

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

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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). This was notable in the modern cotton-spinning industry, which used imported British ring machines and Indian cotton, resulting in Japan outcompeting India in the 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 using imported technologies. This study explores key factors contributing to the successful industrial development in prewar Japan based on a review of the development paths 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.

**Keywords:** selective technology choice; technological adaptations; labor-intensive industrialization; flying-geese pattern of development, cotton industry; silk industry, prewar Japan

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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. By taking advantage of backwardness, Japan caught up with Europe by importing advanced technologies.<sup>1</sup> 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 was concerned with the structural transformation of the Japanese economy during the prewar period.<sup>2</sup> He argues that Japanese industries developed following the inverse V-shape growth path like a flock of wild geese flying. To him, the import of modern goods increases and then declines because domestic production begins and expands, leading to export launching, followed by decreases in domestic production, and eventually, export due to the loss of comparative advantage. He further argues that such a growth pattern, first observed in the cotton-spinning industry, was followed by another flying geese pattern of development in other industries, such as the cotton-weaving industry. Although import substitution is assumed to be assisted by technology import, the process of importing technology is not explicitly incorporated into his flying geese model.

Sugihara argues that Japanese industrial development is characterized by a labor-intensive

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<sup>1</sup> Gerschenkron, *Economic backwardness in historical perspective*; Ohkawa and Rosovsky, *Japanese economic growth*.

<sup>2</sup> Akamatsu, 'A historical pattern of economic growth in developing countries'.

path, using labor-intensive technology in labor-using industries, particularly in the early phase of modern economic development.<sup>3</sup> Considering that Japan was a highly labor-abundant country at 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 that also had abundant labor.

This study explores the key factors leading to the successful industrial development in prewar Japan based on a review of the development paths of four major textile industries (i.e., cotton-spinning and -weaving and silk-reeling and -weaving industries). As 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 many case studies on the development of the modern cotton-spinning industry,<sup>4</sup> cotton-weaving districts,<sup>5</sup> silk-reeling industry,<sup>6</sup> and silk-weaving districts.<sup>7</sup> This study attempts to synthesize the accumulated insights of these studies. Specifically, we hypothesize that the unique and common

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<sup>3</sup> Sugihara, ‘Labour-intensive industrialization in global history: An interpretation of East Asian experiences’; idem, *Miraculous development of East Asia in global history: departure from Euro-centric global history*.

<sup>4</sup> Saxonhouse, ‘A tale of Japanese technology diffusion in the Meiji Period’; idem, ‘Productivity change and labor absorption in Japanese cotton spinning, 1891–1935’; Otsuka et al. *Comparative technology choice in development: the Indian and Japanese cotton textile industries*; Braguinsky and Hounshell ‘Spinning tales about Japanese cotton spinning: Saxonhouse (1974) and lesson from new data’; Braguinsky et al. ‘Acquisitions, productivity, and profitability: evidence from the Japanese cotton spinning industry’.

<sup>5</sup> Abe, *Development of cotton weaving districts in Japan*; Sasaki, *Industrialization in Asia and Japan: production organization and labor in mechanized weaving*; Tamura, *Socio-economic history of fashion*; Tanimoto, *Indigenous economic development and the weaving industry in Japan*.

<sup>6</sup> Nakabayashi, *Organization of modern capitalism: governance of transactions and structure of production in the development process of the silk reeling industry*; Uchida, *History of textile technologies in Japan*.

<sup>7</sup> Hashino and Otsuka, ‘Hand looms, power looms, and changing production organizations: the case of the Kiryū weaving district in early twentieth-century Japan’; idem, ‘Cluster-based industrial development in contemporary developing countries and modern Japanese economic history’; Hashino, ‘Contrasting development paths of silk-weaving districts in modern Japan’; idem, ‘From Lyon to Kyoto: the modernization of a traditional silk-weaving district in Japan’.

feature of the industrial development in prewar Japan was the selective choice of appropriate foreign technologies, combined with their adaptations to factor endowments in prewar Japan, including skill endowment in the traditional textile districts. In the late 19th century, we found that Japan did not always introduce the most advanced technology (e.g., power looms) or selected labor-intensive technology (e.g., handlooms), or even labor-saving technology, such as Jacquard. Also noteworthy is the adaptation of ring-spinning technology to the abundant endowment of labor by developing a unique labor-intensive cotton-mixing technique.<sup>8</sup> 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.** export shares of textile products and number of workers in the textile industries in the prewar Japanese economy (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. <sup>b</sup>	509.1
Cotton weaving	} 943.6 <sup>a</sup>	} 761.3 <sup>b</sup>	221.8
Silk weaving			206.5

*Notes:* <sup>a</sup>Only the total in the cotton- and silk-weaving industry is available. <sup>b</sup>Data is not available.

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

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<sup>8</sup> Ranis, ‘Factor proportions in Japanese economic development’, p. 594, pointed out that in prewar Japan, “There was no wholesale adoption of the advanced techniques elsewhere perfected and now available to her.”

We do not argue that such selective technology choice and adaptations are “causes” for successful industrial development, as technology choice and adaptations are “endogenous” decision variables. We would like to emphasize that the cotton textile and silk industries would not have developed so successfully without appropriate technology choices and adaptations, including the choice of quality and types of cotton and silk products.

The organization of this article is as follows. In the next section, 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 the critical roles played by technology choice and adaptations in the development of these industries. The section after briefly explores the development and technology choices of selected traditional cotton-weaving districts. Then the production and export of raw silk and the supply of raw silk to domestic silk-weaving districts from the traditional and modern silk-reeling industries are discussed. Given that the discussion of detailed production data of the traditional cotton-weaving districts is limited, we pay more attention to contrasting patterns of the development of three silk-weaving districts, for which the detailed data are available. We conclude this study by summarizing lessons from the development experiences of the textile industries in prewar Japan.

## **2. TECHNOLOGY CHOICE AND DEVELOPMENT OF THE MODERN COTTON TEXTILE INDUSTRY**

The cotton textile industry consists of the cotton-spinning and -weaving industries. While the traditional cotton-spinning industry collapsed in the mid-19<sup>th</sup> century due to the import of cheaper and higher quality yarn, as in the case of Southeast Asian countries, the traditional cotton-weaving industry dominated over the modern cotton-weaving industry in prewar Japan.<sup>9</sup> We would like to examine changes in import, domestic production, and export of cotton yarn and fabrics and 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?**

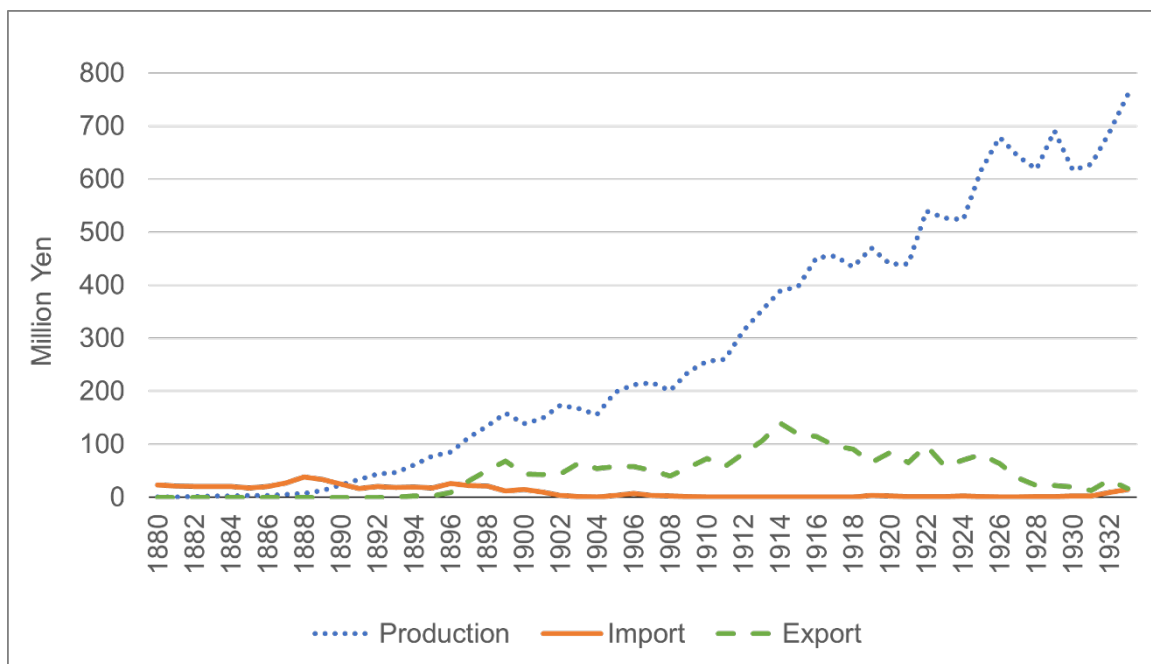
To examine the validity of the flying wild geese model of development, Figure 1 shows changes in import, domestic production, and export of cotton yarn over 52 years. If we focus on the period before the turn of the century, the data are consistent with the prediction of the flying geese model; import increased, followed by a rapid increase in domestic production from 1888 to 1898, and later by an increase in export. However, the production and trade structures changed markedly in the subsequent 30-year period: while the production continued to increase, 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

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<sup>9</sup> Uchida, *History of textile technologies in Japan*; Hymer and Resnick, 'A model of an Agrarian economy'; Resnick, 'The decline of rural industry under export expansion: a comparison among Burma, Philippines, and Thailand'

yarn by the cotton-weaving industry.<sup>10</sup>

Figure 2 shows changes in import, domestic production by traditional and modern sectors, and export of cotton fabrics.<sup>11</sup> Unlike the case of cotton yarn, the 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 cotton fabric production for centuries. The majority were clustered, and many were located in rural towns and cities.<sup>12</sup> Their production increased steadily from 1887 to 1915 and sharply from 1915 to 1933 except during the Great Depression when export declined precipitously.



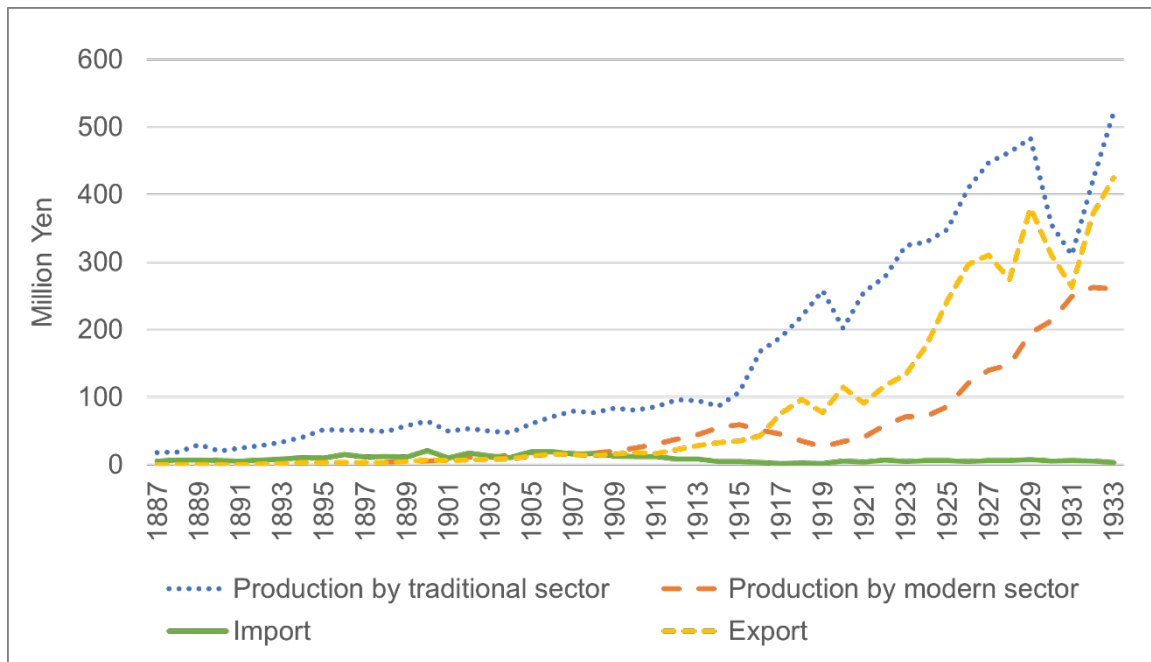
**FIGURE 1** Changes in the real value of import, domestic production, and export of cotton yarn, 1880–1933 (million yen).<sup>a</sup> Sources: <sup>a</sup>Deflated by cotton yarn price index (1934–36=100). Nominal values are deflated by the price index of cotton yarns, 1934–36=100, taken from Fujino et al. (1979, p. 247). The nominal value of production for 1880–93 is from Otsuka et

<sup>10</sup> Kuwahara, *Historical analysis of internationalization of firms*; Takamura, *Introduction to the history of the textile industry in Japan: part I*.

<sup>11</sup> As explained in the footnote for Figure 2, the production of the traditional sector is estimated by subtracting the production of the modern sector from the total production. This procedure can be justified by the finding of Abe (1989, pp. 17–20) that total amount of cotton fabric production reported by the Ministry of Agriculture and Commerce and the Ministry of Commerce and Industry includes the production of the modern weaving sector.

<sup>12</sup> Abe, *Development of cotton weaving districts in Japan*.

al. (1988, pp. 28–29). Since the price index before 1890 is not available, we assume that prices before 1890 did not change. The 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 1890.



**FIGURE 2** Changes in the real value of import, domestic production by traditional and modern sectors, and export of cotton fabrics, 1887–1933 (million yen). Sources and notes: Nominal values are deflated by the price index of cotton textiles, 1934–36=100, 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 data before 1890 are not available, we assume that prices before 1890 did not change. The 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 the Ministry of Agriculture and Commerce (various years) for 1915–23 and the Ministry of Commerce and Industry (various years) for 1924–33. Production of the traditional sector is estimated by subtracting the production of the modern sector from total production.

The modern spinning mills began producing cotton fabrics in the first decade of the 20<sup>th</sup> century, but their production was 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 the flying shuttle, foot-operated “handlooms,” and Jacquard.<sup>13</sup> The continuously increased

<sup>13</sup> Kiyokawa, *Economic development and technology diffusion*.

production of cotton yarn without the 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 the export of cotton fabrics generally exceeded the production by the modern sector, which implies that the traditional sector was also responsible for the continued growth of exported cotton fabrics.<sup>14</sup> 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 export-led growth in the early 20<sup>th</sup> 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 mules and ring-spinning machines, was more capital-intensive than the traditional cotton-weaving industry that used handlooms. Yet, the former grew more rapidly than the latter in the late 19<sup>th</sup> century (see Figure 1 and Figure 2). Such observation appears inconsistent with the labor-intensive growth envisaged by Sugihara.<sup>15</sup> It seems more sensible to argue that the development of the 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.

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<sup>14</sup> Abe, *Development of cotton weaving districts in Japan*.

<sup>15</sup> Sugihara, 'Labour-intensive industrialization in global history: An interpretation of East Asian experiences'; idem, *Miraculous development of East Asia in global history: departure from Euro-centric global history*.

Using primarily long-term economic statistics of Japan, Figure 3 shows changes in the spindle-labor ratio in the cotton-spinning industry and capital stock-labor ratio in the modern cotton textile industry as a whole.<sup>16</sup> Labor is measured by person-days. Since male workers were important in the early phase but gradually replaced by female labor,<sup>17</sup> whose wage rate was roughly one-half of the 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 the male-female wage ratio. Capital stock estimates are available only for the modern cotton textile industry, comprised of the spinning and weaving sectors. Thus, the spindle-labor ratio is a proxy for the capital-labor ratio in the cotton-spinning industry. The potential problem of the spindle-labor ratio is that although mule spinning machines were exclusively used before 1885, they were largely replaced by ring machines in the following 10 years;<sup>18</sup> this ratio does not distinguish between the spindles of the two types of machines. However, the total cost of installing the mule spindle and the ring spindle was roughly the same.<sup>19</sup> Furthermore, the estimated capital stock-labor ratio pertains solely to the cotton-spinning sector before 1910, when cotton textile mills exclusively produced cotton yarn. Therefore, comparing the spindle-labor ratio with the capital stock-labor ratio can check the accuracy of the former as a measure of the capital-labor ratio.

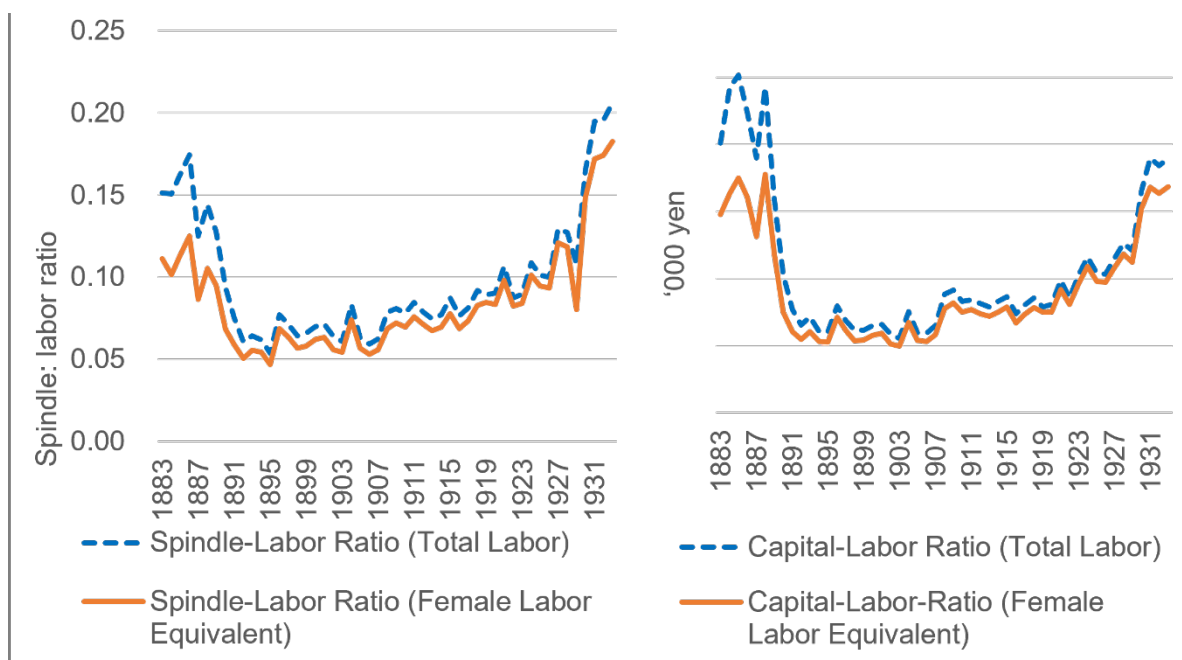
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<sup>16</sup> Fujino et al., *Estimates of long-term economic statistics of Japan since 1868: textile*.

<sup>17</sup> Female workers accounted for 64% in 1884, 72% in 1890, and 78% in 1900.

<sup>18</sup> Otsuka et al. *Comparative technology choice in development: the Indian and Japanese cotton textile industries*.

<sup>19</sup> Ibid



**FIGURE 3** Changes in the spindle-labor ratio in the cotton-spinning industry (left) and real capital stock-labor ratio (right) in the modern cotton-spinning industry, 1883–1933. *Notes and Sources:* Data on the number of spindles were 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 were interpolated. Labor input, measured by person-days, 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 were taken from Fujino et al. (1979, pp. 250–51).

Regardless of the measures of capital-labor ratio, it is remarkable that the ratio declined sharply from 1885 to 1895. As mentioned earlier, this was when ring machines were rapidly introduced. The operation of the ring machine is speedier than the mule machines and, hence, the former is more efficient than the latter if cotton yarns are not broken. However, if short staple cotton is used, only mule machines can be used as the 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. Among the developing countries, only Japan used ring machines in combination with short staple cotton.<sup>20</sup> As shown in Table 2, Japan exclusively imported short staple Chinese cotton in

<sup>20</sup> Saxonhouse and Wright, 'New evidence on the stubborn English mule and the cotton industry, 1878–1920'.

1884 but rapidly increased the import of Indian cotton since then.<sup>21</sup>

**TABLE 2.** Import of cotton to Japan by county of origin in selected years

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

Actually, Japan developed a unique cotton-mixing technique. It was highly unskilled, cheap, and female labor-intensive, but it was identified as epoch-making technological progress by Saxonhouse.<sup>22</sup> Many female workers were employed to sort out and skillfully mix relatively long and short staple cotton to operate the ring machines.<sup>23</sup> Ring spindles accounted for only 4% of total spindles in 1883 but increased to 65% in 1890.<sup>24</sup> Uchida pointed out that cotton mixing using cheap short staple cotton reduced costs.<sup>25</sup> Starting with the spindle-worker ratio of nearly 30 in the 1880s, which was somewhat lower than the ratio of 40 in India around 1885, Japan reduced its spindle-worker ratio to

<sup>21</sup> According to Otsuka et al. (1988, p. 25), Japanese cotton accounted for 14.3% of cotton staple used in 1890 and nil in 1900.

<sup>22</sup> Saxonhouse, 'Productivity change and labor absorption in Japanese cotton spinning, 1891–1935'.

<sup>23</sup> Otsuka et al., *Comparative technology choice in development: the Indian and Japanese cotton textile industries*; Saxonhouse and Wright, 'National leadership and competing technological paradigms: the globalization of cotton spinning, 1878–1933'.

<sup>24</sup> Otsuka et al., *Comparative technology choice in development: the Indian and Japanese cotton textile industries*, p. 208.

<sup>25</sup> Uchida, *History of textile technologies in Japan*.

one-half or even to one-third in 10 years.<sup>26</sup> Almost simultaneously, Japan increased the production and export of cotton yarn to the Asian market (see Figure 1). This labor-using technological progress made it possible for Japan to become a major producer of cotton yarn globally. Although this is consistent with the labor-intensive growth view of Japanese industrial development, it must be emphasized that it was not simply the result of technology choice but more of technological adaptations.<sup>27</sup> Cotton mixing was practiced in India to a limited extent, but cotton mills did not employ mixing using ring technology.<sup>28</sup> One factor leading to the relatively greater use of mules and delayed introduction of rings in India was the preference of Indian consumers for finer count yarns produced by mules (Otsuka et al. p. 178).<sup>29</sup> As suggested by Figure 3, and more rigorously confirmed by econometric analyses by Saxonhouse and Braguinsky et al., subsequent technological progress was labor-saving and capital-using.<sup>30</sup> 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.<sup>31</sup> It is well-known that the real wage 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 the “turning point”

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<sup>26</sup> Note that labor is measured by the number of workers in the discussion in the text, whereas it is measured by person-days in Figure 3. The trends of spindle-labor ratio, however, are similar between the two cases using different measures of labor.

<sup>27</sup> The impact of adopting two-shifts of production on measured capital-labor ratio is likely to be small because the adoption of two-shifts was common already by 1884 (Takamura 1971, p. 102).

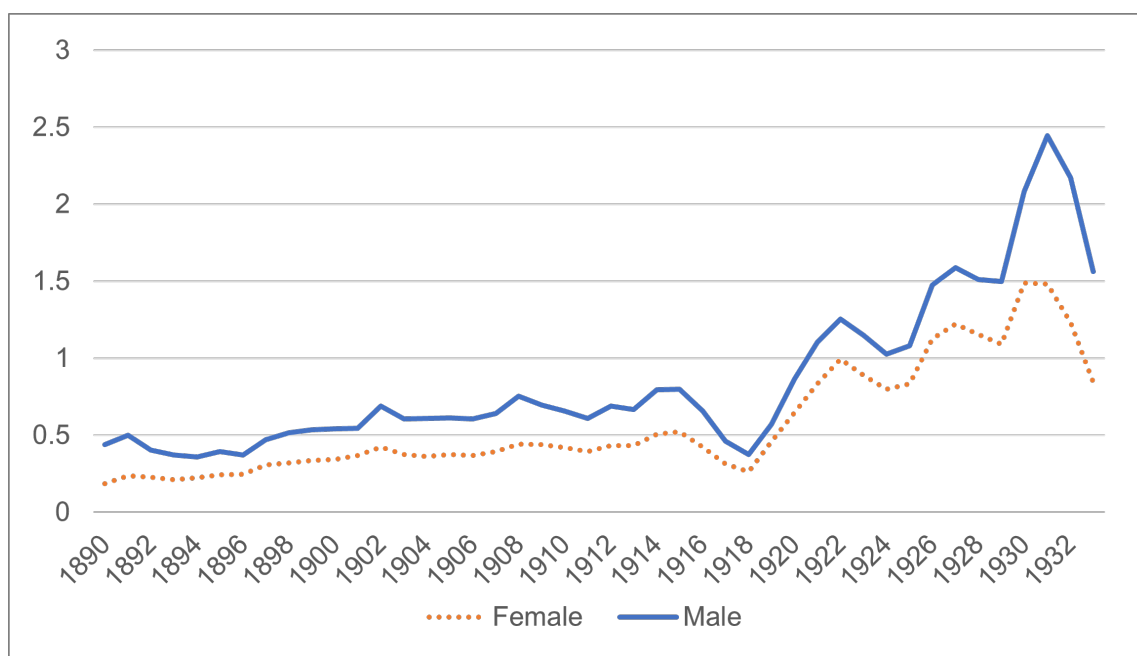
<sup>28</sup> Otsuka et al., *Comparative technology choice in development: the Indian and Japanese cotton textile industries*, p. 54.

<sup>29</sup> *Ibid.*, p. 178.

<sup>30</sup> Saxonhouse, ‘Productivity change and labor absorption in Japanese cotton spinning, 1891–1935’; Braguinsky et al. ‘Acquisitions, productivity, and profitability: evidence from the Japanese cotton spinning industry’.

<sup>31</sup> Ranis (1957) was the first study that pointed out changing capital-labor ratios from labor-using to labor-saving directions in the course of the development of the cotton-spinning industry in prewar Japan.

by Fei and Ranis.<sup>32</sup> In all likelihood, not only did the substitution of labor by capital occur, but labor-saving technological progress also took 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 the 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.<sup>33</sup>



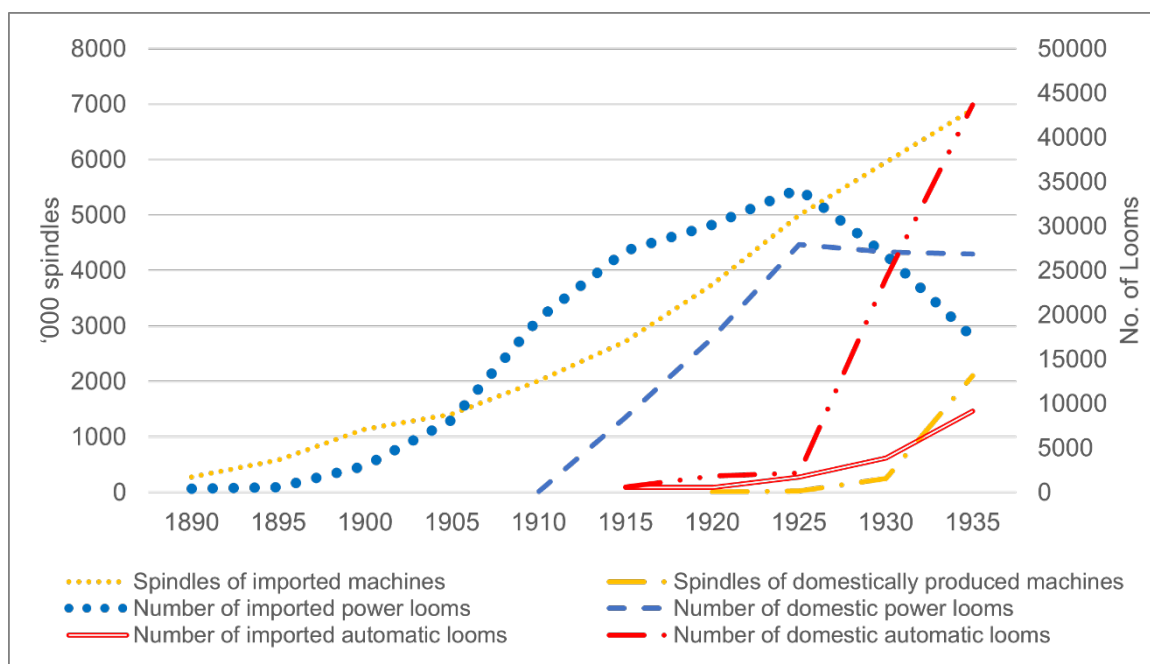
**FIGURE 4** Changes in real wage rate by male and female workers in the cotton-spinning industry, 1890–1933 (yen per day). *Notes and Sources:* Wage data were taken from Fujino et al. (1979, pp. 273–74), the deflator is the price index of cotton yarns (1934–36 = 100) taken from Fujino et al. (1979, p. 247).

Japan relied almost entirely on imported spinning machines until 1930 (Figure 5). Although quantitative data are not available, Japanese cotton-spinning companies increasingly used high-speed,

<sup>32</sup> Fei and Ranis, *Development of the labor surplus economy*.

<sup>33</sup> Sanpei, *History of development of the cotton textile industries in Japan*.

high-draft ring machines.<sup>34</sup> 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 in 1897, among others, by Sakichi Toyoda, the father of the founder of the Toyota Automobile Company. The development of such cheap, capital-saving technology can be considered an adaptation by the labor-abundant and capital-scarce Japanese economy. According to Kiyokawa (1995, pp. 172–74), an imported power loom costs JPY 400 to JPY 6,000, whereas mixed iron and wooden power looms cost JPY 30 to JPY 40 in the late 1890s.



**FIGURE 5** Use of imported and domestically-produced spinning machines (number of spindles), power looms, and automatic looms in the modern cotton textile industry, 1890–1935. Source: Otsuka et al. (1988, pp. 142–43).

Labor abundance ended at the “turning point,” and power looms were replaced by automatic looms in the 1920s. As shown in Figure 5, the use of both imported and domestically-produced

<sup>34</sup> Saxonhouse, ‘A tale of Japanese technology diffusion in the Meiji Period’.

automatic looms increased slowly together from 1915 to 1925, but after that, domestic automatic looms produced by the 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 the cotton-mixing technology in the early phase of industrial development and the adoption of labor-saving technologies in subsequent periods were guided by the level and changes in factor endowment in the Japanese economy from the late 19<sup>th</sup> century to the early 20<sup>th</sup> century.

### **3. TECHNOLOGY CHOICE AND DEVELOPMENT OF THE TRADITIONAL COTTON-WEAVING INDUSTRY**

Japanese economic historians have conducted many case studies on the development of the traditional cotton-weaving districts.<sup>35</sup> Particularly noteworthy is the study of Abe, who identified 27 major traditional districts located in 12 prefectures and classified them into export-oriented and domestic market-oriented ones, among others.<sup>36</sup> The Ministry of Agriculture and Commerce conducted surveys of some of the cotton-weaving districts identified by Abe.<sup>37</sup> This study focused on the Iruma weaving district in the Saitama prefecture (Itoh and Tanimoto 1998) and the Enshu weaving district in the Shizuoka prefecture.<sup>38</sup> Although the Saitama and Shizuoka prefectures were not major cotton fabric-

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<sup>35</sup> Abe, *Development of cotton weaving districts in Japan*; Sasaki, *Industrialization in Asia and Japan: production organization and labor in mechanized weaving*; Tamura, *Socio-economic history of fashion*; Tanimoto, *Indigenous economic development and the weaving industry in Japan*.

<sup>36</sup> Abe, *Development of cotton weaving districts in Japan*.

<sup>37</sup> Ministry of Agriculture and Commerce, A survey of woven fabrics of hosiery.

<sup>38</sup> Itoh and Tanimoto, 'Rural entrepreneurs in the cotton weaving industry of Japan'; Yamazaki, 'The sudden growth of the Enshu cotton textile industry between the two world wars'.

producing regions in prewar Japan, detailed prefecture-level data are available.<sup>39</sup> Furthermore, the two prefectures represent domestic market-oriented and export-oriented weaving districts and contrast in types of products produced, as will be shown shortly.

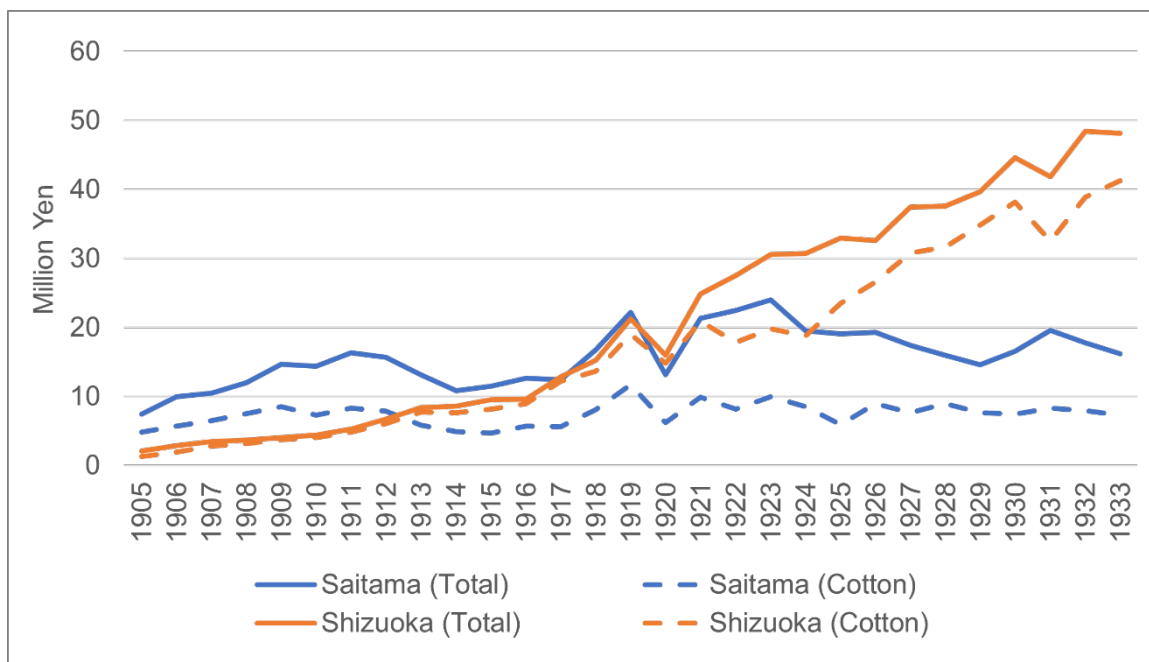
### **3.1. DOMESTIC PRODUCTION AND EXPORT IN SAITAMA AND SHIZUOKA PREFECTURES**

Figure 6 shows the real value of all fabric and cotton fabric production in the Saitama and Shizuoka prefectures from 1905 to 1933. It can be noted that Saitama was a more important producer of cotton and other fabrics 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 modern cotton-spinning industry's newly-emerged supply of high-quality cotton yarn. This is reminiscent of Schumpeter's argument that the discovery of new input is an important category of innovations.<sup>40</sup> Such inter-industry growth linkage was not considered by the flying geese model.

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<sup>39</sup> The 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.

<sup>40</sup> Schumpeter, *The theory of economic development*.



**FIGURE 6** Real value of production of total and cotton fabrics in the Saitama and Shizuoka prefectures, 1905–33. *Notes and Sources:* The nominal value of production data are taken from the Ministry of Agriculture and Commerce (various years) for 1905–23 and from the Ministry of Commerce and Industry for 1924–33. The deflator is the price index of cotton textiles from Fujino et al. (1979, p. 247).

While the production in Saitama had been largely stagnant after conservative growth from 1905 to 1910, the production in Shizuoka continued to increase for the entire 30-year period. Note that Saitama specialized in producing narrow-width cotton fabrics and other fabrics destined for domestic markets, whereas Shizuoka specialized mainly in producing plain wide-width cotton fabrics for export. In 1923, 10.5% of products were exported from Shizuoka, whereas only 2.0% were exported from Saitama. The export of cotton from Shizuoka accelerated in subsequent years.<sup>41</sup> Furthermore, cotton weaving using handlooms were considered farmers’ side-line activity in some cotton-weaving districts in Saitama.<sup>42</sup>

<sup>41</sup> Yamazaki, ‘The sudden growth of the Enshu cotton textile industry between the two world wars’.

<sup>42</sup> Itoh and Tanimoto, ‘Rural entrepreneurs in the cotton weaving industry of Japan’; Tanimoto, *Indigenous economic development and the weaving industry in Japan*.

### 3.2. CHOICE OF HANDLOOMS VS. POWER LOOMS

The difference between the stagnated production in Saitama and the sustainably growing production in Shizuoka corresponds to the difference in the speed of the 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).

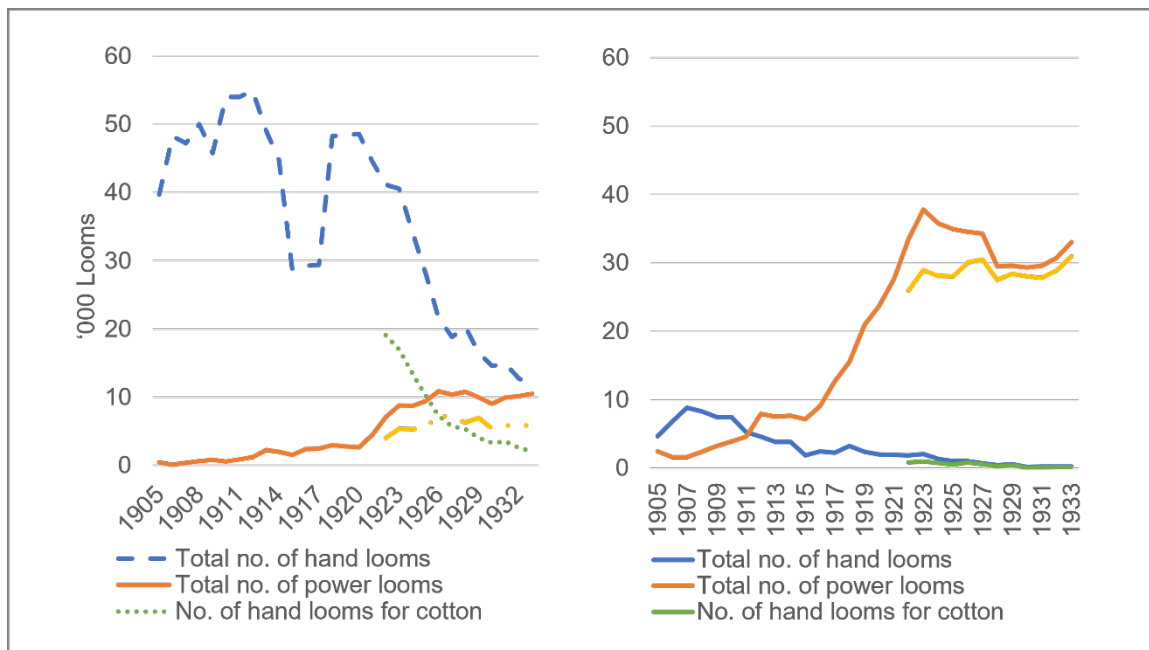
In Saitama, indigenously invented foot-operated looms were common, accounting for 35% of looms in 1923.<sup>43</sup> For simplicity, data on foot-operated looms were combined with handlooms in Figure 7.

Obviously, Saitama exclusively used handlooms in 1905 and produced a much larger volume of fabrics than Shizuoka. This means that the cotton-weaving district in Shizuoka was tiny or almost non-existent in 1905. Yet, Shizuoka began introducing flying shuttles and using foot-operated looms, which were twice as productive as handlooms.<sup>44</sup> In general, the number of handlooms was declining in both prefectures, whereas the number of power looms increased slowly and somewhat substantially after the turning point in Saitama but increased sharply since 1915 in Shizuoka. The rapid growth of cotton fabric production in Shizuoka (Figure 6) can be attributed to the rapid adoption of power looms in this prefecture.

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<sup>43</sup> Ministry of Agriculture and Commerce, A survey of woven fabrics of hosiery.

<sup>44</sup> Yamazaki, 'Structure and dynamism in the Enshu weaving district between the two World War', p. 98.



**FIGURE 7** Adoption of handlooms and power looms in Saitama (left) and Shizuoka (right) prefectures, 1905–33. *Sources:* Ministry of Agriculture and Commerce (various years) for 1905–23 and Ministry of Commerce and Industry for 1924–33.

Popular power looms used in Shizuoka used a mix of wood and iron types produced in the same prefecture. According to Kiyokawa, 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.<sup>45</sup> If the products are simple, plain fabrics, manual work done using handlooms can be easily substituted by power looms. Thus, there was higher adoption of power looms in Shizuoka, closely related to its export-orientation of simple cotton fabrics, and Shizuoka selected power looms as they fitted well with its production of simple fabrics.<sup>46</sup> Furthermore, the rapid adoption of power looms largely coincided with the rapid

<sup>45</sup> The share of imported power looms was a mere 3.3%. Kiyokawa, *Economic development and technology diffusion*, p. 179.

<sup>46</sup> In India, power looms were used to weave medium-count cotton yarn, but not coarse and fine types, which were woven by hand looms (Ray 2020, p. 42). This seems consistent with the use of power looms for simple fabrics in Japan. Minami and Makino, 'Conditions for technological diffusion: case of power looms'.

growth of the wage rate. These observations suggest that increased scarcity of labor induced the adoption of labor-saving technology in the traditional cotton-weaving districts, particularly those producing simple products. In fact, labor productivity significantly increased with the adoption of power looms throughout Japan.<sup>47</sup>

#### **4. TECHNOLOGY CHOICE AND DEVELOPMENT OF THE SILK-REELING INDUSTRY**

The silk-reeling industry in prewar Japan consisted of the mechanized modern and traditional sectors.

The modern sector adopted a factory system and used reeling machines imported mainly from Italy,

while the traditional sector used sedentary reeling technology for producing raw silk and douppion

raw silk. Machine-reeled silk yarn is finer, glossier, and more homogeneous with fewer nodes than

that produced by sedentary reeling.<sup>48</sup> Therefore, the price of the former was roughly 15% higher than

the latter.<sup>49</sup> Production methods employed by the traditional sector were much more labor-intensive.

A question is how the modern and traditional silk-producing sectors are related to the traditional silk-

weaving sector and the 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, the

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<sup>47</sup> Okazaki, 'Disentangling the effects of technological and organizational changes during the rise of the factory: the case of the Japanese weaving industry, 1905–14'.

<sup>48</sup> Uchida, *History of textile technologies in Japan*.

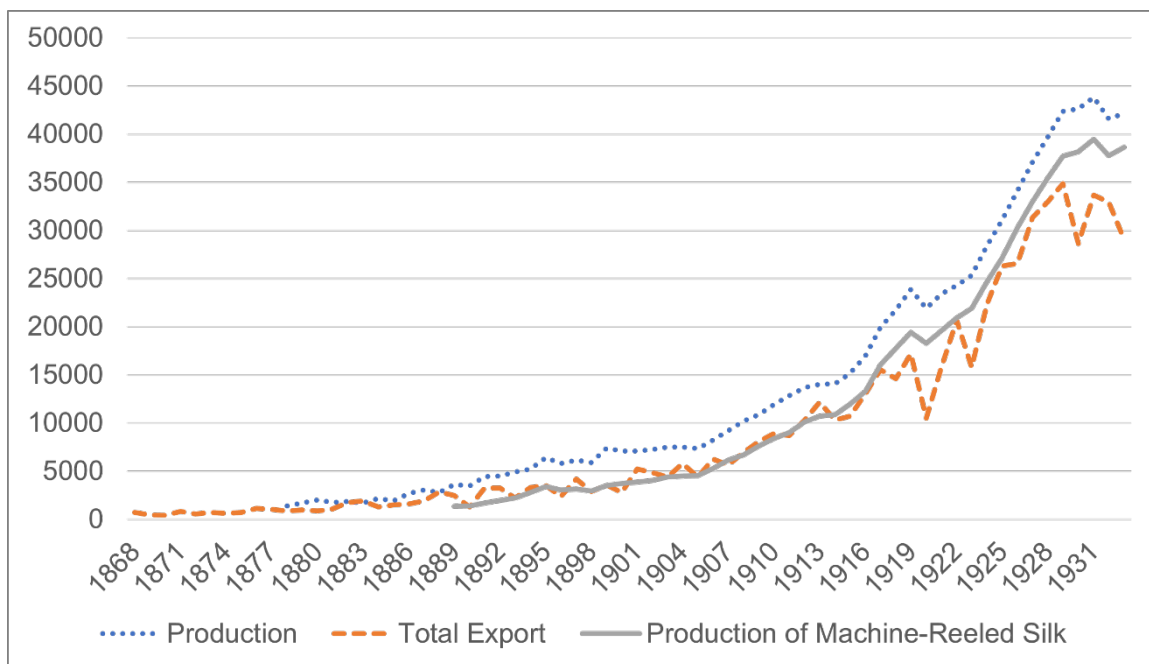
<sup>49</sup> Fujino et al., *Estimates of long-term economic statistics of Japan since 1868: textile*.

argument of the flying geese model does not apply. Figure 8 shows changes in the total volume of raw silk production in Japan from 1868 to 1933, 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 western technology was introduced. Nakabayashi shows that raw silk produced by the traditional method was exported to Europe in the 1860s and 1870s.<sup>50</sup> Second, the 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 the predominant importance of the modern silk-reeling industry. Fourth, the raw silk produced was mostly exported. The amount of export fluctuated widely, reflecting business cycles in advanced countries, particularly in the United States, which was a major importer of raw silk from Japan, owing to the rapid development of the mechanized silk-weaving industry.<sup>51</sup> Lastly, although the production share shrank, 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. Indeed, the production of the traditional sector exceeded that of the modern sector in the early 1890s.

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<sup>50</sup> Nakabayashi, *Organization of modern capitalism: governance of transactions and structure of production in the development process of the silk reeling industry*.

<sup>51</sup> Because of the rapid development of the mechanized silk-weaving industry in the U.S., the production of silk fabrics in the export-oriented Fukui weaving district collapsed (Hashino and Otsuka 2020).



**FIGURE 8** Changes in total raw silk production from 1878, production of machine-reeled silk from 1889 to 1993 (thousand kg), and export from 1868. *Source:* Fujino et al. (1979, pp. 294–95, p. 308).

A number of technologically-simple adaptations, but economically-important innovations, were made in mechanized reeling.<sup>52</sup> The process of cocoon cooking was mechanized and 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 costs and improved reeling efficiency. The most outstanding innovation was the multi-frame reeling machine designed by Minorikwa in 1904, which improved 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 United States to produce stockings made of silk. The Minorikwa reeling machine reduced the speed of spinning to prevent nodes and non-uniformity

<sup>52</sup> Uchida, *History of textile technologies in Japan*, pp. 195–99.

but increased the number of frames to compensate for the production loss associated with the reduction in speed. Such new machines with a number of new improvements became common around 1920. In all likelihood, these adaptive innovations contributed to the accelerated growth of raw silk production in the 1910s and 1920s (see Figure 8).

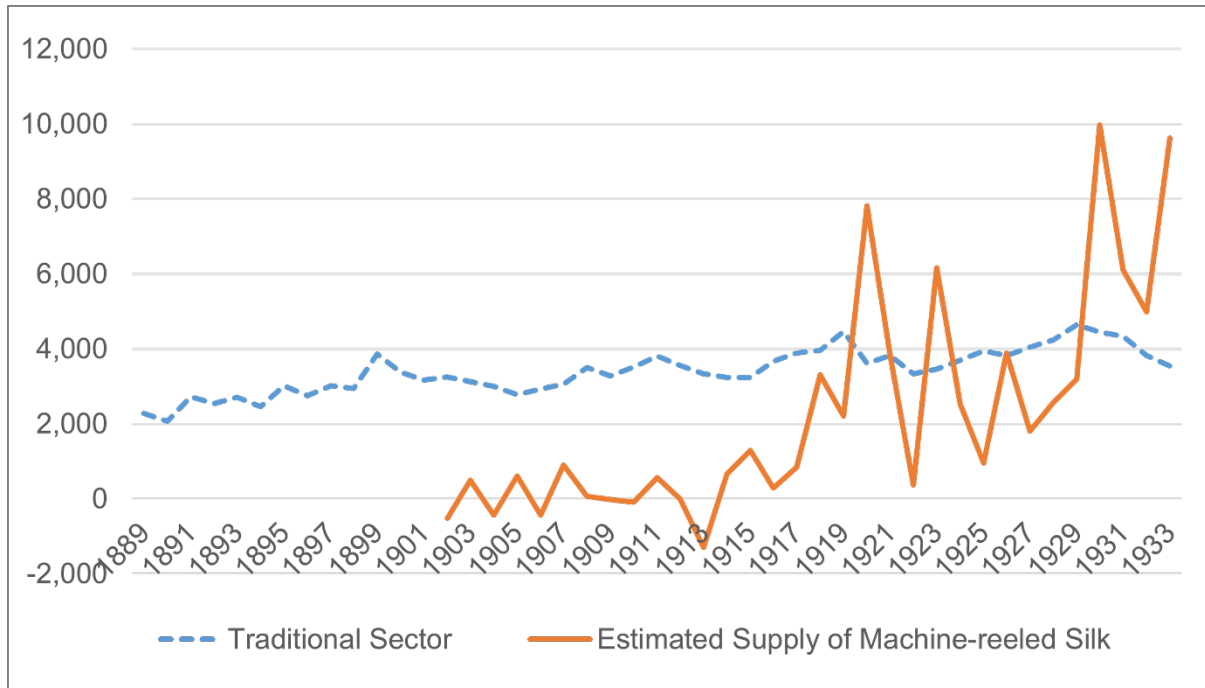
#### **4.2. SILK YARN SUPPLY TO THE WEAVING INDUSTRY FROM THE TRADITIONAL AND MODERN SECTORS**

It is known that silk produced by the traditional sector was used to produce Japanese *kimono* and *obi* produced exclusively by the traditional silk-weaving districts. The question is how much raw silk produced by the modern sector was supplied to the traditional silk-weaving districts. To answer this question, we estimated the volume of 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.<sup>53</sup> Figure 9 shows changes in silk production by the traditional sector and estimated supply of machine-reeled raw silk from the modern sector to domestic fabric production after 1889, for which the data are available. It is clear that the traditional sector was the dominant 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 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 with the foot-driven type, which doubled daily production

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<sup>53</sup> An assumption here is that only the modern sector exported raw silk, which is likely to be valid.

(Uchida 1960, pp. 195–96).<sup>54</sup> 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 to structural changes in the silk-weaving sector is an important issue examined in the next section.



**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, (thousand kg). *Source:* Fujino et al. (pp. 294–95).

## 5. TECHNOLOGY CHOICE AND DEVELOPMENT OF THE TRADITIONAL SILK-WEAVING INDUSTRY

Similar to the case of silk yarn, there was no import of silk fabrics to Japan; and the production of all 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

<sup>54</sup> Uchida, *History of textile technologies in Japan*, p. 195–96.

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 the Japanese kimono and obi production, whereas Kiryu is an imitator of Nishijin.<sup>55</sup> Fukui was a newcomer that learned weaving technology from Kiryu and Nishijin and produced simple silk fabrics, called *habutae*, for export.<sup>56</sup>

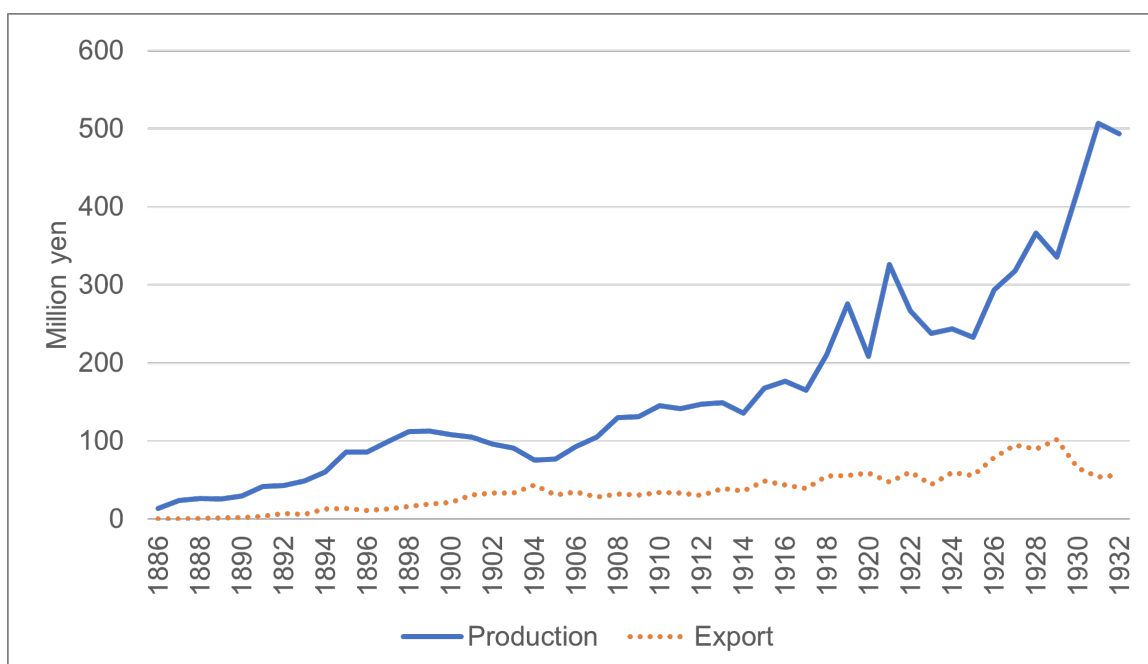
### 5.1. DOMESTIC PRODUCTION AND EXPORT OF SILK FABRICS

Figure 10 shows changes in the real value of production and export of silk fabrics from 1886 to 1932. The production increased substantially from 1886 toward the end of the 19<sup>th</sup> century, termed the “initial growth phase.” This indicates that the industrial districts were tiny in the 1880s. The initial growth phase was followed by a prolonged slow growth period from 1900 to 1918. This “slow growth phase” was followed by a “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 the rapid growth phase corresponds to substantial increases in the supply of raw silk produced by the modern sector for the traditional weaving sector (see Figure 9).

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55 Hashino, ‘From Lyon to Kyoto: the modernization of a traditional silk-weaving district in Japan’; Hashino and Otsuka, ‘Hand looms, power looms, and changing production organizations: the case of the Kiryū weaving district in early twentieth-century Japan’; Hashino and Otsuka, *Industrial districts in history and the developing world*.

56 Hashino and Otsuka, ‘The rise and fall of industrialization: the case of a silk weaving district in modern Japan’.



**FIGURE 10** Changes in the real value of domestic production and export of silk fabrics, 1886-1933 (million yen). *Notes and Sources:* Data on the nominal values of the total production of silk fabrics are from the Ministry of Agriculture and Commerce (various years) for 1915–23 and the Ministry of Commerce and Industry (various years) for 1924–33. Silk fabrics include silk-cotton mixed fabrics. The nominal values of export data are taken from Toyo Keizai Shimposha (1975, p. 230 and p. 50). The deflator is the price index of textile products from Ohkawa et al. (1967).

Unlike the case of raw silk, the export of silk fabrics was small, even though it increased modestly from 1918 to 1930. Indeed, the truly traditional silk-weaving districts, such as Nishijin and Kiryu, specialized in production for the domestic market while the newly-emerged Fukui weaving district specialized in production for export. This indicates that Japan did not have a strong comparative advantage in silk fabric production, unlike raw silk.

## 5.2. PRODUCTION IN THE THREE SILK-WEAVING DISTRICTS

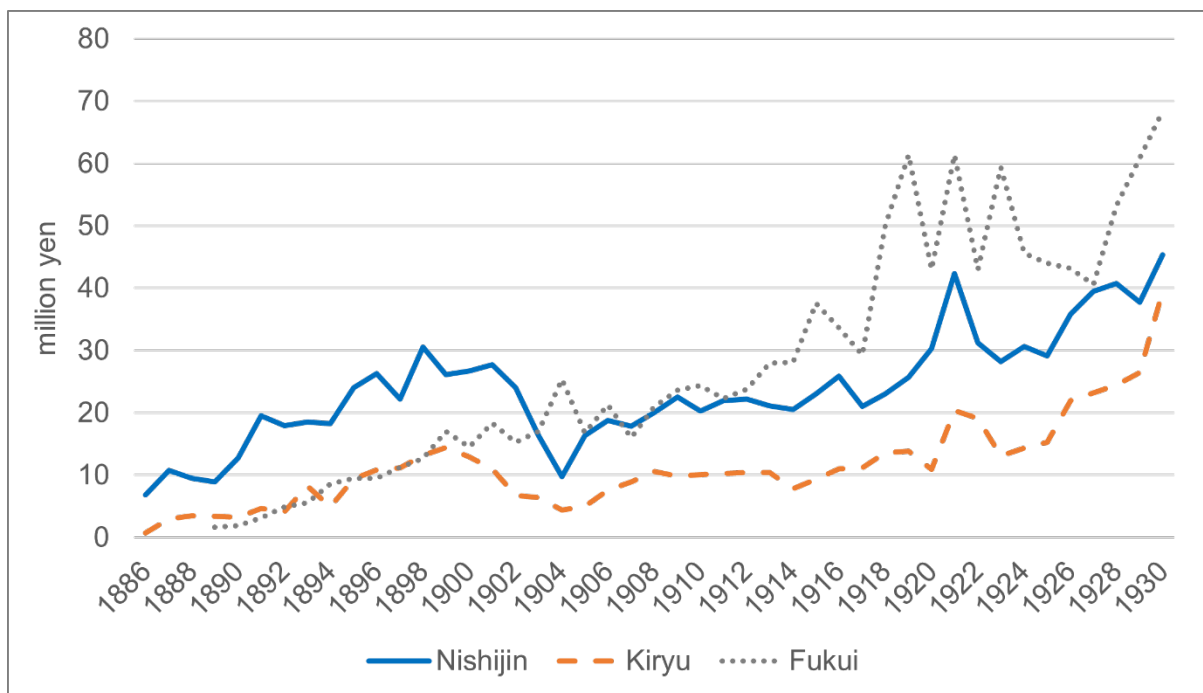
As shown in Figure 11, Nishijin was the largest silk-weaving district in 1886. However, its production value was small, amounting to less than one-fifth of the level in 1930, indicating that this had been the

so-called “survival” cluster without any growth before the initial growth phase. According to Hashino, the Kyoto prefectural government sent three craftsmen from Nishijin to Lyon in 1872 to learn advanced technologies.<sup>57</sup> At the time, Lyon was the most advanced silk-weaving district globally. In particular, the craftsmen were requested to purchase power looms widely used in Lyon at that time. Curiously, however, these craftsmen decided that the use of power looms was too expensive for most of the 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. Instead, they brought back two devices: the Jacquard and the flying shuttle. Jacquard is a highly labor-saving device because the so-called draw boys who pull yarn from the roof of a handloom are replaced by the Jacquard device. According to Hashino, the worker-handloom ratio changed from 3:1 to 1:1 due to the introduction of the Jacquard.<sup>58</sup> In other words, the Jacquard saved labor costs 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 after that, 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 the Saitama cotton-weaving district (Figure 6).

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<sup>57</sup> Hashino, ‘From Lyon to Kyoto: the modernization of a traditional silk-weaving district in Japan’.

<sup>58</sup> Ibid



**FIGURE 11** Changes in the real value of domestic production and export of silk fabrics, 1886–1933 (million yen)

The growth pattern of Kiryu was similar to that of Nishijin, as the former was an imitator of the latter. Jacquard was introduced, and handlooms were used in the initial growth phase. This suggests that the stagnant and small local weaving district of Kiryu 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).<sup>59</sup>

Traditionally, the silk fabric produced in Fukui was the traditional type, small, and destined only for the domestic market in the 1870s. To build a new silk-weaving district, the Fukui prefectural government invited an instructor from Kiryu to train the local people in the late 1870s (Hashino and

<sup>59</sup> Hashino and Otsuka, 'Hand looms, power looms, and changing production organizations: the case of the Kiryū weaving district in early twentieth-century Japan'.

Otsuka 2020).<sup>60</sup> Unlike Nishijin and Kiryu, there were no skilled workers making silk fabrics in Fukui. Thus, Fukui chose to produce simple silk fabrics, called *habutae*, for export. Earlier, Kiryu produced small amounts of *habutae*, but this was discontinued because the accumulated weaving skills of its weavers were not needed to produce such a simple product. Somewhat similar to Shizuoka's case, which was engaged in producing simple cotton fabrics for export, Fukui specialized in the production of *habutae* and succeeded in its expanded export. After 1910, Fukui's production value consistently exceeded Nishijin and Kiryu's.

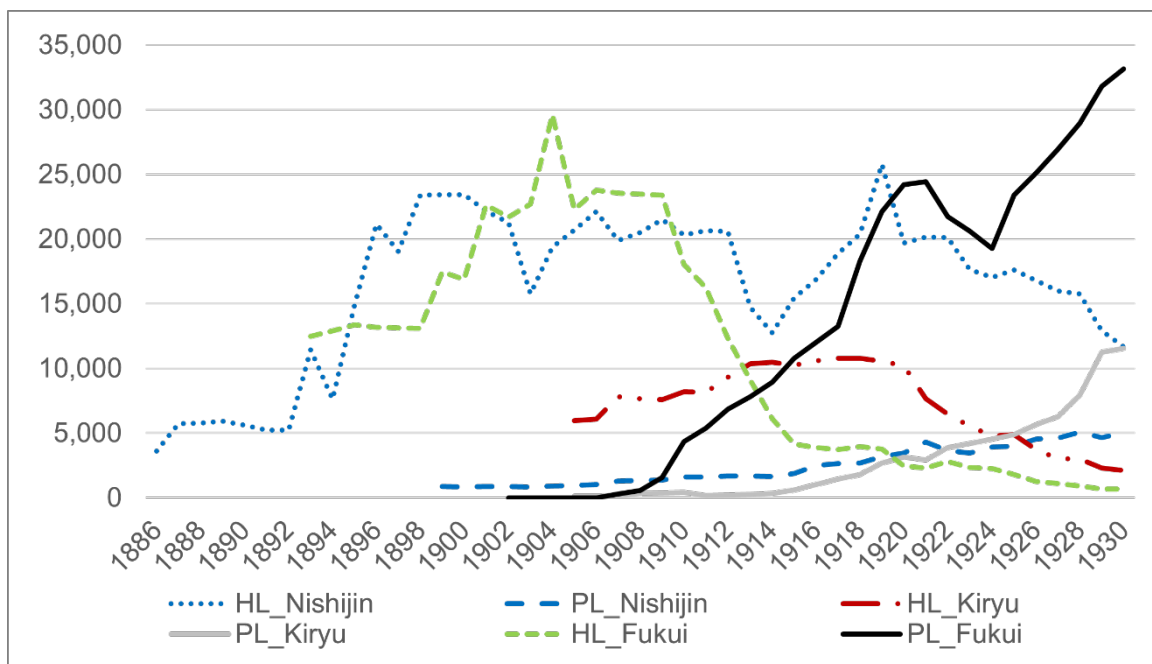
### 5.3. CHOICE OF HANDLOOMS VS. POWER LOOMS

Even though power looms were known, handlooms were predominantly used in the late 19th century (Figure 12). 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.<sup>61</sup> The choice of a handloom-based production system was probably a more appropriate selection from the menu of available western technologies.

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<sup>60</sup> Hashino and Otsuka, 'The rise and fall of industrialization: the case of a silk weaving district in modern Japan'.

<sup>61</sup> There were a few attempts to initiate large-scale factory production in Nishijin and Kiryu without notable success (Hashino and Otsuka 2013a; Hashino 2021).



**FIGURE 12** Changes in the number of handlooms (HL) and power looms (PL) in the three traditional silk-weaving clusters, 1886–1930

Power looms were widely disseminated much later in the 20<sup>th</sup> century. Fukui actively and massively adopted power looms and replaced handlooms 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, implying that Fukui used machine-reeled silk produced by the modern sector, which can be exported 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 more than a few workers that exported their products abroad.<sup>62</sup> The choice of

<sup>62</sup> Hashino, 'From Lyon to Kyoto: the modernization of a traditional silk-weaving district in Japan'.

technology, product types, and marketing channels were closely intertwined. This is consistent with the experience of the silk-weaving industry in India, where hand looms were predominantly used to produce saris, characterized by a variety of sophisticated designs constantly in demand by the domestic markets.<sup>63</sup>

We must also mention that production during 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 contractor-cum-merchants who procure yarns and request designs and dyeing to specialized processors before handing over yarns to out-weavers. The contractor-cum-merchants sell the final products to urban traders after requesting that the finishing process be done by other specialized processors. So far as complicated fabric production using handlooms is subject to scale diseconomies, such a production organization seems to be a rational adaptation to the rich skill endowment in the traditional silk-weaving districts.<sup>64</sup>

## 6. CONCLUDING REMARKS

In this study, we found that Japan made a number of critical technology choices and adaptations behind the successful development of the cotton textile and silk industries. In the late 19<sup>th</sup> century, the ring-spinning machine with cotton-mixing techniques was chosen over the mule spinning machine; sedentary reeling was chosen over machine reeling; and the handloom, with Jacquard in the case of silk

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<sup>63</sup> Roy, *The crafts and capitalism: handloom weaving industry in colonial India*.

<sup>64</sup> Hashino, 'Contrasting development paths of silk-weaving districts in modern Japan'; Hashino and Otsuka, 'Cluster-based industrial development in contemporary developing countries and modern Japanese economic history'.

weaving, was chosen over power looms. Overall, there was a clear tendency to choose labor-intensive production methods. 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 a cotton-mixing technique. The 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 an innovative division of labor among yarn processors, outweavers, and finishing processors in the production of sophisticated silk fabrics under the leadership of contractor-cum-merchants was an important adaptive institutional innovation.

As the wage rate increased, technology choice shifted toward labor-saving technologies. The ring machine was run without labor-intensive cotton-mixing techniques by importing long-staple cotton. Machine reeling dominated over sedentary reeling, and machine-reeled raw silk was shipped to the traditional 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 that introduced power looms more rapidly grew and became larger. These observations suggest that after the turn of the century, and particularly after World War I, labor-saving technological progress became appropriate.

Labor-saving technological progress accompanied the change in the products. Using long-staple cotton, higher quality or higher count yarns were produced in the cotton-spinning industry. Cotton- and silk-weaving districts actively adopted power looms and successfully exported massively.

In other words, the adaptation of main products to new labor-saving machines was actively made to sustain industrial growth with labor-saving technological changes. This was in sharp contrast with the Indian experience where power looms were not introduced even around 1900 because the main silk fabric being produced was for saris, which were deemed too sophisticated and diverse to be produced by power looms. Also earlier, the Indian spinning industry continued to use mules to produce the fine yarns demanded by its domestic markets.

To sum up, this study attempted to deepen our understanding of the process of technological catch-up in prewar Japan. We do not agree with 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 simplistic view that Japanese economic growth was characterized by a labor-intensive path because there was a clear shift from labor-using to labor-saving technological changes. It is probably fair to conclude that the 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 the real wage rate.

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