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Selective Technology Choice, Adaptations, and Industrial Development: Lessons from Japanese Historical Experience

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Abstract

It is well-known that Japan successfully imported advanced technology from Europe during the Meiji era (1868-1912), notably in the modern cotton spinning industry which used imported British ring machines and Indian cotton and outcompeted India in Asian cotton yarn market. It is also true that traditional industries, especially the sedentary silk reeling and the cotton and silk weaving districts located in various parts of the country, successfully developed while using imported technologies. This study attempts to explore key factors contributing to the successful industrial development in prewar Japan based on the review of the development of the modern cotton textile and silk reeling industries, and the traditional cotton and silk weaving and sedentary silk reeling industries. We found that these industries commonly selected appropriate technologies and adapted them to the initially abundant endowment of labor followed by its growing scarcity.

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1. Introduction

While it is well-known that Japan was the first country outside the western world that has successfully industrialized, it is much less known why Japan was so successful in industrialization. It is true that by taking advantage of backwardness, Japan caught up with Europe by importing advanced technologies (Gerschenkron 1962; Ohkawa and Rosovsky 1973). But this technology catch-up hypothesis does not explain why Japan alone was particularly successful in industrial development in Asia. Nor does it explain what industries and what types of imported technologies played critical roles in industrial development in Japan.

Akamatsu (1962) was concerned with structural transformation of the Japanese economy during the prewar period. He argues that Japanese industries developed following the growth paths of inverse V-shape as if a flock of wild-geese fly; import of modern good increases and then declines because domestic production begins and expands, which leads to launching of export, followed by decreases in domestic production and eventually export due to the loss of comparative advantage. He further argues that such growth pattern, firstly observed in the cotton spinning industry, is followed by another flying geese pattern of development in other industries, such as the cotton weaving industry. Although the import substitution is assumed to be assisted by

technology import, the process of technology import is not explicitly incorporated into his flying geese model.

Sugihara (2013) argues that Japanese industrial development is characterized by labor-intensive path, using labor-intensive technology in labor-using industries, particularly in the early phase of modern economic development. Considering that Japan was highly labor abundant country in the beginning of the Meiji era (1868-1912), his argument makes sense, but it does not explain why Japan was particularly successful in industrial development among Asian countries.

This study attempts to explore key factors leading to the successful industrial development in prewar Japan based on the review of the development of the four major textile industries, viz., the cotton spinning and weaving and silk reeling and weaving industries. As is shown in Table 1, these industries were important sources of merchandise export, accounting in total for roughly 50% of export in the prewar period. These industries also provide ample employment opportunities. There are a large number of case studies on the development of the modern cotton spinning industry by Saxonhouse (1974, 1977), Otsuka et al. (1988), Braguinsky and Hounshell (2015), and Braguinsky et al. (2015), and on the development of the silk-weaving districts by Hashino and Otsuka (2013a, 2013b, 2020) and Hashino (2021). This study attempts to

integrate accumulated insights of these studies. Specifically, we hypothesize that unique and common feature of the industrial development in prewar Japan was selective choice of appropriate foreign technologies, combined with their adaptations to factor endowments in prewar Japan including the skill endowment in the traditional textile districts. We found that Japan did not always introduce the most advanced technology, e.g., power looms, and selected labor-intensive technology, e.g., handlooms, as well as such highly labor-saving technology as Jacquard in the late 19th century. Also noteworthy is the adaptation of ring spinning technology to abundant endowment of labor by developing unique labor-intensive cotton mixing technique. [1] Another unique feature is the remarkable development of the traditional cotton and silk weaving districts; the former was closely linked with the development of the modern cotton spinning industry, while the latter was more closely linked with the development of the traditional silk reeling industry.

<Table 1>

We do not argue that such selective technology choice and adaptations are "causes" for the successful industrial development, as technology choice and

[1] Ranis (1957, 594) pointed out that in prewar Japan, "There was no wholesale adoption of the advanced techniques elsewhere perfected and now available to her."

adaptations are “endogenous” decision variables. What we would like to emphasize is that the cotton textile and silk industries would not have developed so successfully without appropriate technology choice and adaptations, which include the choice of quality and types of cotton and silk products.

The organization of this article is as follows. In Section 2 we examine the extent to which the development of the modern cotton spinning and weaving industries followed the flying wild-geese patterns of development and identify critical roles played by technology choice and adaptations in the development of these industries. Section 3 briefly explores the development and technology choice of the selected traditional cotton weaving districts. Section 4 examines production and export of raw silk as well as the supply of raw silk to domestic silk weaving districts from the traditional and modern silk reeling industries. Given that the detailed production data of the traditional cotton weaving districts are limited, we pay more attention to contrasting patterns of the development of three silk-weaving districts in Section 5, for which the detailed data are available. We conclude this study by summarizing lessons from development experiences of the textile industries in prewar Japan in Section 6.

2. Development of the Modern Cotton Textile Industry

The cotton textile industry consists of cotton spinning and weaving industries. While the traditional cotton spinning industry collapsed in the mid-19th century due to the import of cheap and higher quality yarn (Uchida 1960), as in the case of Southeast Asian countries (Hymer and Resnick 1969; Resnick 1970), the traditional cotton weaving industry dominated over the modern cotton weaving industry in prewar Japan. We would like to examine changes in import, domestic production, and export of cotton yarn and fabrics as well as technology choice and adaptations in the modern cotton spinning and weaving industries from the 1880s to the early 1930s.

2-1. Did Wild Geese Really Fly in the Cotton Textile Industry?

In order to examine the validity of the flying wild-geese model of development, Figure 1 shows changes in import, domestic production, and export of cotton yarn over the 50-year period. If we focus on the period before the turn of the century, the data are consistent with the prediction of the flying geese model; import increased, followed by rapid increase in domestic production from 1888 to 1898 and later by increase in export. However, the production and trade structures changed markedly in the subsequent 30-year period: While the production continued to increase, the export declined since the

mid-1910s. While the latter trend can be explained by the establishment of cotton spinning mills by the major Japanese textile companies in China, the former trend can be explained by increased domestic demand for cotton yarn by the cotton weaving industry.

<Figure 1>

Figure 2 shows changes in import, domestic production by traditional and modern sectors, and export of cotton fabrics.[2] Unlike the case of cotton yarn, import of cotton fabrics was negligibly small even in the early period, nullifying the flying geese model. Also important is the dominance of the traditional sector, which had been engaged in the cotton fabric production for centuries. The majority of them were clustered and many of them were located in rural towns and cities. Their production increased steadily from 1887 to 1915 and sharply from 1915 to 1933 except during the Great Depression period when export declined precipitously.

<Figure 2>

The modern spinning mills began producing cotton fabrics in the first decade of the 20th century but their production has been significantly smaller than the production by the traditional sector throughout the prewar period. The traditional sector was not static technologically by any means; it introduced flying shuttle, foot-operated "handlooms,"

[2] As explained in footnote of Figure 2, production of traditional sector is estimated by subtracting production of modern sector from total production.

and Jacquard（e.g., Kiyokawa 1995）. The continuously increased production of cotton yarn without accompanying increased export observed in Figure 1 can be explained by the continuous growth of the domestic cotton weaving sector, particularly the traditional weaving districts. Such inter-industry linkage is not considered in the flying geese model.

It is also interesting to realize that export of cotton fabrics generally exceeded the production by the modern sector, which implies that the traditional sector was also responsible for continued growth of exported cotton fabrics. In fact, export and production by the traditional sector were highly correlated, particularly since the 1910s. Thus, it is clear that the traditional cotton weaving sector achieved the export-led growth in the early 20th century.

2-2. Technology Choice and Adaptations in the Modern Cotton Textile Industry

There is no question that the modern cotton spinning industry equipped with mule and ring spinning machines was more capital-intensive than the traditional cotton weaving industry using handlooms. Yet, the former grew more rapidly than the latter in the late 19th century (see Figures 1 and 2). Such observation appears inconsistent with the labor-intensive growth envisaged by Sugihara (2013). It seems more sensible to argue that the development of labor-intensive traditional cotton weaving industry was stimulated by the

supply of reasonably high quality yarn by the modern cotton spinning industry. If so, the relevant question is how the modern spinning industry developed in the first place.

Using primarily the Long-Term Economic Statistics of Japan (Fujino et al. 1979), Figure 3 shows changes in spindle-labor ratio in the cotton spinning industry and capital stock-labor ratio in the modern cotton textile industry. Labor is measured by person-days. Since male workers were important in the early phase but gradually replaced by female labor,[3] whose wage rate was roughly one-half of male wage rate, both the total number of workers and the number of female labor equivalent workers, which was obtained by summing up the number of female workers and that of male workers multiplied by male-female wage ratio. The estimates of capital stock are available only for the modern cotton textile industry consisting of spinning and weaving sectors. Thus, the spindle-labor ratio is a proxy for capital-labor ratio in the cotton spinning industry. The potential problem of spindle-labor ratio is that although mule spinning machine was exclusively used before 1885 but largely replaced by ring machines in the following 10 years (Otsuka et al. 1988), this ratio does not distinguish between the spindles of the two types of machines. According to Otsuka et al. (1988), however, the total cost of installing mule spindle and ring spindle was roughly the same. Furthermore, estimated capital stock-labor ratio

[3] Female workers accounted for 64% in 1884, 72% in 1890, and 78% in 1900.

pertains solely to the cotton spinning sector before 1910 when cotton textile mills exclusively produced cotton yarn. Therefore, the comparison of spindle-labor ratio with capital stock-labor ratio can check accuracy of the former as a measure of capital-labor ratio.

<Figure 3>

Regardless of the measures of capital-labor ratio, it is remarkable that the ratio declined sharply from 1885 to 1895. As was mentioned earlier, this was the period during which ring machines were rapidly introduced. The operation of ring machine is speedier than mule machines and, hence, the former is more efficient than the latter, if cotton yarns are not broken. If short staple cotton is used, however, only mule machines can be used. Japanese and Chinese cotton staples are very short and unsuitable for the ring machine. Indian cotton staples are longer but Indian cotton spinning factories exclusively used mule machines. It was only Japan among developing countries that used ring machines in combination with such short-staple cotton as Indian (Saxonhouse and Wright 1984). As is shown in Table 2, Japan exclusively imported short staple Chinese cotton in 1884 but rapidly increased the import of Indian cotton in the 1890s. [4]

[4] According to Otsuka et al. (1988, p. 25), Japanese cotton accounted for 14.3% of cotton staple used in 1890 and nil in 1900.

<Table 2>

Actually, Japan uniquely developed cotton mixing technique, which was highly labor intensive and identified to be labor-saving technological progress by Saxonhouse (1977). A large number of female workers were employed to calm, sort out, and skillfully mix relatively long and short staple cotton so as to operate the ring machines (Otasuka et al. 1988; Saxonhouse and Wright 2010). Starting with the spindle-worker ratio of nearly 30, which was somewhat lower than 40 in India around 1885, Japan reduced spindle-worker ratio to one-half or even to one-third. Almost simultaneously Japan increased the production of cotton yarn and its export to Asian market (see Figure 1). This labor-using technological progress made it possible for Japan to become major producer of cotton yarn globally. This is consistent with labor-intensive growth view of Japanese industrial development.

As is suggested by Figure 3 and more rigorously confirmed by econometric analyses by Saxonhouse (1977) and Braguinsky et al. (2015), subsequent technological progress was labor-saving and capital-using. In particular, the two measures of capital-labor ratio shown in Figure 3 indicate that capital deepening gradually took place and accelerated in the 1920s.[5] It is well-known that real wage

[5] Ranis (1957) was the first study that has pointed out changing capital-labor ratios from labor-

rate had been stagnant until around 1920, after which it increased rapidly (see Figure 4). This was the case not only in the cotton textile industry but also everywhere in Japan. This was termed "turning point" by Fei and Ranis (1964). In all likelihood, not only the substitution of labor by capital but also labor-saving technological progress was induced to take place. Indeed, short-staple Indian cotton was replaced by longer-staple American cotton and even by the longest-staple Egyptian cotton in the 1920s (see Table 1), indicating that cotton mixing technology was less intensively used in the 1920s. At the same time, the quality of yarn, measured by count, improved significantly in this period (Sanpei 1941).

<Figure 4>

Japan relied almost entirely on imported spinning machines (Figure 5). Although the quantitative data are not available, Japanese cotton spinning companies increasingly used high-speed, high-draft ring machines (Saxonhouse 1974). In the modern weaving sector, Japanese cotton textile companies relied on imported power looms until 1910, after which domestically produced power looms became common. Many of them were mixed wooden and iron power-looms invented, among others, by Sakichi Toyoda in 1897, father of the founder of Toyota Automobile Company. Development of such cheap

using to labor-saving directions in the course of development of the cotton spinning industry in prewar Japan.

capital-saving technology can be considered as an adaptation to labor-abundant and capital-scarce Japanese economy. According to Kiyokawa (1995, pp. 172-74), imported power loom costed 400 to 6000 yen, whereas mixed iron and wooden power loom costed 30 to 40 yen in the late 1890s.

<Figure 5>

Labor abundance ended at the turning point, and power looms were replaced by automatic looms in the 1920s. As is shown in Figure 5, the use of both imported and domestically produced automatic looms increased slowly together from 1915 to 1925, but after that domestic automatic looms produced by Toyota Automatic Loom Company became predominant. This pattern of development is unexpected in the flying geese model of industrial development.

To sum up, it is likely that the development of cotton mixing technology in the early phase of industrial development and adoption of labor-saving technologies in subsequent periods were guided by level and changes in factor endowment in the Japanese economy from the late 19th century to the early 20th century.

3. Production and Technology Choice in the Traditional Cotton Weaving Industry

Compared with silk-weaving districts to be examined in Section 5, studies on cotton

weaving districts written in English are scant. Two exceptions are study on Iruma in Saitama prefecture by Itoh and Tanimoto (1998) and study on Enshu in Shizuoka prefecture by Yamazaki (2002). Although Saitama and Shizuoka prefectures were not major cotton fabric producing regions in prewar Japan, the detailed prefecture level data are available.[6] Furthermore, the two prefectures are representative of domestic market oriented and export oriented weaving districts and contrasting in types of products and targeted markets, as will be shown shortly.

3-1. Domestic Production and Export in Saitama and Shizuoka Prefectures

According to Figure 6, which shows real value of production of all fabric as well as cotton fabric in Saitama and Shizuoka prefectures from 1905 to 1933, Saitama was more importance producer of cotton as well as other fabrics than Shizuoka until the early 1910s. Consistent with the production data of cotton fabrics shown in Figure 2, the production of cotton fabrics in the two traditional weaving districts increased from 1905 to 1910. This observation strongly suggests that the development of rural cotton weaving districts was stimulated by the newly emerged supply of high-quality cotton

[6] Ministry of Agriculture and Commerce (1925) conducted detailed data collection on weaving districts and showed useful data from 1902 to 1923 for Saitama prefecture and from 1912 to 1923 in Shizuoka prefecture. Although this study does not use this data, we learned useful information from this data set.

yarn by the modern cotton spinning industry. This is reminiscent of the argument of Schumpeter (1912) that the discovery of new input is an important category of innovations. Such inter-industry growth linkage was not taken into consideration by the flying geese model.

<Figure 6>

While the production in Saitama prefecture had been largely stagnant after mild growth from 1905 to 1910, the production in Shizuoka prefecture continued to increase for the entire 30-year period. Note that Saitama prefecture specialized in the production of narrow-width cotton fabrics and other fabrics destined for domestic markets, whereas Shizuoka prefecture specialized mainly in the production of plain wide-width cotton fabrics for export. In 1923, 10.5% of products was exported from Shizuoka, whereas only 2.0% was exported from Saitama. Export of cotton from Shizuoka accelerated in subsequent years (Yamazaki 2002). Furthermore, cotton weaving was farmers' side-line activities using handlooms in some cotton weaving district in Saitama prefecture (Itoh and Tanimoto 1998).

3-2. Choice of Handlooms vs. Power-Looms

Difference between stagnated production in Saitama prefecture and sustainably growing

production in Shizuoka prefecture corresponds to the difference in the speed of shift from handlooms to power-looms. The data on the number of handlooms and power-looms for aggregate fabric production are available from 1905 and onward, whereas the data for cotton production are available since 1922 (see Figure 7). In Saitama prefecture, indigenously invented foot-operated looms were also common, accounting for 35% of looms in 1923 (Ministry of Agriculture and Commerce 1925). For simplicity, it is combined with handlooms in Figure 7. It is obvious that Saitama used exclusively handlooms in 1905 and produced much larger volume of fabrics than Shizuoka. This means that cotton weaving district in Shizuoka prefecture was tiny or almost non-existent in 1905. In general, the number of handlooms were on the declining trend in both prefectures, whereas the number of power-looms increased slowly and somewhat substantially after the turning point in Saitama prefecture but increased sharply since 1915 in Shizuoka prefecture. The rapid growth of cotton fabric production in Shizuoka prefecture observed in Figure 6 can be attributed to rapid growth of the adoption of power-looms in this prefecture.

<Figure 7>

Popular power-looms used in Shizuoka prefecture were mixed wooden and iron type produced in the same prefecture. According to Kiyokawa (1995, p. 179), out of

17,720 power looms used in this prefecture in 1919, 61% were mixed wooden and iron type and only 39% were iron type.[7] Manual work using handlooms can be easily substituted by power-looms, if the products are simple plain fabrics. Thus, higher adoption of power-looms in Shizuoka prefecture was closely related with its export-orientation of simple cotton fabrics (Minami and Makino 1983). It is highly likely that Shizuoka prefecture selected power-looms as they fitted well with its production of simple fabrics. Furthermore, the rapid adoption of power-looms largely coincided with the rapid growth of wage rate. These observations suggest that increased scarcity of labor induced the adoption of the labor-saving technology in the traditional cotton weaving districts. In fact, labor productivity significantly increased with the adoption of power-looms (Okazaki 2021).

4. **Development of the Silk Reeling Industry**

The silk reeling industry in prewar Japan consisted of the mechanized modern sector, which adopted factory system and used reeling machines imported mainly from Italy, and the traditional sector, which used sedentary reeling technology for producing raw silk and douppion raw silk. Machine reeled silk yarn is finer, glossier, and more

[7] Share of imported power looms was mere 3.3%.

homogeneous without fewer nodes than that by sedentary reeling (Uchida 1960). Therefore, the price of the former was roughly 15% higher than the latter (Fujino et al. 1979). Production methods employed by the traditional sector was much more labor-intensive than those employed by the modern sector. A question is how the modern and traditional silk producing sectors are related with traditional silk weaving sector and also with massive export of raw silk from Japan.

4-1. Silk Yarn Production and Export

Unlike the case of cotton yarn, there was practically no import of raw silk in prewar Japan. Thus, argument of the flying geese model does not apply. Figure 8 shows changes in total volume of raw silk production in Japan from 1868 to 1933, along with the production volume of machine reeled silk by the modern sector and total export. Several interesting observations can be made. First, export began quite early, which indicates that Japan had a comparative advantage in raw silk production even before the western technology was introduced. Second, production of raw silk increased rapidly and continuously from the late 1870s to the early 1930s. Third, such rapid production growth was achieved by the equally rapid production growth of machine reeled raw silk, which indicates predominant importance of the modern silk reeling industry. Fourth, produced raw silk was mostly exported. Amount of export fluctuated widely reflecting

business cycles in advanced countries, particularly in the U.S., which was a major importer of raw silk from Japan. Lastly, although the production share was not large, the traditional sector survived sustainably, which is reflected in the persistent gap between total domestic production and production of machine reeled silk by the modern sector.

<Figure 8>

A number of technologically simple adaptations but economically important innovations were made in mechanized reeling (Uchida 1960, pp. 195-99). The process of cocoon cooking was mechanized and it was widely diffused in the late 1910s. Subsequently the method of reeling using cold water, instead of almost boiling water, was developed, which saved fuel cost and improved efficiency of reeling. The most outstanding innovation was multi-frame reeling machine made by Minorikwa, which contributed to improving the quality of raw silk by reducing nodes and non-uniformity. This was important, as the demand for high quality raw silk increased in the U.S.A. to produce stocking made of silk. The Minorikwa reeling machine reduces speed of spinning to prevent nodes and non-uniformity but increased the number of frames to compensate the production loss associated with the reduction in speed. Such new machines with a number of new improvements became common since around 1920. In

all likelihood, these adaptive innovations contributed to accelerated growth of raw silk production in the 1920s (see Figure 8).

4-2. Silk Yarn Supply to the Weaving Industry from the Traditional and Modern Sectors

It is known that silk produced by the traditional sector was used for production of Japanese *kimono* and *obi* produced exclusively by the traditional silk weaving districts with a few exceptions. The question is how much raw silk produced by the modern sector was supplied to the traditional silk weaving districts. In order to answer this question, we estimated the supply of raw silk by the modern sector to the traditional weaving sector by subtracting the amount of export from the amount of production by the modern sector.[8] Figure 9 shows changes in the silk production by the traditional sector and estimated supply of raw silk from the modern sector to domestic fabric production after 1889, for which the data available. It is clear that the traditional sector was a sole supplier of raw silk to the silk weaving districts until around 1915. Thus, unlike the case of cotton weaving districts, the development of the silk weaving

[8] An assumption here is that only the modern sector exported raw silk, which is likely to be valid.

districts, which will be reviewed in the next section, was supported largely by raw silk production by the traditional sector. The traditional sector improved production efficiency by replacing hand-driven reeling by foot-driven type, which doubled production per day (Uchida 1960, pp. 195-96). However, the modern sector became an important source of raw silk for the traditional weaving sector in the 1920s and 1930s. How such changes are related with structural changes in silk weaving sector is an important issue to be examined in the next section.

<Figure 9>

5. Production and Technology Choice in the Traditional Silk Weaving Industry

Similar to the case of silk yarn, there was no import of silk fabrics to Japan and the whole production of silk fabrics was carried out by the traditional weaving districts. The dominance of the traditional sector in the silk weaving industry is highly dissimilar to the case of the cotton spinning and silk reeling industries. After examining the total production and export, we will examine production and the use of handlooms and power-looms in the three major and contrasting weaving districts of Nishijin, Kiryu, and Fukui. Nishijin was the center of production of Japanese *kimono* and *obi* (Hashino 2021), whereas Kiryu is an imitator of Nishijin (Hashino and Otsuka 2013). Fukui was a

newcomer, which learned weaving technology from Kiryu and Nishijin and engaged in the production of the simple silk fabrics, called *habutae*, for export (Hashino and Otsuka 2020).

5-1. Domestic Production and Export of Silk Fabrics

Figure 10 shows changes in the real value of production and export of silk fabrics from 1886 to 1933. The production increased substantially from 1886 toward the end of the 19th century, which may be termed "initial growth phase." This indicates that the industrial districts were tiny in the 1880s. The initial growth phase was followed by prolonged slow growth period from around 1900 to 1918. This "slow growth phase" was followed by "rapid growth phase" from 1918 to 1933. It is important to realize that the initial growth phase corresponds to increases in raw silk production by the traditional sector, whereas rapid growth phase corresponds to substantial increases in the supply of raw silk produced by the modern sector to the traditional weaving sector (see Figure 9).

<Figure 10>

Unlike the case of raw silk, export of silk fabrics was small, even though it increased from 1918 to 1930. Indeed, the truly traditional silk weaving districts, such as

Nishijin and Kiryu, specialized in the production for domestic market. Newly emerged Fukui weaving district, however, specialized in the production for export. This indicates that unlike raw silk, Japan did not have strong comparative advantage in silk fabric production.

5-2. Production in the Three Silk Weaving Districts

As is shown in Figure 11, Nishijin was by far the largest silk weaving district in 1886. Its production value, however, was less than one-fifth of the level in 1930, indicating that this was the so-called “survival” cluster without any growth. According to Hashino (2021), Kyoto prefectural government sent three craftsmen in Nishijin to Lyon, which was the most advanced silk weaving district in the world, to learn advanced technologies. In particular, these craftsmen were requested to purchase power-looms which were widely used in Lyon at that time. Curiously, however, these craftsmen judge that the use of power-looms was too expensive for small-scale family enterprises in Nishijin to adopt, particularly if the cost of installing a large-scale steam engine for operating 70 to 80 power-looms is taken into account. Thus, they actually brought back flying shuttle and Jacquard. Jacquard is highly labor-saving because the so-called draw boys pulling yarn from the roof of handloom were displaced by Jacquard device.

According to Hashino (2021), worker-handloom ratio changed from 3:1 to 1:1 due to the introduction of Jacquard. In other words, Jacquard saved labor cost so much that it was widely adopted, even though it was labor-saving. Owing to the introduction of Jacquard, the production in Nishijin more than tripled from 1886 to 1898. The production stagnated thereafter and the peak production in 1898 was surpassed more than 20 years later in the 1920s. Initial growth followed by long stagnation is somewhat similar to the case of Saitama cotton weaving district shown in Figure 6.

<Figure 11>

The growth pattern of Kiryu was similar to that of Nishijin, as the formers was imitator of the latter. Jacquard was introduced and handlooms were used in the initial growth phase. This suggests that stagnant and tiny local weaving district began growing due to innovations, particularly the introduction of Jacquard. As in the case of Nishijin, the production in Kiryu stagnated from 1900 to 1920 and then increased sharply from the mid-1920s to the early 1930s (Hashino and Otsuka 2013a).

Traditionally there was no silk fabric production in Fukui in the 1870s. In order to build new silk weaving district, Fukui prefectural government invited an instructor from Kiryu to provide training to local people in the late 1870s (Hashino and Otsuka 2020). Unlike Nishijin and Kiryu, there were no skilled workers in the production of

silk fabrics in Fukui. Thus, Fukui chose to produce simple silk fabrics called *habutae* for export. Earlier Kiryu produced small amount of *habutae* but discontinued because its accumulated weaving skill was not utilized for the production of such simple product. Somewhat similar to the case of Shizuoka engaged in the production of simple cotton fabrics for export, Fukui specialized in the production of *habutae* and succeeded in its expanded export. After 1910, the value of production in Fukui consistently exceeded that of Nishijin and Kiryu.

5-3. Choice of Handlooms vs. Power-Looms

Handlooms were predominantly used in the late 19th century, even though power-looms were known. Since handloom is not an expensive fixed factor of production and since handloom-based production does not entail much division of labor among workers, the modern large-scale factory system did not emerge.[9] The choice of handloom-based production system was probably more appropriate selection from the menu of available western technologies.

Power-looms were widely disseminated much later in the 20th century. It was

[9] There were a few attempts to initiate large-scale factory production in Nishijin and Kiryu without notable success.

Fukui that actively and massively adopted power-looms and replaced handlooms since as early as 1908. By 1930, power-looms completely dominated in Fukui. Similar to Shizuoka, manual work to produce simple products could be easily replaced by machines. Fukui procured silk from Yokohama, the most important port, which implies that Fukui used machine reeled silk produced by the modern sector, which can be exported to abroad. In contrast, silk fabric producers in Kiryu and Nishijin began using machine reeled raw silk and power-looms much later. Power-loom adopters were either factories or relatively large family enterprises with the employment of more than a few workers and exported the products abroad (Hashino 2021). That is, choices of technology, product types, and marketing channels were closely inter-related.

We must also mention that production in the stagnant phase in Nishijin and Kiryu was carried out primarily by small-scale out-weavers consisting of a few workers under the leadership of contactor-cum-merchants who procure yarns and request designs and dying before handing over yarns to out-weavers and after finishing sell products to urban traders. So far as complicated fabric production using handlooms is subject to scale diseconomies, such production organization seems to be rational adaptation to the rich skill endowment in the traditional silk weaving districts.

6. Concluding Remarks

We found in this study that behind the successful development of the cotton textile and silk industries, Japan made a number of critical technology choices and adaptations. In the late 19th century, ring spinning machine with cotton mixing techniques was chosen over mule spinning machine, sedentary reeling was chosen over machine reeling, and handloom, with Jacquard in the case of silk weaving, was chosen over power-looms. Overall, there was clear tendency that labor-intensive production methods were chosen. In this sense, the Japanese development path can be characterized by high labor intensity.

A number of technological and institutional adaptations were also made, not to mention the invention of cotton mixing technique. Invention of wooden and iron power-looms was a good example. Sedentary reeling was improved by incorporating new ideas from imported machines from France and Italy. The development of fine division of labor among yarn processors, out-weavers, and finishing processors in the production of sophisticated silk fabrics under the leadership of contractor-cum-merchants is an important institutional innovation.

As wage rate increased, technology choice shifted in favor of labor-saving technologies. By importing long staple cotton, the ring machine was run without labor-intensive cotton mixing techniques. Machine reeling dominated over sedentary reeling

and machine reeled raw silk was shipped to the silk weaving districts, which used to be served by the traditional reeling sector. Handlooms were replaced by power-looms and those cotton and silk weaving districts, which introduced power-looms more actively, grew faster and became larger. These observations suggest that after the turn of the century and particularly after World War I, labor-saving technological progress was became appropriate.

Labor saving technological progress accompanied the change in the products. In the cotton spinning industry, higher quality or higher count yarns were produced by using longer staple cotton. It was cotton and silk weaving districts that adopted power-looms actively and exported massively. In other words, adaptation of main products to new labor-saving machines was actively made to sustain industrial growth with labor-saving technological changes.

To sum up, this study attempted to deepen our understanding of the process of technological catch-up in the prewar Japan. We do not favor the flying geese model of industrial development, partly because it ignores selective technology choice and adaptations and partly because it did not pay attention to the role of inter-industry linkages. We do not favor the view that Japanese economic growth was characterized by labor-intensive path, because there was clear shift from labor-using to labor-saving

technological changes. It is probably fair to conclude that path of industrial development in prewar Japan was consistent with the level and changes in factor endowments which are revealed most clearly in changes in real wage rate.

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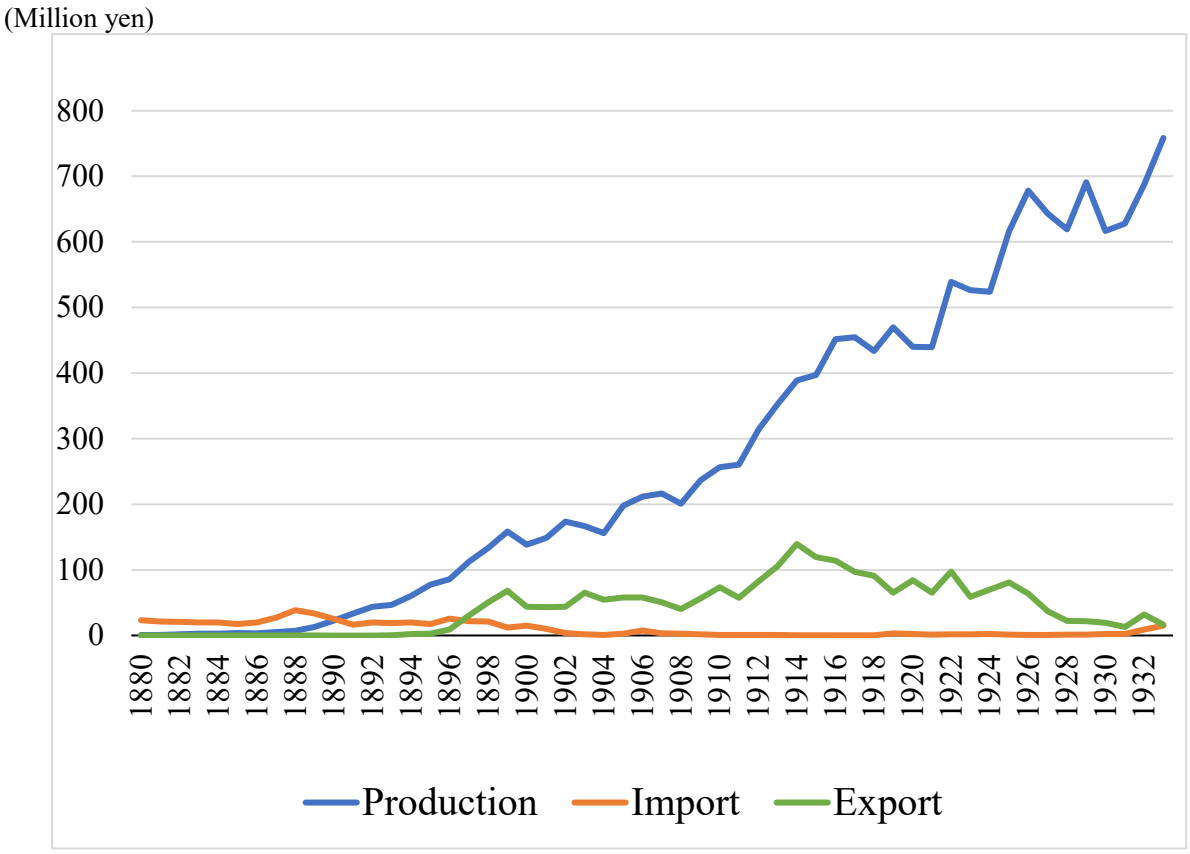
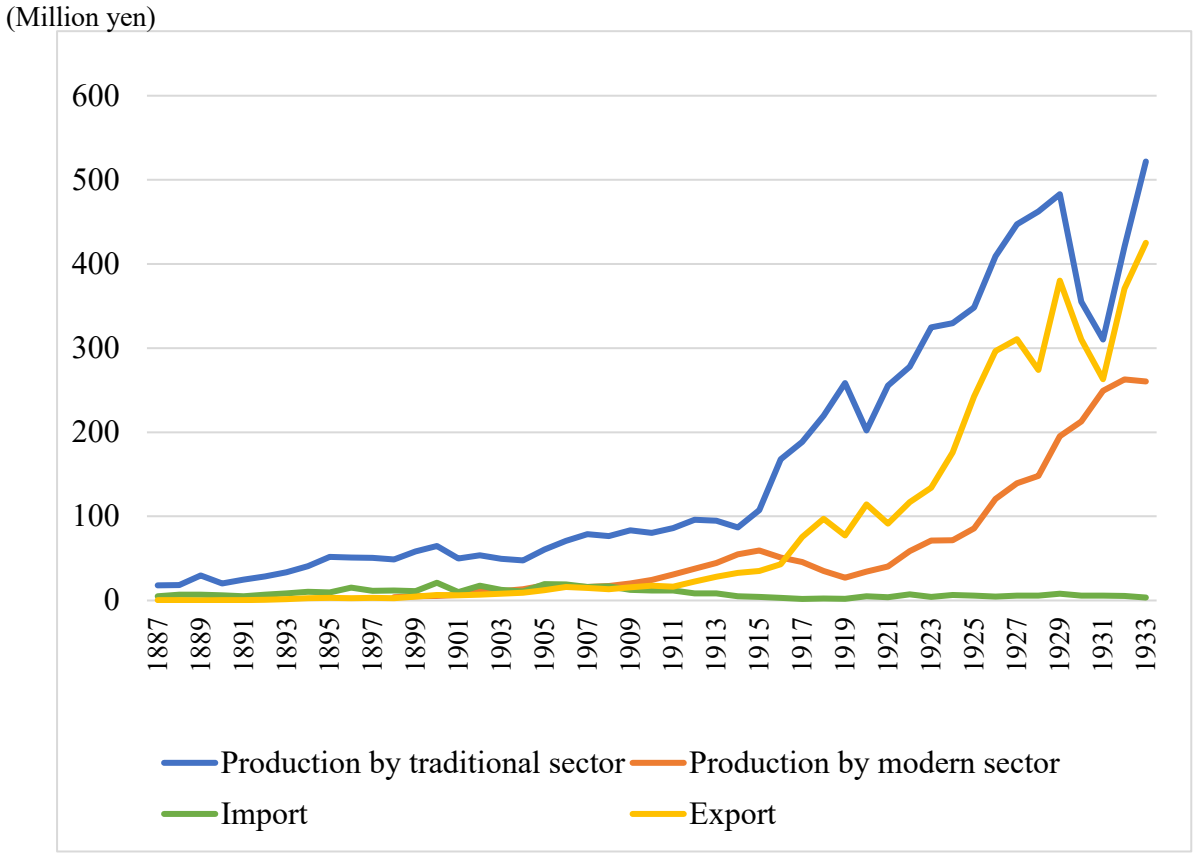
Figure 1. Changes in Real Value of Import, Domestic Production, and Export of Cotton Yarn, 1880-1933 (Million Yen)[a]



Notes and Sources: [a] Deflated by cotton yarn price index (1934-36=100).

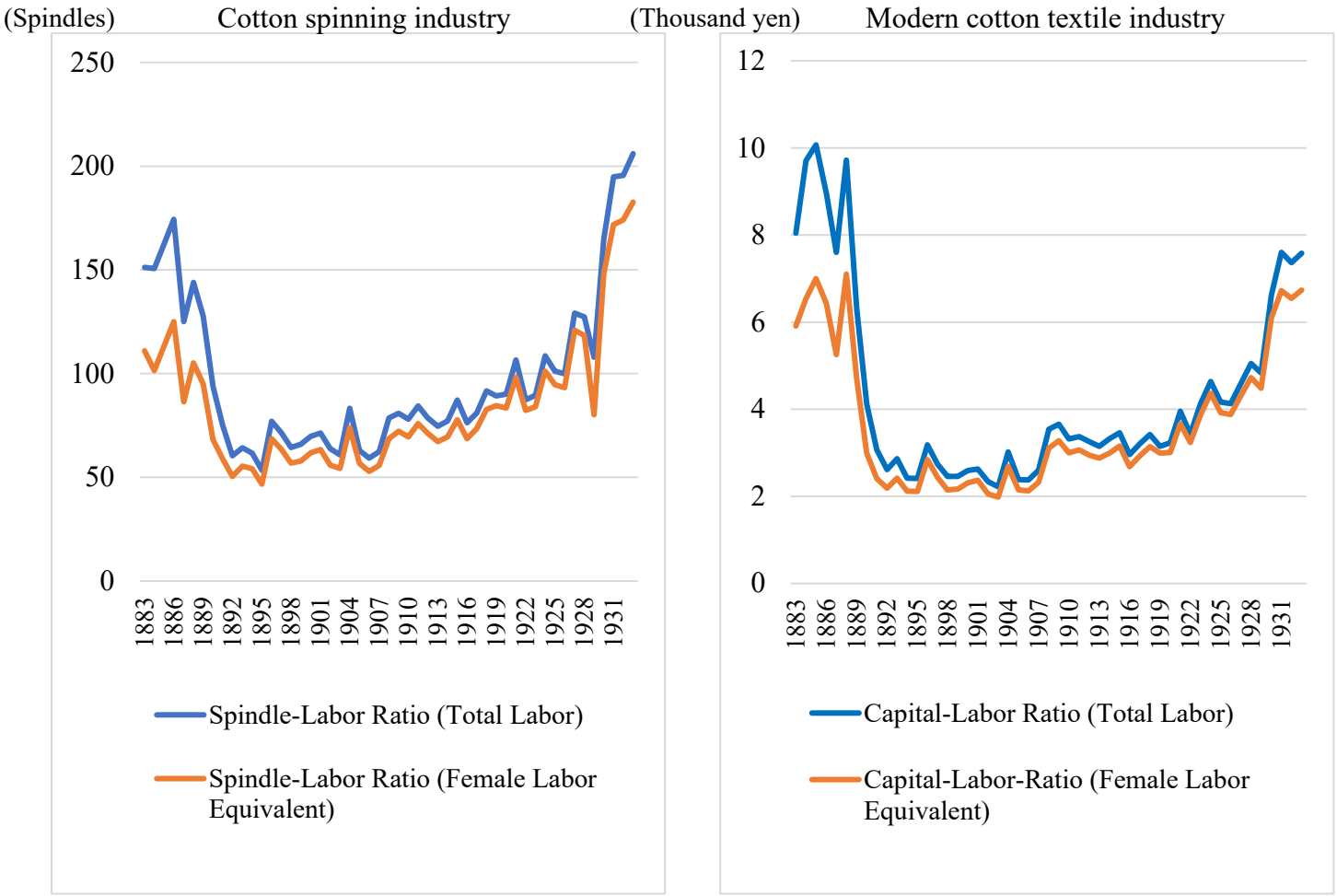
Nominal values are deflated by price index of cotton yarns, 1934-36=100, which is taken from Fujino et al. (1979, p. 247). The nominal value of production for 1880-93 is from Otsuka et al. (1988, pp. 28-29). Since price index before 1890 is not available, we assume that prices before 1890 did not change. Real value of production for 1894-93 is from Fujino et al. (1979, p. 241). Import and export data for 1891-1933 are from Toyo Keizai Shimposha (1975, p. 230 and p. 50). Import data for 1880-90 is from Otsuka et al. (1988, pp. 28-29). Here too, we assume that prices did not change before 1980.

Figure 2. Changes in Real Value of Import, Domestic Production by Traditional and Modern Sectors, and Export of Cotton Fabrics, 1887-1933 (Million Yen)



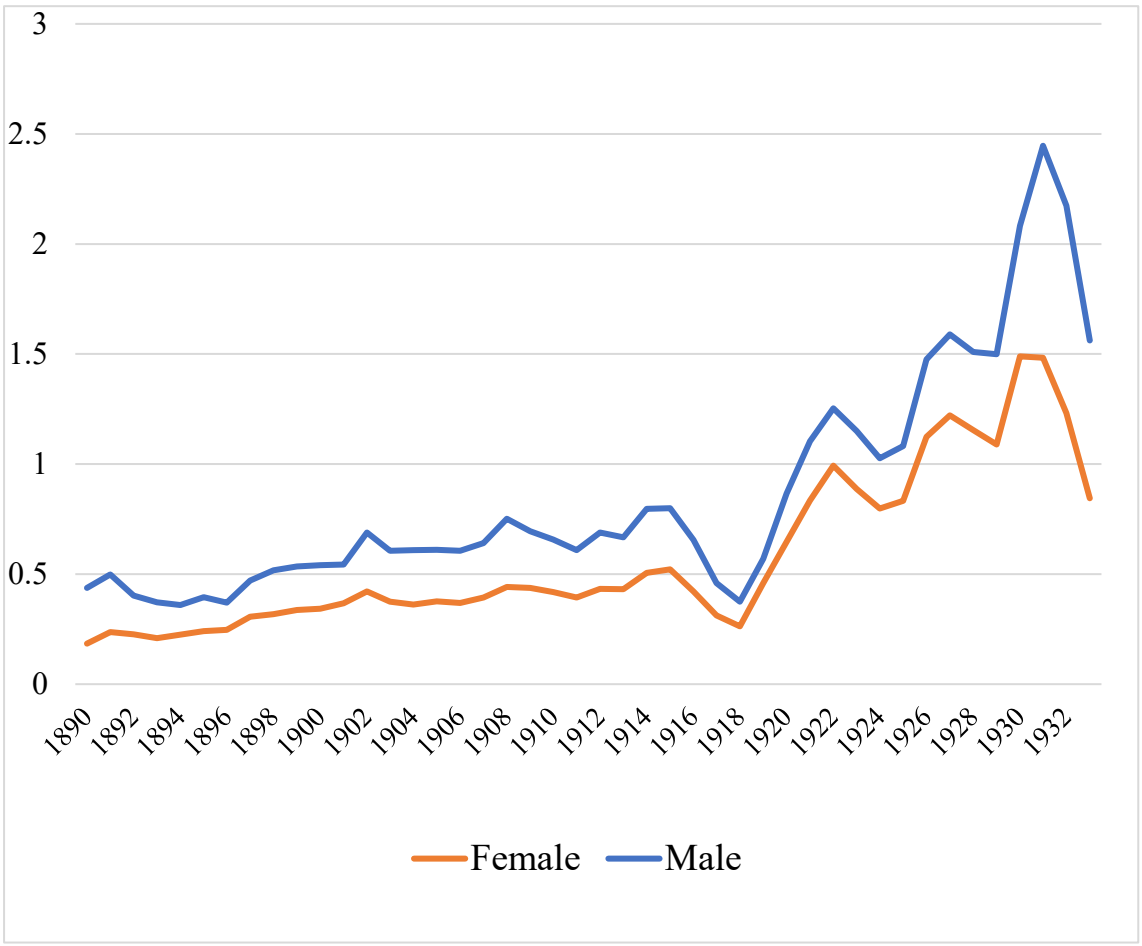
Notes and Sources: Nominal values are deflated by price index of cotton textiles, 1934-36=100, which is taken from Fujino et al. (1979, p. 247). The nominal value of production for 1887-94 is from Otsuka et al. (1988, p. 47). Since price index before 1890 is not available, we assume that prices before 1890 did not change. Real value of production by the modern textile companies for 1898-1933 is taken from Fujino et al (1979, p. 245). Nominal values of total production, import, and export are from Ministry of Agriculture and Commerce (various years) for 1915-23 and Ministry of Commerce and Industry (various years) for 1924-33.

Figure 3. Changes in Spindle-Labor Ratio and Real Capital Stock-Labor Ratio in the Cotton Spinning Industry, 1883-1933



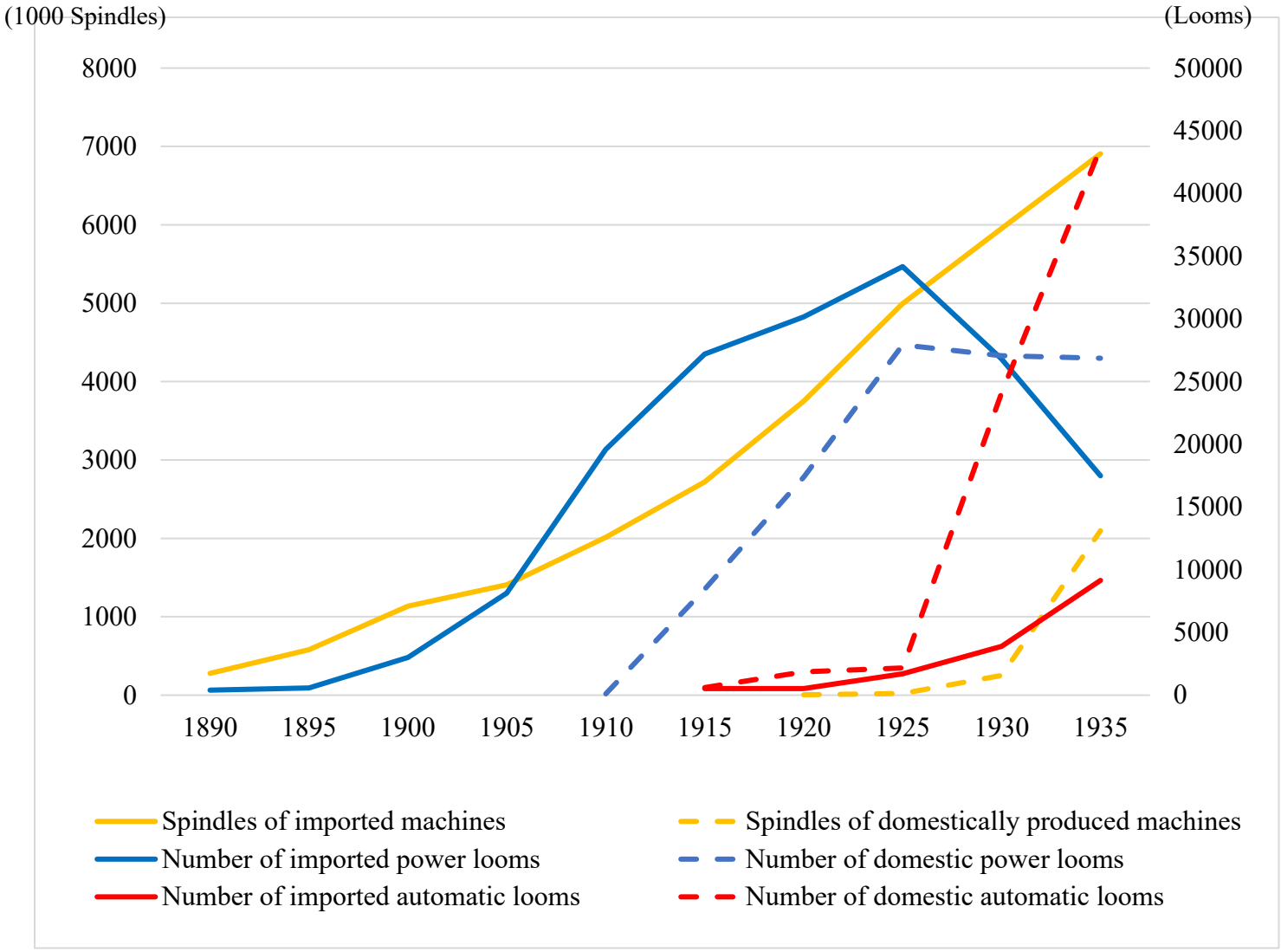
Notes and Sources: The number of spindles is taken from Otsuka et al. (1988, pp. 208-09) for 1883-1900 and from Fujino et al. (1979, pp. 74-83) for 1905-33. Missing data between 1900 and 1905 are interpolated. Labor input and wage data are taken from Otsuka et al. (1988, pp. 211-13) for 1883-89 and from Fujino et al. (1979, pp. 255-57, pp. 273-74) for 1890-1933. Net real capital stock data for 1883-1933 are taken from Fujino et al. (1979, pp. 250-51).

Figure 4: Changes in Real Wage Rate by Male and Female Workers in the Cotton Spinning Industry, 1890-1933 (Yen per Day)



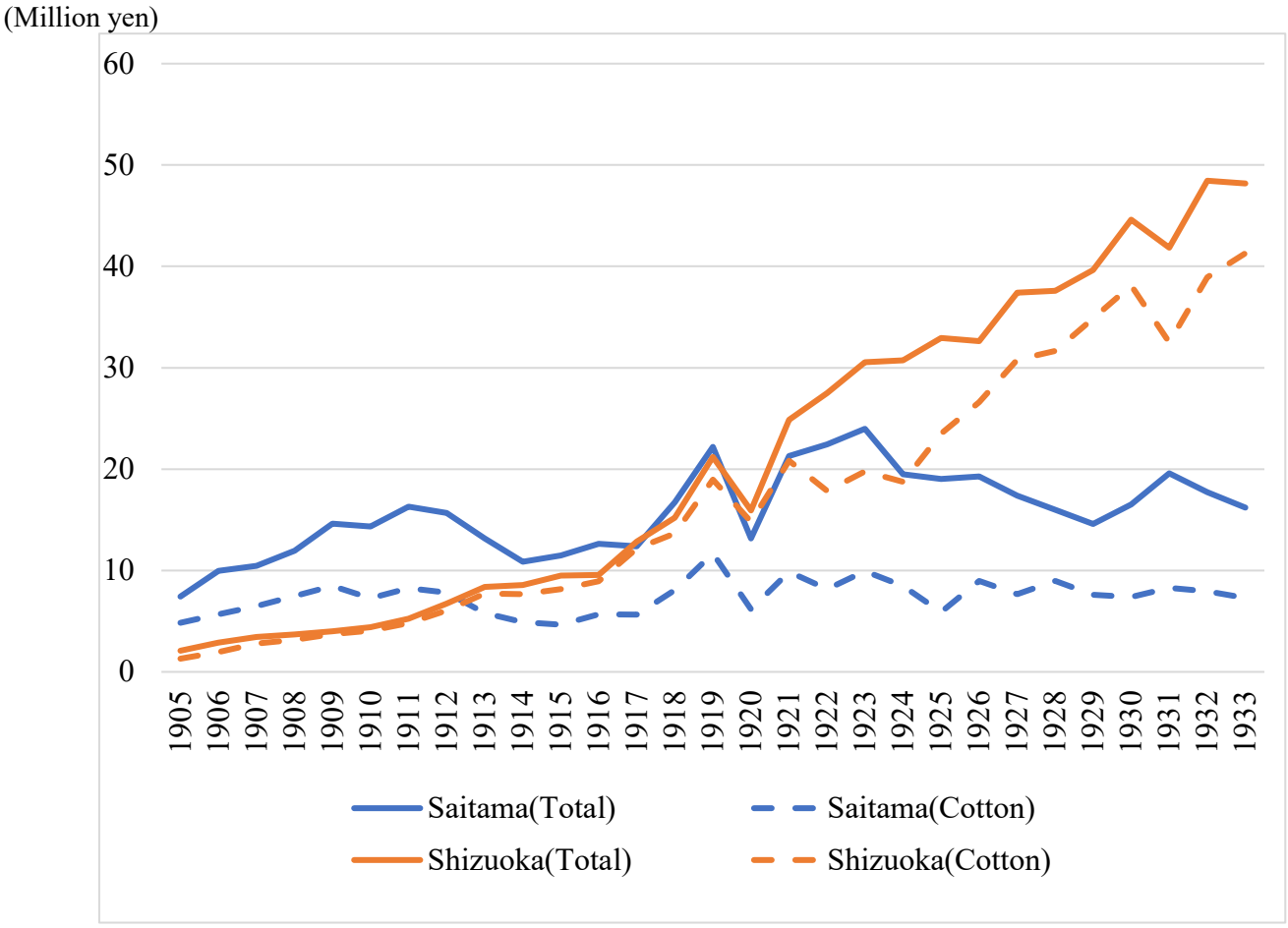
Notes and Sources: Wage data are taken from Fujino et al. (1979, pp. 273-74), and deflator is price index of cotton yarns (1934-36 = 100) taken from Fujino et al. (1979, p. 247).

Figure 5: Use of Imported and Domestically Produced Spinning Machines (the Number of Spindles), Power-Looms and Automatic Looms in the Modern Cotton Textile Industry, 1890-1935.



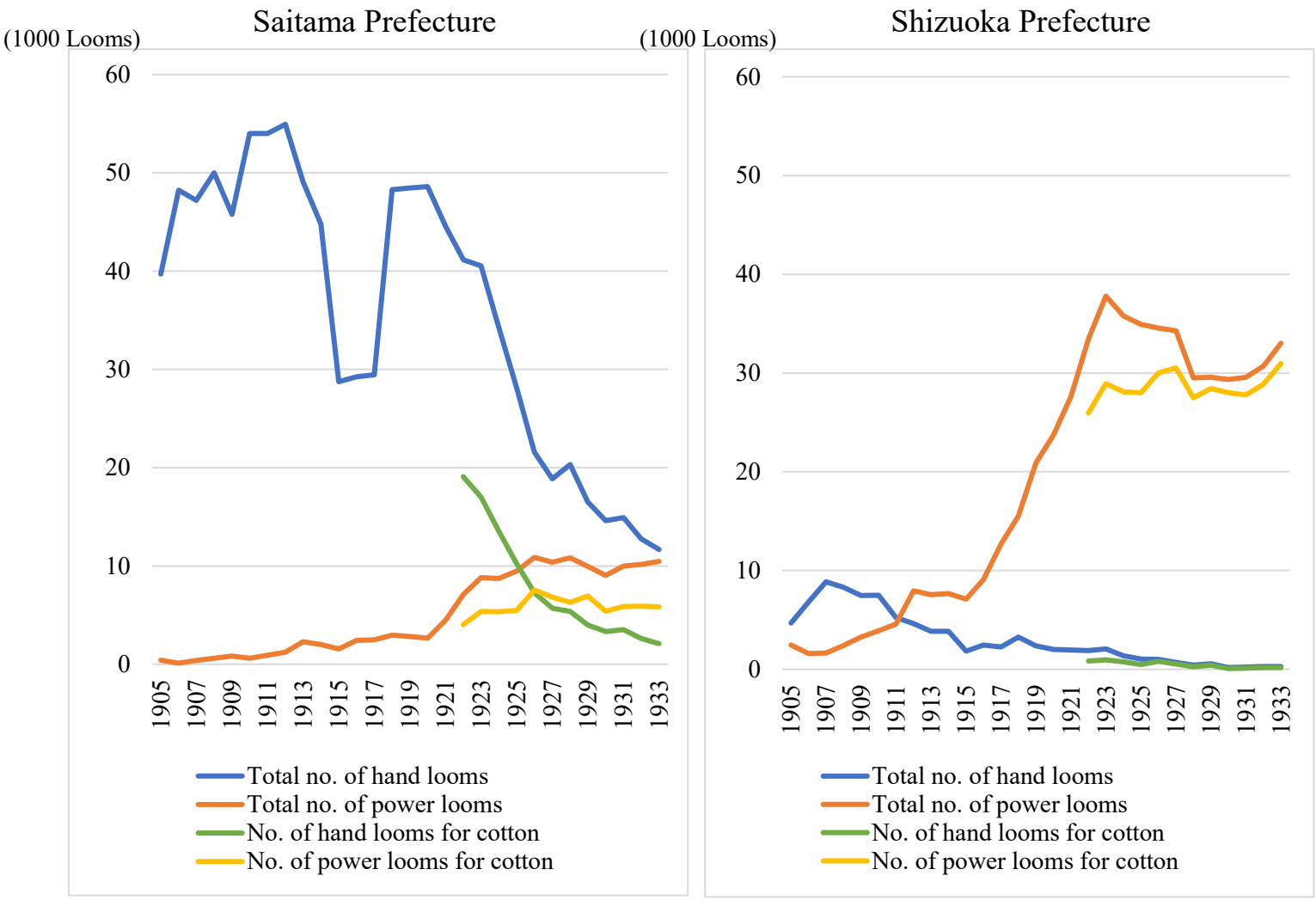
Source: Otsuka et al. (1988, pp. 142-43).

Figure 6: Real Vale of Production of Total and Cotton Fabrics in Saitama and Shizuoka Prefecture, 1905-33



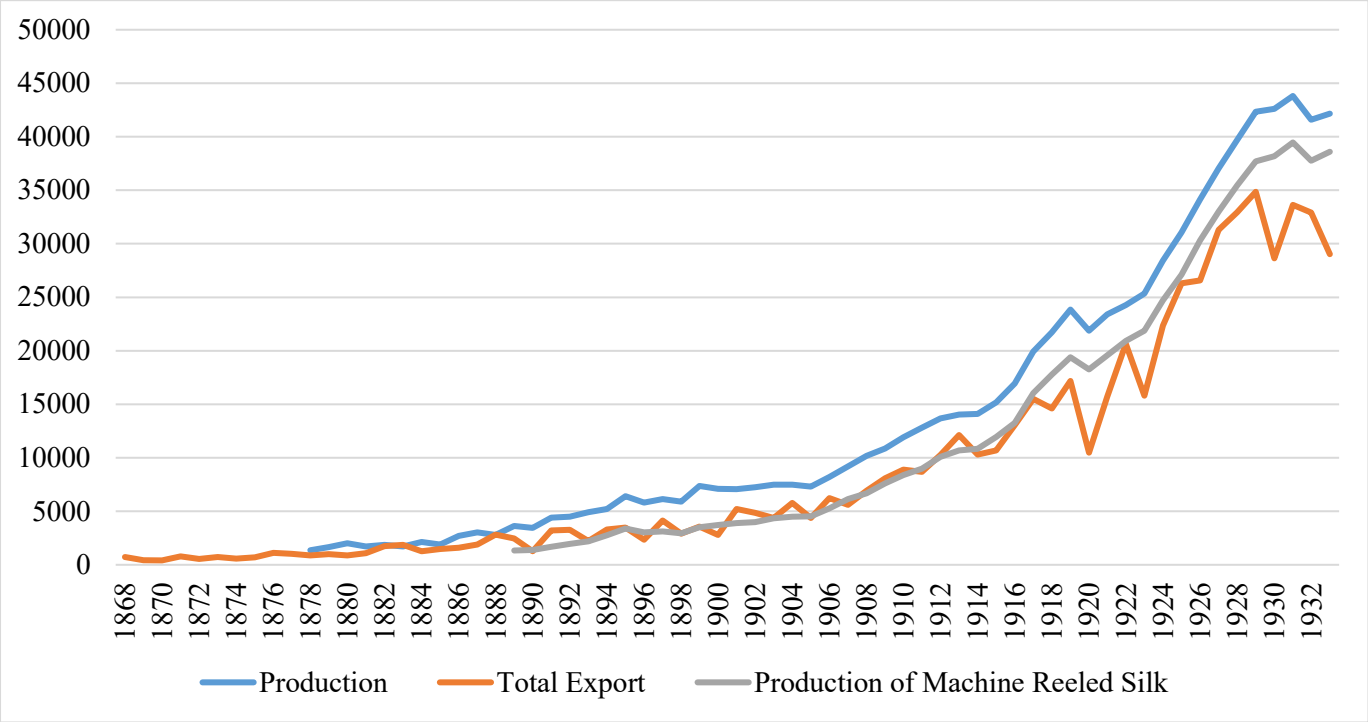
Notes and Sources: The data of nominal value of production are taken from Ministry of Agriculture and Commerce (various year) for 1905-19 and from Ministry of Commerce and Industry for 1924-33. The deflator is the price index of cotton textiles from Fujino et al. (1979, p. 247).

Figure 7: Adoption of Handlooms and Power-Looms in Saitama and Shizuoka Prefecture, 1905-33



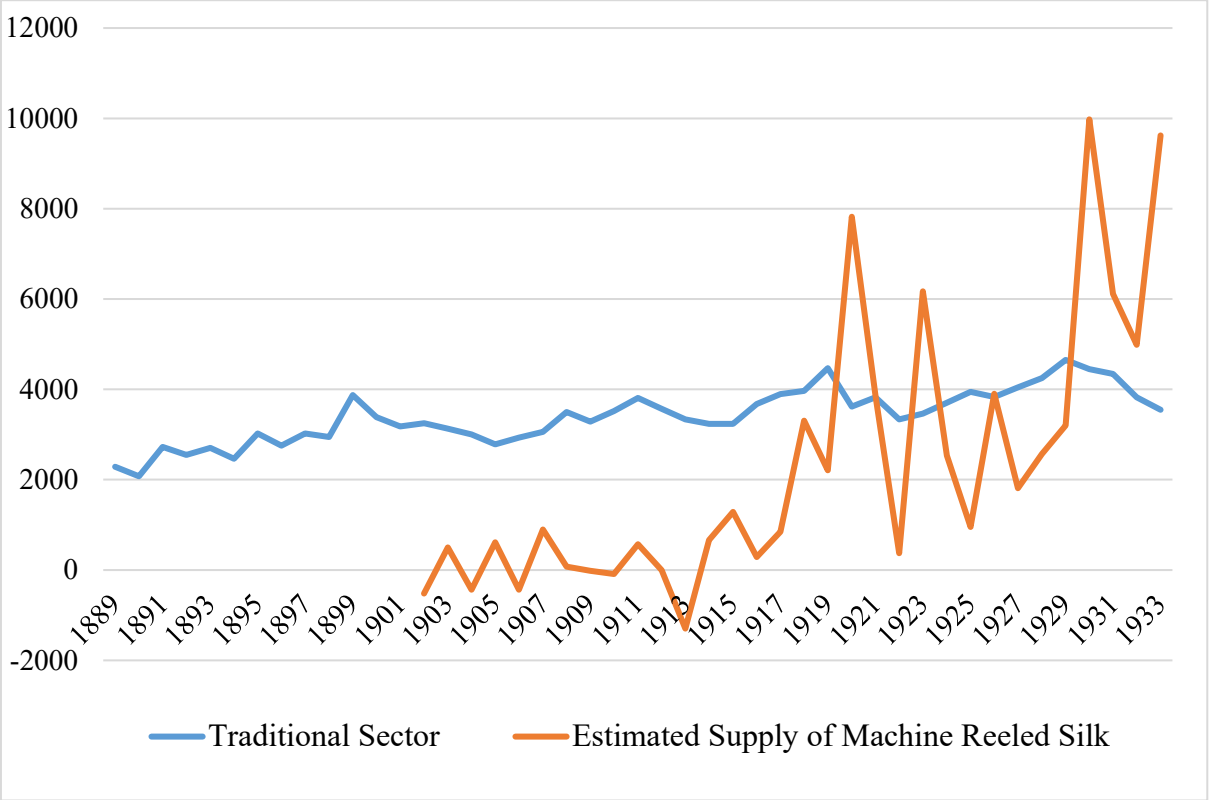
Sources: Ministry of Agriculture and Commerce (various year) for 1905-19 and Ministry of Commerce and Industry for 1924-33.

Figure 8: Changes in Total Raw Silk Production from 1878, Export from 1868, and Production of Machine Reeled Silk from 1889 to 1993 (1,000 kg)



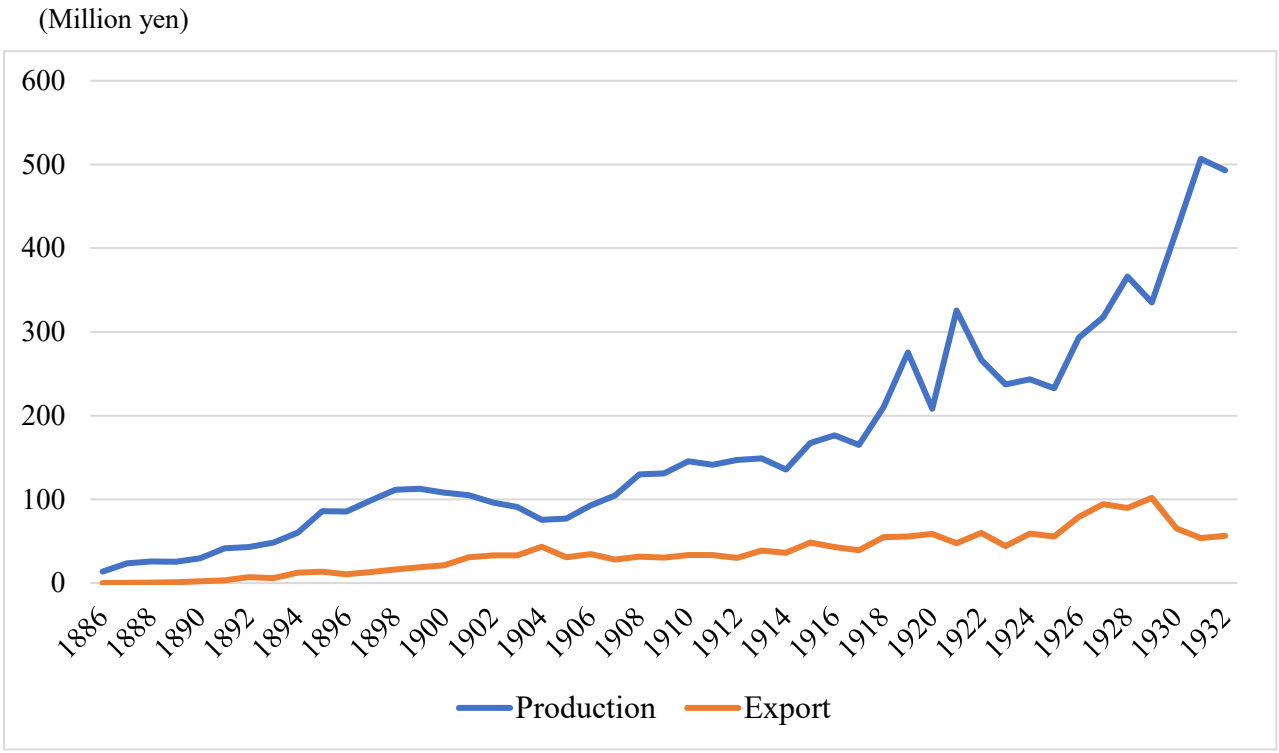
Sources: Fujino et al. (1979, pp. 294-95, p. 308).

Figure 9. Changes in Silk Production in the Traditional Sector, 1889-1933, and Estimated Supply of Machine Reeled Silk to the Domestic Weaving Industry, 1902-33, (1,000 kg)



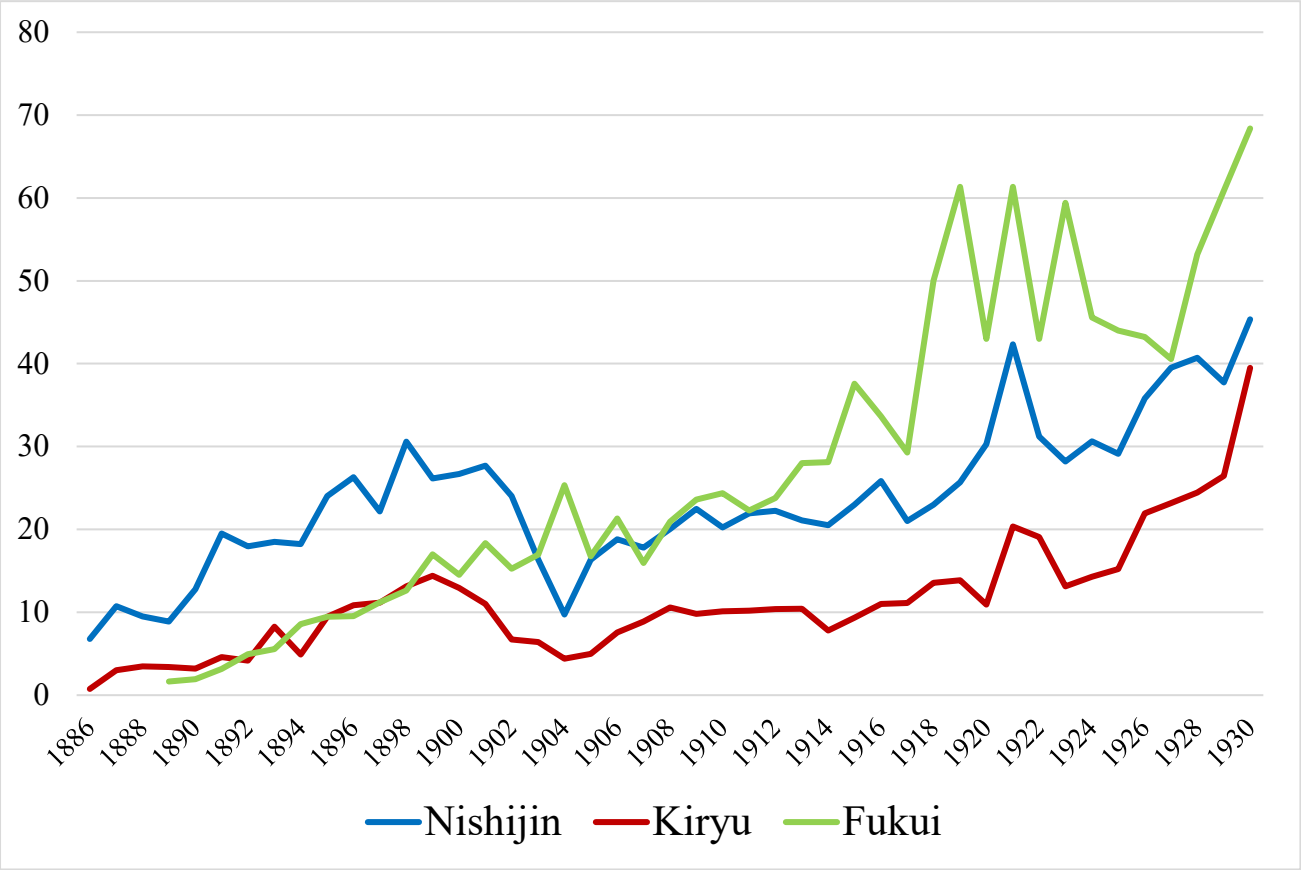
Source: Fujino et al. (pp. 294-95).

Figure 10: Changes in Real Value of Domestic Production and Export of Silk Fabrics, 1886-1933 (million yen)



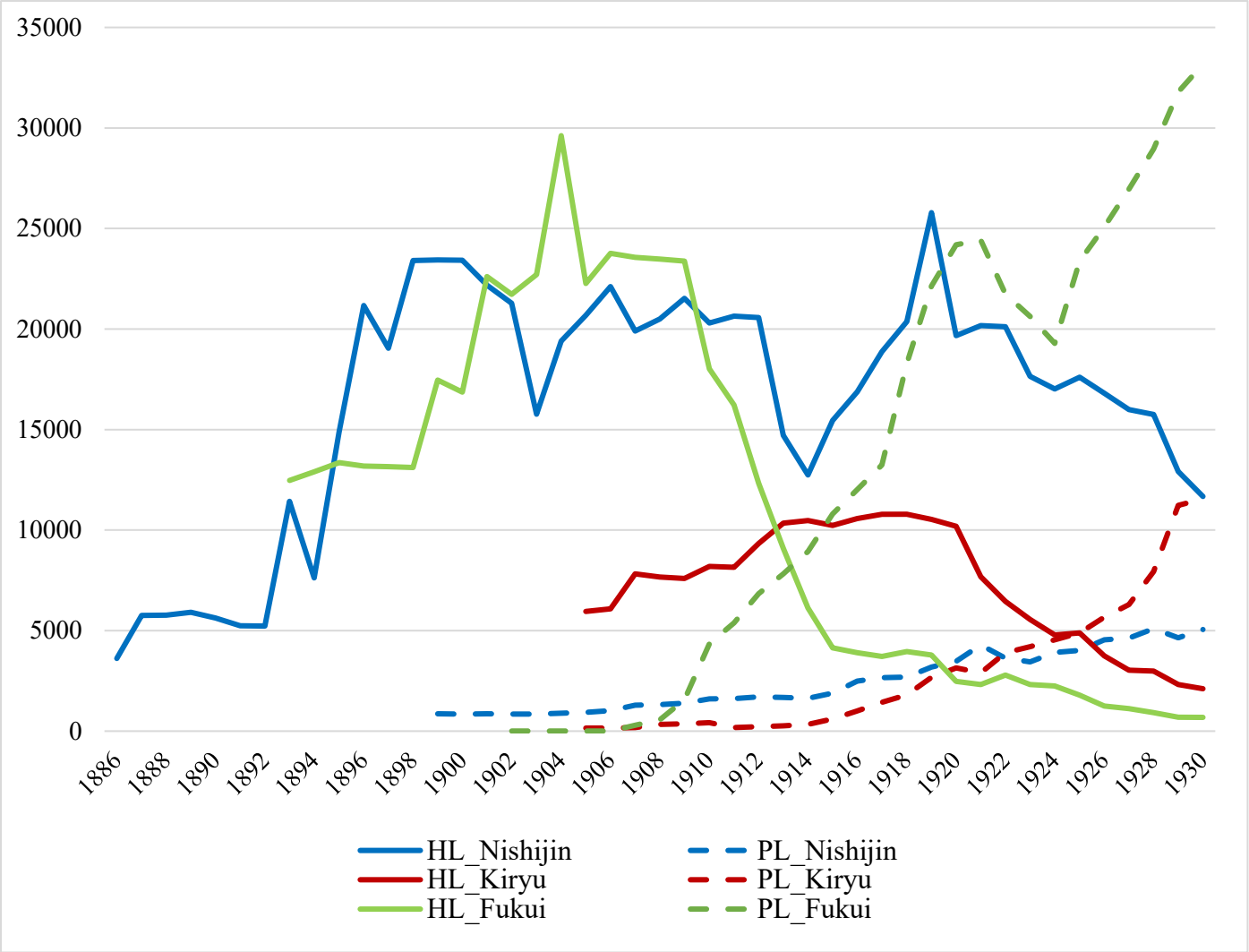
Notes and Sources: Nominal values of total production silk fabrics are from Ministry of Agriculture and Commerce (various years) for 1915-23 and Ministry of Commerce and Industry (various years) for 1924-33. Silk fabrics include silk-cotton mixed fabrics. Nominal value of export data are taken from Toyo Keizai Shimposha (1975, p. 230 and p. 50). Deflater is price index of textile products from Ohkawa et al. (1967).

Figure 11. Changes in Real Value of Domestic Production and Export of Silk Fabrics, 1886-1933 (million yen)



Notes and Sources: Hashino (2016) and Hashino (2019). Deflater is price index of textile products from Ohkawa et al. (1967).

Figure 12. Changes in the Number of Hand Looms (HL) and Power Looms (PL) in the Three Traditional Silk Weaving Clusters, 1886-1930



Notes and Sources: Same as Figure 11.

Table 1. Export Shares of the Textile Products and the Number of Workers in the Textile Industries in the Prewar Japanese Economy in Selected Years

	1894	1910	1930
Export shares (%):			
Cotton yarn	0.8	9.9	1.0
Raw silk	34.8	28.4	28.3
Cotton fabrics	1.6	4.5	18.5
Silk fabrics	7.5	7.2	4.5
Number of workers (1,000)			
Cotton spinning	10.2	29.0	43.0
Silk reeling	117.6	n.a.[b]	509.1
Cotton weaving	} 943.6[a]	} 761.3[a]	221.8
Silk weaving			206.5

a. Only the total in the cotton and silk weaving industry is available.

b. Not available.

Sources: Export data from Toyo Keizai Shimposha (1975, p.2, p. 50, p. 55, p. 72, p. 76). Number of workers in cotton spinning and raw silk from Fujino et al. (1979, p. 257, pp. 300-301); Number of workers in a total of cotton silk fabric production from Ministry of Agriculture and Commerce (1900, 1910). Number of workers in the cotton and silk weaving industries in 1930 is from the Ministry of Commerce and Industry (1930).

Table 2. Import of Cotton to Japan by County of Origin in Selected Years

	Total amount (1000 tons)	Composition (%)				
		China	India	U.S.	Egypt	Others
1884	45	97.3	2.7	0.0	0.0	0.0
1890	333	73.6	21.0	5.3	0.0	0.0
1897	2,229	22.4	62.0	15.6	0.0	0.0
1902	3,386	23.1	53.3	21.6	2.0	0.0
1907	4,601	14.7	58.0	24.2	1.5	1.6
1914	7,839	4.7	70.1	21.7	3.2	0.3
1921	8,605	0.3	60.7	35.4	1.7	1.9
1930	9,573	7.3	49.4	40.6	1.9	0.8
1934	13,554	2.4	42.7	47.9	4.1	2.9

Sources: Sampei (1941).