CONDITIONS FOR TECHNOLOGICAL DIFFUSION: CASE OF POWER LOOMS†

By RYOSHIN MINAMI* AND FUMIO MAKINO**

I. *Introduction*

Technological diffusion being an essential feature of the technological progress, a clarification of the conditions facilitating the diffusion must be substantial to a study of the technological progress. In this paper we intend to study the conditions for the diffusion of power looms, a leading technological change in the weaving industry until W.W.II.

(1) Introduction of Power Looms in Japan—A Brief History

Power looms were first introduced in Japan, three quarters of a century after the invention by Edmund Cartwright in 1785.[1] The Satsuma Clan imported power looms from England, and began weaving in a factory using water power as motive force, to weave cotton cloth between 1856 and 1858. In 1867, one hundred English-made looms, powered by water wheels, were introduced at its Kagoshima Spinning Mill. However, the substantial diffusion of power looms was not seen until the late 1880s. The first private cotton weaving factory to introduce power looms was the Shibuya Cotton Fabric Mill (later, Onagigawa Cotton Fabric Mill), which installed these looms in 1885. In the next ten years many large, export-oriented factories producing cotton fabrics were started. In 1887, for instance, Kyōto Cotton Weaving and Ōsaka Weaving were established.

Broad power looms (power looms for broad fabrics) installed in these and other large weaving plants established at this time were imports. Sakichi Toyoda invented a wooden power loom for narrow-width fabrics in 1897 and a power loom made of wood and iron in 1907. Toyoda also invented three types of all-iron machines in 1908, 1909 and 1914. After these developments, imported power looms were gradually replaced by domestic ones.

In contrast to the large weaving plants, which were equipped with modern technology from the time of their establishment in the 1880s, the small cotton weaving plants, which were decisively dominant over the former in number, continued to employ traditional hand looms until almost the turn of the century. Although these machines had been improved by the batten and jacquard apparatus, they were still operated by human power. The appearance of domestically produced power looms finally made mechanization of small weaving plants possible, as it brought the cost of these machines within the reach of the smaller

* Professor (*Kyōju*) of the Institute of Economic Research, Hitotsubashi University.
** Central Research Institute of Electric Power Industry.
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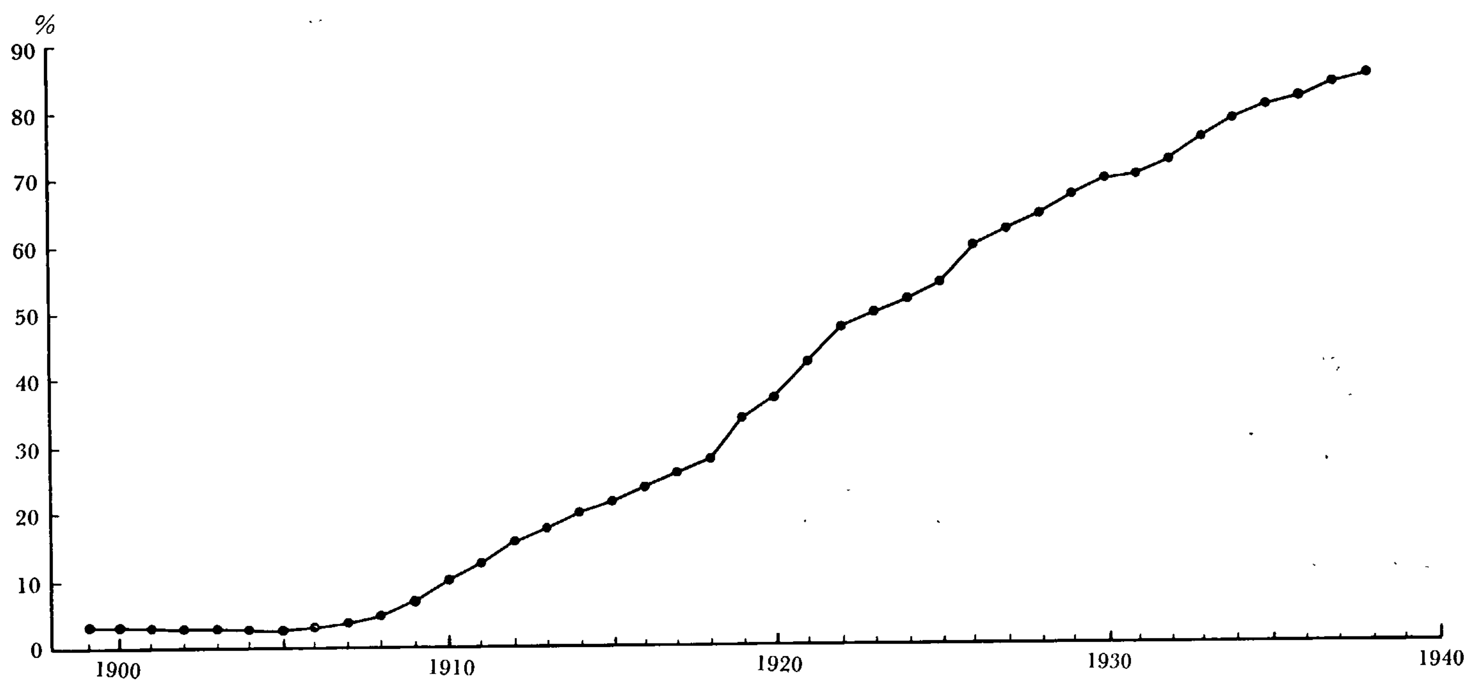
[1] For the history of the power loom utilization in Japan, see Kajinishi 1964.

FIG. 1 PROPORTION OF POWER LOOMS (α)



Notes: α=proportion of power looms in total looms (hand and power looms). Treadle looms are classified as hand looms.
Sources: 1899–1923: *Nōshōmushō* (Ministry of Agriculture and Commerce), *Nōshōmu Tōkei Hyō* (*Statistical Tables for Agriculture and Commerce*). Figures for the number of hand looms for 1899–1923 are those adjusted for overenumeration; see Minami, Ishii and Makino 1982, appendix table. 1924–38: *Shōkōshō* (Ministry of Commerce and Industry), *Shōkōshō Tōkei Hyō* (*Statistical Tables for Commerce and Industry*).

weavers. The wooden power loom for narrow-width fabrics invented by Toyoda in 1897, for instance, cost only ¥93, compared with ¥872 for a German machine and ¥389 for a French one. Small-scale cotton weaving plants rapidly switched from hand looms to power looms once the new technology became available at cheap rates.

Power looms were just applied to silk weaving in 1872 in Kiryū (Gunma Prefecture). In 1882 Nishijin Kyōshin Weaving Company wove satin by steam power. Just like the cotton weaving industry, the substantial diffusion of power looms in the silk weaving industry was made possible by the domestic production of small, inexpensive machines. Yonejirō Tsuda designed a power loom for silk weaving in 1900.

A number of large-scale plants producing worsted cloth were established during the 1880s. These plants, like the large-scale cotton weaving plants, were all equipped with modern power looms. Small- and medium-scale weaving plants, however, did not begin to introduce power looms until well into the first decade of the twentieth century. The Tōkyō Kurihara Plant was the first small-scale worsted factory to use these machines. In 1907 this company also installed ten English and as many Japanese power looms to produce muslin.

(2) Diffusion of Power Looms-A Statistical Survey

Taking all the weaving industries (cotton, silk, worsted and others) together, the proportion of power looms in the total number of looms (expressed as α) increased from a negligible figure in the late 1900s to 85% in 1938 (Fig. 1). This remarkable diffusion of power looms raised labor productivity in two ways. Firstly, the substitution of power looms for hand looms increased output per loom, and, secondly it increased the number of looms operated by each worker. These changes contributed towards raising the technological level in weaving industry.[2] The annual rate of growth of the gross value added per employee in this industry, in real terms, from 1901 to 1938, turns out to be 11.82%. This is composed of two elements: (i) an increase in capital-labor ratio (the power-loom equivalent of the number of looms per employee); and, (ii) the growth rate of total factor productivity. The respective contribution of the two is estimated to be 2.17% and 9.65%.[3] This result may signify that technological progress made a conspicuous effect on raising labor productivity. The rapid substitution of power looms for hand looms should have been an important element of this progress.

Diffusion of power looms was not uniform among regions. Fig. 2 shows that there

[2] For the detailed discussion of this relation, see Minami 1976a, pp. 318–320; 1976b, pp. 155–164; 1977, pp. 951–953.

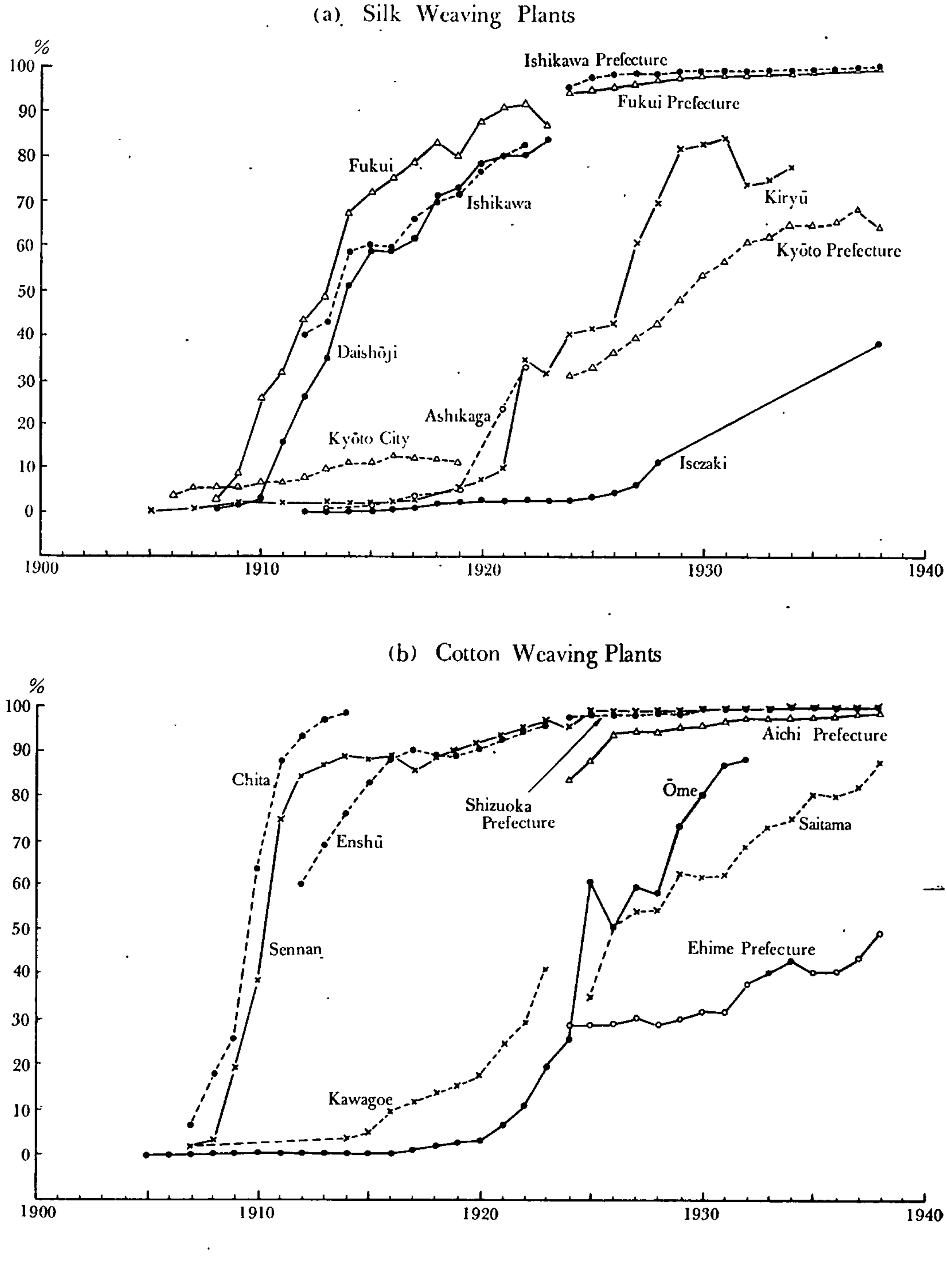
[3] Real gross value added is obtained as the difference between real output (Shinohara 1972, pp. 194–197) and real intermediate inputs. The latter is obtained by deflating a difference between nominal output and nominal value added by a price index for yarns (Shinohara 1972, pp. 188–191). Nominal value added is calculated as a product of nominal gross output and the rate of value added. The rate of value added is calculated based on bench-mark figures in 1902, 1915, 1926 and 1938 for cotton weaving plants (Minami and Makino 1983).

Number of employees is from the *Nōshōmu Tōkei Hyō* for 1901–23 with adjustments and the *Shōkōshō Tōkei Hyō* for 1924–38.

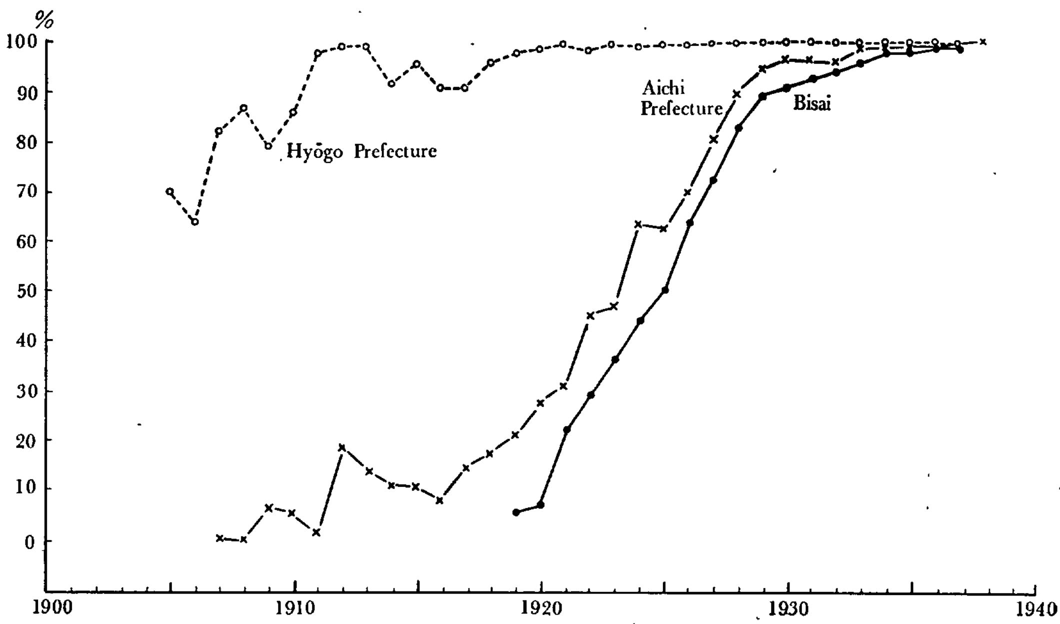
Number of looms, power loom equivalent, is a sum of the number of power looms and the number of hand looms multiplied by the ratio of labor productivity per hand loom to that per power loom. Number of looms is from the same sources as in Fig. 1 and the ratio is calculated in the same fashion as the rate of value added.

Relative income share of labor (substitute for the elasticity of production with respect to labor), which is used in calculating the contribution of increase in capital-labor ratio, is obtained in the same fashion as the rate of value added.

FIG. 2 PROPORTION OF POWER LOOMS (α) FOR REPRESENTATIVE REGIONS



(c) Wool Weaving Plants



Sources: *Silk weaving regions:* Ishikawa, Fukui, and Daishōji: *Nōshōmushō Kōmukyoku* 1925, pp. 252–254, 285–286, and 307–308. Kiryū: *Kiryū Orimonoshi Zokukan Hensankai* 1964, pp. 777–778. Ashikaga: Kajinishi 1964, p. 478. Isezaki: *Isezaki Orimono Kyōdōkumiai* 1966, appendix table. Kyōto City: *Kyōtoshi Tōkei Hyō* (*Statistical Tables for Kyōto City*). Ishikawa Prefecture, Fukui Prefecture and Kyōto Prefecture: *Shōkōshō Tōkei Hyō*. *Cotton weaving regions:* Chita: Yamazaki 1970, p. 38. Sennan: Maekawa and Kuramochi 1960, pp. 194 and 215. Enshū and Kawagoe: *Nōshōmushō Kōmukyoku* 1925, pp. 40–41 and 59. Ōme: *Daitōa Sen-i Kenkyūkai* 1943, p. 215. Shizuoka Prefecture, Aichi Prefecture, Saitama Prefecture and Ehime Prefecture: *Shōkōshō Tōkei Hyō*. *Worsted weaving regions:* Bisai: Mori 1939, p. 164; *Nōshōmushō Kōmukyoku* 1925, p. 127. Aichi Prefecture: Tamaki 1957, p. 255. Hyōgo Prefecture: *Nōshōmu Tōkei Hyō* and *Shōkōshō Tōkei Hyō*.

TABLE 1. PROPORTION OF POWER LOOMS (α) BY TYPE OF PRODUCTS

(%)

	Silk	Cotton	Worsted	Hemp
1922	35.60	56.95	64.00	13.34
1925	41.97	65.41	73.79	14.71
1930	58.91	78.35	96.77	19.58
1935	75.25	86.16	97.77	29.77
1938	80.67	90.61	94.41	41.07

Sources: *Nōshōmu Tōkei Hyō* and *Shōkōshō Tōkei Hyō* for various years.

are significant differences in the speed of an increase in α among regions in respective industry groups; silk, cotton and worsted. In the silk weaving industry power looms were employed first in Ishikawa and Fukui (1910s), next in Kyōto, Kiryū and Ashikaga (Tochigi Prefecture) (1920s) and much later in Isezaki (Gunma Prefecture) (1930s). In the cotton weaving, the diffusion of power looms was seen first in Chita (Aichi Prefecture), Sennan (Ōsaka Prefecture) and Enshū (Shizuoka Prefecture) (1910s), being followed by Kawagoe (Saitama Prefecture) and Ōme (Tōkyō Prefecture) (1920s). In Ehime Prefecture the hand loom occupied 50% of all looms even in 1938. Worsted cloth production in Hyōgo Prefecture was carried out by the factory equipped with power looms since the start of this business, while Aichi Prefecture and Bisai, a part of this prefecture, showed an increase in α in the 1920s.

In short, the speed of diffusion of power looms differed widely among regions even in the same industry group. Needless to say, α showed a difference among industry group. It was higher in worsted, cotton, silk and hemp in that order (Table 1). In 1922, there is a 28 percentage points difference between worsted and silk. However, this difference in α among the industries is smaller as compared with that among the regions. In the same year for silk weaving there is a 89 percentage points difference between Fukui and Isezaki, and for cotton weaving, a 85 percentage points difference between Sennan and Ōme, and, for worsted production, a 70 percentage points difference between Hyōgo and Bisai. This fact brings out clearly the importance of a study of the regional differences in the speed of the diffusion of power loom technology. These considerations may be essential to reveal the conditions for the diffusion of this modern technology.

II. *The Hypotheses and Their Tests*

(1) Three Hypotheses

We intend to test three basic hypotheses that try to explain the observed regional differences in the rate and timing of diffusion of power looms. These hypotheses refer to three determinants of technological diffusion, namely, 1) the diffusion of the factory system, 2) the technological adaptation of power looms determined by composition of products by kind, and 3) the availability of electric power. The three hypotheses are discussed and presented below in a testable form.

1) Power looms tend to be adopted more easily in the factory system than in the domestic production system dominated, largely, by the putting-out system mainly because of three reasons.

a) Incentives for mechanization are decisively larger in the factory system than in the traditional system. In the latter, weaving, more often than not, is a side job of the peasants in their slack season, therefore labor costs (measured by their opportunity cost) are so small that benefits of labor-saving innovation are negligible.[4] Also peasants are not interested in profitability of weaving, because this activity is inseparably connected with farming and household economy.[5] On the other hand factory owners, who have strong interests in their business, are keen on cost-down through mechanization.

b) Because of small-scale of production, with a few power looms, in the traditional system, the power costs per loom tend to be so high that mechanization is not lucrative. Even one-horsepower electric motor can operate several power looms. Consequently, in a factory

[4] Sakai 1962, p. 137.

[5] Tamaki 1957, p. 76.

with a number of power looms, average power cost of operation can be maintained at a low level.[6]

c) Factory owners have the much larger financing ability than peasants to buy and run modern equipments.[7]

Advanced mechanization in the factory system as compared with that in the traditional system is confirmed by Table 2. For 1905–20 α is much higher in the former than in the latter. The factory here is defined as a plant with ten or more employees. For 1922–38 α was decisively higher in the factory or the plant with ten or more looms than the smaller scales. Factories, especially those equipped with power looms, have economic advantages over traditional production units. This brought about a change-over from the traditional to the modern production system. A ratio of the number of looms of factories to the total number (β), which is an index for the diffusion of factory system, showed a steady increase for the entire period from 1905 to 1938 (Fig. 3).

2) Introduction of power looms is easier in weaving fabrics of simpler structure.[8] For cotton weaving, mechanization is the easiest in plain fabrics such as *shiro momen* (gray cloth), shirtings and sheeting. It is the most difficult in figured texture, *kasuri* (cottons woven with mottled thread) and stuff for an *obi*. Cotton crape, striped cloth and cotton carpet lie somewhere between the two. For silk weaving, mechanization is easier in *habutae* (plain silk) than in silk crape, striped cloth, figured texture, *obi* and *tsumugi* (pongee). This assertion (technical ease and difficulty to mechanize weaving is different among products) may be

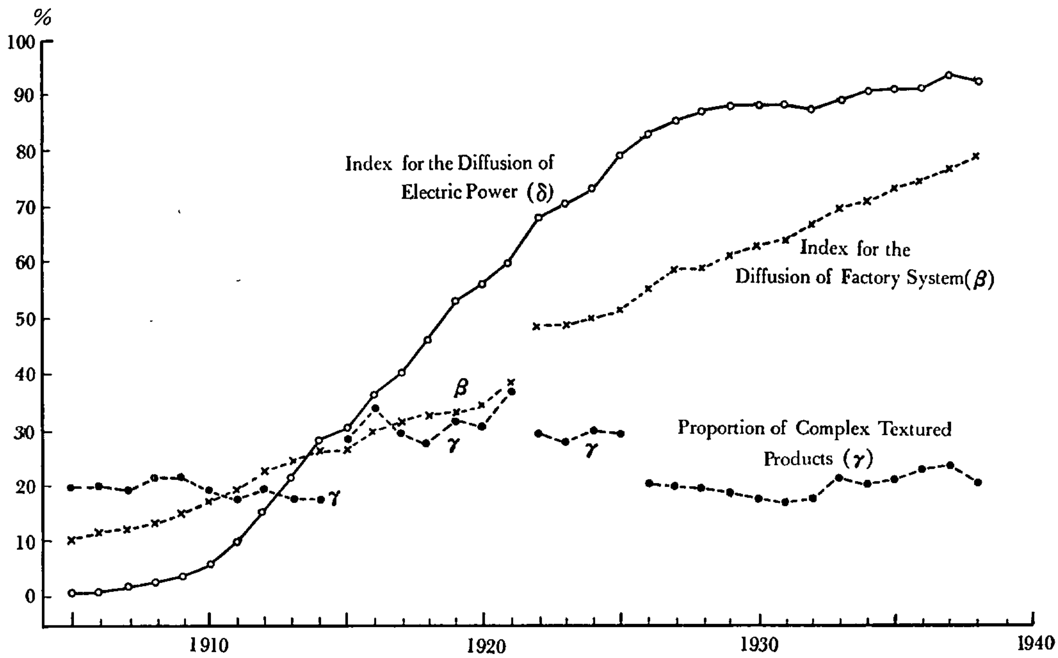
TABLE 2. PROPORTION OF POWER LOOMS (α) BY TYPE OF PLANTS AND BY SCALE OF PLANTS (%)

	Putting-out System		Independent Weavers		
	Weavers	Master Weavers	Domestic Weavers	Factories[1]	Average
1905	0.58	0.15	0.98	19.46	2.59
1910	0.62	2.87	1.57	49.19	9.56
1915	1.78	11.35	3.34	73.58	22.08
1920	9.95	26.49	10.60	83.80	36.77
	Scale (Number of Looms)				
	1～9	10～49	50 or More	Factories (10 or More)	Average
1922	9.21	75.68	95.07	86.20	47.72
1925	12.30	85.00	97.72	92.48	54.63
1930	21.05	93.62	98.63	96.71	69.90
1935	31.35	94.42	98.81	97.10	80.54
1938	34.48	94.77	98.94	97.39	84.97

Note: 1) Plants with ten or more employees.
Sources: Same as Fig. 1. Also see a footnote to the Table 5 in Minami, Ishii and Makino 1982.

[6] This will be argued in Minami and Makino 1983.
[7] Kajinishi 1964, p. 482; Koshō 1980, pp. 11–12.
[8] This is evident in the fact that the revolutions of a power loom with 36 inches reed are only 130–140 per minute in weaving figured cloth, while they are 180 in weaving plain cloth (Tsuda 1925, p. 212).

FIG. 3 CHANGES IN VARIABLES, 1905–1938



Notes: β=proportion of looms in plants with ten or more employees in total looms in all plants for 1905–21 and that of looms in plants with ten or more looms in total looms in all plants for 1922–38.
γ=proportion of complex textured products such as striped cloth, figured cloth, crape, cotton carpets, *kasuri, tsumugi* and *obi* in total products.
δ=proportion of households with electric light in total households.

Sources: Number of looms and output by type of products: Same as Fig. 1. Number of households with electric light: *Teishinshō Denkikyoku* (Ministry of Communications, Bureau of Electricity), *Denki Jigyō Yōran (Manuals for Electric Enterprises).* Figures for 1905–06 are our estimates extrapolated from the later period.
Number of total households: For 1905–19, *Denki Jigyō Yōran.* For 1920, 25, 30, 35 and 40, *Naikaku Tōkeikyoku* (Cabinet Statistical Office), *Kokusei Chōsa (Population Census).* For other years we have estimated the figures by linear interpolation by prefecture.

endorsed by the episode of a cotton weaving company in Higashi Mikawa (Aichi Prefecture), which wove simple cloth in its own factory with power looms and made peasants weave more complex textured cloth by treadle looms, which had been used before in the company.[9]

A ratio of the output of complex texture such as figured cloth, striped cloth, crape, cotton carpet, *kasuri, tsumugi* and *obi* to that of all weaving products is calculated as γ and is drawn in Fig. 3. Because of changes in classification of products in 1915, 1922 and 1926, γ is discontinuous in these years. During respective sub-periods (1905–14, 1915–21, 1922–25 and 1926–38) the ratio did not show any distinct trends.

3) Power looms tend to be easily employed when and where electric power is available. Of course, electric power is not the only source of power: large-scale factories run by cotton-

[9] Aida 1974, p. 86.

TABLE 3. RELATION BETWEEN THE PROPORTION OF POWER LOOMS (α) AND INDEPENDENT VARIABLES (β, γ and δ): TIME-SERIES ANALYSIS

	β	γ	δ
1905–38	0.995**		0.956**
1905–14		0.481*1	
1915–21		0.306	
1922–25		0.905*1	
1926–38		0.356*1	

Notes: Figures in this table are coefficients of determination adjusted by the degree of freedom.
1) Coefficient of correlation is negative.
* and ** stand for the coefficient of determination beingstatistically significant at 95% and 99% significance level respectively.

Sources: See Fig. 3.

TABLE 4. PROPORTION OF POWER LOOMS (α) AND INDEPENDENT VARIABLES (β, γ and δ) FOR REPRESENTATIVE PREFECTURES (%)

		α	β^1	γ^2	δ
A (Group of Prefectures with Low α)					
Gunma	1910	3.21	6.28	39.67	13.47
	1920	7.55	7.68	77.32	36.77
	1930	40.23	29.98	26.61	88.86
	1938	65.92	51.22	39.02	91.98
Saitama	1910	1.09	8.20	41.65	0.49
	1920	5.20	5.44	54.47	39.91
	1930	38.22	33.83	16.52	91.90
	1938	69.73	62.34	7.29	87.05
Kyōto	1910	6.46	16.97	25.78	8.11
	1920	20.04	22.20	80.38	81.83
	1930	54.98	32.22	26.03	97.97
	1938	65.40	52.56	24.68	108.41
Ehime	1910	1.80	9.38	49.25	2.47
	1920	31.31	31.85	47.14	26.46
	1930	32.19	32.71	15.22	90.34
	1938	49.68	50.83	10.55	95.96
Fukuoka	1910	1.53	8.45	92.29	5.47
	1920	6.68	14.47	67.89	66.59
	1930	16.37	29.20	62.62	86.81
	1938	29.49	47.20	48.60	82.81
Mean	1910	2.82	9.86	49.73	6.00
	1920	14.16	16.32	65.44	50.32
	1930	36.40	31.59	29.40	91.18
	1938	56.04	52.83	26.03	93.24

TABLE 4. Continued

B (Group of Prefectures with High α)

Ishikawa	1910	17.08	55.91	3.92	3.24
	1920	76.92	78.36	16.56	60.17
	1930	78.82	77.14	16.11	92.16
	1938	93.23	91.47	22.88	96.05
Fukui	1910	17.41	49.84	2.33	7.25
	1920	80.81	69.55	24.23	64.73
	1930	97.98	93.22	21.30	98.73
	1938	99.70	95.36	18.56	102.42
Shizuoka	1910	34.33	33.71	56.68	4.18
	1920	92.25	57.33	46.66	77.04
	1930	99.39	94.84	22.58	100.57
	1938	99.73	93.75	14.71	104.68
Aichi	1910	25.59	37.61	12.31	6.95
	1920	48.83	42.99	16.00	72.60
	1930	94.17	88.84	4.24	100.00
	1938	97.92	92.06	5.90	105.43
Ōsaka	1910	39.17	44.26	0.35	28.34
	1920	90.41	93.83	2.74	87.49
	1930	97.29	97.11	1.70	98.55
	1938	97.86	97.37	1.79	96.20
Mean	1910	26.72	44.27	15.12	9.99
	1920	77.84	68.41	21.24	72.41
	1930	93.53	90.23	13.19	98.00
	1938	97.69	94.00	12.77	100.96
National Mean	1910	9.45	18.19	34.04	5.12
	1920	33.99	35.11	41.32	52.96
	1930	64.49	59.59	17.91	87.63
	1938	77.96	72.66	13.74	90.10

Notes: 1) Concept is not the same between 1910–20 and 1930–38.
2) Discontinuous in 1910, 1920 and 1930–38.

Sources: See Fig. 3.

TABLE 5. RELATION BETWEEN THE PROPORTION OF POWER LOOMS (α) AND INDEPENDENT VARIABLES (β, γ and δ): CROSS-PREFECTURAL ANALYSIS

	β	γ	δ
1905	0.273**	0.049	−0.020
1910	0.708**	0.143**	0.195**
1915	0.805**	0.311**	0.184**
1920	0.789**	0.423**	0.110*
1925	0.839**	0.098**	0.090*
1930	0.779**	0.352**	0.203**
1935	0.680**	0.245**	0.267**
1938	0.759**	0.110*	0.379**

Notes and *Sources:* See Table 3.

TABLE 6. ESTIMATES OF REGRESSIONS EXPLAINING THE PROPORTION OF POWER LOOMS (α)

	Constant	Parameters			$\bar{R}^2$
	a	b	c	d	
1905•1910	0.568	0.435	−0.070	0.538	0.513
	(0.28)	(8.16)	(1.83)	(2.37)	
1915•1920	0.685	0.791	−0.102	0.181	0.828
	(0.19)	(13.27)	(2.39)	(3.28)	
1930•1935•1938	3.679	0.711	−0.202	0.272	0.794
	(0.51)	(16.83)	(3.05)	(3.47)	

Note: Figures in parentheses are t-values of parameters.

spinning companies operated power looms by steam engines, and some small- and medium-scale weaving plants utilized internal combustion engines.[10] However the internal combustion engine did not complete mechanization of small weavers: in 1909 95% of weaving plants with 5–9 employees were not mechanized and in 1919 67% were still in the same condition.[11] Full mechanization of small plants was first realized when local electric power companies began to supply electric power.[12] The internal combustion engine was more suitable for small-scale production than the steam engine in the divisibility of power and the ease in use, but much less suitable than the electric motor.[13] As an index of the availability of electricity we calculate a ratio of the number of households which used electric light to the total households. Changes in the ratio, denoted as δ, indicate that availability of electricity was very limited until about 1910, increased very rapidly thereafter until it reached a saturation level in the latter half of the 1920s.[14]

(2) Test of the Hypotheses

Table 3 indicates that the time-series of α has positive and statistically significant correlation with the series of β and δ and a negative and significant correlation with that of γ. Next we are examining similar relations by using cross-sectional data. Table 4 gives figures of all variables for ten prefectures; out of these, Gunma, Saitama, Kyōto, Ehime and Fukuoka are representatives of prefectures with low α (group A), while Ishikawa, Fukui, Shizuoka, Aichi and Ōsaka represent prefectures with high α (group B). Roughly speaking prefectures of group B have higher β and δ and lower γ than those of group A. In 1910, for instance, mean of group B is higher than that of group A by 34 percentage points in β, lower by 35 percentage points in γ, and higher by 4 percentage points in δ. The existence of relationships between α and respective independent variables can be confirmed more strictly by using all samples (47); the coefficient of determination of these relations is statistically significant for all variables and for all years with exceptions for γ and δ in 1905 (Table 5).

[10] Wide utilization of gas engines and petroleum engines was seen in plants with 5–49 employees during the 1910s (Minami 1976b, p. 149).

[11] Minami 1976b, p. 150.

[12] Kajinishi 1964, p. 481; Koshō 1980, p. 11; Minami 1976b, pp. 153–154; Miyaide 1937, p. 38; Sanpei 1961, p. 408; Suzuki 1951, p. 125.

[13] Comparison of economic advantages between internal combustion engines and electric motors will be attempted in Minami and Makino 1983.

[14] Kurihara 1964, pp. 180–181.

Next we are setting forth a model in which α is explained by the three variables β, γ and δ. In order to increase sample size and obtain stable relations we estimate this model by using prefectural statistics for two or three years combined. The model to be estimated is

$$\alpha_{i,t}=a+b\ \beta_{i,t}+c\ \gamma_{i,t}+d\ \delta_{i,t}+\varepsilon_{i,t}$$

where ε stands for the error term and subscripts i and t denote prefectures and years respectively. According to Table 6, estimated parameters have proper signs (b and $d>0$, $c<0$) and are statistically significant for respective periods. This result as well as the previous tests in Tables 3 and 5 substantiates our three hypotheses.

III. *Further Examination of the Hypotheses*

In this section we are examining relative importance of the three hypotheses in explaining a diffusion of power looms by using relative contributions of the three variables, β, γ and δ, to an increase in α and to the regional difference in this variable.

(1) Estimation of Relative Contributions of Variables

In Table 7 products of national average of individual variables and their estimated parameters ($b\beta$, $c\gamma$ and $d\delta$) are calculated for respective sub-periods. Summing up these increments for sub-periods we obtain the following figures:

$b\Delta\beta$	$c\Delta\gamma$	$d\Delta\delta$	$\Delta\alpha$ (estimated)
18.85	1.10	7.96	27.91
(67.5)	(4.0)	(28.5)	(100.0)

This demonstrates that the diffusion of power looms through the entire observation period depended largely on the diffusion of factory system. The diffusion of electric power had the second largest contribution to the diffusion of power looms and a change in the composition of products had rather negligible contribution. Considering by sub-periods, relative contribution of the diffusion of electric power was the largest among those of three factors in the

TABLE 7. DETERMINANTS OF THE PROPORTION OF POWER LOOMS (α)

	Constant	Determinants of α			α	
		$b\beta$	$c\gamma$	$d\delta$	Theoretical	Actual
1905	0.57	6.14	−2.22	0.45	4.95	4.33
1910	0.57	7.90	−2.40	2.76	8.83	9.45
Increase	0	1.76	−0.18	2.31	3.89	5.12
		(45.2)	(−4.6)	(59.4)	(100.0)	
1915	0.68	19.96	−4.67	4.58	20.56	20.35
1920	0.68	27.76	−4.23	9.56	33.78	33.99
Increase	0	7.80	0.44	4.98	13.22	13.64
		(59.0)	(3.3)	(37.7)	(100.0)	
1930	3.68	42.40	−3.62	23.83	66.29	64.49
1938	3.68	51.69	−2.78	24.50	77.09	77.96
Increase	0	9.29	0.84	0.67	10.80	13.47
		(86.0)	(7.8)	(6.2)	(100.0)	

TABLE 8. DETERMINANTS OF THE PROPORTION OF POWER LOOMS (α): COMPARISON AMONG REGIONS

(%)

		Constant	Determinatns for α			α	
			$b\beta$	$c\gamma$	$d\delta$	Theoretical	Actual
	A	0.57	3.70	−3.52	1.87	2.62	2.09
1905•1910	B	0.57	13.52	−1.19	3.09	15.99	18.33
	Difference	0	9.82	2.33	1.22	13.37	16.24
			(73.5)	(17.4)	(9.1)	(100.0)	
	A	0.68	11.07	−7.70	7.27	11.30	42.37
1915•1920	B	0.68	54.19	−1.93	10.10	63.04	71.28
	Difference	0	43.12	5.77	2.83	51.74	28.91
			(83.3)	(11.2)	(5.5)	(100.0)	
	A	3.68	30.41	−6.00	25.32	53.41	60.72
1930•1935•	B	3.68	65.56	−2.51	27.22	93.95	96.00
1938	Difference	0	35.15	3.49	1.90	40.54	35.28
			(86.7)	(8.6)	(4.7)	(100.0)	

first period and decreased in the second and third periods. On the other hand, relative contribution of the diffusion of the factory system increased and dominated that of electric power in the second and third periods. A decrease in the relative contribution of electric power resulted from the fact that the diffusion of electric power reached a saturation during the latter half of the 1920s.

According to Table 8 a difference in α between A and B increased from 16% for 1905–10, to 29% for 1915–20 and to 35% for 1930–38. This was due, largely, to a difference in β, which explained 70–90% of the difference in α. The difference in γ had the second largest contribution and the difference in δ had the smallest contribution to the difference in α. Through the observation period the relative contribution of the difference in β increased, while those of the difference in γ and δ decreased.

Based on these results let us make further comments on the contributions of the three variables respectively.

(2) Significance of the Diffusion of Factory System

It has been revealed that the diffusion of factory system had the largest contribution in the diffusion of power looms with respect to both the changes overtime and to the regional differences. Furthermore, its contribution increased relatively to those of other variables.

The effect of the diffusion of factory system is substantiated by the historical examples below:

1) Traditional silk weaving regions such as Kiryū, Ashikaga and Nishijin (Kyōto Prefecture), faced with an increased demand, could increase production simply by expanding the putting-out system. On the other hand the newly developed regions such as Ishikawa and Fukui, which did not have the foundation of this system, were forced to introduce power looms based on the factory system. In this way there appeared a considerable difference in the diffusion of power looms between the two groups of silk weaving regions.[15]

[15] Kajinishi 1964, pp. 478–479; Kobayashi 1960, pp. 245–248 and 251.

2) Bisai, a region of cotton and worsted cloth production, was characterized by a fairly well developed putting-out system. It is said that this caused a delay in introducing power looms, because of small incentives for mechanization in the domestic production. An important fact is that within this region there was a local difference in the diffusion of power looms, which can be attributed to a difference in the development of the putting-out system. In Kaifu Gun (province) where the putting-out system was most developed, power looms were rarely employed, while in Nakajima Gun without the well-developed putting-out system power looms were widely introduced.[16]

Finally we must put a reservation to the conclusion that the development of the factory system (or an underdevelopment of the putting-out system) facilitated the diffusion of power looms. That is, there are some authors who emphasize the relation that the former was a result of the latter.

1) Small weavers, who employed power looms, succeeded in output expansion and capital accumulation, and finally became independent of the putting-out system. In many regions including Mikawa and Enshū the putting-out system declined and the factory system developed during the W.W.I. prosperity owing to this reason.[17]

2) Introduction of power looms was underdeveloped in Kiryū and Nishijin, because hand looms were rather suitable to the small-scale production of wide-variety of products. As a result of this the putting-out system remained unchanged for a long time.[18]

Nobody can deny these possibilities; strictly speaking the relationships between the diffusion of factory system and the mechanization were mutually reinforcing to some extent.

(3) Significance of Technical Ease to Adopt Power Looms Depending on Products by Kind

As pointed out above, though a change in the composition of products by kind did not contribute significantly to the diffusion of power looms through time, a regional difference in the composition caused a regional difference in the diffusion of power looms.

Introduction of power looms started in regions producing plain cloth, in cotton weaving for instance Sennan, Chita, Mikawa and Enshū. We notice in Fig. 2 that proportion α increased very early in Sennan, Aichi Prefecture (including Chita and Mikawa) and Shizuoka Prefecture (including Enshū). Owing to an improvement in power looms and a rise in wages, the power loom utilization diffused to regions which produced more complex textured cloth. Ōme, which produced striped cotton cloth, was one of these regions. Mechanization was delayed the most in regions producing *kasuri* such as Kurume (Kumamoto Prefecture), Satsuma (Kagoshima Prefecture) and Iyo. Proportion α increased very slowly in Ehime Prefecture (Fig. 2) because it included Iyo.[19]

It is appropriate here to put two comments to this conclusion:

1) Some authors argue that power looms tended to be introduced earlier in the regions with larger concerns with foreign markets rather than domestic market. A reason for this is that export activities are based on mass-production of few kinds of products, while pro-

[16] Tamaki 1957, pp. 72–76 and 113–114.

[17] Suzuki 1951, pp. 120–123; Yamazaki 1969, p. 98.

[18] Horie 1976, p. 103; Kobayashi 1960, p. 246; Sanpei 1961, p. 417.

[19] Proportion of power looms in cotton weaving plants in Iyo Gun in 1933 was only 0.3%. *Shōwa 8-Nen Ehimeken Tōkeisho, Dai 3-Pen (Statistical Volume of Ehime Prefecture 1933, Part 3).*

duction for domestic demand is characterized with small-quantity production of various kinds of products.[20] In our view, however, the distinction between export-oriented production and that for domestic use in explaining a difference in the timing of the power loom utilization seems to come eventually from the distinction among kinds of products which we have emphasized. That is, the export products were largely plain cloth such as shirtings, sheeting, and *habutae*, while production for domestic demand was mainly of more complex textured cloth such as striped and figured cloth, *kasuri* and *tsumugi*.

2) Influence of the difference in products is not necessarily independent of an influence of the differences in the types of management. It is said, for instance, that striped cotton weavers in Bisai, organized in the putting-out system, inclined towards diversification of products based on manual labor, because small-scale unmechanized production was appropriate to side-jobs of peasants.[21]

(4) Significance of the Diffusion of Electric Power

It has been revealed that the diffusion of electric power facilitated substantially the power loom utilization, even though it did not cause the regional difference in the utilization. This is attributable to the fact that electric power became available during the 1910s and 1920s rather uniformly among the prefectures.

The relation between the timing of the establishment of electric utilities and that of the introduction of power looms is confirmed by the following examples:[22]

1) The introduction of power looms in silk weaving enterprises in Kiryū and Ashikaga occurred after the Watarase Electric Company began supplying electric power in 1908.

2) Silk, cotton, and worsted weaving plants in Ichinomiya (Aichi Prefecture) introduced power looms after cheap electric power became available from the Ichinomiya Electric Company founded in 1923.

3) Power looms gained widespread application among silk weaving plants in Yonezawa (Yamagata Prefecture) after the establishment of the Yonezawa Hydroelectric Company in 1897.

4) In the silk weaving district of Kawamata (Fukushima Prefecture) power looms were introduced after the establishment of the Kawamata Electric Company in 1907.

5) Mechanization of silk weaving in Fukui was attributable to the foundation of an electric utility there during W.W.I.

6) The introduction of power looms among silk weaving plants in Ishikawa Prefecture followed the development of electric companies such as Komatsu Electric and Daishōji Electric.

7) The number of power looms increased rapidly after electric power became available in 1921 in Chichibu (Saitama Prefecture).[23]

8) In Higashi Mikawa electric power became available by the establishment of Okazaki Electric Light Company in 1914 and in the next year they started to run power looms by electric power.[24]

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[20] Kajinishi 1964, pp. 210–212 and 478; Kiyokawa 1973, p. 134.
[21] Kajinishi 1964, p. 248.
[22] The following examples (from 1 to 6) are cited from Sanpei 1961, p. 408.
[23] Katsura 1925, p. 54.
[24] Tanihara 1958, p. 85; Aida 1974, p. 82.

Two comments are needed to close this section:

1) Electric power was not a unique power source; for instance, in a part of Sennan without electric distribution line, gas engines were widely used, and in mountainous regions of Enshū, gas engines and petroleum engines were employed.[25]

But small-scale weaving plants were not fully mechanized in the stage of internal combustion engines, because the production of small-capacity engines appropriate to these plants was technically impossible and because unsmooth rotation of these engines caused uneven weaving.

2) There were big differences among regions within individual prefectures as regards the availability of electric power because public utilities in the early years were very small in scale and their service areas were pretty limited. Therefore weaving plants located in remoted places, sometimes, could not utilize this power. It is assumed in our study that both the net-work of electric power distribution and weaving plants were distributed uniformly within respective prefectures.

IV. *Concluding Remarks*

In this paper we picked up three factors affecting the power loom utilization and examined their significance quantitatively. We found that the diffusion of factory system was the most important among these factors; it accounted for a large portion of an increase in the diffusion of power looms over-time and caused the regional differences in the diffusion to a large extent. Moreover, the relative significance of this effect increased as time passed on. The increasing availability of electric power explained mechanization significantly especially in the earlier years of rapid electrification, while the availability of electric power did not cause the regional differences in mechanization because of uniform electrification among prefectures. As for the regional differences in mechanization, a difference in products by kind made non-negligible influences. Regions producing simple textured cloth, which was appropriate for adopting power looms than complex textured cloth, saw earlier diffusion of power looms.

Besides these factors there are several things which must be considered:

1) As was shown in the first section, cheap power looms were developed and produced by Toyoda (cotton looms) and by Tsuda (silk looms). This facilitated the diffusion of power looms among small- and medium-scale weavers who could not afford purchasing expensive foreign looms.[26]

2) Relative advantages of the labor-saving technique, or introduction of power looms increased by means of an improvement in the machine and a wage increase especially during and after W.W.I. In another paper we will argue that the rate of profit in weaving cotton cloth by a power loom increased and exceeded that by a hand loom.[27]

3) The financing ability to purchase power looms and other equipment increased through a development of the weaving industry. This has been reported for some regions. For in-

[25] *Nōshōmushō Kōmukyoku* 1925, pp. 65 and 108–109.

[26] For the development and production of power looms in Japan, see Ishii 1979 and Minami, Ishii and Makino 1982, Section 3.

[27] Minami and Makino 1983.

stance weavers in Enshū expanded the factory system and increased power looms by investing profits raised during the W.W.I. prosperity.[28] As for the financing problem, contribution by local governments and trade associations cannot be neglected. In Yonezawa, for instance, the government gave a subsidy of 15 yen per power loom to weavers in 1904, and, in 1937, the Yonezawa Silk-Weaving Trade Association assisted weavers financially who purchased iron-made power looms.[29] The Nishijin Silk-Weaving Trade Association and the Ashikaga Credit Association offered a low-interest loan to their members.[30]

4) The role of weavers' associations should be highly appreciated. Small-scale weavers in various regions organized manufacturing associations and sometimes trade associations together with related professions such as dyers and merchants. There existed 60 manufacturing associations and 128 trade associations in 1931.[31] Furthermore the former formed national federations. The most important mission of these associations was to carry out the quality inspection of products. It seems that this system promoted the introduction of power looms, because power looms were far more appropriate than hand looms in producing uniform quality goods.[32] As was mentioned above, these associations promoted power loom utilization by assisting their members financially. Generally speaking the role of the manufacturing and trade associations in various manufacturing industries in developing appropriate technologies and promoting their diffusion deserves greater attentions of scholars who study the technological progress in Japan.[33]

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[28] Yamazaki 1969, pp. 103 and 140. Similar facts have been pointed out for other regions by Abe (1980, p. 16), Koshō (1980, p. 9), and Sanpei (1961, p. 405).
[29] Imai 1940, pp. 408 and 414–415.
[30] For Nishijin, Ōtsuki 1939, p. 83 and for Ashikaga, Koshō 1980, p. 12.
[31] *Nippon Orimono Shimbunsha Hensambu* 1940, p. 206.
[32] Fujii 1960, p. 135; Tsukada 1937, pp. 33.
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