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, if manufacturers closely collude with each other when trading with subcontractors, if information about subcontractors’ past actions is only imperfectly shared by manufacturers as hearsay, and if demand shock is considerable, then premium subcontractors suffer more from market volatility than ordinary subcontractors would 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.

1. 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 observed in developed or emerging economies [for Western countries, see Sable and Zeitlin (1997) and Becchetti and Rossi (2000); for Japan, see Hashino and Otsuka (2013a, b); 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 et al. (2010) and Kimura (2011); for India, see Chari (2000); and for Ethiopia, see Sonobe et al. (2009), Zhang et al. (2011), Ali and Peerlings (2011) and Gebreeyesus and Mohnen (2013)]. While technological economies of agglomeration, as defined by Marshal (1920), are widely observed (see Morrison and Siegel, 1999; Ellison et al., 2010), it is known that organizational efficiency affects clusters’ overall performance. Furthermore, the path-dependent effects of organizational efficiency when clusters were formed sometimes dominate the technological economy of agglomeration, 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 (see Guiso and Schivardi, 2007;
Yamamura, 2009), as well as in emerging economies (see Weijland, 1999; Sandee and Rietveld, 2001; Miguel et al., 2005; Gebreeyesus and Mohnen, 2013). 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 early-twentieth-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 1910s and of cotton goods in the 1930s. Thus, the silk-reeling industry based on the factory system, along with the cotton spinning industry, was a driving force behind the country’s industrialization (see Nakabayashi, 2006, 2014). At the same time, industrialization and urbanization created a new demand for a greater variety of high quality, but not expensive kimono brocades. This urban mass demand was met by weaving clusters, which introduced synthetic dyes and systematic patterns from the West, while expanding their flexible putting-out, or outsourcing, 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 (Figure 1). In Kiryu, kimono manufacturers extended their network of subcontracting weavers rather than employing them in their own factories.

The kimono manufacturers’ choice to subcontract weaving is not a technological puzzle. The technologically optimal size of the high-mix, low-volume production of final goods, such as fabrics, is likely to be smaller than that of uniform intermediate goods, such as silk or cotton yarns. However, even if decentralized organizations are technologically desirable, they might not outperform centralized organizations when asymmetric information can be exploited. Imperfect monitoring of weavers’ actions after concluding putting-out contracts might result in a moral hazard of weavers. 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 (2007) and Hashino and Otsuka (2013a). This study analyzes the organizational characteristics of the Kiryu cluster at its peak in the 1900s.

The rest of the paper is organized as follows. Section 2 briefly describes the development of the Kiryu silk weaving cluster.

Section 3 introduces a simple model to capture the organizational structure of the cluster, which we test empirically. While our benchmark is standard infinitely repeated game settings such as Greif (1983), we also consider the risk attitudes of weaver agents, which generate different implications. Typical relational contracts in infinitely repeated game settings can be self-enforcing 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. Then, it turns out that subcontracting weavers who produced premium products might suffer more from market volatility because they then had something to lose. Our model captures this feature. An insight from our model is that subcontracting weavers of premium products suffer more from market volatility 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 4 empirically documents whether our prediction holds by examining contemporary material from the early 1900s, on which manufacturers shared information about their subcontracting weavers. Manufacturers attempted to share information, not about cheating subcontractors, but about excellent subcontractors. If the intention of information sharing was to punish cheaters, this is counterintuitive. 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 against this volatility.

2. Formation of an Industrial Cluster

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, many manufacturers chose to keep the putting-out system, which organized hand-loom weavers, meeting the growing demand from Tokyo and other metropolises. In contrast to Kiryu, in the city of Fukui, in the Fukui prefecture, silk weaving factories with power looms prevailed. Fukui mainly produced cheap habutae, a non-dyed silk fabric with a plain weave, which was exported to the USA. Power looms were easily used to weave plain, white silk fabrics (see Hashino and Otsuka, 2013b).

The silk fabric industry emerged in the mid-eighteenth century in Kiryu Town, as well as neighboring areas. The industry then developed remarkably after the early nineteenth century, mainly stimulated by demand from the Shogunate capital, Edo, which was later renamed Tokyo after the Meiji Restoration (see Kiryu Orimonoshi Hensankai, 1935).

In the Kiryu weaving industry, the factory system, equipped with hand looms, had been chosen to weave luxury fabrics (see Kimura, 1960, p. 137), while the putting-out system was used for most other fabrics. This only changed when factories equipped with power looms became dominant for most kinds of fabrics in the 1910s and later (see Kameda, 1989, pp. 561–565; Hashino, 2007, p. 19). 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 manufacturers’ 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/craftswomen who specialized in each process were organized as subcontractors by the manufacturers (see Kimura, 1960; Kawamura, 1991).

With the transition from the production of 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 craftsmen/craftswomen.

Demand for Variety in the Market

In the 1880s, products already spanned a wide range from the piece-dyed fabrics to the yarn-dyed fabrics. Until the 1900s, the production of yarn-dyed fabrics such as kaiki (lustering), shusu (satin), shuchin (satin) and habutae (plainly woven) increased to become a large portion of total production (see Table 1). 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
| Year | Ro (Gauze) | Habutae (Plain) | Kaiki (Lustring) | Chirimen (Crepe) | Hakama Ji | Ito Ori | Fushi Ito Ori | Shike Ginu | Rinzu (Figured Satin) | Shusu (Satin) | Others | Total |
|------|------------|----------------|-----------------|-----------------|-----------|--------|---------------|-------------|----------------------|---------------|--------|-------|
|      | (m²) | (m²) | (1,000 yards) | (m²) | (m²) | (1,000 yards) | (m²) | (m²) | (m²) | (m²) | (m²) | (1,000 yards) |
| 1892 | 8,522 | 832 | 825,262 | 20,480 | 38,451 | 0 | 5,632 | 0 | 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 | 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 | 0 | 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 | 0 | 35,007 | 990,979 |
| 1896 | 165,453 | 3,994 | 162,458 | 217,958 | 36,73(8) | 14,464 | 75,520 | 12,800 | 31,130 | 55,296 | 0 | 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 | 0 | 70,272 | 848,102 |
| 1898 | 127,027 | 3,750 | 187,149 | 312,576 | 36,014 | 3,072 | 90,880 | 16,128 | 34,560 | 0 | 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 | 0 | 82,644 | 240 |
| 1900 | 107,671 | 0 | 3,741 | 3,384 | 33,516 | 5,345 | 66,017 | 10,752 | 0 | 1,843 | 1,597 | 426,368 | 0 |
| 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 |

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. For 1901 and 1901, production in Yamada County that includes Kiryu Town and suburban villages. The volumes of Chirimen in 1898 and 1899 are as written in the original source.

Source: Gunma Ken Tokei Sho (Statistics of the Prefecture of Gunma), the Prefecture of Gunma.
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 demand for high-quality shusu (satin) was in Tokyo was also strong, which suggests a wide range of prices of a great variety (see Kawamoto et al., 1901, p. 222; Nakabayashi, 2007, pp. 133–142, 161).

In general, in larger cities, especially in the Tokyo metropolitan area, mass consumers came to demand greater variety along with 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 (Tamura, 2004, pp. 177–210). Kiryu was an example of the nationwide trend.

For a greater variety of products, power looms 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 (Minami and Makino, 1983). Instead, synthetic dyeing, rather than the power loom, was critical to realizing the greater variety of fabrics in the traditional weaving industry (Tamura, 2004, pp. 133–175).

Let us 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, the association of silk fabric manufacturers established in 1898. During the period 1900–1903, articles related to designs, including dyeing, patterning and texture, were predominant (Nakabayashi, 2007, pp. 142–143). Dyeing techniques such as alizarin and aniline 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. By combining those factor techniques, manufacturers attempted to extend the variety of fabrics rather than those for mass-producing plain fabrics.

Moreover, the Commercial and Industrial Association of Kiryu (Kiryu Sho Ko Dogyo Kumiai) established a vocational school focusing on dyeing and patterning, the Textile School of Kiryu Town (Kiryu Cho Ritsu Kiryu Orimono Gakko), which was later extended, becoming a formal secondary school, 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 (Nakabayashi, 2007, p. 144).

Thus, manufacturers collectively introduced the knowledge of synthetic dyeing and systematic patterning from the West and openly shared the critical knowledge to extend variety by establishing a technical school, as discussed by Hashino and Kurosawa (2013).

Both the synthetic dyeing and systematic patterning techniques enabled the modularization of the preparation processes, such as the dyeing process, and the weaving process. A greater variety of products became less costly and created an increasing demand. The change was swift. While most weaving manufacturers dyed their products in their workshops in 1900, by 1904, subcontracting dyers were predominant (Kawamoto et al., 1901, p. 228; The Prefecture of Gunma, Third Department, 1909, pp. 88–89; Nakabayashi, 2007, pp. 144, 162). The rapid expansion of subcontracting of the dyeing process was part of an extension of the putting-out system that affected both dyers and weavers.

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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 (see Tables 2 and 3), a stark contrast to the overall trend in the Gunma prefecture. 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. It meant that the average number of subcontracting weavers per putting-out manufacturer tripled (see Table 4). In some households of subcontracting weavers, more than one family member was engaged in the business. Hence, the number of subcontracting hand looms and operatives was greater than that of households, as shown in Table 2.

The weaving manufacturers (motobataya) purchased the yarn material, then either subcontracted it to independent producers or dyed and 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/craftswomen were in Kiryu and in the surrounding areas (Kawamoto et al., 1901, p. 225; Nakabayashi, 2007, pp. 146, 162).

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 (lustring) (Kawamoto et al., 1901, p. 225; Nakabayashi, 2007, pp. 146, 162).

3. The Model

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 (The Prefecture of Gunma, Department of Interior, 1904, pp. 61–62):

Document 1

... advantages of having subcontracting weavers are in that it:

(1) can flexibly increase or decrease [manufacturers’ own, by the quoter] business depending on market circumstances and manufacturers’ conditions [compared with the factory system];
(2) can save on the costs and efforts 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;
(4) can save on 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.
Table 2. Production Organization of the Silk Fabric Industry in Yamada County, the Prefecture of Gunma

| Year | No. of independent weaving houses | No. of subcontracting weaving houses | Total | No. of looms | No. of operatives | Weaving operatives | Supporting operatives |
|------|----------------------------------|-------------------------------------|-------|--------------|------------------|-------------------|---------------------|
|      |                                  |                                     |       |              |                  | Power Male | Female | Hand 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 |
| 1904 | 468                              | 2,751                               | 3,219 | 167          | 5,629            | 903      | 1,946  | 1,884    | 7,928  |

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).

Source: Gunma Ken Tokeisho (Statistics of the Prefecture of Gunma), the Prefecture of Gunma.
The disadvantages include:

1. harmful effects such as that subcontractors embezzle or pledge material yarns;
2. deteriorating quality of fabrics;
3. hardly standardized fabrics;
4. a failure to meet delivery times;
5. little monitoring of 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 yields a technically efficient organization. The aforementioned advantages are mostly still true for many modern industries.

However, once we consider production of the premium specialties in the Kiryu cluster and the physical and human capital investment required to do so, the advantages are in themselves no longer 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 4 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. At the same time, the fact that Kiryu established a reputation for producing specialties indicates that 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 model in the following subsection.
Table 4. Putting-out Manufacturers and Subcontractors in Yamada County, the Gunma Prefecture

| Year | No. of manufacturers | Power | Hand | No. of looms | Power | Hand | Male | Female | No. of weavers | Power | Hand | Male | Female | No. of looms | Power | Hand | Male | Female |
|------|----------------------|-------|------|-------------|-------|------|------|--------|-------------|-------|------|------|--------|-------------|-------|------|------|--------|
| 1905 | 199                  | 0     | 417  | 13          | 529   | 3,540| 0    | 4,202  | 65          | 4,630 | 0    | 217  | 5,002  | 4,034       | 0     | 5,650| 263  | 5,562  |
| 1906 | 109                  | 0     | 293  | 26          | 382   | 3,663| 0    | 4,161  | 217         | 5,002 | 0    | 217  | 5,002  | 4,034       | 0     | 5,650| 263  | 5,562  |
| 1907 | 139                  | 0     | 388  | 37          | 468   | 4,070| 0    | 5,594  | 301         | 5,473 | 0    | 293  | 5,433  | 4,070       | 0     | 5,594| 301  | 5,473  |
| 1908 | 124                  | 0     | 343  | 40          | 418   | 4,155| 0    | 5,439  | 293         | 5,433 | 0    | 293  | 5,433  | 4,155       | 0     | 5,439| 293  | 5,433  |
| 1909 | 97                   | 0     | 280  | 24          | 446   | 4,560| 0    | 5,950  | 324         | 5,892 | 0    | 324  | 5,892  | 4,560       | 0     | 5,950| 324  | 5,892  |
| 1910 | 104                  | 0     | 322  | 32          | 405   | 4,713| 0    | 6,176  | 279         | 6,029 | 0    | 279  | 6,029  | 4,713       | 0     | 6,176| 279  | 6,029  |
| 1911 | 70                   | 0     | 0    | 0           | 0     | 5,337| 0    | 7,347  | 287         | 7,144 | 0    | 287  | 7,144  | 5,337       | 0     | 7,347| 287  | 7,144  |
| 1912 | 99                   | 0     | 76   | 21          | 76    | 5,337| 0    | 7,347  | 287         | 7,144 | 0    | 287  | 7,144  | 5,337       | 0     | 7,347| 287  | 7,144  |

Source: Gunma Ken Tokeisho (Statistics of the Prefecture of Gunma), the Prefecture of Gunma.
Suppose that there are homogeneous \( m \) manufacturers and homogeneous \( n \) subcontracting weavers and that each manufacturer trades with a weaver in each period. We assume that \( n \) and \( m \) are sufficiently large that individual manufacturers cannot record all the past actions of individual weavers and that manufacturers can only share imperfect hearsay about individual weavers’ past actions.

Let \( w_h \) denote the subcontracting fee for a premium fabric, \( c_h \) the cost of premium weaving, \( w_l \) the subcontracting fee for an ordinary fabric, \( c_l \) the cost of ordinary weaving, where \( c_h > c_l \) and \( q > 1/2 \) the reliability of hearsay shared among manufacturers regarding whether a weaver cheated in the past. Thus, if a weaver has never cheated, this fact is trusted by manufacturers with probability \( q \). The probability that a manufacturer judges against the hearsay is then \( 1 - q \). Here, by “cheat,” we mean that a weaver receives a fee for premium weaving, but weaves an ordinary fabric instead, earning \( w_h - c_l \). Naturally \( q \) is assumed to be decreasing in \( n \) and increasing in the degree of cooperation among manufacturers to share information about subcontractors. In addition, \( \varepsilon \sim N(0, \sigma^2) \) denotes a 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). Let \( d \) denote 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 \( u(CE) = -\exp(-r(CE)) = E[u(V)] = E[-\exp(-rV)] \). Given the reputation of the Kiryu cluster for its specialties, we assume that honest premium weaving brings about greater profits to manufacturers than honest ordinary weaving would and that weavers earn non-negative quasi-rent by honest premium weaving as well such that \( w_h - c_h \geq 0 \). Considering the competitive market condition for subcontracting weavers (see Table 4), we further assume a zero quasi-rent condition for honest ordinary weaving, such that \( w_l - c_l = 0 \). This revenue from honest ordinary weaving forms reservation value and hence, whichever premium weaving or ordinary weaving offered, the weaver takes the contract.

The structure of the game is as follows. In each period after the first period, weavers choose between premium weaving, with a cost of \( c_h \), and ordinary weaving,
with a cost of \( c_t \). Although individual manufacturers cannot observe all actions of individual weavers, they know hearsay regarding whether a specific weaver cheated in the past. If a weaver has always chosen premium weaving, hearsay tells so and the hearsay is trusted with a probability of \( q \). 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: All manufacturers offer the premium fee, \( w_t \).
  2. Second period and later:
     - If the shared hearsay tells that a weaver has always chosen premium weaving in the past, then the manufacturer offers the premium fee, \( w_t \) to the weaver with probability \( q \) and offers the ordinary fee, \( w_l \) to the weaver with probability \( 1 - q \).
     - If the shared hearsay tells that a weaver cheated in the past on at least one occasion, the manufacturer offers the ordinary fee, \( w_l \) to the weaver with probability \( q \) and the premium fee \( w_t \) to the weaver with probability \( 1 - q \).

- **Weavers:**
  1. First period: Being offered premium fee \( w_t \), all 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 \( w_t \), 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 given by

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

which is rearranged to

\[
V_p = \frac{(1 + \epsilon)(w_t - c_h)}{1 - dq}
\]

and hence

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

The discounted value of cheating, \( V_c \) in this period is given by
\[ V_c = (1 + \epsilon)(w_h - c_l) + d[q(w_l - c_l) + (1 - q)V_c], \]

which is rearranged to

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

and hence,

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

Furthermore, the certainty equivalents of honest premium weaving, \( CE_p \), and cheating, \( CE_c \), are given as follows:

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

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

Then, the incentive compatibility constraint for honest premium weaving is

\[ CE_p \geq CE_c \]

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

**Theoretical Prediction**

As a benchmark, let us first consider a case where weavers are risk-neutral. We have the following lemma.

**Lemma 1.** Suppose that 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 the Appendix.

This is a reproduction of the conventional folk theorem, as in Greif (1983). If weavers are risk-neutral, more tightly collective punishment by manufacturers (greater \( q \)) always decreases the incentive to cheat and lowers the optimal fee, \( w_h^* \), for premium weaving.
Next, we allow 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 compatibility constraint (1) is rewritten as follows:

$$\frac{[1 - (1 - q)d]c_h + (1 - dq)c_l]}{(2 - d)r \sigma^2} + 2\left[1 - d + (1 - q)qd^2\right]$$

$$\leq w_h \leq \frac{[1 - (1 - q)d]c_h + (1 - dq)c_l]}{(2q - 1)d}.$$ (2)

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

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

**Proof.** See the Appendix.

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. Thus, we have the following proposition.

**Proposition 1.** There exists a certain level of risk, $\sigma^2$ such that only if $\sigma^2 < \sigma^2$, 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 the Appendix.

A tighter collusion implies that the honest premium weavers suffer more from order volatility, $\sigma^2$ than cheating weavers do and hence, $w^*_h$ is decreasing in the degree of manufacturers’ collusion, $q$ only if $\sigma^2 < \sigma^2$.

A relational contract that allows earning quasi-rent is a kind of island in a competitive market. This island could provide an incentive for honest premium weaving by potentially throwing cheaters out to the competitive market, where quasi-rent could never be earned. At the same time, because of these asymmetric payoffs between being inside and outside the quasi-rent island, risk also asymmetrically affects premium weaving. Proposition 1 indicates that manufacturers must contain the risk associated with premium weaving within a reasonable range. Only then a tighter collusion between manufacturers would make premium weavers more diligent, which in turn implies that premium weavers would accept a lower equilibrium fee, $w^*_h$. 

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4. Empirical Results and Descriptive Evidence

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 manufacturers’ association, 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 53–63 in 1903, issues 53–58 and 61–63 are available to us. The introductions cite the respective names of the manufacturer and subcontractor referred to, the respective municipalities where they dwell and describe how diligent, honest and skilled each 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 the Appendix and the data are available in the online Appendix (see Supporting Information at the end of this paper). Of the features mentioned describing 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 a 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, this was all we found available at this time.

Diligence, Honesty and Specialization

Table 5 regresses the degree of honesty ($H$, column (1)), degree of diligence ($D$, column (2)) and level of skill ($S$, columns (3) and (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 referring manufacturer and referred 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, the years of relational transactions with the referring manufacturer ($Y$), and the specialty dummy variable ($d_s$), which takes the value 1 if a referred subcontractor has a specialty, such as *shusu* (satin) or *kaiki* (lustre).

The regression of honesty ($H$) in column (1) shows that years of relational transactions $Y$ do not affect it and that geographical closeness $d_{kk}$ has a significantly negative effect. The former result shows that on the equilibrium path, dishonest weavers, if any, had already been excluded from the network of relational contracts, such that length of existing relational contracts did not affect the degree of honesty of existing relationally contracted weavers. The latter result 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.

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Table 5. Honesty, Diligence and Skill of Subcontractors in the Kiryu Region, 1903

| Dependent variable | (1) H (honesty) | (2) D (diligence) | (3) S (skill) | (4) S (skill) |
|--------------------|----------------|------------------|--------------|--------------|
| Estimation method  | Ordered probit | Ordered probit   | Ordered probit | Ordered probit |
| Number of samples  | 192            | 192              | 192          | 192          |
| Independent variables |                |                  |              |              |
| d_m (male dummy)   | -0.3161        | -0.2677          | -0.1703      | -0.1703      |
| d_kk (both in Kiryu dummy) | -0.5177        | 0.0772           | -0.0995      | -0.0995      |
| Y (years of relation) | 0.0135         | 0.0252           | 0.0064       | 0.0064       |
| d_s (specialty dummy) | 0.2135         | 0.1313           | 0.6381       | 3.8709***    |
| H (honesty)        | 0.3876         | 2.8445***        | 0.0969       | 1.4597       |
| D (diligence)      | 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), Nos. 53-58, Orimono Kogyo (Weaving Industry), whose title was changed from Kiryu no Kogyo, Nos. 61-63, Kiryu: Kiryusha, 1903. ***,*** Denote significance of 1%, 5% and 10% levels respectively.
The regression of diligence ($D$) in column (2) shows that years of relational transactions $Y$ 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 fee.

The regression of skill ($S$) in column (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 certain product to premium subcontractors, which somehow shielded premium weavers from the volatile market. 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 elevated the level of honesty 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 in combinations for premium weaving between 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 the relational trades earning quasi-rent.

On the equilibrium path, honesty worked through a different channel. The regression of skill level $S$ in column (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 the 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 by Holmstrom and Milgrom (1991) provides us with an insight. Effort for skill acquisition is hardly observed in a short-term contract. Meanwhile, if stable contract and fee are guaranteed and risk is reasonably contained, honest and proud agents would invest in the hardly observable but self-empowering activity, skill acquisition.

**Smaller Risk by Better Match?**

Although dishonest behaviors were not very rare among subcontractors introduced in *Kiryu no Kogyo* (*Manufacturing of Kiryu*) (Matsumura, 2002; Nakabayashi, 2007), 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 (The Prefecture of Gunma, Department of Interior, 1904, pp. 65–66):
(1) The consigner [manufacturer] 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...
(2) The subcontractor should report to [the consigner] 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 not feasible anyway, it would be better to share information about skilled or promising subcontractors and to provide them with a 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 (2)–(4) in Table 5. Furthermore, this would make the premium fee lower than would otherwise have been the case.

5. Conclusion

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 as essential 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. Instead, by holding stable long-term relationships with “first-tier” subcontractors, Toyota does care about optimal risk absorption for “first-tier” subcontractors (Asanuma and Kikutani, 1992).

In real modern economies, outside of relational contracts earning quasi-rent, competitive markets dominate. Keeping marginal subcontractors from cheating is not critical 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 the others who...
may be operating anywhere in the world. In such a real context, repeated and stable 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 are now seen regularly in daily life.

Appendix

Proof of Lemma 1

**Proof.** The incentive compatibility constraint is as follows:

$$CE_p|_{r=0} \geq CE_c|_{r=0}$$
$$\iff \frac{w_h - c_h}{1 - dq} \geq \frac{w_h - c_l}{1 - d(1 - q)}$$
$$\iff w_h \geq \frac{[1 - d(1 - q)]c_h - (1 - dq)c_l}{(2q - 1)d}.$$  \hspace{1cm} (A1)

Hence, the optimal contract, which is the least $w_h$ that satisfies (A1), is

$$w_h^* = \frac{[1 - d(1 - q)]c_h - (1 - dq)c_l}{(2q - 1)d},$$  \hspace{1cm} (A2)

$$\frac{\partial w_h^*}{\partial q} = - \frac{(2 - d)(c_h - c_l)}{(2q - 1)^2 d} < 0,$$  \hspace{1cm} (A3)

and

$$\frac{\partial w_h^*}{\partial d} = - \frac{c_h - c_l}{(2q - 1)d^2} < 0,$$  \hspace{1cm} (A4)

where (A4) holds under the assumption $q > 1/2$. (A3) and (A4) prove the lemma.

Proof of Lemma 2

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

$$R_h = \frac{r(w_h - c_l)^2 \sigma^2}{2(1 - dq)^2} > \frac{r(w_h - c_l)^2 \sigma^2}{2[1 - d(1 - q)]^2} = R_c$$  \hspace{1cm} (A5)
if
\[ q > \frac{c_h - c_l + (w_h - c_h)d}{(2w_h - c_h - c_l)d} \equiv q. \]  
(A6)

**Proof of Proposition 1**

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

\[ w_h^* = \frac{[1 - (1 - q)d]c_h + (1 - dq)c_l r^2 + 2[1 - d + (1 - q)d^2]}{(2 - d)r^2}, \]  
(A7)

and

\[ \frac{\partial w_h^*}{\partial q} = d \frac{(c_h - c_l)r^2 + 2(1 - 2q)d}{(2 - d)r^2} \leq 0 \]
\[ \Leftrightarrow \sigma^2 \leq \frac{2(2q - 1)d}{(c_h - c_l)r^2} \equiv \bar{\sigma}^2. \]  
(A8)

**Definitions of variables and summary statistics.**

| 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.” |        |         |                    |
### Definitions of variables and summary statistics. Continued

| Variable | Definition | Median | Mean  | Standard deviation |
|----------|------------|--------|-------|--------------------|
| $D$ 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.” | 1.5156 | 1.1711 |
|          | 1 “relatively diligent.” | 0.4427 | 0.4980 |
|          | 0 “neither good nor bad”; no description. | 0.0000 | 0.4427 | 0.4980 |
| $S$ 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.” | 1.5156 | 1.1711 |
|          | 1 “technique is fairly good”; “fairly good products”; “technique is fairly good”; “not the most skilled”; “promising.” | 0.4427 | 0.4980 |
|          | 0 “ordinary technique”; no description. | 0.0000 | 0.4427 | 0.4980 |
| $Y$ Years of relational transactions | Described years or 1 if not mentioned. Maximum: 30, minimum: 1, 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), Nos. 53-58, Orimono Kogyo (Weaving Industry), whose title was changed from Kiryu no Kogyo, Nos. 61-63, 1903.
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Notes

1. For change in products from the 1880s to the 1900s and for production statistics that cover a longer period, see Nakabayashi (2007), pp. 133, 138–139, 142.
2. In the Gunma prefecture, the number of factories equipped with power looms steadily increased through the 1900s to the early 1910s. See Nakabayashi (2003), pp. 39–41, tables 1–9 (a) and 1–10 (a).
3. Names and municipalities are included in the data set published as part of the online version (for details see Supporting Information at the end of this paper). For a summarized description of introductions in the documents, see Nakabayashi (2007), pp. 151–159.
4. Note that most manufacturers were located in the Town of Kiryu.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Data S1 Data set that is used for estimations in Table 5. Names of manufacturers and subcontractors and municipalities where manufacturers and subcontractors were located are also included both in original Japanese and Romanized.