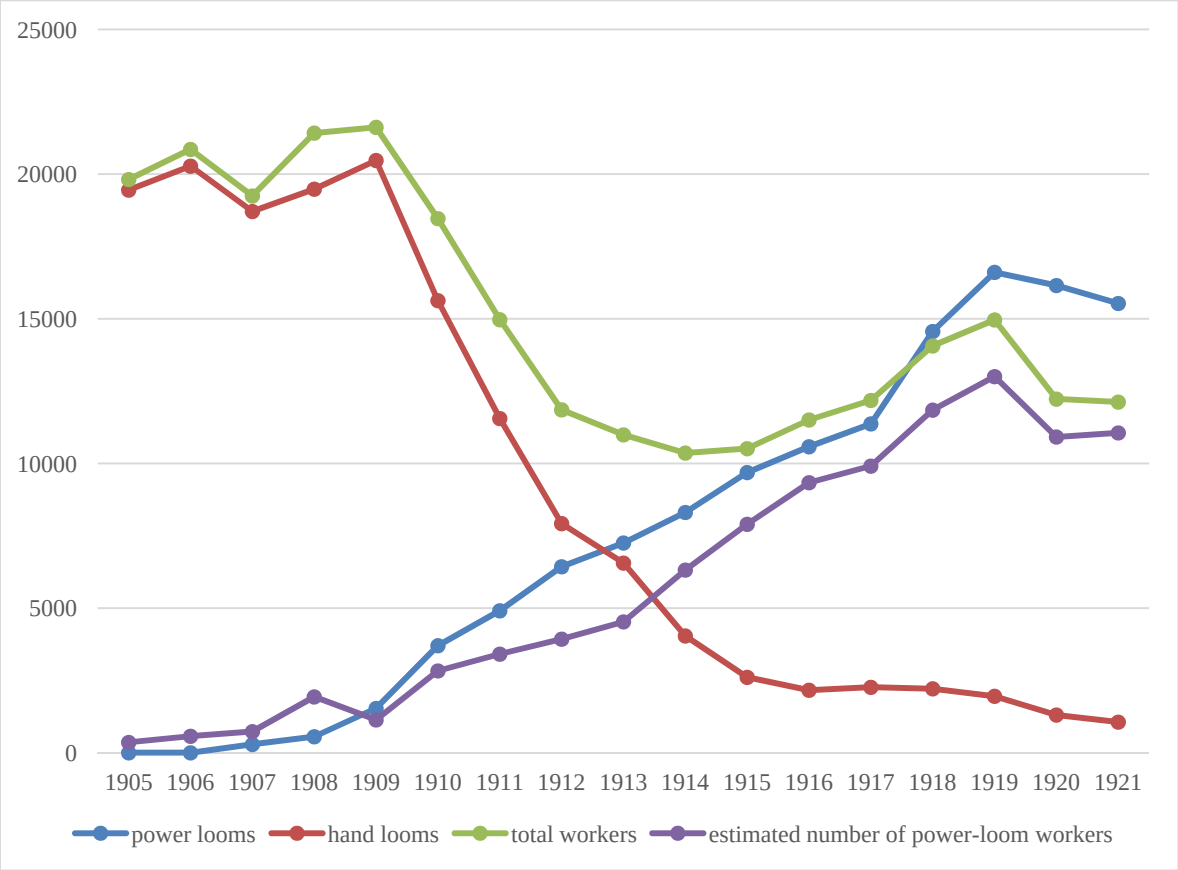
Note: For deflator, we used price index of *habutae* in manufactured goods by commodity (1902=100), Ohkawa et al. (1967), p. 199.

Figure 3: Changes in export of raw silk from Japan to the U.S. and the Europe from 1892 to 1923 (three-year moving average, in ton)



Source: Nakabayashi (2003), pp. 470-72.

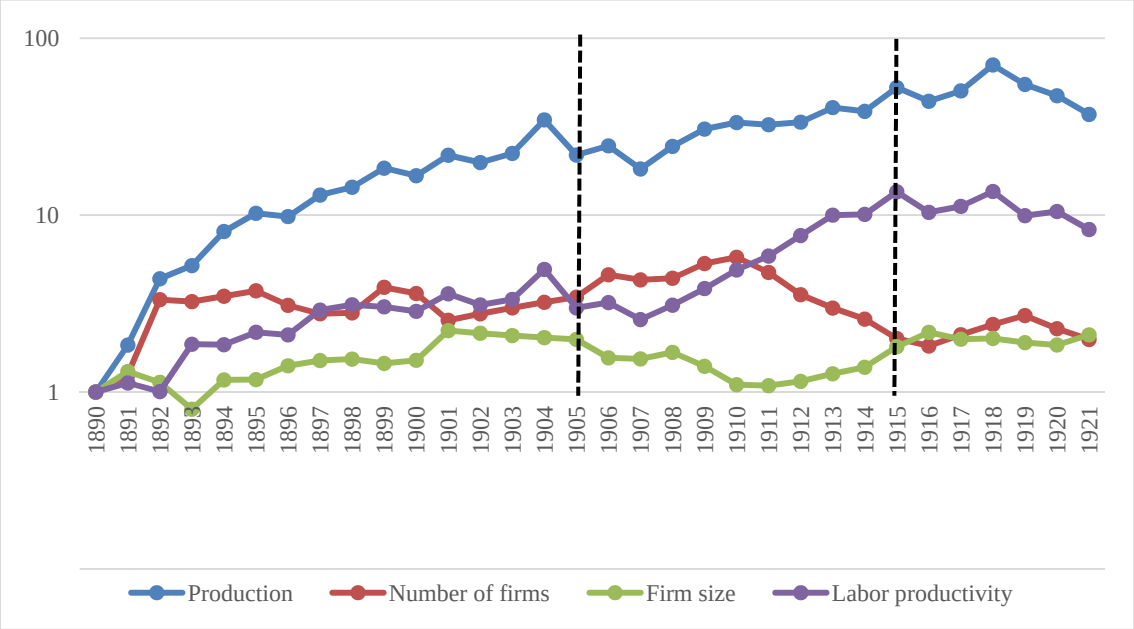
Figure 4: Changes in the number of handlooms, power looms, total workers, and estimated number of power-loom workers from 1905 to 1921



Sources: Fukui Prefecture (1905-1920) *Fukuiken tokeisho*.

Note: The number of power loom workers was estimated by subtracting the number of hand looms from the total number of workers, assuming that one hand-loom worker used one hand loom.

Figure 5: Indexes of production, the number of firms, firm size, and labor productivity in Fukui *habutae* weaving district from 1890 to 1921 (1890=1)



Sources:

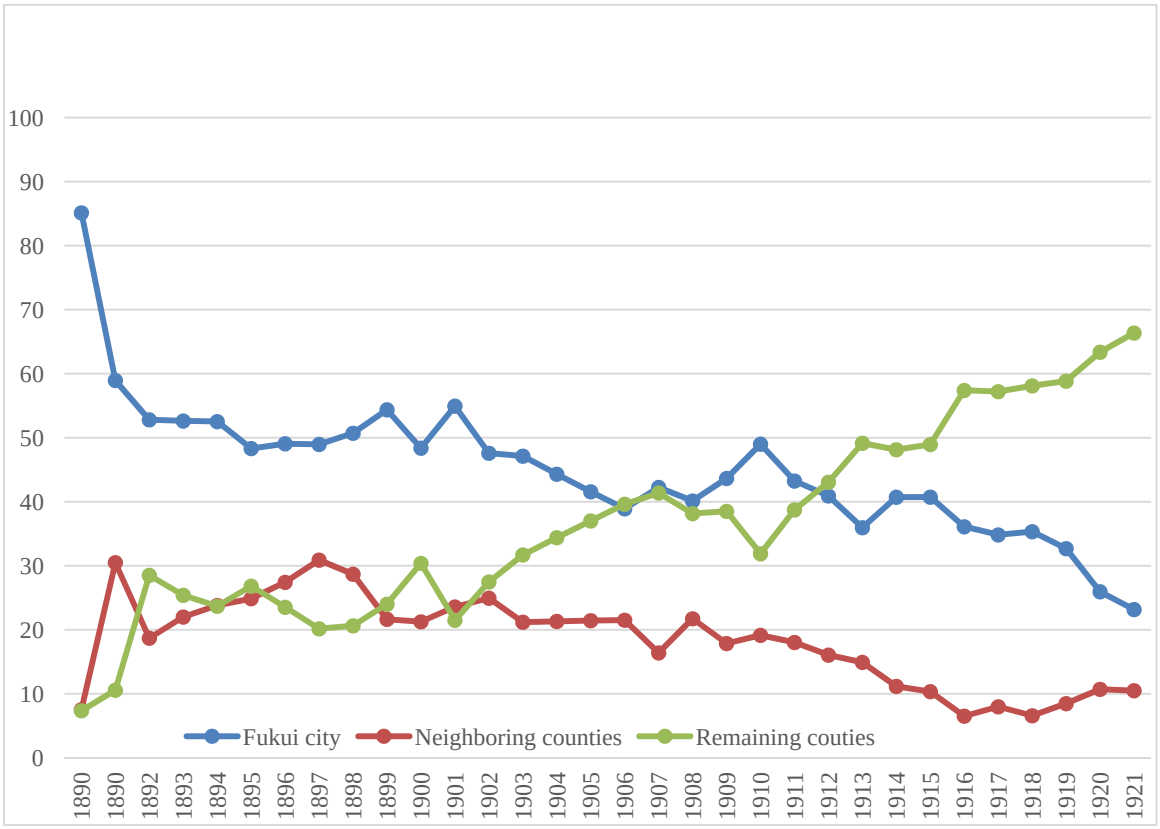
(1) Production: Fukui Prefecture (1890-1901) *Fukuiken kangyo nenpo* for data from 1890 to 1901; Fukui Prefecture (1993) *Fukuikenshi shiryohen 17: tokei*, for data from 1902 to 1904; Fukui Prefecture (1905-1921) *Fukuiken tokeisho* for data from 1905 to 1921.

(2) Number of firms and workers: Mikami and Debuchi (1900) for data from 1890 to 1892; Fukui Prefecture (1893-1900) *Fukuiken kangyo nenpo* for data from 1893 to1900; Fukui Prefecture (1901) *Fukuiken noshoko nenpo* for data in 1901; Fukui Prefecture (1905-1921) *Fukuiken tokeisho* for data from 1905 to 1921.

Notes: A value of production is deflated by the *habutae* price index. See the note of Table 1 for deflator. Linear interpolation was used for data of number of firms and workers from 1902 to 1904.

Figure 6: Changes in regional share of value of habutae production from 1890 to 1921

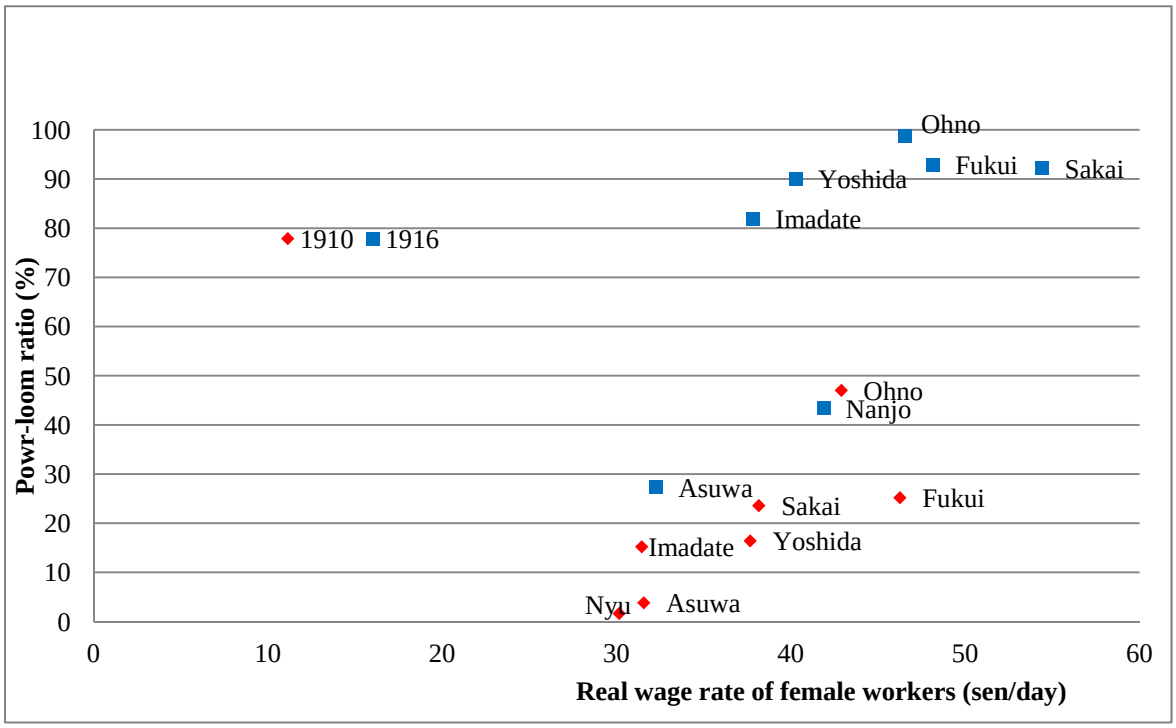
(%)



Sources: Fukui Prefecture (1890-1903) *Fukuiken noshoko nenpo* for data from 1890 to 1903; Fukui Prefecture (1905-1921) *Fukuiken tokeisho* for data from 1905 to 1921.

Notes: We categorized capital city and seven counties into following three groups. Fukui city; Fukui; Neighboring counties; Yoshida and Sakai; and Remaining counties; Sakai, Imadate, Ohno, Nyu, and Nanjo. Liner interpolation was used for data for 1893 and 1904.

Figure 7: Relationship between real wage rate and power-loom ratio by location in 1910 and 1916



Sources: Fukui Prefecture (1910 and 1916) *Fukuiken tokeisho*.

Notes: Daily wage rate is deflated by the consumer price index of all items in Ohkawa et al. (1967), p. 135. The wage rate of individual firms with more than 10 workers is available. We calculated weighted average wage rate of female workers in each counties by dividing the total wage paid for female workers by the total number of female workers. A hunred sen is equivalent to one yen.