

# Honesty, Diligence, and Skill

## Risk Sharing and Specialization in the Kiryu Silk Weaving Cluster, Japan\*

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### Abstract

Many economies have seen growth in industrial clusters during their industrialization, and the relational contracts between manufacturers and subcontractors are often the organizational basis of clusters. We predict that, if manufacturers form relational contracts with subcontractors and if manufacturers closely collude when trading with subcontractors, then premium subcontractors suffer more from market volatility than ordinary subcontractors and hence it is optimal for manufacturers to shield premium subcontractors against the risk. We then study Kiryu, a kimono weaving cluster that expanded from the late nineteenth century with the development of new synthetic dyeing techniques. We show that premium subcontracting weavers were allowed long-term relational contracts and specialization, which shielded already honest weavers against market volatility and induced them to be diligent and to acquire skills.

**Key words:** industrial clusters; relational contracts; putting-out system; risk sharing; textile industry; Japan.

**JEL:** O12; O14; L14.

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## Introduction

There is a developing awareness that in addition to large-scaled factories, clusters of small manufacturers can be a driving force of industrialization, as has been increasingly observed in developed or emerging economies.<sup>1</sup>

While technological economies of agglomeration, as defined by Marshal (1920), are widely observed,<sup>2</sup> it is known that organizational efficiency affects clusters' overall performance. Furthermore, the path-dependent effects of organizational efficiency sometimes dominate the technological economy of agglomeration when clusters were formed, as discussed by Rosenthal and Strange (2003) and Buenstorf and Klepper (2009). In particular, social interactions and networks have a significant impact on efficiency within industrial clusters in developed economies,<sup>3</sup> as well as in emerging economies.<sup>4</sup> This study also addresses the implications of social interactions (or relational contracts) within industrial clusters, focusing on the risk attitudes of small subcontractors organized by manufacturers.

To this end, this study deals with nineteenth-century Japan, when the economy grew from a vibrant emerging economy to become an industrial giant. Japan became the world's largest exporter of raw silk in the 1900s, and of cotton goods in the 1930s. Thus, the silk-reeling and cotton spinning industries, based on the factory system, were the driving force behind the country's industrialization. At the same time, growth in the mass demand for high-quality cloth during the period of industrialization and urbanization resulted in the emergence of weaving clusters, rather than large factories. Thus, weaving clusters became another engine

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<sup>1</sup>For Western countries, see Piore and Sable (1984), Sable and Zeitlin (1997), and Becchetti and Rossi (2000)); for Japan, see (Hashino and Otsuka (2013a, 2013b); for Taiwan, see Sonobe and Otsuka (2006); for Indonesia, see Weijland (1999) and Sandee and Rietveld (2001); for China, see Ruan and Zhang (2009) and Long and Zhang (2012); for Vietnam, see Nam, Sonobe and Otsuka (2010) and Kimura (2011); for India, see Chari (2000); and for Ethiopia, see Sonobe, Akoten and Otsuka (2009), Zhang, Moorman and Ayele (2011), Ali and Peerlings (2011), and Gebreeyesus and Mohnen (2013).

<sup>2</sup>See Morrison and Siegel (1999) and Ellison, Glaeser and Kerr (2010)

<sup>3</sup>See Guiso and Schivardi (2007), Yamamura (2009), and Rosenthal and Strange (2012).

<sup>4</sup>See Weijland (1999), Sandee and Rietveld (2001), Miguel, Gertler and Levine (2005), and Gebreeyesus and Mohnen (2013).

of growth by meeting this urban consumer demand.

The growth in urban consumption created a new demand for a greater variety of high-quality, but not expensive kimono brocades. This demand was met by weaving clusters, which introduced synthetic dyes and systematic patterns from the West, while keeping to their flexible putting-out system. This study centers on a representative kimono weaving cluster, namely the Kiryu region of the Gunma prefecture, near Tokyo, which was the largest consumer of these goods. In Kiryu, kimono manufacturers expanded their network of subcontracting weavers rather than employing them in their own factories.

The kimono manufacturers' choice to subcontract weavers is not a technological puzzle. It is likely that the technologically optimal size of the high-mix, low-volume production of final goods, such as fabrics, was smaller than that of uniform intermediate goods, such as silk or cotton yarns. However, this does not necessarily mean that technologically efficient, decentralized organizations always outperform centralized organizations under asymmetric information. Imperfect information about weaver agents' actions after concluding putting-out contracts might result in a moral hazard of weavers, as emphasized by Landes (1986). In addition, risk sharing might matter, as argued in this study. For a cluster of putting-out contracts to work, specific organizational devices are intrinsically indispensable.

The rise and fall of the Kiryu cluster as technology evolved over the longer term is described well by Hashino (2005) and Hashino and Otsuka (2013a). This study analyzes the organizational characteristics of the Kiryu cluster at its peak, between the 1890s and the 1900s.

The rest of the paper is organized as follows. Section 1 briefly describes the development of the Kiryu silk weaving cluster.

Section 2 introduces a simple model to capture the organizational structure of the cluster, which we test empirically. Our benchmark is standard infinitely repeated game settings, such as Greif (1983). However, we also add the risk attitudes of weaver agents, which generate different implications to those from the standard settings. Typical trigger strategies or rela-

tional contracts in infinitely repeated game settings can be self-enforcing precisely because both players have something to be lost if they deviate—quasi-rent. Such rent could be earned in our case when manufacturers and subcontractors produced premium kimono piece goods. However, subcontractors who produced ordinary pieces using arms-length transactions in a competitive market had nothing to lose, in either a boom or a downturn. Thus, it follows that subcontracting weavers who produced premium products were vulnerable to market volatility because they then had something to lose and, hence, suffered more. Our model captures this feature. An insight from our model is that subcontracting weavers of premium products suffer more when collusion among manufacturers performs well. Related to this point, another noteworthy prediction is that greater collusion among manufacturers could curb the subcontracting fee for honest premium weaving, but only if the order volatility is constrained beneath a certain threshold. Standard settings emphasize the possible punishment of dishonest agents. Instead, our model finds that premium subcontractors should be guaranteed stable trades.

Section 3 empirically documents whether our prediction holds by examining contemporary material from the early 1900s, on which manufacturers shared information about their subcontracting weavers. Manufacturers tried sharing information, not about cheating subcontractors, but about excellent subcontractors. If the intention of information sharing was to punish cheaters, this is counter intuitive. However, if manufacturers wanted to limit their orders to excellent subcontractors when demand shrank and, thus, reduce the compensation of risk paid to honest premium subcontractors who suffered more from demand volatility, then this is consistent with our theoretical prediction. Evidence also shows that long-term repeated transactions affected diligence, not honesty, and that specialization led to acquiring more skills. On the equilibrium path, whether to be honest was not an issue, because any cheaters had already been excluded. After excluding cheating weavers, an urgent issue was to diminish the volatility burden on their premium weavers, typically by continuing transactions, because when collusion among manufacturers worked well, honest premium weavers suffered more

from the order volatility. Responding to this shield against market volatility, subcontracting weavers showed diligence and commitment to such relational contracts, as our model predicts. While specialization in a specific product is a less costly way for subcontracting weavers to acquire better skills, it potentially meant greater exposure to the risk of market volatility. Thus, subcontracting weavers were only motivated to specialize in a specific product if they were shielded from this volatility.

## 1 Formation of an industrial cluster

### 1.1 Silk weaving industry of Kiryu

Since the mid-1880s, the factory system rapidly diffused among the silk-reeling, cotton spinning, cotton weaving, and, in some regions, silk weaving industries. However, in Kiryu, the silk weaving industry was not dominated by the factory system during this period, but most many manufacturers chose to keep the putting-out system. This maintenance of the traditional organization did not imply stagnancy in the silk fabric industry in Kiryu. Rather, production grew in line with the domestic demand from Tokyo. Region-level data reveal that both the traditional weaving and traditional hand silk-reeling industries grew. The putting-out system, which organized hand-loom weavers, continued to dominate. In contrast to Kiryu, in the city of Fukui, in the Fukui prefecture, silk weaving factories with power-looms prevailed, using machine-reeled raw silk, or *filature*. Fukui mainly produced cheap *habutae*, a non-dyed silk fabric with a plain weave, which was exported to the United States. Power-looms were easily used to weave plain, white silk fabrics.<sup>5</sup>

The silk fabric industry emerged in the mid-eighteenth century in Kiryu Town, in the state of Kozuke, as well as neighboring areas. The industry then developed remarkably after the early nineteenth century, mainly stimulated by demand from the Shogunate capital, Edo,

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<sup>5</sup>See Hashino and Otsuka (2013b).

which was later renamed Tokyo after the Meiji Restoration.<sup>6</sup> Kozuke was also renamed the Gunma prefecture.

Raw silk was Japan's most important export after Japan joined international free trade in 1859. Prior to the early 1880s, most of the exported raw silk was hand-reeled and produced by peasant agriculture in Northern Kanto, Chubu, and Southern Tohoku. Subsequent to the mid-1880s, exports to the United States were dominated by filature, a product from the modern silk-reeling industry, centered in the Nagano prefecture. This trend accelerated from the late 1880s onwards, when railway trunk lines built in East Japan greatly facilitated the supply of cocoons (i.e., the raw material) from farmers to the silk-reeling factories.<sup>7</sup> After this period, the only areas in which traditional hand-reeling dominated were Kiryu, Maebashi, Ashikaga, and Isezaki (see Figure 1), the cluster where the traditional silk fabric industry still grew.

INSERT Figure 1 HERE

In weaving clusters, given the conditions at the time, the choice of production organization was between the putting-out system and the factory system.<sup>8</sup> In the Kiryu weaving industry, the factory system, equipped with hand-loom, had been chosen to weave luxury fabrics,<sup>9</sup> while the putting-out system was used for most other fabrics. This only changed when factories equipped with power-loom became dominant for most kinds of fabrics in the 1910s, and later.<sup>10</sup> Instead of being replaced, the putting-out system developed and dispersed within Kiryu, especially from the 1880s to the 1900s, when the main products of Kiryu were yarn-dyed silk fabrics. "Yarn-dyeing" means material yarn is dyed before weaving. For luxury piece-dyed fabrics that were dyed after weaving, the weaving was conducted inside the man-

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<sup>6</sup>See Kiryu Orimonoshi Hensankai (Editorial Committee of the History of Kiryu Weaving), ed (1935).

<sup>7</sup>See Nakabayashi (2006, 2015).

<sup>8</sup>See Hashino (2005) and Okazaki and Nakabayashi (2007).

<sup>9</sup>See Kimura (1959a), pp. 385–399 and Kimura (1960), p. 137. In Ashikaga, luxury fabrics and exported *habutae* (plain, white fabric) were also woven using the factory system and hand-loom. See Wasedaigaku Keizaishigakkai (Society for Economic History, Waseda University), ed (1960), pp. 208–300, Kosho (1963, 1972) and Kawamura (1987, 1995).

<sup>10</sup>See Tsujimoto (1978), p. 48, Kameda (1989), pp. 561–565 and Hashino (2005), p.19.

ufacturers' workshops. In the production of yarn-dyed fabrics, adopting synthetic dyes and systematic patterning made it possible to modularize dyeing, arranging warps, cleaning yarn, throwing, re-reeling, other preparation processes and the weaving process. Because these processes needed special skills, the craftsmen who specialized in each process were organized as subcontractors by the manufacturers.<sup>11</sup>

With the move from the production of traditional piece-dyed fabrics to the production of yarn-dyed silk fabrics, the throwing, finishing, designing, and weaving processes came to be put out. Manufacturers decreased production in their workshops and established subcontracting relations with independent artisans.

## 1.2 Diversified demand in the market

Products ranged from the traditional luxury piece-dyed fabrics, which included *ryumon* (patterned fine gauze), *sa aya* (gauze), and *chirimen* (crepe), to the yarn-dyed fabrics that developed after the mid-nineteenth century, and fabrics that were a mixed weave of silk and cotton. The luxury piece-dyed fabrics were woven from *hiraito* (flatly thrown silk yarn), which was produced in Omama Town, Yamada County, while the yarn-dyed fabrics and the mixed fabrics were woven from ordinary hand-reeled raw silk and cotton yarn. Some weavers also copied specialties from other weaving districts, such as Nishijin in the Kyoto prefecture, Yonezawa in the Yamagata prefecture, Chichibu in the Saitama prefecture, and Hachioji in the Kanagawa prefecture. This broad list of products indicates that Kiryu manufacturers made an effort to diversify their product.<sup>12</sup>

INSERT Table 1 HERE

Until the 1900s, the production of yarn-dyed fabrics such as *kaiki* (lustrine), *shusu* (satin), *shuchin* (satin), and *habutae* (plainly woven) increased to become a large portion of total

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<sup>11</sup>See Kimura (1959a, 1959b, 1961) and Kawamura (1983, 1991).

<sup>12</sup>See Nakabayashi (2007), pp. 133–137.

production (see Table 1).<sup>13</sup> Note that the components and the region's total output changed every year, which indicates that the cluster faced a highly volatile and, in that sense, risky market. The demand for silk fabrics was highly responsive to business cycles and, naturally, to fashion trends. Luxury piece-dyed fabrics, such as *ro* (fine gauze, leno), were mainly shipped to Kyoto, while the yarn-dyed fabrics, such as *shusu* (satin) and *shuchin* (satin), were destined for the larger cities, such as Tokyo and Osaka. The yarn-dyed products contained fabric lower-priced than the piece-dyed fabrics, but the "high-quality" *shusu* (satin) destined for Tokyo suggests that the demand for yarn-dyed fabrics in the larger cities ranged from the low end to the high end.<sup>14</sup>

In general, in larger cities, especially in the Tokyo metropolitan area, mass consumers came to demand higher quality and more diversified fabrics from the 1890s onwards. This accompanied an increasing level of industrialization and urbanization. Thus, the more diversified fashions, composed of various materials, textures (combinations of warp and weft), and dyes, came to be supplied by weaving districts.<sup>15</sup> Kiryu was an example of the response to the change in demand in Tokyo and Osaka, producing more yarn-dyed fabrics such as *shusu* (satin).

For a greater variety of products, power-loom were still irrelevant until the 1910s, because they were difficult to apply to weaving yarn-dyed fabrics, such as patterned cloths, striped cloths, and broad sashes, which were primary products of Kiryu.<sup>16</sup> Instead, synthetic dyeing, rather than the power-loom, was critical to realizing the greater variety of fabrics in

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<sup>13</sup>For a detailed description of the 1900s and for production statistics that cover a longer period, see Nakabayashi (2007), pp. 133, 138–139, 142.

<sup>14</sup>Of the total sales in Kiryu in 1886, 55 percent went to Tokyo, 17 percent to Osaka, 12 percent to Kyoto, and 4 percent to Nagoya in the Aichi prefecture (Kiryu Orimonoshi Hensankai (Editorial Committee of the History of Kiryu Weaving), ed (1938), pp. 553–554). In about 1900, the "biggest of the domestic destinations ... is the Kyoto-Osaka area, followed by Tokyo. Of the total domestic sales, 70 percent goes to the Kyoto-Osaka area and Nagoya, and 30 percent goes to Tokyo, ..., the many *obi ji* (fabrics for broad sashes for kimonos), *han eri ji* (for decorative collars) and *shusu* (satin) are destined for Osaka, with mainly *ro* and *chirimen* going to Kyoto, and *shusu*, *shuchin* (satin), and other high-quality fabrics going to Tokyo" (Kawamoto, Miura and Ando (1901), p. 222).

<sup>15</sup>See Tamura (2004), pp. 177–210.

<sup>16</sup>See Minami and Makino (1983).

the traditional weaving industry.<sup>17</sup> If the technologies for the greater variety of products generated more profit than those for the mass-production of intermediate goods, such as plain, white fabrics, producers naturally chose the former option. Furthermore, the inapplicability of power-looms implied that sunk costs of weavers were accordingly lighter. If lower sunk costs relative to the thickness of the market are accompanied by a less vertically integrated production organization, as discussed by Langlois (2003), the dominance of hand-looms, along with the growth in mass demand in Tokyo, might have favored the horizontal network of putting-out contracts.

As an example supporting our inference, we take the number of articles related to techniques and technologies of the fabric industry published in *Kiryu no Kogyo (Manufacturing of Kiryu)*, issued by Kiryusha, an industrial body established by weaving and dyeing manufacturers in 1898. During the period 1900–1903, articles related to designs, including dyeing, patterning, and texture, were predominant.<sup>18</sup> Dyeing technique such as alizarin and anilin were related to colors, patterning meant a combination of patterns and colors, and texture was related to the combination of warp and weft that resulted in different looks for the cloth surface. In the early 1900s, manufacturers in Kiryu were more interested in techniques and technologies that could be applied to extend a variety of fabrics rather than those for mass-producing plain fabrics. Moreover, the Commercial and Industrial Association of Kiryu (Kiryu Sho Ko Dogyo Kumiai) wanted to have an institute of research and education especially dedicated to dyeing, and so established the Textile School of Kiryu Town (Kiryu Cho Ritsu Kiryu Orimono Gakko), a school for apprentices. This school was later extended, becoming a formal secondary school, and was renamed the Kiryu Textile School of the Prefecture of Gunma (Gunma Ken Kiryu Orimono Gakko) in 1900. The Textile School surveyed designing and dyeing methods in Western countries and systematically taught them to apprentices. It also

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<sup>17</sup>See Tamura (2004), pp. 133–175.

<sup>18</sup>See Nakabayashi (2007), pp.142–143.

affiliated a Special Program (Bekka) for craftsmen for dyeing and weaving.<sup>19</sup>

Thus, manufacturers collectively introduced the knowledge of synthetic dyeing and systematic patterning from the West, which was essential to realize the new standard of variety from the West, and openly shared the critical knowledge by establishing a technical school, as discussed by Hashino and Kurosawa (2013). This externality is thought to have prompted the vertical separation of production and the modularization through the network of putting-out contracts, as described in Langlois and Garzarelli (2008). Furthermore, the strong technology externality may have decreased individual manufacturers' incentives to invest in technologies and techniques, as discussed by Duranton (2000). A joint investment in a technical school could have been a way to avoid such a trap, while deepening the vertical separation.

Both the synthetic dyeing and systematic patterning techniques enabled the modularization of the preparation processes, such as the dyeing process, and the weaving process. Greater diversity of products became less costly and created a greater demand. The change was swift. While most weaving manufacturers dyed their products in their workshops in 1900, by 1904, subcontracting dyers were predominant.<sup>20</sup> The rapidly expanding subcontracting of the dyeing process was part of an extension of the putting-out system that affected both dyers and weavers.

### **1.3 Development of the putting-out system**

In Yamada County, which included the Kiryu Town, the number of power-looms actually decreased from the 1900s to the early 1910s, a stark contrast to the overall trend in the Gunma

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<sup>19</sup>See Nakabayashi (2007), p. 144.

<sup>20</sup>In 1900: "Dyeing is conducted by the special method of each weaving manufacturer so that there is no independent dyer" (Kawamoto et al. (1901), p. 228). In 1904: Putting-out [of dyeing] had not previously been conducted in Kiryu, but during this time the weaving industry became much more complicated. As a result, each weaving manufacturer could not afford to worry about dyeing, and improvements in dyeing have become necessary. Therefore, independent specialized dyers emerged" (The Prefecture of Gunma, Third Department (1909), p. 88). There were seven independent dyers, four of whom owned boilers for heating (The Prefecture of Gunma, Third Department (1909), pp. 88–89).

prefecture (see Table 2 and Table 3).<sup>21</sup> Another impressive feature of Yamada County is that the number of putting-out manufacturers dropped by half from 1905 to 1912, while the number of subcontracting weavers increased during the same period. The result was that the number of subcontracting weavers per putting-out manufacturer tripled (see Table 2 and Table 4). In some subcontracting weavers' households, more than one family members, were engaged in the business. Hence, the number of subcontracting hand-loom and operatives was greater than that of households, as shown in Table 3.

This expansion of the putting-out system occurred at the same time as the increase in the production of diversified yarn-dyed fabrics for the mass consumption in the large cities. Thus, the expanding putting-out sector was a new phenomenon in the early twentieth century, being stimulated by mass consumption, and became feasible because of the technological progress of synthetic dyeing, which enabled a greater variety of design.

INSERT Table 2, Table 3 AND Table 4 HERE

The weaving manufacturers (*motobataya*) purchased the yarn material, then either subcontracted with independent producers to weave the yarn or weaved it themselves in their own workshops. When subcontracting, a manufacturer first ordered patterns, followed by throwing, dyeing, warp setting, weaving, and the cleaning of products before shipment (see Figure 2). Spatially, manufacturers were concentrated in Kiryu Town, while craftsmen/women were in Kiryu and in the surrounding areas.<sup>22</sup>

INSERT Figure 2 HERE

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<sup>21</sup>In the Gunma prefecture, the number of factories equipped with power-loom steadily increased through the 1900s to the early 1910s. See Nakabayashi (2003a), pp.39–41, Tables 1–9 (a) and 1–10 (a).

<sup>22</sup>“Subcontractors include those who design (and make patterns), prepare looms, weave, throw, and so on. Of these, subcontracting weavers and throwsters prospered, and in most small streets in Kiryu, you could hear the sounds of shuttles. In addition, in Nanbu Shinjuku of Kiryu, there are a great many throwing houses equipped with water wheels along a ditch. Furthermore, every house with a thatched roof in the neighboring villages has a loom so that weaving was conducted” (Kawamoto et al. (1901), p. 225).

In 1900, the subcontracting weavers usually wove on looms that they owned, using reeds and heddles they leased from the manufacturers to which they were subcontracted. These subcontracting weavers worked mainly on yarn-dyed fabrics, such as *shusu* (satin) and *kaiki* (lustrine).<sup>23</sup>

## 2 The model

### 2.1 Advantages and disadvantages of the putting-out system

The advantages of the putting-out system were largely strategic. A survey report by the prefectural government of Gunma summarized the advantages and disadvantages of the putting-out system, where subcontractors conducted production processes, as opposed to the factory system, where employed workers did the same:<sup>24</sup>

#### Document 1

...advantages of having subcontracting weavers are that it

1. can flexibly increase or decrease [manufacturers' own] business depending on market circumstances and manufacturers' conditions [compared with the factory system].
2. can save on the costs and effort of maintaining looms, facilities, and factories which would be necessary under the factory system.
3. can make it unnecessary to retain slack female workers when sales fall or profits are not earned.

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<sup>23</sup>“Most subcontracted weaving is that of *shusu*, while *kobai kaiki* and *mon habutae* (plainly patterned) are also subcontracted. ..., generally, the weaving of fabrics that do not need power-looms is subcontracted, with only the reeds and heddles being leased to subcontractors, making them to weave using their own looms... Sometimes looms are also leased. As is usually seen in other textile regions, prepared warp with weft is consigned” (Kawamoto et al. (1901), p. 225).

<sup>24</sup>See The Prefecture of Gunma, Department of Interior (1904), pp. 61–62.

4. can save the recruitment costs, wages, and other expenses to employ female workers and can produce large lots cheaply.
5. makes it unnecessary to specifically train female workers when changing the production of fabric items.

The disadvantages include

1. harmful effects such as that subcontractors embezzling or collateralizing material yarns.
2. deteriorating quality of fabrics.
3. hardly standardized fabrics.
4. a failure to meet delivery times.
5. little monitoring the production process.

For high-mix, low-volume production, the optimal size of production in each process could be small. Furthermore, in order to set or respond in a timely way to fashion trends, modularized and interchangeable processes, either yarn-dyeing or weaving, might be helpful. In this case, the putting-out system yield a technically efficient organization. The aforementioned advantages are mostly still true for many modern industries.

However, once we consider producing the premium specialty of the Kiryu cluster and the physical and human capital investment required to do so, the advantages are no longer necessarily consistent. For example, the first and the third advantages indicate that a manufacturer did not provide job security for subcontracting weavers, which would have been provided to employed weavers under the factory system. Then, the second and fifth advantages mention that subcontractors themselves were expected to invest sufficiently in physical and human capital. At the same time, the disadvantages suggest that manufacturers did recognize embezzlement and the laziness of some subcontractors under weaker monitoring, but still hired them.

The numbers of manufacturers and subcontracting weavers in Table 3 suggest that the market was extremely competitive for subcontractors. Thus, a straightforward inference would be that some weavers who tended to cheat were often changed by manufacturers, such that the weavers did not earn quasi-rent in the competitive market. However, some weavers were allowed to earn quasi-rent in the form of a higher subcontracting fee, which they could invest in physical and human capital. To provide a rigorous understanding of this arrangement, we build a simple model in the following section.

## 2.2 A model with risk-averse agents

Let  $w_h$  denote the subcontracting fee for a premium fabric,  $c_h$  the cost of a premium weave,  $w_l$  the subcontracting fee for an ordinary fabric,  $c_l$  the cost of ordinary weaving, and  $q$  the probability of a contract in this period if the weaver had not cheated in the past. Here, by “cheat,” we mean that a weaver receives a fee for premium weaving, but weaves ordinary fabric instead, earning  $w_h - c_l$ . In addition,  $\epsilon \sim N(0, \sigma^2)$  denotes a symmetric shock in the current period, such as an unexpected cancellation or booking resulting from a demand shock. Note that demand shocks to the Kiryu cluster were considerable (see Table 1). In addition,  $d$  denotes the discount factor. We assume that manufacturers are risk-neutral, but that subcontracting weavers have a constant absolute risk-averse utility function,  $u(w - c) = -\exp\{-r(w - c)\}$ , where  $r$  denotes the absolute risk-averse coefficient. Then, letting  $CE$  and  $V$  denote the certainty equivalent and the discounted present value of future revenue, respectively, we have  $u(CE) = -\exp\{-r(CE)\} = E[u(V)] = E[-\exp\{-rV\}]$ . Considering the competitive market condition for subcontracting weavers (4,000 weavers against 100 manufacturers in the late 1900s; see Table 3), we further assume a zero quasi-rent condition for honest, ordinary weaving, such that  $w_l - c_l = 0$ .

The structure of the game is as follows. In each period, weaver agents choose between premium weaving, with a cost of  $c_h$ , and ordinary weaving, with a cost of  $c_l$ . If a weaver has

always chosen premium weaving in the past, she/he is known as a premium weaver among manufacturers, with a probability of  $q > 1/2$ . The subcontracting fee is determined at the beginning of each period and paid as stipulated in the contract.

Then, we consider the following strategy.

- Manufacturers:

1. First period: Manufacturers offer the premium fee  $w_h$ .

2. Second period and later:

- If a manufacturer knows that a weaver has always chosen premium weaving in the past, then the manufacturer offers the premium fee,  $w_h$ , to the weaver in this period.
- If a manufacturer knows that a weaver cheated (chose ordinary weaving, earning  $w_h - c_l$ ) in the past on at least one occasion, the manufacturer offers the ordinary fee,  $w_l$ , to the weaver in this and future periods.

- Weavers:

1. First period: Weavers choose premium weaving.

2. Second period and later:

- If a weaver is offered the ordinary fee,  $w_l$ , she/he weaves an ordinary product.
- If a weaver is offered the premium fee,  $w_h$ , the weaver chooses between premium weaving (honest) and ordinary weaving (cheat), such that his/her payoff is maximized.

Then, the discounted present value of a weaver's revenue stream from premium weaving,  $V_p$ , is

$$V_p = (1 + \epsilon)(w_h - c_h) + d[qV_p + (1 - q)(w_l - c_l)],$$

which is rearranged to

$$V_p = \frac{(1 + \epsilon)(w_h - c_h)}{1 - dq},$$

and hence

$$E[V_p] = \frac{w_h - c_h}{1 - dq}, \quad \text{Var}[V_p] = \frac{(w_h - c_h)^2 \sigma^2}{(1 - dq)^2}.$$

The discounted value of cheating,  $V_c$  (i.e., choosing ordinary weaving, but receiving a fee for premium weaving,  $w_h$ ) in this period is

$$V_c = (1 + \epsilon)(w_h - c_l) + d[q(w_l - c_l) + (1 - q)V_c],$$

which is rearranged to

$$V_c = \frac{(1 + \epsilon)(w_h - c_l)}{1 - d(1 - q)},$$

and, hence,

$$E[V_c] = \frac{w_h - c_l}{1 - d(1 - q)}, \quad \text{Var}[V_c] = \frac{(w_h - c_l)^2 \sigma^2}{[1 - d(1 - q)]^2}.$$

Furthermore, the certainty equivalents of premium weaving,  $CE_p$ , and cheating,  $CE_c$ , are given as follows:

$$CE_p = E[V_p] - r \frac{\text{Var}[V_p]}{2} = \frac{w_h - c_h}{1 - dq} - \frac{r(w_h - c_h)^2 \sigma^2}{2(1 - dq)^2}$$

and

$$CE_c = \frac{w_h - c_l}{1 - d(1 - q)} - \frac{r(w_h - c_l)^2 \sigma^2}{2[1 - d(1 - q)]^2}.$$

Then, the incentive constraint for honest premium weaving is

$$(1) \quad CE_p \geq CE_c \Leftrightarrow \frac{w_h - c_h}{1 - dq} - \frac{r(w_h - c_h)^2 \sigma^2}{2(1 - dq)^2} \geq \frac{w_h - c_l}{1 - d(1 - q)} - \frac{r(w_h - c_l)^2 \sigma^2}{2[1 - d(1 - q)]^2}.$$

## 2.3 Theoretical prediction

Let us assume that reservation value is 0, and, hence, individual rationality constraint is satisfied. Then we have the following lemma.

**Lemma 1.** *Suppose that agent weavers are risk-neutral ( $r = 0$ ). Then, the optimal fee for premium weaving,  $w_h^*$  is decreasing in the degree of collusion between manufacturers,  $q$ , and in the discount factor,  $d$ .*

*Proof* See **Appendix I**.

This is a reproduction of the conventional folk theorem, as in Greif (1983). If agents are risk-neutral, more tightly collective punishment by manufacturers (greater  $q$ ) simply decreases the incentive to cheat, makes premium weaving a more stable equilibrium outcome, and lowers the optimal fee,  $w_h^*$ , for premium weaving.

Next, we allow agent weavers to be risk-averse,  $r > 0$ , and assume that the difference in costs between premium and ordinary weaving is not negligible, such that

$$\frac{d(2q - 1)}{r\sigma^2} < c_h - c_l.$$

Then, the incentive constraint equation (1) is rewritten as follows:

$$(2) \quad \leq w_h \leq \frac{[[1 - (1 - q)d]c_h + (1 - dq)c_l] r\sigma^2 + 2[1 - d + (1 - q)qd^2]}{(2 - d)r\sigma^2} \cdot \frac{[1 - (1 - q)d]c_h - (1 - dq)c_l}{(2q - 1)d}.$$

First, we show that premium weavers suffer more from risk when manufacturers better cooperate with each other.

**Lemma 2.** *There exists a collusion level  $\underline{q}$  such that honest premium weavers suffer more from order volatility than cheating weavers do, only if  $q > \underline{q}$ .*

*Proof* See **Appendix I**.

A greater degree of collusion among manufacturers increased the urgency of stabilizing orders for honest premium weavers, for instance in an economic downturn or a change in fashion trend. Otherwise, the risk compensation to be paid to premium weavers increases asymmetrically in the order volatility  $\sigma^2$ . In practice, it would be possible to share information about premium weavers and to favorably allocate orders to them.

From equation (2), we have the following proposition.

**Proposition 1.** *There exists a certain level of risk  $\bar{\sigma}^2$  such that only if  $\sigma^2 < \bar{\sigma}^2$ , the optimal fee for premium weaving,  $w_h^*$ , is decreasing in the degree of collusion between manufacturers,  $q$ ; and otherwise it is increasing in  $q$ .*

*Proof* See **Appendix I**.

A tighter collusion means the honest premium weavers suffer more from order volatility  $\sigma^2$  than cheating weavers do and  $w_h$  is decreasing in the degree of manufacturers' collusion  $q$  only if  $\sigma^2 < \bar{\sigma}^2$ ,

A relational contract with earning quasi-rent is a kind of island in a competitive market. This island could provide a strong incentive for premium weaving by potentially throwing cheaters out to the competitive market, where quasi-rent could never be earned. At the same time, because of this asymmetric payoff between being inside and outside the quasi-rent island, risk also asymmetrically affects premium weaving. In the conventional folk theorem captured by **Lemma 1**, assuming the risk-neutrality of agents, tighter manufacturers' collusion (greater  $q$ ) always serves as a threat to potential cheaters. In other words, a long-term relationship between a manufacturer and a weaver would result solely in honesty by the weaver. Meanwhile, **Proposition 1** indicates that manufacturers must contain the risk associated with premium weaving within a reasonable range. Only then a tighter collusion between manu-

facturers would make premium weavers more diligent, which in turn implies that premium weavers would accept a lower equilibrium fee  $w_h^*$  while letting cheating weavers keep doing ordinary weaving in the competitive market, where they cannot earn rent.

### 3 Empirical results and descriptive evidence

#### 3.1 Data

As in other cases, there is little quantitative information on the honesty, diligence, and skill of small subcontractors. Fortunately, in the case of Kiryu, the association of silk fabric manufacturers, Kiryusha, issued a monthly periodical, *Kiryu no Kogyo (Manufacturing of Kiryu)*, later renamed to *Orimono Kogyo (Weaving Industry)* in 1903, in which issues in 1903 published introductions of subcontractors by manufacturers. Of the issues 53 to 63 in 1903, issues 53–58 and 61–63 are available to us. The introductions describe how diligent, honest, and skilled a particular subcontractor was, how many years the subcontractor had traded with the manufacturer, and whether the subcontractor had any specialty products. These introductions are highly qualitative, but we transformed them into quantitative values using the measures described in **Appendix II**.<sup>25</sup> Out of introduced features of weavers, “diligence” is not a straightforward expression. However, provided that these introductions are expressed by profit-maximizing manufacturers, we can infer that a positive expression indicates a feature that contributes to profit. Here we interpret “diligence” as tendency to achieve the same performance by being paid a lower fee.

From these introductions, we have data on 32 manufacturers and 189 subcontractors. Three of the 189 subcontractors had long-term relationships with two manufacturers. Four of the 189 subcontractors were throwsters, and the others were weavers. While the sample size is quite small, given the total number of subcontracting weavers in the period, roughly

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<sup>25</sup>For a summarized description of introductions in the documents, see Nakabayashi (2007), pp. 151–159.

4,000 (see Table 2), this is all we can know at this moment.

### 3.2 Diligence, honesty, and specialization

Table 5 regresses the degree of honesty ( $H$ , column 5–1), degree of diligence ( $D$ , column 5–2), and degree of skill ( $S$ , columns 5–3 and 5–4) on the male dummy variable ( $d_m$ ), the dummy variable indicating whether both are Kiryu residents ( $d_{kk}$ ), which takes the value 1 if both the manufacturer and subcontractor dwell in the Town of Kiryu as the administrative district, the core of the Kiryu cluster, rather than in suburban areas and, hence, captures geographical closeness;<sup>26</sup> the number of years of relational transactions ( $Y$ ); and the specialty dummy variable ( $d_s$ ), which takes the value 1 if a subcontractor has a specialty, such as *shusu* (satin) or *kaiki* (lustrine).

INSERT Table 5 HERE

The regression of honesty ( $H$ ) in column (5–1) shows that years of relational transactions do not affect it, and that geographical closeness ( $d_{kk}$ ) has a significantly negative effect. The former effect shows that on the equilibrium path, dishonest weavers, if any, had already been excluded from the network of relational contracts, such that difference in existing relational contracts did not affect the degree of honesty of existing relational subcontracts. The latter effect indicates that geographical closeness on its own did not contribute to honest trades in the Town of Kiryu. There, subcontractors intended to cheat, and manufacturers intended to beat prices down in the competitive market. By doing so, neither party earned quasi-rent.

The regression of diligence ( $D$ ) in column (5–2) shows that years of relational transactions contributed to an increase in diligence. The more stable transactions were, the more diligently subcontractors seemed to work. Job security intensified diligence. This result is consistent with our theoretical predictions, **Lemma 2** and **Prediction 1**, interpreting “diligence” as propensity to deliver a high performance with being paid a lower wage.

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<sup>26</sup>Note that most manufacturers were located in the Town of Kiryu.

The regression of skill ( $S$ ) in column (5–3) shows that specialization in a specific product, as captured by the specialty dummy variable ( $d_s$ ), contributed to skill acquisition. It was essential to the skill acquisition of subcontracting weavers that manufacturers allowed them to specialize in a product or that they stabilized the order volume of a product to premium subcontractors, which somehow shielded premium weavers from the volatile market (see Table 1). This is consistent with our theoretical prediction **Lemma 2** that premium weavers are more vulnerable to market volatility if manufacturers collude closely.

In summary, neither the duration of relational transactions nor geographical closeness promoted honest trades on the equilibrium path. This result does not mean that repeated transactions were not helpful in maintaining the honesty of subcontractors. In Kiryu, an established cluster, the prevention of cheating by the repetition of trades was already the outcome of a dominant strategy because of the rent earned between premium manufacturers and subcontractors. This is why a regression model, which needs a variance from some off-the-equilibrium-path behaviors for identification, cannot find a significantly positive effect of the duration of a relational contact or geographical closeness on the degree of honesty ( $H$ ). Subcontractors who were inclined to cheat and manufacturers who beat prices down traded fairly in the competitive market, outside of the relational trades earning quasi-rent.

On-the-equilibrium path, honest trades worked through a different channel. The regression of skill ( $S$ ) in column (5–4) clearly shows that the degree of honesty ( $H$ ) and specialization ( $d_s$ ) significantly contributed to skill acquisition. Honest weavers devoted themselves to skill acquisition, rather than fearing punishment in the coming periods.

Although relation between honesty and skill acquisition is not addressed in our model and hence we cannot give a strong reasoning, the multi-task principal agent model setting by Holmstrom and Milgrom (1991) provides us with an insight. Effort for skill acquisition is hardly observed in a short-term contract. Thus, if stable contract and fee are guaranteed and risk is reasonably contained, honest and proud agents would invest in the hardly observable

activity, skill acquisition.

### 3.3 Smaller risk by better match?

Although dishonest behaviors were not very rare among subcontractors introduced in *Kiryu no Kogyo (Manufacturing of Kiryu)*,<sup>27</sup> the greater part of the introduction was a description of diligent or skilled subcontractors. The primary purpose of introducing subcontractors in *Kiryu no Kogyo* does not seem to have been revealing information about cheating subcontractors and/or their punishment. The association of manufacturers in Kiryu did not exclude multi-relational contracts between a subcontractor and manufacturers. The standard format of a subcontracting contract, as designated by the Kiryu Weaving Association, stipulated the following:<sup>28</sup>

#### Document 2

##### Clause 3

1. The consigner [manufacturer, by the quoter] promises following items.  
... snip ...
2. The consigner should report to the subcontractor when the consigning party suspends the consignment of materials and cancels this contract because of one's own convenience.  
... snip ...

##### Clause 4

1. The subcontractor should honestly conduct the subcontracted process beyond doubt and has the following obligations.  
... snip ...

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<sup>27</sup>See Matsumura (2002) and Nakabayashi (2007).

<sup>28</sup>The Prefecture of Gunma, Department of Interior (1904), pp. 65–66.

2. The subcontractor should report to as soon as possible should he/she decline the subcontract and cancel the contract.

... snip ...

Furthermore, as the decreasing number of manufacturers in Table 4 shows, the market was competitive for manufacturers as well. Hence, even if manufacturers wanted to enclose skilled and diligent weavers, it was unlikely successful. Now that enclosure was impossible anyway, it would be better to share information about skilled or promising subcontractors and to provide them with better match and job security. This, in turn, would encourage already honest weavers to work diligently and to acquire the necessary skills by specialization, as predicted by **Proposition 1** and **Lemma 2**, and as shown in columns (5–2), (5–3), and (5–4) in Table 5. Furthermore, this would make the premium fee lower than would otherwise have been the case.

## Concluding remarks

Our findings are not necessarily similar to standard repeated game settings. However, in successful relational trades in the real world, cheating is a dominated strategy and, hence, should never explicitly emerge on the equilibrium path. Instead, it is recognized that it is critical to take care of risk-averse premium subcontractors. For instance, Toyota, the automobile manufacturer, holds rigorously stable long-term relationships with premium subcontractors only. These subcontracting firms are already loyal and are referred to as “first tier,” and Toyota does not necessarily care about potential cheaters. By holding stable long-term relationships with “first-tier” subcontractors, Toyota does care about optimal risk absorption for “first-tier” subcontractors.<sup>29</sup>

In real modern economies, outside of relational contracts earning quasi-rent, competitive

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<sup>29</sup>See Asanuma and Kikutani (1992).

markets dominate. Keeping marginal subcontractors from cheating is not essential to the profitability of the nexus of subcontractors, given the competitive markets. Cheaters might be replaced immediately, or may be utilized by receiving a discounted fee in such a competitive market. This so-called globally optimal procurement by multinational companies is composed of the long-term relationships with premium subcontractors and the competitive purchases from others who may be operating anywhere in the world. The reliance on such global procurement tends to be greater for more efficient multinationals.<sup>30</sup> In such a real context, infinitely repeated transactions can increase the utility of trustable premium agents, rather than punishing cheaters. The Kiryu weaving cluster, which emerged in the late nineteenth century, provides an early example of modern clusters as we now see in daily life.

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<sup>30</sup>See Defever and Toubal (2013).

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## Appendix I

### *Proof of Lemma 1*

*Proof.* The incentive constraint is as follows:

$$\begin{aligned} CE_p|_{r=0} &\geq CE_c|_{r=0} \\ \Leftrightarrow \frac{w_h - c_h}{1 - dq} &\geq \frac{w_h - c_l}{1 - d(1 - q)} \\ \Leftrightarrow w_h &\geq \frac{[1 - d(1 - q)]c_h - (1 - dq)c_l}{(2q - 1)d}. \end{aligned}$$

Hence, the optimal contract, which is the least  $w_h$  that satisfies (AP1), is

$$(AP2) \quad w_h^* = \frac{[1 - d(1 - q)]c_h - (1 - dq)c_l}{(2h - 1)d},$$

$$(AP3) \quad \frac{\partial w_h^*}{\partial q} = -\frac{(2 - d)(c_h - c_l)}{(2q - 1)^2 d} < 0,$$

and

$$(AP4) \quad \frac{\partial w_h^*}{\partial d} = -\frac{c_h - c_l}{(2q - 1)d^2} < 0,$$

where (AP4) holds under the assumption  $q > 1/2$ . (AP3) and (AP4) prove the lemma. □

### *Proof of Lemma 2*

*Proof.* The magnitude of risk associated with honest premium weaving  $R_h$  and that for cheating  $R_c$  is as follows:

$$(AP7) \quad R_h \equiv \frac{r(w_h - c_h)^2 \sigma^2}{2(1 - dq)^2} > \frac{r(w_h - c_l)^2 \sigma^2}{2[1 - d(1 - q)]^2} \equiv R_c$$

if

$$(AP8) \quad q > \frac{c_h - c_l + (w_h - c_h)d}{(2w_h - c_h - c_l)d} \equiv \underline{q}. \quad \square$$

### *Proof of Proposition 1.*

*Proof.* From equation (2), we have the optimal fee for premium weaving,

$$(AP5) \quad w_h^* = \frac{[[1 - (1 - q)d]c_h + (1 - dq)c_l] r\sigma^2 + 2[1 - d + (1 - q)qd^2]}{(2 - d)r\sigma^2},$$

and

$$(AP6) \quad \begin{aligned} \frac{\partial w_h^*}{\partial q} &= \frac{(dc_h - dc_l)r\sigma^2 + 2(d^2 - 2qd^2)}{(2 - d)r\sigma^2} \leq 0 \\ \Leftrightarrow \sigma^2 &\leq \frac{2(2q - 1)d}{(c_h - c_l)r} \equiv \bar{\sigma}^2. \end{aligned}$$

□

**Appendix II** Definitions of variables.

Variable	Definition	Median	Mean	Standard deviation
$d_m$ male dummy variable	=1 if the subcontractor is male	1.0000	0.8021	0.3995
$d_{kk}$ dummy variable of both residents in Kiryu	=1 if the manufacturer and the subcontractor reside in Kiryu Town, Yamada County, Gunma prefecture	0.0000	0.4740	0.5006
$H$ Degree of honesty	3 "very honest"; "extremely honest"; "loyal through thick and thin"; "very sincere."	1.0000	1.2656	0.6116
	2 "honest"; "loyal"; "behaviors are good"; "sincere";			
	1 "behaviors are fairly good"; "neither good nor bad"; "behaviors are ordinary"; "ordinary"; no description.			
	0 "a leader of fraud"; "embezzles weft"; "collateralizes weft"; "woven products sometime disappear"; "pounds (of woven products) are unexpectedly light"; "not so good"; "pounds (of woven products) are unexpectedly light in good times."			
$D$ Degree of diligence	3 "the most steady"; "is earnestly devoted to job"; "is devoted to job"; "faithful to job"; "faithfully"; "is devoted to job through thick and thin"; "work diligently"; "conscientious through thick and thin"; "really conscientious"; "very conscientious"; "is patiently and conscientiously devoted to job."	2.0000	1.6615	1.2215
	2 "conscientious"; "works well and satisfies the manufacturer"; "conscientiously and diligently work"; "diligently work"; "is devoted to job"; "never tired of job."			
	1 "relatively diligent."			
	0 "neither good nor bad"; no description.			
$S$ Level of skill	3 "products for competitive exhibition are ordered to"; "products are the best"; "products are extremely fine"; "recent products for competitive exhibition are woven by"; "products are especially fine"; "technique is very good"; "products are extremely good"; "the first subcontractor"; "skill is very good"; "if the best products are necessary, they are ordered to"; "products are very good"; "distinguished subcontractor"; "earnestly good".	2.0000	1.5156	1.1711
	2 "large amount and good quality"; "good quality"; "products are good"; "products are fine"; "good products"; "fine products"; "technique is fine"; "technique is good," "skill is good"; "skill is fine."			
	1 "technique is fairly good"; "fairly good products"; "technique is fairly good"; "not the most skilled"; "promising."			
	0 "ordinary technique"; no description.			
$Y$ Years of relational transactions	Described years or 1 if not mentioned. Maximum: 30, minimum: 1, mean: 7.5391, median: 5.0000, standard deviation: 7.3863, skewness: 1.4224.	5.0000	7.5391	7.3863
$d_s$ Specialty dummy variable	=1 if specialty product is mentioned and 0 otherwise.	0.0000	0.4427	0.4980

*Source* : Kiryu no Kogyo (*Manufacturing of Kiryu*), no. 53–58, Orimono Kogyo (*Weaving Industry*), whose title was changed from Kiryu no Kogyo, no. 61–63, 1903.

**Table 1** Production of silk fabric in Kiryu Town, Yamada County, the Gunma prefecture: Decomposed to kinds of fabrics.

Year	Woven of Omama <i>Hiraito</i>		<i>Habutae</i> (Plain)	<i>Kaiki</i> (Lustrine)		<i>Chirimen</i> (Crepe)	<i>Hakama</i> <i>Ji</i>	<i>Ito Ori</i>	<i>Fushi</i> <i>Ito Ori</i>	<i>Shike</i> <i>Ginu</i>	<i>Rinzu</i> (Figured Satin)	<i>Shusu</i> (Satin)	Others	Total			
	<i>Ro</i> (Gauze) <i>a</i>	Others <i>b</i>															
	m <sup>2</sup>	m <sup>2</sup>	m <sup>2</sup>	1,000 Yards	m <sup>2</sup>	1,000 Yards	m <sup>2</sup>	m <sup>2</sup>	m <sup>2</sup>	m <sup>2</sup>	m <sup>2</sup>	m <sup>2</sup>	m <sup>2</sup>	m <sup>2</sup>	1,000 Yards	m <sup>2</sup>	1,000 Yards
1892	8,522	832	825,262		20,480		38,451	0	5,632	0	0	0	63,565		962,744		
1893	60,178	5,133	2,059,648		24,550		23,045	2,196	11,159	476	8,207	0	28,751		2,223,345		
1894	114,278	8,463	963,776		321,608		16,745	6,920	15,634	676	182,477	5,635	42,545		1,678,756		
1895	336,586	15,250	223,598		244,283		49,421	9,935	22,467	1,533	46,886	5,412	35,607		990,979		
1896	165,453	3,994	162,458		217,958		36,736	14,464	75,520	12,800	31,130	55,296	50,373		826,181		
1897	133,862	3,968	178,790		233,728		40,858	8,192	72,960	16,640	29,440	59,392	70,272		848,102		
1898	127,027	3,750	187,149		312,576		36,014	3,072	90,880	16,128	34,560	0	147,866		959,022		
1899	122,138	0		1,395		3,532	36,014	6,016	132,454	15,040	143,759	28,288	82,644	240	566,354	5,166	
1900	107,671	0		3,741		3,384	33,516	5,345	66,017	10,752	0	1,843	1,597	426,368	0	653,110	7,125
1901	238,520	0	808,115		83,389		31,526	12,928	72,371	13,312	0	2,125	6,400	209,818		1,478,505	
1902	210,755	0	595,251		91,136		23,281	4,124	51,149	14,715	0	4,198	3,750	260,838		1,259,197	

**Source :** *Gunma Ken Tokei Sho (Statistics of the Prefecture of Gunma)*, the prefecture of Gunma.

**Notes :** *Hiraito* is a flat-thrown silk thread. "Others" of "woven of omama *hiraito*" contain *sha* (gauze), *ryumon*, *kame aya ori* (patterned with hexagons), and *kame mon ori* (patterned with hexagons). Handkerchiefs are not included in this table.

**Table 2** Production organization of the silk fabric industry in Yamada County, the prefecture of Gunma.

Year	Number of independent weaving houses	Number of subcontracting weaving houses	Total	Number of looms		Number of operatives Weaving operatives		Supporting operatives	
				Power	Hand	Male	Female	Male	Female
1901	724	3,796	4,520	455	6,558	1,050	7,258		
1902	714	3,691	4,405	168	6,307	1,026	7,132		
1903	704	4,331	5,035	181	6,429	2,070	10,984	810	1,227
1904	468	2,751	3,219	167	5,629	903	1,946	1,884	7,928

**Source :** *Gunma Ken Tokeisho (Statistics of the Prefecture of Gunma)*, the prefecture of Gunma.

**Notes :** The difference in number of subcontracting weavers from that of **Figure 2** in 1904 is presumed to come from whether counted at the beginning of 1904 (**Figure 2**) or at the end of 1903 (this table).

**Table 3** Choice of the factory system in Yamada County, the Gunma prefecture.

Year	Factory industry					Cottage industry				
	Number of factories	Number of looms		Number of operatives		Number of cottages	Number of looms		Number of operatives	
		Power	Hand	Male	Female		Power	Hand	Male	Female
1905	39	152	438	58	648	302	0	898	37	1,078
1906	35	152	388	70	897	394	0	1,245	91	1,297
1907	33	173	418	59	876	418	0	1,367	95	1,447
1908	32	330	432	60	872	390	0	1,298	81	1,382
1909	41	356	503	54	1,005	423	5	1,369	64	1,463
1910	73	420	625	63	1,195	385	0	1,291	60	1,384
1911	66	163	569	46	754	375	12	1,399	51	1,377
1912	59	204	555	33	816	377	12	1,357	35	1,341

*Source* : Gunma Ken Tokeisho (Statistics of the Prefecture of Gunma), the prefecture of Gunma.

**Table 4** Putting-out manufacturers and subcontractors in Yamada County, the Gunma prefecture.

Year	Manufacturers putting-out weaving					Subcontracting weavers' households				
	Number of manufacturers	Number of looms		Number of operatives		Number of weavers	Number of looms		Number of operatives	
		Power	Hand	Male	Female		Power	Hand	Male	Female
1905	199	0	417	13	529	3,540	0	4,202	65	4,630
1906	109	0	293	26	382	3,663	0	4,161	217	5,002
1907	139	0	388	37	468	4,034	0	5,650	263	5,562
1908	124	0	343	40	418	4,070	0	5,594	301	5,473
1909	97	0	280	24	446	4,155	0	5,439	293	5,433
1910	104	0	322	32	405	4,560	0	5,950	324	5,892
1911	70	0	0	0	0	4,713	0	6,176	279	6,029
1912	99	0	76	21	76	5,337	0	7,347	287	7,144

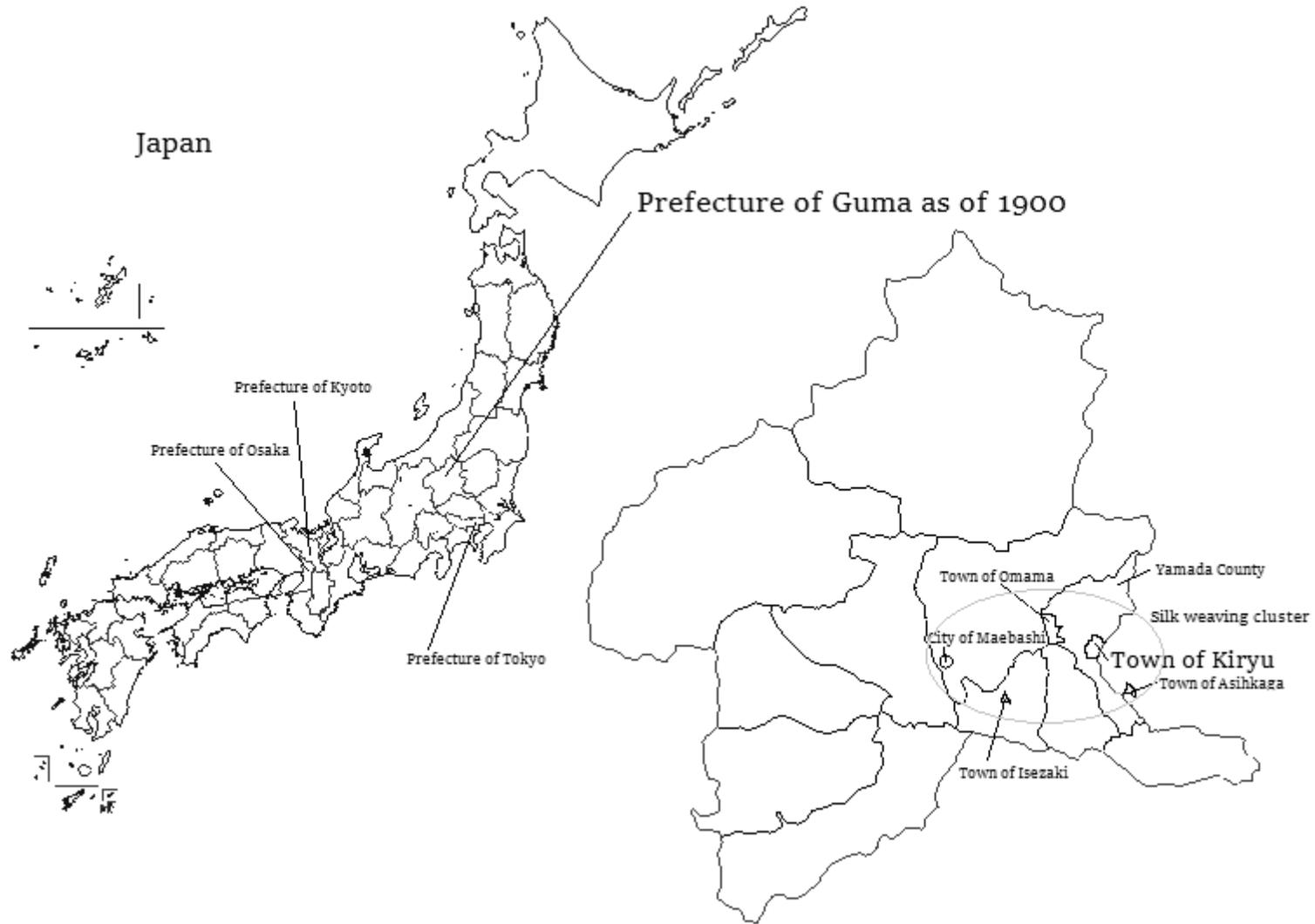
*Source* : Gunma Ken Tokeisho (Statistics of the Prefecture of Gunma), the prefecture of Gunma.

**Table 5** Honesty, diligence and skill of subcontractors in the Kiryu region, 1903.

Dependent variable	5-1 <i>H</i> (honesty)		5-2 <i>D</i> (diligence)		5-3 <i>S</i> (skill)		5-4 <i>S</i> (skill)	
Estimation method	Ordered probit		Ordered probit		Ordered probit		Ordered probit	
Number of samples	192		192		192		192	
Independent variables	<i>z</i> -statistic		<i>z</i> -statistic		<i>z</i> -statistic		<i>z</i> -statistic	
$d_m$ (male dummy)	-0.3161	-1.4384	-0.2677	-1.2530	-0.1703	-0.8160		
$d_{kk}$ (both in Kiryu dummy)	-0.5177	-2.8444 ***	0.0772	0.4595	-0.0995	-0.6042		
<i>Y</i> (yeas of relation)	0.0135	1.1342	0.0252	2.2838 **	0.0064	0.5877		
$d_s$ (specialty dummy)	0.2135	1.2176	0.1313	0.7906	0.6381	3.8709 ***	0.5928	3.6208 ***
<i>H</i> (honesty)							0.3876	2.8445 ***
<i>D</i> (diligence)							0.0969	1.4597
Pseudo R <sup>2</sup>		0.0361		0.0185		0.0326		0.0488
Log likelihood		-161.8096		-218.6757		-246.7317		-242.6141
LR statistic		12.1275 **		8.2342 *		16.6326 ***		24.8679 ***

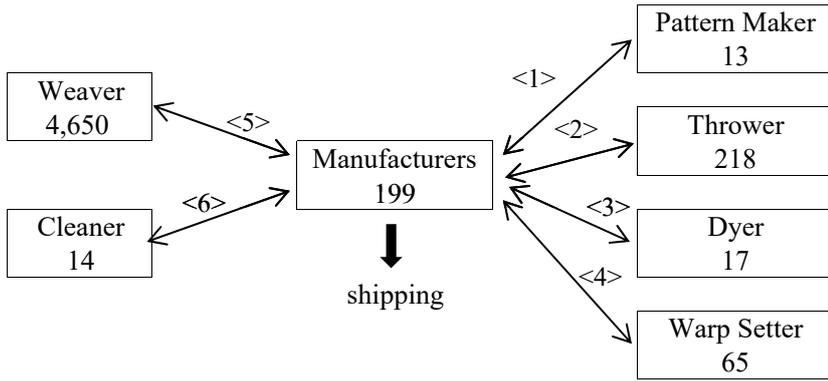
**Source** : *Kiryu no Kogyo (Manufacturing of Kiryu)*, no. 53–58, *Orimono Kogyo (Weaving Industry)*, whose title was changed from *Kiryu no Kogyo*, no. 61–63, Kiryu: Kiryusha, 1903. \*\*\*, \*\*, and \* respectively denote significance of 1, 5, 10 percentage levels.

**Figure 1** Kiryu silk weaving cluster.



*Source:* Produced by the author from copyright free sources created by Satoshi Ishida (url: <http://www.tt.rim.or.jp/~ishato/tiri/huken/huken.htm>: Last visited on January 23, 2016).

**Figure 2** Number of subcontractors in the Kiryu silk fabric cluster, 1904.



**Source** : Sucontractors: The prefecture of Gunma, Third Department (1909), pp. 217–218. Manufacturers: The number in 1905 in **Table 3**.