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Distinctive Pricing in the Metropole of the Integrated Empire’s Economy:
Japan’s Central and Local Rice Markets, 1900–1939

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Distinctive Pricing in the Metropole of the Integrated Empire's Economy: Japan's Central and Local Rice Markets, 1900–1939*

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Abstract

This study explores the spot and futures pricing of rice in Japan's central and local cities during the period 1900–1939 to detect how importing primary products from the colonies impacted the commodity market in the metropole. The imperial country imported colonial primary products different in quality than the domestic ones to accelerate industrialization and the export of industrial goods to the colonies. During the process of commodity market to accommodate the trade expansion of colonial goods, the futures prices in the central cities, which were hubs of colonial goods, reflected the price fluctuation of imported goods. On the other hand, the minor exchange in the local cities, which tended not to trade colonial goods, augmented its price formation function. Based on the geographical heterogeneity of colonial goods circulation, this mechanism promoted economic growth and widened economic disparity within the empire.

Keywords: imperialism, primary product, colonial trade, Japanese Empire, futures trade, rice

JEL classification codes: F54, G13, N25, N75

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1. Introduction

This study focuses on Japan's rice market to investigate how the growth of commodity supply from the colonies altered the market in the metropole of the imperial country; rice was a staple food and one of the principal commodities in East and Southeast Asia. Acemoglu et al. (2001) depict that imperialism shaped the basis of the contemporary world and has caused some economic difficulties, such as the North-South gap. Therefore, imperialism has been a principal contention in the academic community of modern history. There is vast literature on the multi-faceted impact of imperialism on the colonies, which is the adverse direction of the impact against the object of this study.

During the 19th century, peripheral countries did not protect their traditional industries and specialized in the production of primary products to export to countries reaching the early stage of industrialization. Williamson (2011) asserts that this specialization suppressed peripheral countries' industrialization. The industrialized countries often colonized the peripheral countries in Asia, South America, and Africa. Mitchener and Weidenmier (2008) mention that the colonial trade of the industrialized countries surpassed the trade with foreign countries at an increasing rate before the First World War.

Findlay and O'Rourke (2007) and Havinden and Meredith (2002) reveal that Western countries' colonies enhanced the supply of primary products, which were indispensable to economic growth. Therefore, imperial countries promoted the export of industrial products to their colonies and import of primary products from their colonies after the First World War. Consequently, as Acemoglu et al. (2001) indicate, the colonizers altered economic institutions in their colonies and widened economic disparity within their empires. For example, Tadei (2020) clarifies that French trading companies manipulated commodity prices and squeezed about one-third of the potential income for farmers in African French colonies in the 1930s. This case means that the imperial countries forced their colonies to contribute to the industrial development of the metropole through the exploited colonial trade. Hence, the industrial export and import of primary products with the colonies formed a cyclic structure. Even the Japanese Empire, a follower imperial country in the modern world, also had this characteristic structure of colonial trade.

Bolt and Van Zanden (2014) estimate that Japan comprised only 29% of the gross domestic product (GDP) per capita in England in 1800 since it opted to be excluded from international trade until the middle 19th century. In 1853, as a part of the Western powers' enforcement of "free" trade, the United States threatened Japan to open the ports. Finally, in 1859, Japan launched international trade. It introduced Western technology and systems to promote rapid economic growth after the late 1880s (Gordon 2021). However, Japan did not possess the sufficient economic capacity to colonize distant locations in contrast to the Western powers. Accordingly, as the consequences of the First Sino-Japanese War of 1894–1895 and Russo-Japanese War of 1904–1905, Japan colonized its adjacent regions: Taiwan (Formosa) in 1895, Southern Sakhalin in 1905, and Korea in 1910 (Beasley 1987). Specifically, Taiwan and Korea influenced the commodity market in the metropole because Japan exploited its geographical proximity to its colonies to enhance its colonial trade. Japan heavily relied on the supply of colonial commodities, and its market experienced structural changes during the first half of the 20th century.

Okubo (2007) indicates that the degree of colonial trade linkage within the Japanese Empire was higher than other imperial countries after the First World War. Ayuso-Díaz and Tena-Junguito (2020) and Li (2019) contend that Japan actively exported industrial products to its colonies, while Taiwan and Korea could not upgrade their industrial structure because they specialized in agricultural production during the inter-war period. Tipton (2016) claims that these two colonies exported primary products to Japan, which was experiencing industrialization and urbanization from the turn of the 20th century. Wilson and Cribb (2018) highlight that Japan and its colonies built a mutually dependent relationship as a result. Accordingly, these characteristics of the colonial trade require historians to investigate the impact of imperialism on the colonies and metropole.

Although previous research gives little thought to the economic impact of the colonies on the metropole, some economic historians shed light on the impact of African colonies on Europe. Frankema et al. (2018) examine how the construction of railways and increase in the price of indigenous goods in Africa promoted colonial imports in Europe. Kamenov (2019) describes that the cooperative movements in African and Asian colonies influenced those in other colonies and nations. Regarding the Japanese Empire, Nakajima and Okazaki (2018) assert that the demographics altered geographically to reflect the integration of the market in Japan and Korea after the annexation of 1910. However, scholars do not analyze the changes in Japan's commodity market, a variation factor in population distribution, when Japan deepened economic ties to its colonies.

The representative colonial commodity in Japan was rice, as Fabiosa (2012) and Latham (2022) state. Fukao and Settsu (2021) and Kaneda (1970) argue that the per-capita consumption of rice rose along with industrialization, promoting the improvement of the living level in Japan. Howe (1999) maintains that Japan suffered from a rice shortage and increased imports of rice from East and Southeast Asian countries since the 1890s. As Seth (2020) emphasizes, Japan procured colonial rice after possessing its colonies. During the interwar period, according to Basu and Miroshnik (2020), Taiwan and Korea exported about 40% of their rice crops to Japan. The colonial rice supply contributed to mitigating the rice shortage in Japan. Nevertheless, colonial rice had a different texture and taste than domestic rice due to the difference in the breed.

Domestic, Korean, and Taiwanese rice were classified into a japonica, a subspecific japonica, and an indica breed, respectively. Consequently, only the central cities, which are far from the region that produces domestic rice, consumed colonial rice, as Francks (2015) asserts. The expansion of colonial imports diversified a variety of circulated goods and converted the market into a two-tiered structure. One was the market in the central cities, which traded domestic and colonial goods, and the other dealt only with domestic goods in the local cities, which were adjacent to the agricultural producing areas (Duus 1984). Although this conversion of the market structure might alter the pricing in the two types of cities, previous literature does not shed light on this alteration in the pricing.

Much Japanese literature on the commodity trade in Japan focuses on the rice transaction, and Mochida (1970) and Omameuda (1993) examine the distribution and policies of rice. Based on these studies, Ito et al. (2017; 2018) and Shizume (2011) analyze the pricing of the rice futures market in Japan's two central cities, Tokyo and Osaka, before 1939 and have two limitations. First, they focus only on the central markets and do not clarify the difference in the pricing between the central and local cities. Studies analyzing the pricing of the futures markets tend to pay attention to the world's large commodity exchanges in the major cities, such as the Chicago Board of Trade, New York Mercantile Exchange, and Liverpool Cotton Exchange, which Jacks (2007) focuses on. Consistent with this research trend, Japanese historians also deny the minor exchanges in the local cities. Second, these studies investigate only the futures market. All of Japan's futures markets listed only domestic rice and did not trade colonial rice. Hence, they do not explore the effect of an increase in the colonial rice trade on rice pricing. Accordingly, we extend our scope to the futures market in the local cities and spot market to scrutinize the alteration process of the rice market resulting from an increase in the colonial rice trade in Japan.

The rice market in Japan is a suitable case for the analysis on the effect of the colonial trade expansion on the imperial country's market during the interwar period when the world economy went into blocks. During this period, the commodity market in the metropole experienced qualitative changes to fit an increase in the trade of colonial goods, which had some quality differences from the domestic ones. These changes promoted more expansion of colonial trade, and the metropole relied on the imports of colonial primary products to become industrialized after the First World War. Finally, the imperial country produced and exported industrial goods to its colonies by utilizing colonial food and raw materials. That is, the qualitative changes in the metropole's commodity market were keys to industry growth in the imperial country through enhancing the cyclic structure of colonial trade. Accordingly, we pay attention to the qualitative changes in the commodity market by focusing on rice pricing during the period 1900–1939 in three cities: Tokyo, Osaka, and Kumamoto.

In the remainder of this section, we provide the basic knowledge of these three Japanese cities. Tokyo and Osaka are two major central cities on Honshu Island (the Main Island of Japan). The former is the capital and largest city in Japan, while the latter is the hub of the economic sphere in western Japan. These cities are about 400 kilometers away from each other and had populations of 6.8 million and 3.3 million, respectively, in 1940 (Cabinet Statistics Bureau 1941). Notably, Osaka had been the center of the rice trade since the pre-modern period. During the Tokugawa period covering 1603–1867, many clan governments imposed a heavy tax on paddy fields and collected it with physical rice. They transported the collected rice from their domains to Osaka to turn into money (Ohno 2018). As Blank et al. (1991) and Schaede (1989) describe, Osaka became the rice distributing center, and the Shogunate certified the futures market named *Dojima Kome Kaisho* (the Dojima Rice Exchange) in 1730.

In contrast to these cities, Kumamoto is a typical local city on Kyushu Island, which is located west of Honshu Island. It is about 900 kilometers from Tokyo and about 500 kilometers from Osaka. Kumamoto is the main producing area of high-quality domestic rice because it is warmer than the two central cities. It has provided rice to Osaka since the Tokugawa period, and the Dojima Rice Exchange designated the rice from Kumamoto as one of the standard goods (Schaede 1989). During the modern period, Kumamoto continued to be one of the main suppliers of staple food and exported rice to the major cities (see Figure A.1).

These cities already satisfied the conditions of market integration at the end of the 19th century. Federico (2021) asserts that the reductions in transportation and information costs facilitated the integration of the domestic market. The intensification of the competition among conveyances promoted the former, and the improvement of information propagation achieved the latter. For example, the laying of railroads triggered escalating the competition in transportation, and the installation of telegraph cable stimulated information communication (Dobado-González et al. 2012; Donaldson 2018; Federico 2007; Kaukiainen 2001). The three cities gained these infrastructures of transportation and communications until the 1890s.

The Tokugawa Shogunate improved the main roads and coastlines in the 17th century. Totman (2005) stated that the massive coastal shipping between Tokyo (Edo) and Osaka was developed until the 1670s. The coastlines also connected to Kumamoto and transported agricultural commodities. Transportation conveyances were improved further from the middle 19th century. Japan opened the Port of Yokohama, which is about 30 kilometers from Tokyo, and the Port of Kobe, which is about 20 kilometers from Osaka, in 1859 and 1867, respectively (Ports and Harbours Association of Japan 2007). In 1889, the government completed the laying of the Tokaido Line connecting Tokyo and Kobe via Yokohama and Osaka by rail. Furthermore, it built the transport infrastructure even in the local cities and constructed the Port of Misumi near Kumamoto in 1887 (Kumamoto Prefectural Government 1961). In 1899, the Kyushu Railway Company laid the Misumi Line from Kumamoto to Misumi (Japan National Railways 1985). These improvements in transport infrastructure intensified the competition between maritime traffic and the railroad in the late 19th century. During the same period, the Japanese government also began to construct communications infrastructure in the central and local cities.

The government laid telegram lines within the cities of Tokyo and Osaka in 1869 and 1870, respectively, and connected these two lines in 1872 (Osaka Central Telegraph Office 1928; Tokyo Central Telegram Office 1958). It extended the lines to Kumamoto and Misumi in 1875 and 1887, respectively (Kumamoto Post and Telegram Office 1902).

Until the 1890s, Tokyo, Osaka, and Kumamoto were equipped with various infrastructures to streamline the commodity trade. These upgraded basic facilities reduced the transaction cost and increased the speed of transportation and communications. That is, the transaction environment was already improved during the period 1900–1939, which this study focuses on.

The remainder of this study is organized as follows. Section 2 explains the structure of the rice market and the system of rice trade in Japan during the first half of the 20th century. Section 3 shows our econometric methodology to analyze the pricing of domestic and colonial rice. Sections 4 and 5 employ the time-series analysis to investigate the pricing of rice futures and spot markets, respectively. Section 6 interprets the result of the time-series analysis in Sections 4 and 5 by utilizing the statistics of rice circulation. Finally, Section 7 presents the conclusion.

2. Historical Settings

2.1. Imports of colonial rice and the central markets

Japan's self-sufficiency ratio of rice sank below 100% in the 1890s and fell below 90% in the 1920s (see Figure A.2). During these decades, the Japanese colonies produced rice profusely, and Japan relied on the colonial rice supply. For an advance in demand for colonial rice in Japan, the Japanese colonial authorities improved the breed of colonial rice to suitable for Japanese consumers' tastes and supervised the production process to enhance the control of rice quality in Taiwan and Korea in the 1910s. These measures contributed to expanding the consumption of colonial rice in Japan. As a result, foreign rice imports disappeared at the beginning of the 1930s. Colonial rice consisted mostly of imported rice in the same decade and was shipped from Korea and Taiwan to Tokyo and Osaka (see Figure A.2).

These two central cities have each port city and form two central markets. One is the eastern central market comprised of Tokyo and Yokohama, and the other is the western central market constituted by Osaka and Kobe. These central markets functioned as the distributing centers of various commodities and supplied rice to local cities in Japan. The eastern central market sent rice to the metropolitan area and northern Japan. The western central market provided rice to broad regions extending from northern to southern Japan (see Figure A.3). Hence, the latter was the largest rice market in Japan. Colonial rice was also circulated via these distributing centers, and these two central markets traded more than half of colonial rice in Japan (see Figure A.4).

2.2. Imported rice circulation in Tokyo and Osaka

There are no data on the trading volume of imported rice in the spot market. Alternatively, we can obtain three types of monthly data on the imported rice circulation in the central cities. The first type is the volume of stocked rice in the major warehouses. This type of data for Tokyo are available for October 1902–March 1939, while data for Osaka are available for January 1900–March 1939.[1] The second type is the volume of rice inflowing to the central cities, and we can utilize the data for January 1900–March 1939 for Tokyo derived from the Tokyo-Fukagawa Rice Spot Market, the largest rice spot market in Tokyo, while that for Osaka gleaned from the major warehouses within the city is in existence in January 1917–March 1939. The third type is the volume of rice outflowing from Tokyo and Osaka to other cities. This type of data for Tokyo provided by the Tokyo-Fukagawa Rice Spot Market is available for January 1900–March 1939, while that for Osaka supplied by the major warehouses within the city is available for January 1917–March 1939 (see Figure A.5). As Federico (2021) asserts "domestic trade can be estimated with data on transportation," we are left with no other option but to estimate the trend of the imported rice trade by using the above-mentioned circulation data. Accordingly, we explore the circulation data to grasp the trend of the colonial rice trade.

Until the middle 1920s, these three types of imported rice ratios had similar trends in the two central

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[1] In detail, the data for Tokyo denotes the stocked volume in the Tokyo-Fukugawa Rice Spot Market during the period October 1902–December 1908.

cities and notably increased three times: 1913–1915, 1919–1921, and 1924–1926. These expansions of the imported rice trade resulted from diverse reasons.

There were two reasons for the increase in rice imports during the first period. First, rice cropping was hit by a contiguous famine during the period 1912–1913. Second, the Ching Dynasty of China collapsed in 1912, and international affairs in East Asia deteriorated. These factors caused a rise in the annual average prices of rice in Tokyo by 24% during the period 1911–1914, and rice imports expanded during the period 1913–1914. However, Japan had a bumper rice crop in 1914. The annual average rice prices in Tokyo decreased by 25% from the previous year, and the rice imports shrunk in 1915 (Nakazawa 1933 and Figure A.2).

During the second period, Japan sent its troops to Siberia in 1918 as a part of commitments to the First World War. The Japanese government bought a large amount of rice for military use. This caused a rice shortage, and merchants hoarded their rice in the expectation of higher prices. The annual average prices of rice in Tokyo skyrocketed by 64% from the previous year, and the nationwide rice riots, *kome-sōdō*, occurred in July 1918 (Francks 2015). As a result, Japan's rice imports expanded to mitigate the rice shortage (see Figure A.2).

During the third period, the Great Kanto Earthquake occurred on September 1, 1923. It turned Tokyo into burned-out ruins and killed about 100,000 people in and around the city (Central Meteorological Observatory 1924). The enormous amount of rice stocked in Tokyo was also burned, and the survivors were afflicted by food shortage. The government sent stored rice from western cities, such as Osaka, to Tokyo and imported rice to supply a deficiency (Ota 1938; Figure A.2).

After the middle 1920s, the ratio of imported rice to the stocked volume was lower than the ratios of imported rice to the inflowing and outflowing volumes in Tokyo and Osaka. The difference in the trends of these ratios arose due to the government's political responses under the *Beikoku Hō* (the Rice Law) enacted in 1921.

This law reflecting the market disturbance under the nationwide rice riots of 1918 allowed the government to trade in the rice market to adjust supply and demand, and the Ministry of Agriculture and Forestry bought and stocked only domestic rice after 1925 (Ota 1938). Hence, the data on the stocked rice contains the government's stockpiled domestic rice and overestimates the proportion of domestic rice in the spot market after 1925. Consequently, we consider the ratios of imported rice to the inflowing and outflowing volume as proxy indexes for the imported rice trade during the period 1925–1939. However, the fluctuations of the two indexes were also different (see Figure A.5). These proxy indexes inevitably deviate from the true ratio of imported rice to the trade volume in the spot market. On the one hand, the correlation coefficients between these two indexes are 0.837 in Tokyo and 0.525 in Osaka. Thus, these proxy indexes indicate roughly the same tendency. Accordingly, we pay attention to the analogous trends in the ratios of imported rice to the inflowing and outflowing volumes to capture the propensity for imported rice trade with little regard for minute changes in the proxy indexes.

According to these proxy indexes, the traders in the central cities sold and bought colonial rice rather than domestic rice after the middle 1920s. Furthermore, Osaka was no longer the venue for the domestic rice trade and became the market for Korean rice (see Figure A.5). These two central cities had each major rice exchange: the Tokyo Rice and Merchandise Exchange (TRME) and Osaka-Dojima Rice Exchange (ODRE).

2.3. Rice futures trades in the central and local cities

The Japanese government enacted the *Kome Shōkaisho Jōrei* (the Rice Exchange Law) in 1876 and *Kabushiki Torihikijo Jōrei* (the Stock Exchange Law) in 1878. According to the Rice Exchange Law, the ODRE and TRME were established in 1876 and 1883, respectively (Osaka-Dojima Rice Exchange 1912; Tokyo Grain Exchange 2003). Following the establishment of these major exchanges, many minor exchanges in the local cities were also established. There were 137 commodity and stock exchanges in 1897. However, many minor exchanges faced financial troubles and closed shortly after their establishment. The number of exchanges decreased sharply to 64 in 1902 and reached 37 in 1923. This number stabilized after the middle 1920s, and Japan had 33 exchanges in 1938 (Kotani 1953). Rice was one of the major trading goods and traded in more than half of the exchanges. In 1938, 18 exchanges listed rice as a trading good, and rice exchanges were located all over Japan (see Figure A.6). In the rice exchanges, the brokers traded only domestic rice.

Every rice exchange dealt with a single brand of domestic rice, and there were three different contract months: a nearby contract (one month), second-nearest contract (two months), and deferred contract (three months). The buyers could choose settlement on balance or delivery of physical rice on the expiration date of the nearby contract, and the exchanges accepted Korean rice as an alternative deliverable good after June 1912 (Ito et al. 2017). However, many brokers refrained from using this settlement system. They mainly traded the deferred contract. The trading volume of the deferred contract accounted for approximately 70% of the futures rice trade (Ito et al. 2018).[2] This volume fluctuated over time.

The volume of futures trade sustained less than 10 million *koku*s until the middle of 1914.[3] The government imposed a tax on the brokers' trades in exchanges in 1882 and reduced the tax rate in September 1914 (Ministry of Finance 1938). This tax reduction eliminated the dealing cost. As a result, the trade volume surged to over 30 million *koku*s (see Figure A.7). However, the nationwide rice riots toppled the Cabinet in 1918, and the government suppressed the rice futures trade to control prices under the Rice Law after the 1920s. It regarded some minor exchanges as gambling places.

In 1923, the government criticized that the minor exchanges only mirrored prices in the central cities (Nakanishi 1940). It considered that a surge in rice prices resulted from the disruption of the pricing in the dubious exchanges and ordered eight rice exchanges to disband in 1924. Consequently, the volume of

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[2] See Ito et al. 2017 for further information on the trade system in the Japanese rice exchanges.
[3] The "*koku*" is a standard unit of measurement in Japanese agriculture. One *koku* is equal to 180.39 liters and is roughly equivalent to 150 kilograms.

futures trade in the local cities decreased (see Figure A.7). In contrast, the TRME and ODRE sustained leading positions in the rice futures trade.

Even in the early 1900s, these two major exchanges had already established their solid positions in Japan's rice futures market. The ODRE reduced the fidelity guarantee deposit for its brokers in 1905 and became lower in the deposit amount than the TRME (Osaka City Government 1934; Tokyo Grain Exchange 2003). As a result, it succeeded in increasing its trade volume and competed with the TRME in the ratio to the total trade volume in all of Japan's exchanges after the 1910s. In addition, the TRME could not trade at all during the period September–October 1923 because the Great Kanto Earthquake destroyed the TRME's buildings, and the rice futures trade concentrated on the ODRE. Accordingly, the ODRE surpassed the TRME in the ratio to the total trade volume after the earthquake and became the largest rice exchange. Although both exchanges altered their relative positions, their combined volume continued to hold about half of the total volume of rice futures trade (see Figure A.7). They achieved dominant shares of the rice futures market in Japan.

Japan embarked on the Second Sino-Japanese War in July 1937 and began serious border incidents with the Soviet Union in May 1939 (Holcombe 2017). The Tokyo Grain Exchange (2003) states that the Japanese economy was placed on a war footing and this social change significantly reduced the requirement for the rice futures trade under these circumstances. The Japanese government ordered the shutdown of all rice exchanges to tighten the rice price control in September 1939 (Osaka-Dojima Rice Exchange 1939a).

In summary, Japan had two kinds of rice exchanges until 1939. One was the major exchange providing the index prices of the rice market, and the other was the minor exchange mirroring the prices in the major exchange. Nevertheless, as mentioned in the Introduction, previous literature addresses only the major exchanges. Accordingly, we broadened our scope to the Kumamoto Rice Exchange (KRE) to focus on the minor exchange.

The KRE was located in Kumamoto, a typical local city on Kyushu Island. This exchange was the southernmost rice exchange in Japan (see Figure A.6). It launched its operation in January 1894, and the government abolished the KRE with any other rice exchange in September 1939 (Kotani 1953). However, the KRE halted the deferred contract of the futures trade in March 1939. The government announced the policy to abolish all rice exchanges in February 1939 (Ministry of Agriculture and Forestry, Minister's Secretariat, 1959). In response to this announcement, the brokers exhibited a wait-and-see attitude and interrupted the futures trade for the long-term (Kumamoto Rice Exchange, 1939).

The KRE was a typical minor rice exchange. Its monthly average volume of futures trade was only 136,284 *koku*s in the 1930s. This volume was ranked tenth on all 17 rice exchanges, which existed at the end of 1938. It was equal to 3.7% of the ODRE (3,657,485 *koku*s) and 5% of the TRME (2,704,285 *koku*s) (see Figure A.8). We analyze the KRE's pricing and compare it against the TRME and ODRE by utilizing a vector error correction (VEC) model.

3. Methodology

We employ a three-dimensional VEC model for the multiple time-series data of the futures prices in the three exchanges and arrange these exchanges in the following sequence: the ODRE, TRME, and KRE. There are three reasons to put the ODRE in the lead. First, the ODRE surpassed the TRME and KRE in their trade volume (see Figure A.8). Second, Osaka was broader in the serving area of rice than Tokyo. The Osaka-centered market provided rice to northern and southern Japan, whereas the serving area of the Tokyo-centered market was only around Tokyo and in northern Japan (see Figure A.3). Third, Osaka was the central trading hub of Korean rice in Japan (see Figures A.4 and A.5).

A VEC model is derived from a vector autoregressive (VAR) model. A VAR model is:

$$\boldsymbol{y_t} = \boldsymbol{v} + \textstyle\sum_{i=1}^{p} \boldsymbol{A_1^i}\, \boldsymbol{y_{t-i}} + \boldsymbol{\varepsilon_t} \tag{1}$$

where $\boldsymbol{y_t} = [y_{1t}, y_{2t}, y_{3t}]'$: y_{1t}, y_{2t}, and y_{3t} are the futures prices of a differed contract (three months) in the ODRE, TRME, and KRE, respectively; $\boldsymbol{v}$ is a three-dimensional constant vector; $\boldsymbol{A_1^i}$ is a three-by-three parameter vector; a three-dimensional white-noise vector $\boldsymbol{\varepsilon_t} = [\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}]'$. We convert from Equation 1 to Equation 2 by subtracting $\boldsymbol{y_{t-1}}$ from both sides. Equation 2 is as follows:

$$\Delta\boldsymbol{y_t} = \boldsymbol{v} + \boldsymbol{\Pi}\boldsymbol{y_{t-1}} + \textstyle\sum_{i=1}^{p} \boldsymbol{\Gamma_i}\Delta\boldsymbol{y_{t-i}} + \boldsymbol{\varepsilon_t} \tag{2}$$

where a coefficient matrix $\boldsymbol{\Pi} = \sum_{j=1}^{p} \boldsymbol{A_j} - \boldsymbol{I_m}$ and $\boldsymbol{\Gamma_i} = -\sum_{j=i+1}^{p} \boldsymbol{A_j}$. The coefficient matrix is decomposed into a loading matrix $\boldsymbol{\alpha}$ and a cointegration matrix $\boldsymbol{\beta}$, such that $\boldsymbol{\Pi} = \boldsymbol{\alpha\beta'}$. If the cointegration order is r, both matrices have r values less than three. Thus, a VEC model is as follows:

$$\Delta\boldsymbol{y_t} = \boldsymbol{v} + \boldsymbol{\alpha\beta'}\boldsymbol{y_{t-1}} + \textstyle\sum_{i=1}^{p} \boldsymbol{\Gamma_i}\Delta\boldsymbol{y_{t-i}} + \boldsymbol{\varepsilon_t} \tag{3}$$

A VEC model enables us to utilize an innovation accounting that derives an impulse response function (IRF) and a relative variance composition (RVC). These show the time path of the various shocks on the variables in a VEC system and demonstrate the relative contribution degree of dispersion of an impulse on a variable to other variables' dispersions (Sims 1980). It is necessary to multiply parameters by impulses that are derived from supplying a standard deviation unit of impulse on the disturbance term at the zero period in Equation 3 to employ an innovation accounting. An IRF indicates how an impulse influences each variable, while an RVC shows how much the fluctuation of a variable affects other variables.

This methodology is heavily used for the empirical study of economic history because it is not based on strong theoretical assumptions (Enders 2015). However, it captures only an influence on the variables by single shocks and does not reveal the fluctuation of the variables reflected from a subsequent shock (Balcilar et al. 2018). It assumes that the market structure was invariable, and an IRF and RVC only exhibit the average structure of the market. In contrast to this assumption, the rice market experienced structural changes subsequently according to the previous section. Hence, we utilize a historical decomposition (HD) to overcome these problems. This method enables us to demonstrate cumulative effects of subsequent shocks and the variability of relative shocks (Kilian and Lütkepohl 2017).

Burbidge and Harrison (1985) propose an HD. Analyses on commodity pricing and the macroeconomic behavior in the discipline of economics and economic history employ this methodology (Breitenlechner et al. 2021; Erol and Saghaian 2022; Shibamoto and Shizume 2014). This method is derived from a VEC model in Equation 3 and is specified as follows:

$$\boldsymbol{y}_{t+j} = \sum_{i=0}^{j-1} \boldsymbol{\psi}_i \boldsymbol{\varepsilon}_{t+j-i} + \left[\boldsymbol{X}_{t+j}\boldsymbol{\beta} + \sum_{i=j}^{\infty} \boldsymbol{\psi}_i \boldsymbol{\varepsilon}_{t+j-i}\right] \quad (4)$$

where $\boldsymbol{y}_{t+j}$ is a multivariate stochastic process; $\boldsymbol{\varepsilon}$ is its multivariate noise process; $\boldsymbol{X}$ is the deterministic part of $\boldsymbol{y}_{t+j}$; $\boldsymbol{i}$ is a counter for the number of periods. The first term on the right-hand side of Equation 4 demonstrates the part of $\boldsymbol{y}_{t+j}$ resulted from the shock, and the second term represents the prediction of price series stemmed from the information at time $\boldsymbol{t}$ denoting the date of the event.

4. The Futures Pricing in the Local City

4.1. The price data of the futures trade

We explore the weighted monthly average data on the futures prices of the differed contract in the ODRE, TRME, and KRE during the period January 1900–March 1939. The KRE halted the differed contract trade in the last month of our observation period, as described in Section 2. The time-series data on the futures prices in the minor exchanges are hard to find, and the KRE is a rare case that provides long-term continuous data on the futures trade during the period. We utilize 33 sources to obtain the data of the three exchanges, and these sources are divided into two types (see Table A.1).

The first type is the statistical surveys issued by the central government. The Ministry of Finance released the futures prices in the major exchanges in its statistical surveys to supervise the general price trends in 1908. In 1918, the Ministry of Agriculture and Commerce holding jurisdiction over the administration of commodity exchange also began to report the futures prices in every exchange in its statistical surveys. In 1925, the government split this ministry into two institutions: the Ministry of Agriculture and Forestry and Ministry of Commerce and Industry. The latter took over the administration of exchange and continued to report the futures prices. However, these records do not carry the futures prices in the major exchanges before 1907 and the price data of the minor exchanges before 1917. Accordingly, we use another type of source to obtain the lack of data.

The second type is the annual statistics issued by the city governments. Some cities published their annual city statistics from the turn of the 20th century, and some of these statistics provide the rice futures prices in each city. The city office of Kumamoto reported the KRE's prices in its city statistics from January 1900. This data is the oldest series of futures prices in Japan's minor rice exchange, and we refer to the

Table 1

Descriptive statistics and unit root test results of rice futures prices

	Level			First difference		
	Osaka	Tokyo	Kumamoto	Osaka	Tokyo	Kumamoto
Mean	3.080	3.097	3.043	0.002	0.002	0.002
Median	3.152	3.147	3.078	0.005	0.004	0.005
Maximum	3.918	3.928	3.935	0.191	0.208	0.216
Minimum	2.290	2.347	2.310	-0.307	-0.319	-0.336
Std. Dev.	0.422	0.416	0.420	0.057	0.056	0.063
ADF	-2.982	-2.940	-2.640	-17.314***	-17.050***	-15.820***
Lags	1	1	2	0	0	1
PP	-2.556	-2.552	-2.559	-16.891***	-16.570***	-17.132***
Bandwidth	8	7	11	16	16	20
N	471	471	471	470	470	470

Notes) The "ADF," "Lags," "PP," "Bandwidth," and "*N*" denote the Augmented Dickey-Fuller test statistics with a time trend and a constant, lag order selected by the Schwartz Bayesian information criteria, Phillips-Perron test statistics, Newey-West bandwidth by using Bartlett kernel, and number of observations, respectively. "***" means significant at the 1% level.

Kumamoto City Statistics until 1917. Furthermore, we secure the futures prices in the ODRE and TRME until 1907 from the city statistics of Osaka and Tokyo, respectively. Nevertheless, the Annual Statistics of the City of Tokyo do not put the futures prices in the TRME until December 1901.[4] Hence, we utilize Nakazawa (1932) showing the rice prices in Japan to obtain the futures prices in the TRME during the period 1900–1901.

There are two breaches in the price data series of the KRE and TRME. First, the KRE did not provide the futures price in October 1913 because it suspended the trade temporarily to suppress a surge in prices. Second, the price data of the TRME in September–October 1923 are missing because the rice trade in Tokyo was brought to a standstill by the Great Kanto Earthquake. Accordingly, we apply the Catmull-Rom spline interpolation technique to interpolate these missing data (see Figure A.9). We employ interpolated data to estimate a VEC model. Our estimation procedure is as follows.

First, we take the first difference in the natural log of each series. Second, we apply the Augmented

[4] The National Diet Library of Japan discloses the statistical surveys, which were issued by the Ministry of Finance, Ministry of Agriculture and Commerce, and Ministry of Commerce and Industry, and the city statistics of Tokyo, Osaka, and Kumamoto on its website (https://ndlonline.ndl.go.jp/). However, it does not hold a part of the Kumamoto City Statistics, and we gained the cooperation of Hokkaido University in Sapporo to obtain Kumamoto City Government (1918; 1919).

Table 2

Cointegration test results of rice futures prices

		Trace test		Maximal eigenvalue test	
	Eigenvalue	Test statistics	Critical value	Test statistics	Critical value
None	0.0754	59.29	35.46	35.54	25.86
At most 1	0.0413	22.75	19.94	19.65	18.52
At most 2	0.0066	3.10	6.63	3.10	6.63

Notes) The "Trace test" and "Maximum eigenvalue test" denote the result of Johansen's (1991) trace test and Johansen's (1988) maximal eigenvalue test, respectively. The "Critical value" is the critical value at the 1% significance level for each test.

Dickey-Fuller (ADF) test and Phillips-Perron (PP) test as the unit root test to confirm whether the variables satisfy the stationary condition. In this process, we utilize the Schwartz Bayesian information criteria (SBIC) to choose the optimal lag length for the ADF test and Newey and West's (1987) method by using the Bartlett kernel to set the optimal bandwidth for the PP test. Table 1 displays the descriptive statistics and unit root test results of the data.

Table 1 indicates that all variables in the first difference column satisfy the stationarity condition. Finally, we apply Johansen's (1991) trace test and Johansen's (1988) maximal eigenvalue test to confirm cointegration relations among the valuables. Table 2 demonstrates the results of the cointegration test.

These cointegration tests reject two null hypotheses at the 1% significance level: $r = 0$ (no cointegration) and $r = 1$ (at most one cointegration). Hence, we estimate a VEC model under the assumption that the valuables have two cointegration relationships.

4.2. The relationships in the pricing among rice exchanges

The estimation process of a VEC model requires us to select the optimal lag length, and we apply the lag exclusion Wald test. This test reports that the optimal joint lag length is eight at the 1% significance level (see Table A.2). Accordingly, we estimate a VEC model with the eight-lagged structure (see Table A.3).

In the next step, we calculate the HD to capture the time-varying structure of the rice futures market. In this process, we determine the Cholesky ordering as follows: the ODRE, TRME, and KRE. This is arranged in order of the monthly average volume of the futures trades in these exchanges (see Figure A.8). Figure 1 illustrates the HD of the futures prices in the three rice exchanges.[5]

The pricing of the ODRE was independent and constantly affected other exchanges. It basically determined the prices even in the TRME, one of the major exchanges. The TRME had a little noticeable

[5] We also compute the IRF and the RVC by employing the same Cholesky ordering as the calculation for the HD. Figure A.10 demonstrates the IRF and RVC.

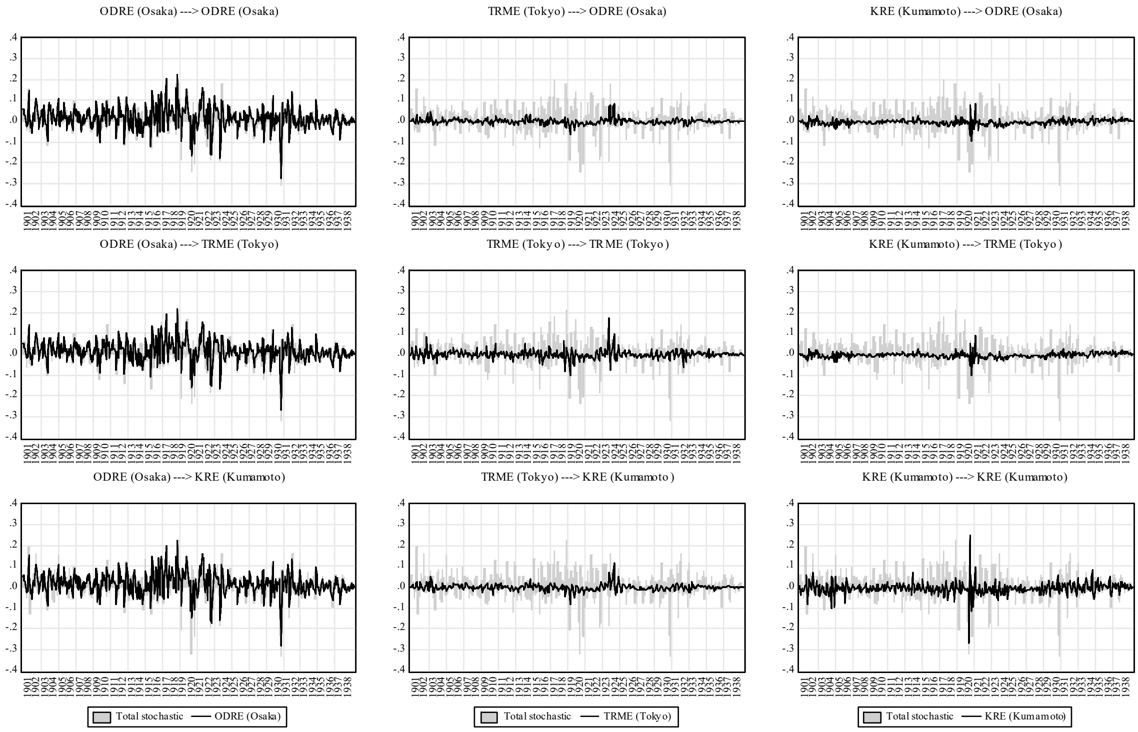

Figure 1. HDs of futures rice prices

effect on its pricing. That is, the ODRE provided the standard index prices in Japan's rice futures markets. On the other hand, Figure 1 exhibits that the HD value to and from the KRE is higher than that to and from the TRME. It suggests that the KRE served more distinctive pricing than the TRME.[6]

In summary, the minor exchange also formed the prices while the largest exchange furnished the index prices for other exchanges. However, all values of the HD fluctuate over time. Specifically, the HD values from the ODRE to all exchanges vary wildly. It means that the rice market structure changed over time. Accordingly, we focus on the diachronic changes in the KRE's HD value to scrutinize the relationship in the pricing between the major and minor exchanges.

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[6] The IRF and RVC denote the same results as the HD (see Figure A.10). We observe the 99% confidence bands of the IRF deviating from zero and recognize that the pricing of the ODRE obviously affected itself and other rice exchanges. Although the pricing of the TRME also affected itself, the ODRE is higher in the value of the IRF than the TRME. That is, the rice futures prices in Japan were basically determined by the pricing of the ODRE. In fact, the ratios of the ODRE in the TRME's and the KRE's RVCs are 89.5% and 80.6%, respectively, in the first period while the KRE is higher in the ratio of its RVC than the TRME from the first to the tenth periods. The KRE has 19.0% percent of its RVC in the first period. It is about 1.8 times higher than the ratio of the TRME in the TRME's RVC in the same period. The KRE's pricing was more distinctive than the TRME's pricing.

4.3. The distinctiveness of the minor exchange's pricing

The HD value to and from the KRE increased after the middle 1910s when the colonial rice circulation expanded in the central cities. However, the rice exchanges listed only domestic rice. As a result, two types of rice markets emerged in the central cities: the futures market trading only domestic rice and spot market trading domestic and imported rice. This change also widened the structural difference in the rice market between the central and local cities. The central market traded domestic and imported rice, whereas the local market traded only domestic rice. Accordingly, we focus on the geographical heterogeneity of the colonial rice circulation.

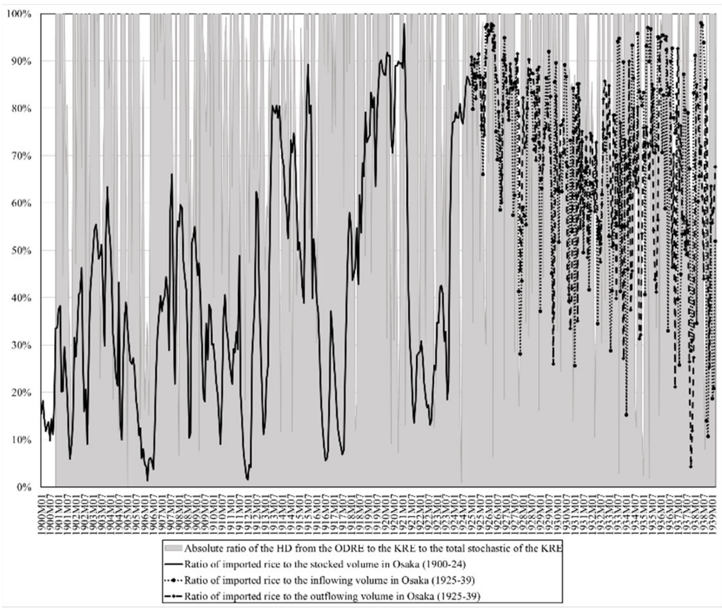
Our estimated VEC model provides three HD values per exchange. An HD ratio is calculated by dividing an HD value by the total stochastic, which is equal to the sum of relevant HD ratios. For example, the total stochastic of the KRE is equivalent to the sum of three HD values: from the ODRE to the KRE, from the TRME to the KRE, and to and from the KRE. The ratio of the HD to and from the KRE is calculated by dividing the HD value to and from the KRE by the total stochastic of the KRE. This ratio means the relative contribution to the price fluctuations in the KRE, and its deviation from 0% indicates the power to alter the prices. Accordingly, we convert the ratio to the absolute HD ratio (AHDR) to capture the contribution to the price movements. However, the AHDR occasionally surpasses 100% because each HD value is not always synchronized with the movement of the total stochastic. These AHDRs include some outliers, and their maximums to and from the KRE and from the ODRE to the KRE reach 7,081% and 5,280%, respectively. These outliers preclude our observations of the changes in the variables, and we capture the AHDR below 100% to overcome this problem. Figure 2 illustrates the AHDR of the KRE.

Panels A and B of Figure 2 demonstrate the AHDR from the ODRE to the KRE and that to and from the KRE, respectively. These panels also illustrate the ratio of imported rice to the stocked volume before 1924 and the ratios of imported rice to the inflowing and outflowing volumes after 1925 as proxy indexes for the trend of the imported rice trade in Osaka. The AHDRs in the early 1900s and the late 1930s are not strictly accurate because the HD value has burn-in and burn-out effects, and we observe the remaining term from the middle 1900s to the middle 1930s.

Panel A denotes that the AHDR from the ODRE to the KRE reaches 100% for most of the observational period. The price fluctuation in the ODRE heavily affected the price formation of the KRE. By contrast, Panel B indicates that the AHDR to and from the KRE varies over time. This ratio increases when the imported rice ratios sustain a high level.

The imported rice ratio reaches over 80% and remained at that level for about two years over three time periods: March 1919–March 1921, May 1924–May 1926, and May 1934–September 1936. As we mentioned in Section 2, in the first and second periods, the imported rice trade expanded because of the dispatch of the Japanese army in 1918 and the Great Kanto Earthquake of 1923. In the third period, Japan was hit by famine during the period 1934–1935. It increased the rice imports to supply a deficiency and its self-sufficiency ratio of rice was sluggish during the period 1934–1936 (See Figure A.2). According to Figure 2, the AHDR to and from the KRE does not drop to less than 50% for more than four consecutive

(A) From the ODRE to the KRE



(B) To and from the KRE

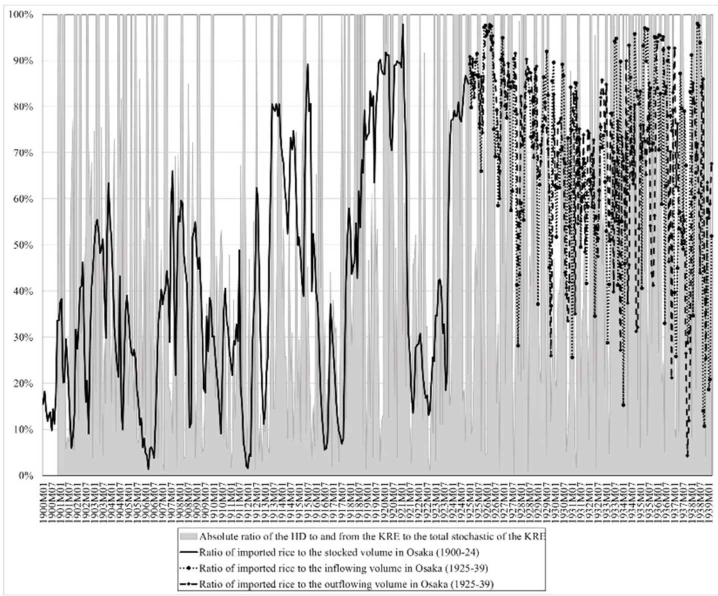


Figure 2. AHDRs of the KRE

Notes) The "AHDR" indicates the absolute historical decomposition ratio. The ratio of imported rice in Osaka is composed of the ratio of imported rice to the stocked volume during the period 1900–1924 and that to the inflowing volume during the period 1925–1939.

Sources) Governor-General of Taiwan, Industrial Bureau, 1937; 41; Ministry of Agriculture and Forestry, Agricultural Bureau, 1925; 28; Ministry of Railways, Transportation Bureau, 1925; Osaka Chamber of Commerce, 1918; Osaka City Government, 1905; 09; 15; Osaka-Dojima Rice Exchange, 1912b; 13–20; 21a; 22a; 23a; 24a; 25a.

months during these three periods. Its averages for these three periods are 104%, 297%, and 360%. Furthermore, this AHDR skyrockets simultaneously with surges in the imported rice ratios over a short term at times other than the three periods. These observations suggest that the KRE's pricing obtained distinctiveness when the imported rice trade expanded in Osaka. Hence, we use a regression analysis to investigate the relationship between the KRE's pricing and imported rice trade in Osaka.

4.4. The pricing of minor exchange and the imported rice trade in the central city

We apply the ordinary leased squared (OLS) regression equation to verify the relationship between the AHDR to and from the KRE and the imported rice ratios in Osaka. In this step of our analysis, we add the trade volume of the KRE as an explanatory variable in the equation since the study of futures pricing often mentions that the relationship between the trade volume and price variability exists (Rutledge 1986). Specifically, we employ the following equation:

$$ln\,AHDR = \beta_0 + \beta_1\,ln\,TV + \beta_2\,ln\,IRR \qquad (5)$$

TV and *IRR* mean the volume of futures trade in the KRE and imported rice ratio in Osaka, respectively.[7] As we mentioned in Section 2, our analysis focuses on the variable trends in the two ratios of imported rice to the inflowing and outflowing volumes to seize the propensity for imported rice trade without paying close attention to minute changes in the variables. Accordingly, we utilize these two types of the imported rice ratio as the *IRR* and convert the explained and explanatory variables in the regression formula to a six-month moving average (MA) and 12-month MA. We apply these values to Equation 5 and estimate the coefficients (β_1 and β_2) and constant coefficient (β_0). Table 3 illustrates the estimation result of four regression equations.

All F-values of four regression equations are less than 0.01 according to the result of variance analysis. Hence, these equations are significant at the 1% level. The four coefficients of *IRR* are also significant at the 1% level and are positive values while all coefficients of *TV* are negative values. Consequently, these regression analyses suggest that an expansion of the imported rice trade in Osaka promoted the

[7] We utilize the volume of futures trade in the KRE, which contains all futures trades of three contracts, as a proxy for the volume of deferred contract trade to employ our regression analysis. In ordinary circumstances, we should use the volume of deferred contract trade because we apply the deferred contract prices of the KRE to calculate HD values in Figures 1 and 2. However, our data sources shown in Table A.1 demonstrate only the total volume of all contracts in the KRE. We cannot find the time-series volume of deferred contract trade in the KRE during our sample period, but the volume of all futures trades is an appropriate proxy. Tokyo Stock Exchange, Investigation Department (1919–29; 30a), which is exclusively owned by Keio University in Tokyo, indicates the fragmentary volume date of futures trade by each contract in the KRE. Concretely, it carries that date during the periods November 1919–April 1920, June–October 1920, December 1920–January 1922, January 1923–September 1925, November 1925–May 1929, and July 1929–August 1930. According to the date for these 115 months, the deferred contract held 81% of all futures trades in the KRE.

Table 3

OLS regression analysis of the KRE's AHDRs

			Inflowing volume		Outflowing volume	
			6-month	12-month	6-month	12-month
Regression analysis	Constant	Coefficient	2.136***	2.723***	3.585***	4.078***
		SE	0.525	0.402	0.529	0.469
		T-value	4.069	6.781	6.773	8.692
	Trade volume	Coefficient	-0.180***	-0.208***	-0.267***	-0.287***
		SE	0.042	0.032	0.042	0.037
		T-value	-4.264	-6.473	-6.297	-7.677
	Imported rice ratio	Coefficient	0.387***	0.484***	0.474***	0.603***
		SE	0.066	0.056	0.070	0.066
		T-value	5.868	8.621	7.121	9.195
	Adjusted R-square		0.107	0.214	0.172	0.247
	N		456	450	456	450
Variance analysis	Regression	DF	2	2	2	2
		Sum of squares	42.34	48.90	73.54	79.86
		Mean square	21.17	24.45	36.77	39.92
		F-value	0.000	0.000	0.000	0.000
	Residual error	DF	453	447	453	447
		Sum of squares	339.8	175.5	345.2	238.7
		Mean square	0.750	0.393	0.762	0.534
	Total	DF	455	449	455	449
		Sum of squares	382.1	224.4	418.8	318.6

Notes) This table shows the OLS regression analysis of monthly moving average data of the explained and explanatory variables. The "SE," "*N*," and "DF" indicate the standard error, the number of observations, and the degree of freedom, respectively. "***" means significant at the 1% level.

distinctiveness of the KRE's pricing.

The formation of the futures prices in the KRE had relevance to the imported rice trade in the spot market in Osaka. However, even in the three periods, the averages of the AHDR from the ODRE to the KRE are 165%, 179%, and 148%. This fact means that the pricing of the ODRE stably affected that of the KRE. Thus, we should reveal how the fluctuation of the imported rice trade in Osaka's spot market affected the pricing of the ODRE to capture the mechanism of the alteration in the pricing of the KRE. Concretely, in the next section, we employ a VEC model to analyze how the ODRE determined its future prices when the imported rice trade expanded in Osaka.

5. The Pricing in the Central City

5.1. The price data of domestic and imported rice in Osaka

We investigate the data of rice prices in Osaka by employing the same technique as the analysis in the previous section and assign the futures prices of a differed contract, spot prices of Korean rice, and spot prices of domestic rice for y_{1t}, y_{2t}, and y_{3t}, which constitute the left-hand matrix $\boldsymbol{y_t}$ in Equation 3. Our investigation focuses on the period spanning from January 1919 to March 1939. During this period, Korean rice mainly constituted the imported rice in Osaka, and authorities recorded the monthly average prices of Korean rice in Osaka on their statistical surveys (see Figure A.5). We receive the price data from these statistical surveys issued by the Ministry of Agriculture and Commerce, Ministry of Agriculture and Forestry, Ministry of Commerce and Industry, Ministry of Railways, and Governor-General of Taiwan (see Table A.4).[8]

According to these data, there was a difference in the price trend between Korean and domestic rice, and the relative price ratio of Korean rice to domestic rice fluctuated over time (see Figure A.11). This fluctuation has two characteristic points.

First, the relative price ratio tended to increase. This tendency was reflected by the rise in the quality of Korean rice as mentioned in Section 2.[9] Korean rice prices relatively increased in the 1920s and caught up with domestic rice prices in the early 1930s.

Second, the fluctuation of the relative price ratio had seasonality. In detail, this ratio tended to decrease in a few months before the end of each year. Japanese and Korean farmers began to crop rice in September, and the monthly average real prices of domestic and Korean rice had the same tendency before the harvest season. These prices began to increase in April and reached their zenith in August. After September, these prices decreased. However, Korean rice prices reached a bottom in November while domestic rice prices touched a foot in December. Korean farmers cropped rice from the beginning of September to the middle of November, and the Korean rice circulation in Japan reached full bloom in November, whereas the circulation of domestic rice expanded in December (Hishimoto 1938). Hence, the gap between these prices widened from September to November, and the price ratio of Korean rice to domestic rice decreased for three months (see Figure A.11).

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[8] The National Diet Library of Japan posts the statistical surveys published by the Ministry of Agriculture and Commerce, Ministry of Agriculture and Forestry, Ministry of Commerce and Industry, and Governor-General of Taiwan on the Internet (https://ndlonline.ndl.go.jp/). Nevertheless, it has only a part of the statistics issued by the Governor-General of Taiwan, and we received collaboration from Oita University in Oita to inspect the Governor-General of Taiwan, Industrial Bureau (1941).

[9] The price gap between domestic and Korean rice did not move in conjunction with changes in freight costs from Korea to Japan. Hishimoto (1938) reports the freight cost of Korean rice during the period January 1924–April 1935, which decreased when newcomers appeared. Tatsuuma Steamship Corporation and Iino Steamship Corporation started their services between Japan and Korea in December 1927 and October 1932, respectively, and the freight cost decreased in February 1928 and May 1933. However, the trend of the price gap between domestic and Korean rice did not change after these months, and the freight cost increased in July 1929 and November 1933.

Table 4

Descriptive statistics and unit root test results of rice prices in Osaka

	Level			First difference		
	Futures	Korean (spot)	Domestic (spot)	Futures	Korean (spot)	Domestic (spot)
Mean	3.426	3.386	3.458	-0.000	-0.001	-0.001
Median	3.444	3.413	3.474	0.004	0.003	0.001
Maximum	3.918	3.934	4.016	0.175	0.338	0.288
Minimum	2.749	2.773	2.850	-0.307	-0.324	-0.373
Std. Dev.	0.212	0.245	0.252	0.061	0.067	0.057
ADF	-2.951	-2.962	-2.418	-11.944***	-13.108***	-13.976***
Lags	1	1	0	0	0	0
PP	-2.158	-2.521	-1.770	-11.640***	-13.071***	-13.975***
Bandwidth	0	1	0	8	4	4
N	243	243	243	242	242	242

Notes) The "ADF," "Lags," "PP," "Bandwidth," and "*N*" denote the Augmented Dickey-Fuller test statistics with a time trend and a constant, lag order selected by the Schwartz Bayesian information criteria, Phillips-Perron test statistics, Newey-West bandwidth by using Bartlett kernel, and number of observations, respectively. "***" means significant at the 1% level.

The price trend of Korean rice differed from that of domestic rice, and this difference varied over time for these two reasons. We apply the HD to examine the diachronic change in the relationship between the price formations of Korean and domestic rice. Our estimation procedure is as previously stated in Section 3. Table 4 shows the descriptive statistics of the variables and the results of the ADF test and PP test.

According to Table 4, all variables in the first difference column satisfy the stationarity condition. The next procedure is applying the trace test and maximal eigenvalue test as the cointegration test. Table 5 displays the results of these tests.

Both tests reject two null hypotheses at the 1% significance level: $r = 0$ (no cointegration) and $r = 1$ (at most one cointegration). Hence, we assume that there are two cointegration relationships.

Table 5

Cointegration test results of rice prices in Osaka

		Trace test		Maximal eigenvalue test	
	Eigenvalue	Test statistics	Critical value	Test statistics	Critical value
None	0.1621	64.89	35.46	42.28	25.86
At most 1	0.0777	22.61	19.94	19.33	18.52
At most 2	0.0136	3.28	6.63	3.28	6.63

Notes) The "Trace test" and "Maximum eigenvalue test" denote the result of Johansen's (1991) trace test and Johansen's (1988) maximal eigenvalue test, respectively. The "Critical value" is the critical value at the 1% significance level for each test.

5.2. The pricing of futures and spot markets in Osaka

We apply the lag exclusion Wald test, and the result of this test indicates that the optimal joint lag length is three (see Table A.5). Accordingly, we estimate a VEC model with the three-lagged structure to calculate the HD (see Table A.6).

In the calculation process of the HD, we determine the Cholesky ordering as follows: the futures prices of domestic rice, spot prices of Korean rice, and spot prices of domestic rice. This order of spot prices is ranked by the circulation volume of each rice in Osaka after the 1920s (see Figure A.5). Figure 3 shows the HD of the futures and spot rice prices in Osaka.[10]

Figure 3 indicates that the futures market independently formed its prices and constantly affected the spot prices of Korean and domestic rice. This fact suggests that the futures market provided the index prices of the spot market. However, the pricing of domestic rice in the futures market and Korean rice in the spot market did not have a unilateral relationship. The pricing of Korean rice also affected the futures pricing.

Figure 3 illustrates that the HD value from Korean rice to the futures is more variable than that from domestic rice in the spot market to the futures.[11] Accordingly, we delve into the interrelation of the pricing between domestic rice in the futures market and Korean rice in the spot market. Figure 4 demonstrates two AHDRs between these two prices and the imported rice ratios in Osaka. This figure shows the AHDRs below 100% in the same manner as Figure 2.

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[10] We also calculate the IRF and the RVC of the rice market in Osaka by employing our estimated VEC model following the same Cholesky ordering as the calculation for the HD. Figure A.12 demonstrates the IRF and RVC.

[11] The IRF and RVC of the rice market in Osaka are almost identical to the HD. According to Figure A.12, the futures prices were independently formed and influenced the spot prices of Korean and domestic rice. Furthermore, the RVC demonstrates that the pricing of Korean rice marginally affected the futures pricing. Although the 99% confidence band of the IRF from Korean rice prices in the spot market to the domestic rice prices in the futures market does not deviate from zero, the ratio of Korean rice in the RVC of the futures after the fifth period is more than 2%.

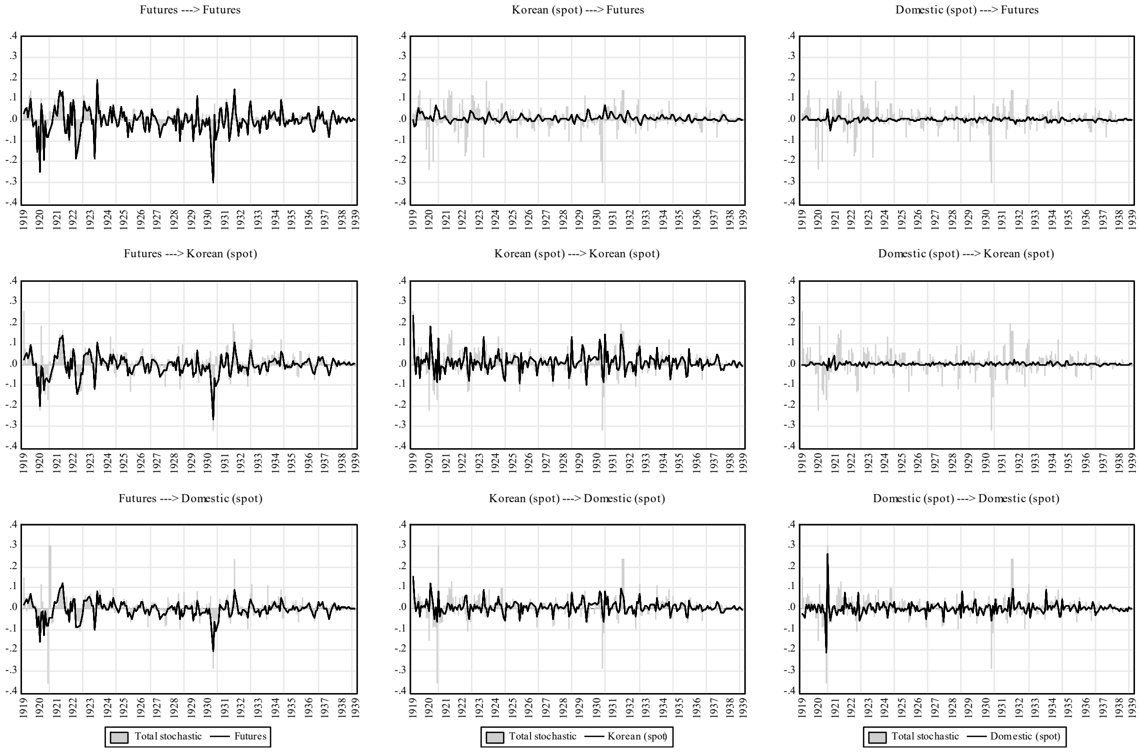
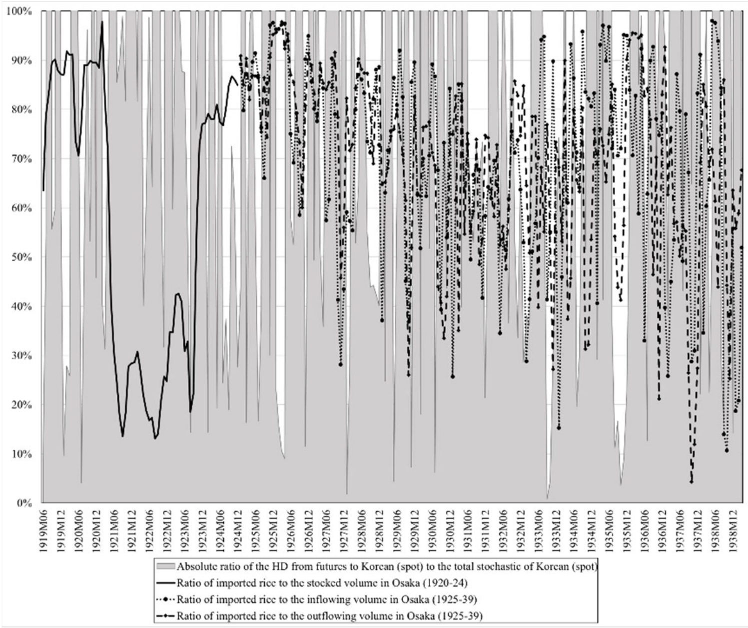


Figure 3. HDs of rice prices in Osaka

Figure 4 denotes that the AHDR from the futures to Korean rice is higher than that of the opposite direction and frequently rises to 100%. The pricing of the futures market constantly determined the Korean rice prices in the spot market. By contrast, Panel B of Figure 4 exhibits that the AHDR from Korean rice to the futures varies wildly over time and surges following increases in the imported rice ratios. This trend is similar to the AHDR to and from the KRE shown in Figure 2. As we mentioned in the previous section, the imported rice ratios sustained at a high level during three periods: March 1919–March 1921, May 1924–May 1926, and May 1934–September 1936. The averages of the AHDR from Korean rice to the futures for these three periods are 351%, 260%, and 435%, whereas this ratio frequently falls to less than 20%.[12] This fact indicates that the fluctuation of Korean rice prices in the spot market partially determined domestic rice prices in the futures market during these periods. Hence, we employ a regression analysis to investigate the interrelation between the pricing of the ODRE and Korean rice pricing in the spot market in Osaka.

[12] We estimate the HD only from June 1919 because our estimated VEC model utilizing the price data from January 1919 has a three-lagged structure and two cointegration relationships. Accordingly, we calculate the average of the AHDR from Korean rice to the futures for the first period by using the data from June 1919 to March 1921.

(A) From futures to Korean (spot)



(B) From Korean (spot) to futures

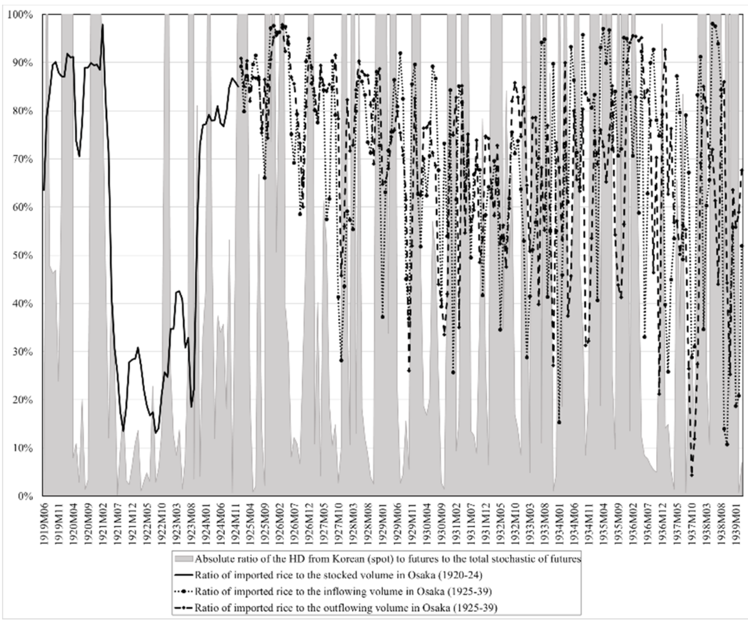


Figure 4. AHDRs of futures and Korean (spot) in Osaka

Notes) The "AHDR" indicates the absolute historical decomposition ratio. The ratio of imported rice in Osaka means the ratio of imported rice to the stocked volume in 1900–1924 and that ratio to the inflow volume in 1925–1939.

Sources) Governor-General of Taiwan, Industrial Bureau, 1937; 41; Ministry of Agriculture and Forestry, Agricultural Bureau, 1925; 28; Ministry of Railways, Transportation Bureau, 1925; Osaka-Dojima Rice Exchange, 1920; 21a; 22a; 23a; 24a; 25a.

5.3. The influence of Korean rice pricing on the futures market

We apply Equation 5 to employ a regression analysis. *AHDR* is the AHDR from Korean rice prices in the spot market to the futures prices in the ODRE, *TV* is the volume of deferred contract trade in the ODRE, and *IRR* is the ratio of imported rice to the inflowing or outflowing volumes in Osaka.[13] In analogy with the regression analysis in the previous section, we utilize two types of the imported rice ratio to *IRR* in Equation 5 and convert the explained and two explanatory variables to six-month MA and 12-month MA. Finally, we estimate the coefficients (β_1 and β_2) and constant coefficient (β_0). Table 6 demonstrates the estimation result of four regression equations.

According to the result of variance analysis, all F-values of four regression equations are less than 0.01. These equations are significant at the 1% level. The result of the regression analysis inhibits that the four coefficients of *IRR* are also significant at the 1% level and are positive values. These observations indicate that an expansion of the imported rice trade accelerated the influence of Korean rice pricing in the spot market on the pricing of the ODRE.

6. The Heterogeneity of Japan's Market Structure and Korean Rice

6.1. The results of econometric analysis

Section 4 suggests that the distinctiveness of the KRE's pricing increased when the imported rice trade expanded in the spot market in Osaka. Nevertheless, the price fluctuation in the ODRE surely determined the prices in the KRE. These facts require an analysis of the change in the relationship of the pricing between the futures and spot markets in Osaka along with the variation in the trade of imported rice. Accordingly, the next section investigates how the fluctuation of the imported rice trade in the spot market affected the pricing of the ODRE.

Section 5 indicates that the price fluctuations of Korean rice in the spot market in Osaka temporarily influenced the futures prices in the ODRE when the imported rice trade thrived there. When these episodic changes in the price formation in Osaka arose, the role of the KRE in the pricing increased. Hence, we focus on the heterogeneity of the rice market in Osaka and Kumamoto concerning the circulation of Korean rice to explore the cause of temporary changes in the relationship of the futures rice pricing between the two cities.

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[13] We can easily acquire the monthly volume of deferred contract trade in the ODRE after November 1919 from Osaka-Dojima Rice Exchange (1921b; 22b–25b; 26–28; 29b; 30–32; 33a; 33b; 34–38; 39b; 39c). However, there are no published data on the monthly trade volume by contract before October 1919. To overcome this problem, we utilize Osaka-Dojima Rice Exchange (1919b) held by Kansai University in Suita, Osaka Prefecture. This material carries the daily volume of deferred contract trade, and we calculate the monthly volume during the period January–October 1919.

Table 6

OLS regression analysis of the AHDRs and the imported rice ratio in Osaka

			Inflowing volume		Outflowing volume	
			6-month	12-month	6-month	12-month
Regression analysis	Constant	Coefficient	6.833***	6.917***	6.597***	6.694***
		SE	1.842	1.823	1.858	1.839
		T-value	3.710	3.795	3.551	3.640
	Trade volume	Coefficient	-0.431***	-0.440***	-0.416***	-0.426***
		SE	0.124	0.123	0.125	0.124
		T-value	-3.470	-3.575	-3.318	-3.428
	Imported rice ratio	Coefficient	1.263***	1.212***	1.213***	1.160***
		SE	0.195	0.195	0.197	0.197
		T-value	6.460	6.198	6.162	5.890
	Adjusted R-square		0.198	0.195	0.187	0.184
	N		233	227	233	227
Variance analysis	Regression	DF	2	2	2	2
		Sum of squares	73.78	69.10	69.77	65.18
		Mean square	36.89	34.55	34.88	32.59
		F-value	0.000	0.000	0.000	0.000
	Residual error	DF	230	224	230	224
		Sum of squares	285.8	272.4	289.8	276.3
		Mean square	1.242	1.216	1.260	1.234
	Total	DF	232	226	232	226
		Sum of squares	359.5	341.5	359.5	341.5

Notes) This table shows the OLS regression analysis of the monthly moving average data of the absolute historical decomposition ratios (AHDRs) from Korean (spot) to futures and the imported rice ratio in Osaka. The "SE," "*N*," and "DF" indicate the standard error, number of observations, and degree of freedom, respectively. "***" means significant at the 1% level.

6.2. Korean rice circulation in the spot market

Korean rice was rarely circulated in the local cities, such as Kumamoto. The annual average volume of Korean rice imports in Kumamoto during the period 1923–1938 was paltry 3,199 *koku*s. This was equal to only a thousandth of Osaka whose volume was 3,196,277 *koku*s (see Figure A.13).[14] These data include

[14] The annual average volume of Korean rice imports per 100 populations in Kumamoto Prefecture during

only Korean rice directly shipped from Korea to each city. However, a small volume of rice was transported from Korea through the distribution centers in Japan.

The Ministry of Agriculture and Forestry inspected the Korean rice circulation within Japan during the period 1936–1937. According to this inspection, Kumamoto imported Korean rice from Korea and Fukuoka City on Kyushu Island. Fukuoka and Kumamoto are located on the same island, and both cities are about 100 kilometers from each other (see Figure A.14). Fukuoka had the largest population on the island and was one of the regional distributing centers of rice. It imported rice from Korea, and its annual average volume of rice directly imported from Korea during the period 1923–1938 was 132,762 *koku*s (Governor-General of Taiwan, Industrial Bureau, 1937; 41; Ministry of Agriculture and Commerce, 1921–25; Ministry of Agriculture and Commerce, Commercial Bureau, 1922; 25–26; Ministry of Commerce and Industry, 1930–32; Ministry of Commerce and Industry, Commercial Bureau, 1927–29; 33–40). This volume represented about 41-fold of Kumamoto's volume and about 4% of Osaka's volume. Fukuoka sent a part of its imported Korean rice to some cities.

During the period 1936–1937, Fukuoka re-exported 44,821 *koku*s of Korean rice, which was 20% of its imported rice from Korea. This re-exported volume was equivalent to 4% of that volume from Osaka (Hishimoto 1938). Accordingly, Fukuoka certainly acted as a distributing center of Korean rice, but the scale of its re-exported rice was small rather to the major distributing centers. We cannot observe the transportation volume of Korean rice from Fukuoka by the destinations due to the lack of the date on the rice re-exports. However, Hishimoto (1938) describes that there were four types of Korean rice destinations from Fukuoka (see Figure A.14).

The first type was the major cities in Western Japan. Fukuoka is Japan's proximate city to Korea. It is about 200 kilometers away from Busan, which is one of the largest ports located at the south end of the Korean Peninsula, and served as a transit point for Korean rice. Fukuoka imported Korean rice and re-exported it to major cities, such as Osaka and Kobe.

The second type was the cities within Kyushu Island. Fukuoka was the economic hub of the island and sent Korean rice to adjacent cities, such as the cities of Saga, Nagasaki, Oita, and Kumamoto. These destination cities are located within a radius of about 100 kilometers from Fukuoka. Fukuoka functioned as the regional distributing center of Korean rice on Kyushu Island.

The third type was the Japanese colony. Micronesia comprises numerous small islands in the South Pacific Ocean and was colonized by Germany in 1885. Germany lost Micronesia after the defeat in the First World War, and the Treaty of Versailles granted Japan the mandate over Micronesia. Micronesia is situated far away from Japan. Saipan Island, the center of the Micronesian economy during the era of Japanese colonial rule, is about 2,600 kilometers from Fukuoka. Fukuoka sent Korean rice to Micronesia and played a role as the original port for the Japanese colony.

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the period 1923–1938 was also critically small. This volume was 0.23 *koku* while that in Osaka Prefecture was 66.69 *koku*s (Cabinet Statistics Bureau 1941).

The transportation volume of Korean rice from Fukuoka was not too much, and several cities and areas shared the transported rice thinly and broadly. Accordingly, we can suppose that the transportation volume of Korean rice from Fukuoka to Kumamoto was extremely small. This supposition is confirmed by the Korean Rice Association's report. This association promoted the selling of Korean rice in Japan and reported that Kumamoto had tiny demand for Korean rice because it was the production area of domestic rice (Korean Rice Association 1934). Hence, Kumamoto imported only a tiny volume of Korean rice, and there was a sharp difference in the circulation volume of Korean rice from Osaka. Furthermore, there was also a difference in the quality of imported Korean rice between the two cities.

6.3. Korean rice quality in the spot market

Korea exported two types of rice: unpolished and polished rice. Unpolished rice is not pleasant to the palate because it is covered by bran, and most consumers have a penchant for polished rice. On the other hand, polished rice is perishable. In general, retailers polished rice after purchasing unpolished rice from wholesalers in the major distributing centers who tended to deal with unpolished rice. As a result, the annual average ratios of polished rice to the total Korean rice imports in Tokyo and Osaka during the period 1926–1938 were 26% and 40%, respectively. However, these ratios in Kumamoto and Fukuoka were 67% and 68%, respectively. Furthermore, the ratio in Kumamoto frequently reached more than 90% (see Figure A.13). The cities on Kyushu Island near Korea mainly imported polished Korean rice.

In 1937, Busan in Korea had more than 400 rice milling plants and exported much of the polished rice to Kyushu Island in Japan (Hishimoto 1938). Kumamoto was a consumption city, and the consumers in this city could eat Korean rice immediately after purchasing it. Fukuoka acted as a regional distributing center of Korean rice in its neighboring area of about a 100-kilometer radius, and the transportation distance and the shipping time of re-exported rice were short compared to the distance from the major distributing centers, such as Osaka. Accordingly, Fukuoka could re-export polished rice, and Kumamoto traded polished Korean rice that was pleasant to the palate.

There were two differences in the circulation volume and quality of Korean rice between Kumamoto and Osaka. These gaps determined the structural difference in the rice spot market between the central and local cities, and the quality gap caused the difference in Korean rice usage in the futures market between the two types of cities.

6.4. Korean rice usage in the futures market

We can observe the delivery volume of Korean rice in each exchange from the 1920s, and the TRME and ODRE actively delivered Korean rice. The ratio of Korean rice to the total delivery volume in these two exchanges often reached more than 90% from the 1920s. In contrast to both exchanges, the KRE did not deliver Korean rice at all, although its ratio exceptionally deviated from 0% during the period October 1937–October 1938 (see Figure A.15).

Kumamoto rarely imported rice from Korea, and the sellers in the KRE could not procure Korean rice as a deliverable good. Additionally, most Korean rice in Kumamoto was polished. It was not suitable for delivery while the suitable good for delivery in the exchanges was unpolished rice that could be stored for quite a while (Enatsu 1930). Consequently, the major exchanges actively delivered Korean rice since the central cities imported much of the unpolished rice from Korea. By contrast, the delivery of Korean rice in the KRE was floundering. That is, the central and local cities had structural differences in the spot market and futures market.

7. Conclusion

Colonial rice had a different texture and taste from the domestic one when Japan possessed its colonies at the turn of the 20th century. The colonial governments improved the production process of rice in their territories, and colonial rice became on par with the quality of domestic rice. As a result, Japan increased the imports of colonial rice after the 1910s, and colonial rice overtook domestic rice in price after the 1930s. However, there was a geographical heterogeneity of colonial rice circulation in Japan. Specifically, colonial rice was mainly distributed as unpolished rice only in the central cities. It can be stored for a long time and had the requisite characteristic for a deliverable good of the futures trade. By contrast, the volume of colonial rice distribution was small in the local cities, which was the producing area of domestic rice. Furthermore, Kyushu Island, which is adjacent to the Japanese colonies, imported perishable polished rice, and the rice exchange on the island did not use colonial rice for delivery.

The expansion of colonial rice circulation widened the difference in the structure of the rice spot markets between the central and local cities. In contrast to the spot market, every futures market continued to trade only domestic rice as a standard good. Under these circumstances, although the futures trade in the central cities provided index prices to the minor exchanges in the local cities from the 1900s, the expansion of colonial rice circulation caused the change in the pricing of the major and minor exchanges after the First World War. In the central cities, the pricing of colonial rice in the spot market temporarily affected the pricing of domestic rice in the futures market when the colonial rice trade expanded. That is, the futures prices in the central cities reflected the price fluctuation of colonial rice. They were not suitable for the index prices of the futures market in the local cities because colonial rice held only a small portion of the physical rice trade there. Consequently, when the trade of colonial rice expanded in the central cities, the distinctiveness of the rice pricing of the exchange in the local cities increased to complement the major exchanges' role in a generating the index prices. The geographical heterogeneity of colonial goods circulation, along with the economic convergence within the empire, occasionally augmented the price formation function of the market in the local cities.

Many historians have investigated the impact of imperialism on the colonies of the imperial country. In contrast, this study, focusing on the cyclic structure of the colonial trade, scrutinizes the adverse direction of the impact against the object of previous literature. Until the first half of the 20th century, the imperial country imported primary products from its colonies and used them as food and raw materials to industrialize its metropole. Finally, this industrialization accelerated the economic growth and promoted the exports of industrial goods to the colonies. We shed light on the other aspect of this cycle, which the previous studies tend not to focus on, and draw the process that the imperial country satisfied a requirement for industrialization and the economic growth. The commodity market in the metropole was forced to alter its structure to accept the colonial primary products that had a quality difference from the domestic ones. The central market obviously altered its structure, but the local market also experienced the structural changes to perform a complementary role of the pricing. In short, the commodity market was altered across the metropole of the imperial country to accommodate the expansion of colonial goods trade, which circulated in specific districts. Previous research does not mention these findings because its main preoccupation is the impact of imperialism on the colonies or the major markets in large cities. Our findings suggest that the substantial changes of the market acted as the solid foundation to expand the colonial goods trade in the metropole. Through this process, the metropole of the imperial country formed an industrialized economy and achieved economic growth, while the economic disparity from the colonies widened.

There are two limitations to this study. First, further research will be necessary to detect other factors to augment the price formation function of the futures market in the local cities. Although this study regards the expansion of colonial goods trade in the central cities as one of the factors, our results of the regression analysis also indicate that other factors may exist because the adjusted coefficients of determination shown in Tables 3 and 6 are rather low. Second, further research will require investigating the pricing of the minor exchanges in the local cities in the areas that grew rice vigorously and non-producing areas of rice. However, the central cities that had the major exchanges, which we scrutinized in this study, were also the non-producing areas of rice. Hence, based on the results of this study, the minor exchanges in the non-producing areas might not form the distinctive price because both types of exchanges had a similar structure.

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Appendix A. Additional tables and figures

Table A.1

Data sources of rice futures prices in the ODRE, TRME, and KRE

Duration	ODRE (Osaka)	TRME (Tokyo)	KRE (Kumamoto)
Jan. 1900–Dec. 1901	Osaka City Government (1905)	Nakazawa (1932)	Kumamoto City Government (1904)
Jan. 1902–Dec. 1902	Osaka City Government (1905)	Tokyo City Government (1904)	Kumamoto City Government (1904)
Jan. 1903–Dec. 1903	Osaka City Government (1909)	Tokyo City Government (1909)	Kumamoto City Government (1904)
Jan. 1904–Dec. 1907	Osaka City Government (1909)	Tokyo City Government (1909)	Kumamoto City Government (1909)
Jan. 1908–Dec. 1908	Ministry of Finance, Financial Bureau (1918)		Kumamoto City Government (1909)
Jan. 1909–Dec. 1913	Ministry of Finance, Financial Bureau (1918)		Kumamoto City Government (1914)
Jan. 1914–Dec. 1916	Ministry of Finance, Financial Bureau (1918)		Kumamoto City Government (1918)
Jan. 1917–Dec. 1917	Ministry of Finance, Financial Bureau (1918)		Kumamoto City Government (1919)
Jan. 1918–Mar. 1921	Ministry of Agriculture and Commerce (1920–23)		
Apr. 1921–Dec. 1921	Ministry of Agriculture and Commerce, Commercial Bureau (1922)		
Jan. 1922–Dec. 1923	Ministry of Agriculture and Commerce (1924–25)		
Jan. 1924–Dec. 1925	Ministry of Agriculture and Commerce, Commercial Bureau (1925–26)		
Jan. 1926–Dec. 1928	Ministry of Commerce and Industry, Commercial Bureau (1927–29)		
Jan. 1929–Dec. 1931	Ministry of Commerce and Industry (1930–32)		
Jan. 1932–Mar. 1939	Ministry of Commerce and Industry, Commercial Bureau (1933–40)		

Table A.2

Chi-squared test statistics of the lag exclusion Wald test for the VEC of rice futures prices

	y_1	y_2	y_3	Joint
D (lag 1)	134.277 (0.000)	158.183 (0.000)	170.595 (0.000)	250.955 (0.000)
D (lag 2)	102.593 (0.000)	121.103 (0.000)	157.007 (0.000)	220.756 (0.000)
D (lag 3)	80.211 (0.000)	97.096 (0.000)	135.591 (0.000)	195.097 (0.000)
D (lag 4)	50.033 (0.000)	54.352 (0.000)	87.382 (0.000)	124.929 (0.000)
D (lag 5)	48.846 (0.000)	51.303 (0.000)	80.801 (0.000)	108.666 (0.000)
D (lag 6)	25.435 (0.000)	28.413 (0.000)	49.962 (0.000)	82.322 (0.000)
D (lag 7)	15.031 (0.002)	15.903 (0.001)	31.752 (0.000)	56.221 (0.000)
D (lag 8)	19.422 (0.000)	18.468 (0.000)	27.428 (0.000)	37.832 (0.000)
D (lag 9)	7.731 (0.052)	8.079 (0.044)	8.724 (0.033)	15.038 (0.090)

Note) The numbers in parentheses are *p*-values.

Table A.3

VEC estimations of rice futures prices

	Cointegration equation		
	Equation 1	Equation 2	
$y_{1,t-1}$	1.0000	0.0000	
$y_{2,t-1}$	0.0000	1.0000	
$y_{3,t-1}$	-0.8934 [0.0226]	-0.9220 [0.0247]	
Constant	-0.0005	-0.0004	
	Error correction		
	$\Delta y_{1,t}$	$\Delta y_{2,t}$	$\Delta y_{3,t}$
Cointegration equation 1	-3.1340 [0.9453]	-0.6392 [0.9316]	-0.3820 [1.0143]
Cointegration equation 2	1.9821 [0.8174]	-0.6942 [0.8055]	1.9745 [0.8770]
$\Delta y_{1,t-1}$	1.9410 [0.8826]	0.6848 [0.8698]	0.6639 [0.9470]
$\Delta y_{1,t-2}$	1.8600 [0.8068]	1.0564 [0.7951]	1.0343 [0.8657]
$\Delta y_{1,t-3}$	1.7763 [0.7084]	1.2464 [0.6981]	1.2644 [0.7601]
$\Delta y_{1,t-4}$	1.4352 [0.6039]	1.1270 [0.5952]	1.2136 [0.6480]
$\Delta y_{1,t-5}$	1.2267 [0.4945]	1.0834 [0.4873]	1.1961 [0.5305]
$\Delta y_{1,t-6}$	0.7280 [0.3811]	0.6980 [0.3756]	0.8262 [0.4089]
$\Delta y_{1,t-7}$	0.1187 [0.2637]	0.0556 [0.2599]	0.1386 [0.2829]
$\Delta y_{1,t-8}$	0.2005 [0.1611]	0.1640 [0.1588]	0.2661 [0.1728]
$\Delta y_{2,t-1}$	-1.6157 [0.7629]	-0.1287 [0.7519]	-1.5645 [0.8186]
$\Delta y_{2,t-2}$	-1.4051 [0.7009]	-0.3874 [0.6908]	-1.5168 [0.7521]
$\Delta y_{2,t-3}$	-1.2595 [0.6155]	-0.5306 [0.6066]	-1.4374 [0.6604]
$\Delta y_{2,t-4}$	-1.0983 [0.5221]	-0.6226 [0.5145]	-1.3427 [0.5602]
$\Delta y_{2,t-5}$	-0.9539 [0.4218]	-0.6416 [0.4156]	-1.2170 [0.4525]
$\Delta y_{2,t-6}$	-0.5305 [0.3233]	-0.3745 [0.3186]	-0.9096 [0.3469]
$\Delta y_{2,t-7}$	-0.1862 [0.2241]	-0.0538 [0.2208]	-0.4005 [0.2404]
$\Delta y_{2,t-8}$	-0.2374 [0.1468]	-0.1687 [0.1447]	-0.3741 [0.1576]
$\Delta y_{3,t-1}$	-0.7552 [0.4825]	-1.0474 [0.4755]	0.2476 [0.5177]
$\Delta y_{3,t-2}$	-0.8763 [0.4394]	-1.1447 [0.4330]	-0.1945 [0.4715]
$\Delta y_{3,t-3}$	-0.9124 [0.3932]	-1.1697 [0.3875]	-0.4951 [0.4219]
$\Delta y_{3,t-4}$	-0.6623 [0.3932]	-0.8532 [0.3368]	-0.4251 [0.3667]
$\Delta y_{3,t-5}$	-0.6077 [0.2859]	-0.7811 [0.2818]	-0.5033 [0.3068]
$\Delta y_{3,t-6}$	-0.3922 [0.2267]	-0.5259 [0.2235]	-0.2967 [0.2433]
$\Delta y_{3,t-7}$	-0.0997 [0.1655]	-0.1661 [0.1631]	-0.0434 [0.1776]
$\Delta y_{3,t-8}$	-0.1216 [0.0982]	-0.1437 [0.0968]	-0.1051 [0.1053]

Constant	0.0001 [0.0026]	0.0000 [0.0026]	0.0003 [0.0028]
$\bar{R}^2$	0.3621	0.3518	0.4038

Note) $\bar{R}^2$ denotes adjusted R-squared, and the standard errors are in brackets.

Table A.4

Data sources of rice prices in Osaka

Duration	Domestic rice in the futures market	Korean rice in the spot market	Domestic rice in the spot market
Jan. 1919 –Dec. 1919	Ministry of Agriculture and Commerce (1920)	Ministry of Railways, Transportation Bureau (1925)	
Jan. 1920 –Mar. 1921	Ministry of Agriculture and Commerce (1921–23)	Ministry of Agriculture and Forestry, Agricultural Bureau (1925)	
Apr. 1921 –Dec. 1921	Ministry of Agriculture and Commerce, Commercial Bureau (1922)	Ministry of Agriculture and Forestry, Agricultural Bureau (1925)	
Jan. 1922 –Dec. 1923	Ministry of Agriculture and Commerce (1924–25)	Ministry of Agriculture and Forestry, Agricultural Bureau (1925)	
Jan. 1924 –Dec. 1924	Ministry of Agriculture and Commerce, Commercial Bureau (1925)	Ministry of Agriculture and Forestry, Agricultural Bureau (1925)	
Jan. 1925 –Dec. 1925	Ministry of Agriculture and Commerce, Commercial Bureau (1926)	Ministry of Agriculture and Forestry, Agricultural Bureau (1928)	
Jan. 1926 –Oct. 1926	Ministry of Commerce and Industry, Commercial Bureau (1927)	Ministry of Agriculture and Forestry, Agricultural Bureau (1928)	
Nov. 1926 –Dec. 1928	Ministry of Commerce and Industry, Commercial Bureau (1928–29)	Governor-General of Taiwan, Industrial Bureau (1937)	
Jan. 1929 –Dec. 1931	Ministry of Commerce and Industry (1930–32)	Governor-General of Taiwan, Industrial Bureau (1937)	
Jan. 1932 –Dec. 1936	Ministry of Commerce and Industry, Commercial Bureau (1933–37)	Governor-General of Taiwan, Industrial Bureau (1937)	
Jan. 1937 –Mar. 1939	Ministry of Commerce and Industry, Commercial Bureau (1938–40)	Governor-General of Taiwan, Industrial Bureau (1941)	

Table A.5

Chi-squared test statistics of the lag exclusion Wald test for the VEC of rice prices in Osaka

	y_1	y_2	y_3	Joint
D (lag 1)	66.275 (0.000)	76.039 (0.000)	82.562 (0.000)	118.695 (0.000)
D (lag 2)	33.405 (0.000)	38.124 (0.000)	34.697 (0.000)	61.564 (0.000)
D (lag 3)	10.084 (0.018)	17.570 (0.001)	11.010 (0.012)	27.327 (0.001)
D (lag 4)	7.142 (0.068)	8.884 (0.031)	10.731 (0.013)	14.628 (0.102)

Note) The numbers in parentheses are p-values.

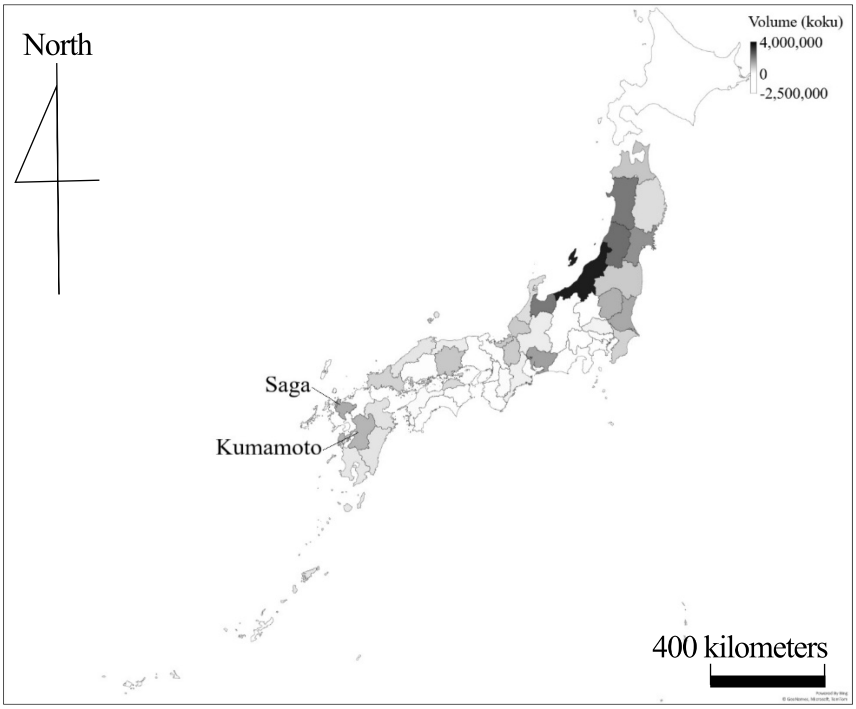
Table A.6

VEC estimations of rice prices in Osaka

	Cointegration equation		
	Equation 1	Equation 2	
$y_{1,t-1}$	1.0000	0.0000	
$y_{2,t-1}$	0.0000	1.0000	
$y_{3,t-1}$	-1.0442 [0.0948]	-1.2111 [0.0341]	
Constant	-0.0012	-0.0007	
	Error correction		
	$\Delta y_{1,t}$	$\Delta y_{2,t}$	$\Delta y_{3,t}$
Cointegration equation 1	-0.2480 [0.1782]	1.0004 [0.1774]	0.7226 [0.1540]
Cointegration equation 2	0.4283 [0.3187]	-1.5726 [0.3173]	0.7898 [0.2756]
$\Delta y_{1,t-1}$	-0.1629 [0.1612]	-0.4159 [0.1605]	-0.3091 [0.1394]
$\Delta y_{1,t-2}$	0.0240 [0.1314]	-0.1525 [0.1308]	-0.1353 [0.1136]
$\Delta y_{1,t-3}$	0.0577 [0.0981]	-0.0768 [0.0976]	0.0462 [0.0848]
$\Delta y_{2,t-1}$	-0.4207 [0.2654]	0.4027 [0.2642]	-0.4497 [0.2295]
$\Delta y_{2,t-2}$	-0.3206 [0.1916]	0.2565 [0.1908]	-0.1774 [0.1657]
$\Delta y_{2,t-3}$	-0.1907 [0.1085]	0.0449 [0.1080]	-0.1045 [0.0938]
$\Delta y_{3,t-1}$	0.0488 [0.3028]	-0.7173 [0.3015]	0.2719 [0.2618]
$\Delta y_{3,t-2}$	-0.0698 [0.2130]	-0.5495 [0.2121]	0.0064 [0.1842]
$\Delta y_{3,t-3}$	0.0318 [0.1203]	-0.1995 [0.1198]	-0.0399 [0.1041]
Constant	-0.0001 [0.0041]	0.0012 [0.0041]	0.0001 [0.0036]
$\bar{R}^2$	0.2298	0.4334	0.4904

Note) $\bar{R}^2$ denotes adjusted R-squared, and the standard errors are in brackets.

(A) Net export volume



(B) Export volume from Kumamoto Prefecture

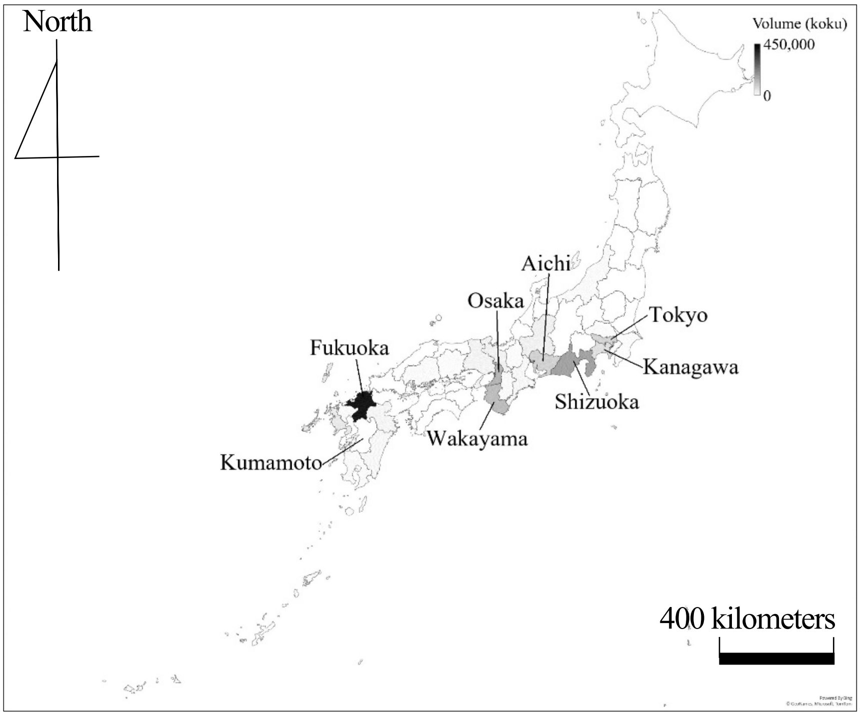


Figure A.1. Export volume of rice by prefecture (annual average during the period 1926–1930)

Note) There are no data on the net export volumes of Tokyo, Yamanashi, Nagano, Shizuoka, Wakayama, Nagasaki, and Okinawa Prefectures.

Source) Ministry of Agriculture and Forestry, Rice Bureau, 1932, pp. 2–5.

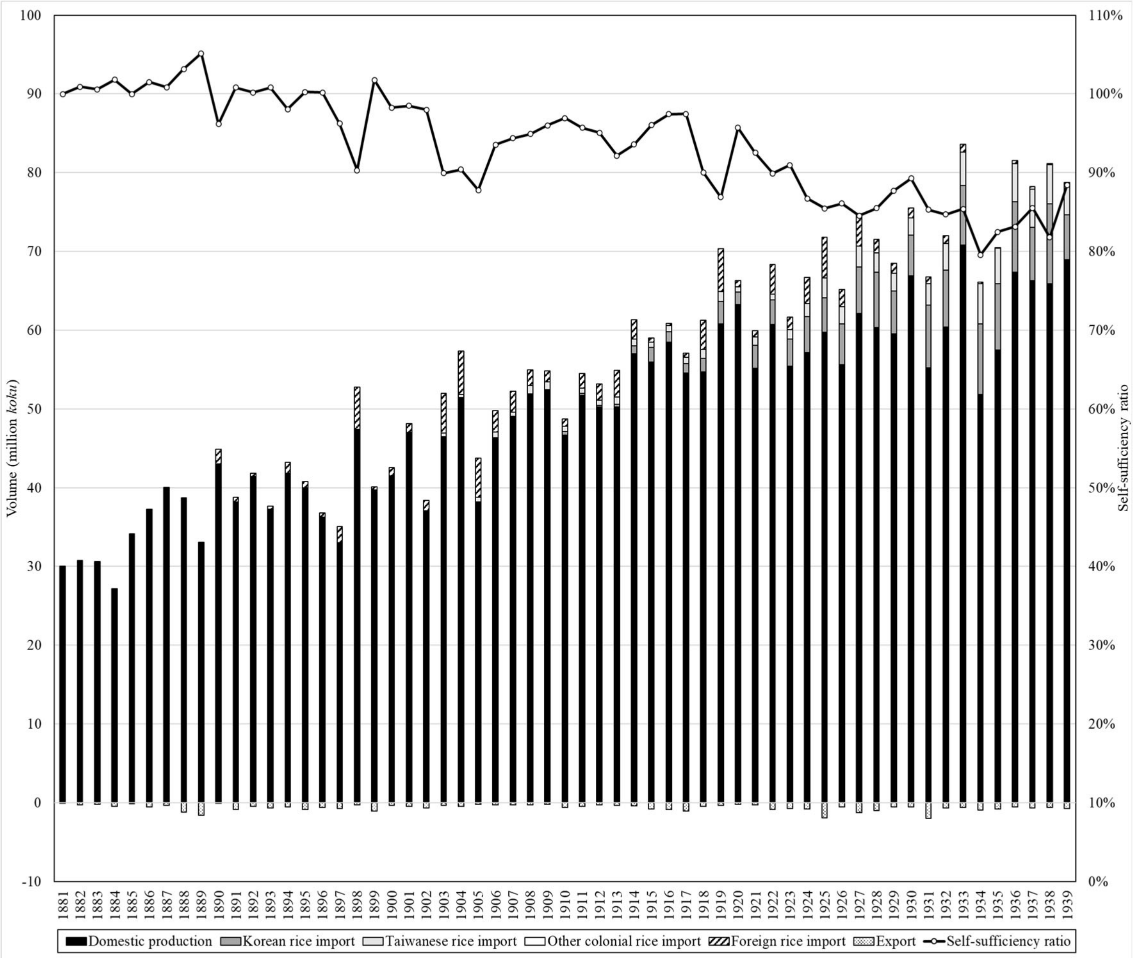
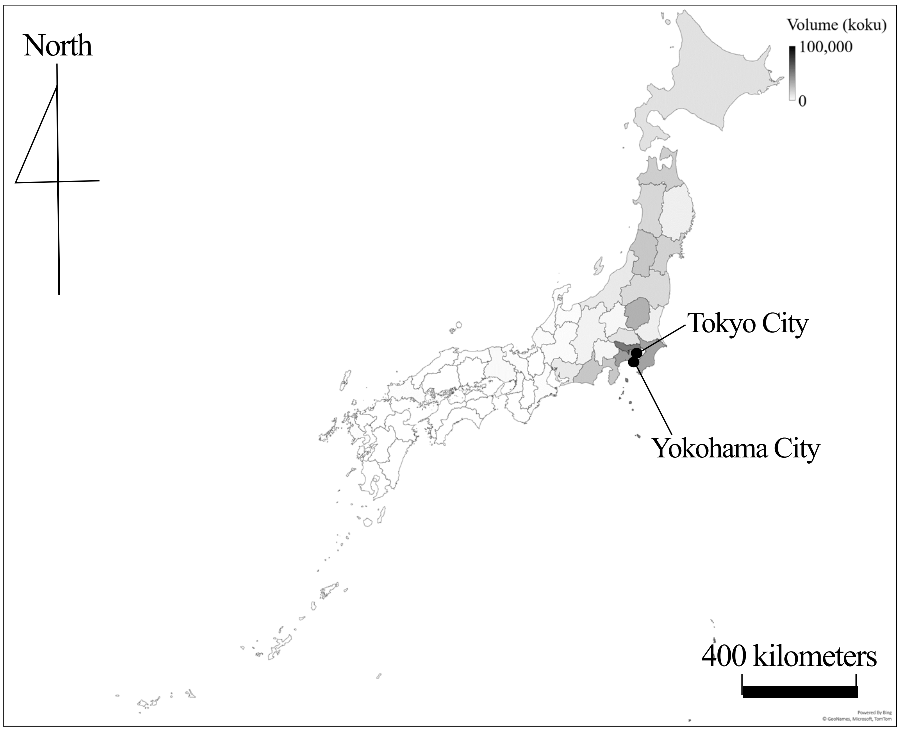


Figure A.2. Supply volume of rice in Japan (1881–1939)

Sources) Ministry of Agriculture and Commerce, Food Control Bureau, 1944, pp. 50–51; Ministry of Agriculture and Forestry, Economy of Agriculture and Forestry Bureau, Statistical Investigation Unit, 1955, pp. 160–161; Toyo Keizai Shimpo Sha, 1935, pp. 484–485; 592–593.

(A) From Tokyo City and Yokohama City



(B) From Osaka City and Kobe City

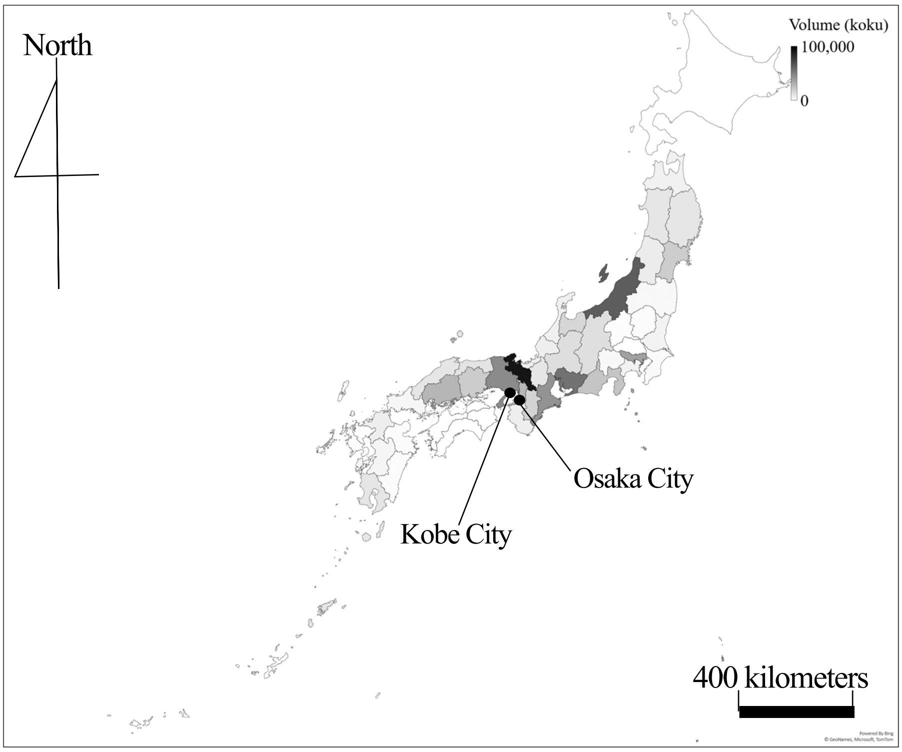
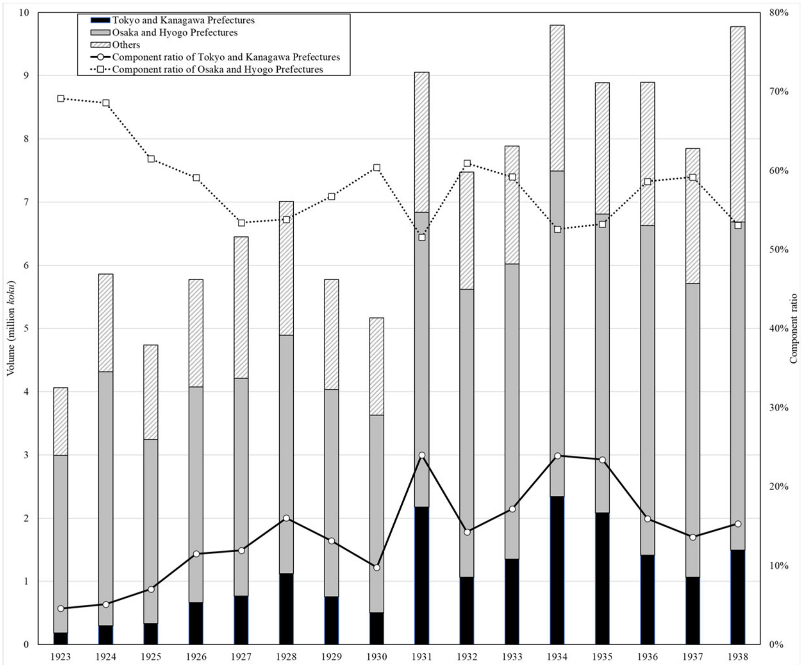


Figure A.3. Volume of domestic and imported rice transferred from the central cities (1920)
Source) Ministry of Railways, Transportation Bureau, 1925, pp. 392–393.

(A) Korean rice



(B) Taiwanese rice

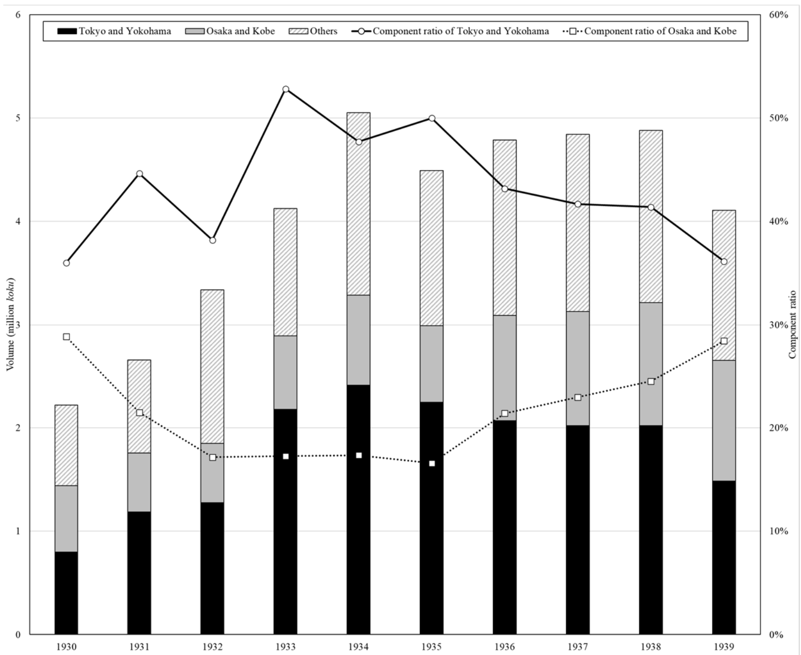
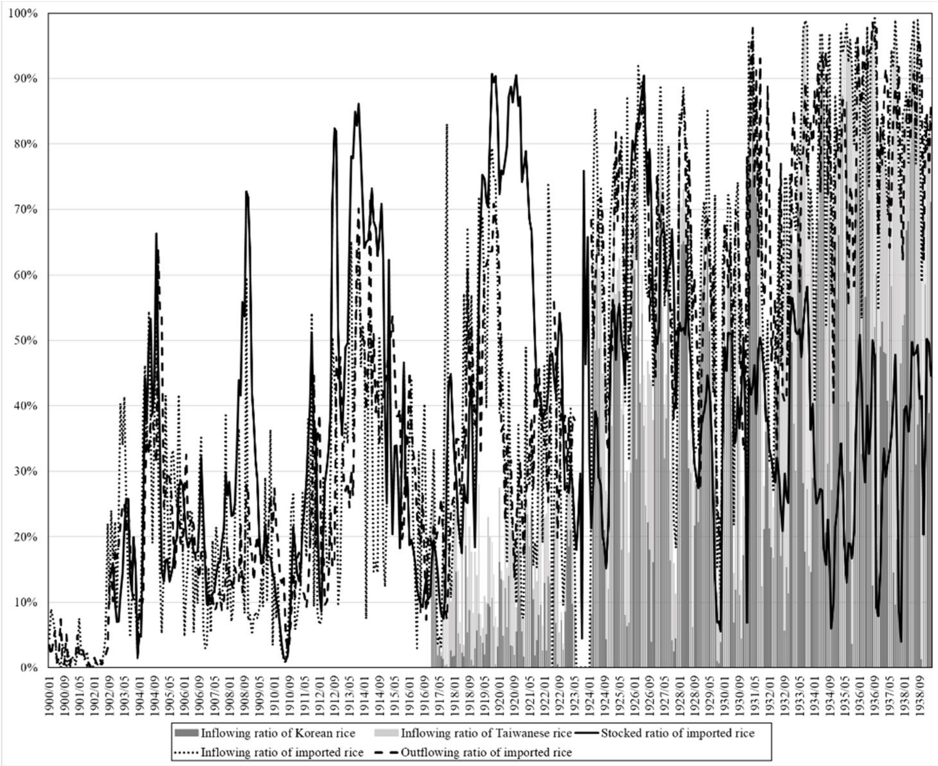


Figure A.4. Volume of colonial rice imports (1923–38)

Note) Kanagawa and Hyogo Prefectures are centered on Yokohama and Kobe Cities, respectively.

Sources) Governor-General of Korea, Agriculture and Forestry Bureau, 1935, pp. 60–71; Governor-General of Korea, Agriculture and Forestry Bureau, 1940, pp. 64–69; Governor-General of Korea, Industrial Bureau, 1928, pp. 40–43; Governor-General of Taiwan, Food Bureau, 1942, pp. 89–91.

(A) Tokyo



(B) Osaka

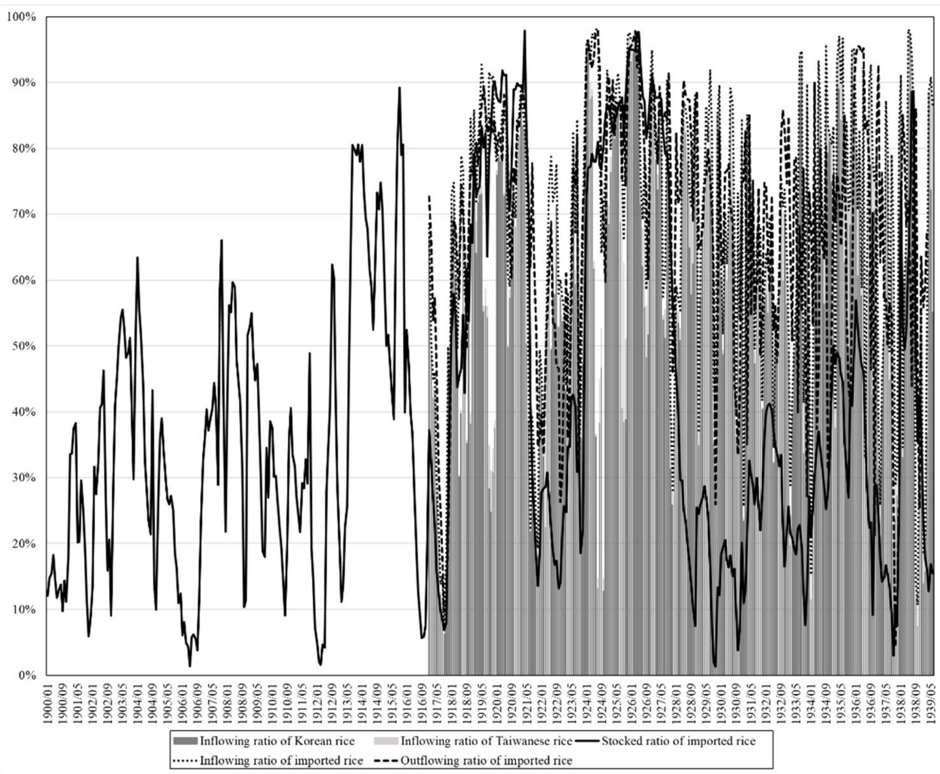


Figure A.5 Ratio of imported rice in Tokyo and Osaka (1900–1939)

Notes) Panel A denotes the stocked and inflowing ratios of imported rice in the major warehouses in Tokyo and in the Tokyo-Fukagawa Rice Spot Market, respectively. The inflowing ratio until September 1902, in May 1922, and during the period June 1923–January 1924 is missing because the sources were destroyed by fire in the Great Kanto Earthquake of September 1, 1923. Panel B demonstrates the stocked, inflowing, and outflowing ratios of imported rice in the major warehouses in Osaka. The data of the inflowing and outflowing ratios are available after 1917.

Sources) Governor-General of Taiwan, Industrial Bureau, 1937; 41; Ministry of Agriculture and Forestry, Agricultural Bureau, 1925; 28; Ministry of Railways, Transportation Bureau, 1925; Osaka Chamber of Commerce, 1918; 20a; 20b; 22; 23a; 23b; 24–28; 39a; 39b; Osaka City Government, 1905; 09; 15; Osaka-Dojima Rice Exchange, 1912b; 13–18; 19a; 20; 21a; 22a; 23a; 24a; 25a; 28; 29b; 32; 33a; 33b; 34–38; 39b; 39c; Tokyo Chamber of Commerce, 1901–03; 16–17; Tokyo Chamber of Commerce and Industry, 1918–19; 21–22; 24; 26–27; 28a–29a; 28b-37b; 31a–37a; 38–40; Tokyo City Government, 1904–05; 07–09; 11a; 11b; 12–30.

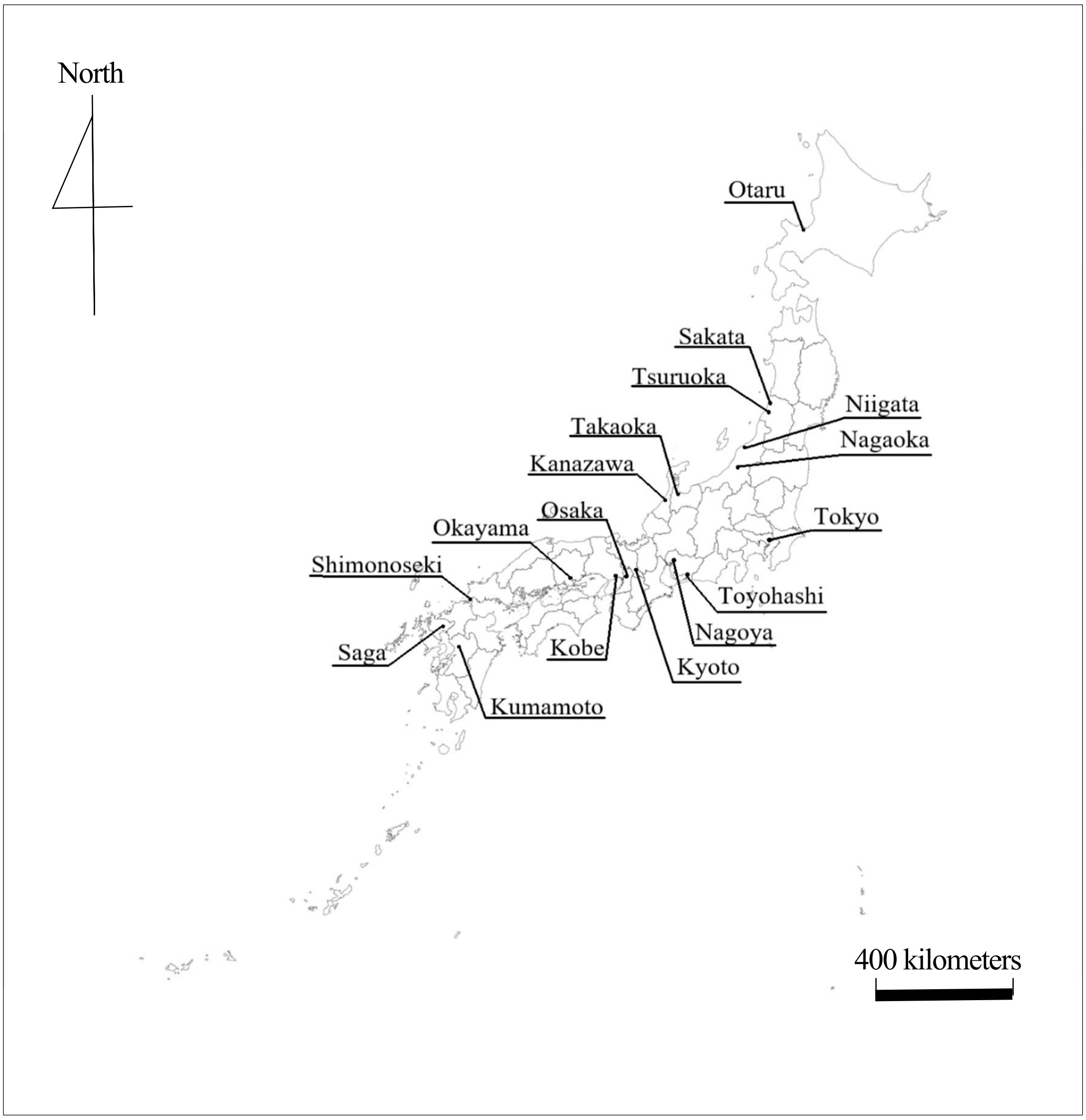


Figure A.6 Location of rice exchanges in Japan (1938)

Source) Tokyo Stock Exchange, Investigation Department, 1938–39

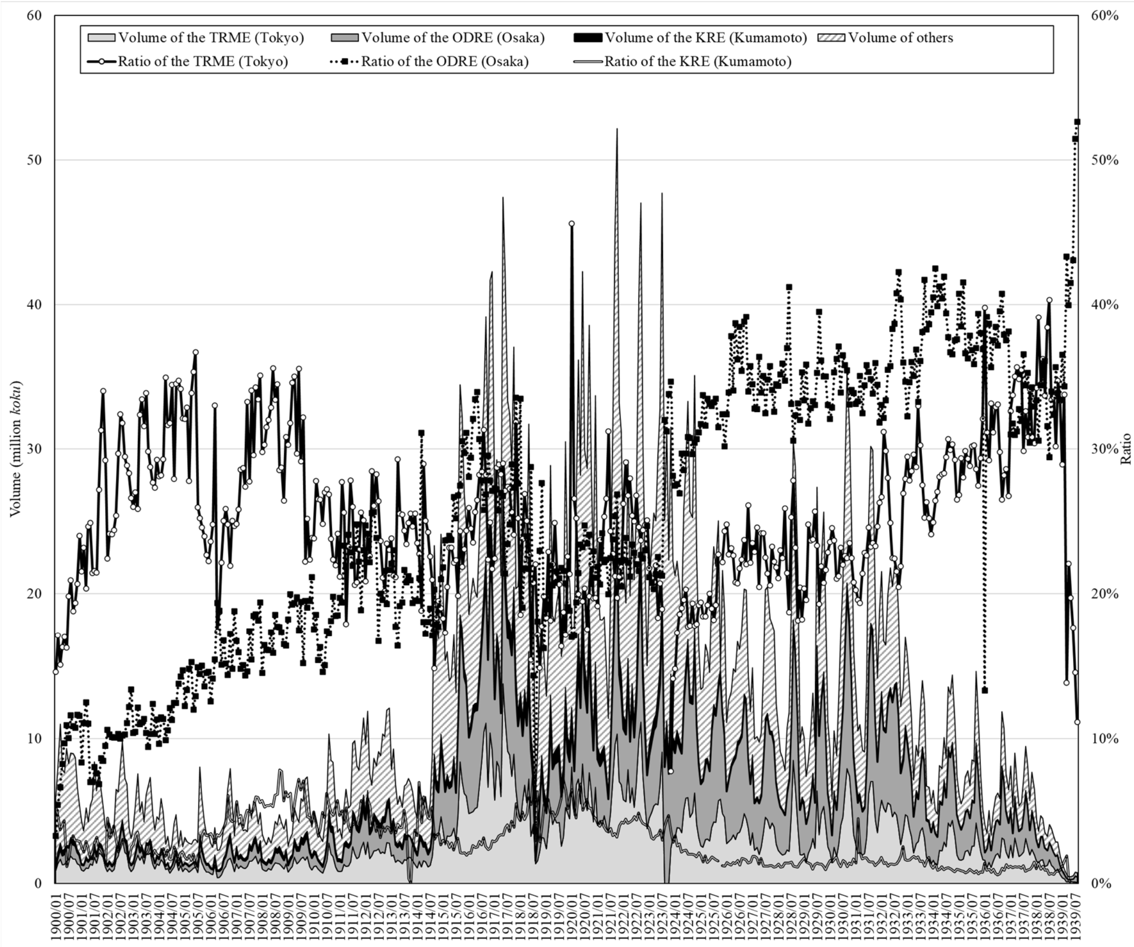


Figure A.7 Volume of futures trade in rice exchanges (January 1900–August 1939)

Sources) Kumamoto Prefectural Government, 1922; 24; 27; 31; Ministry of Agriculture and Commerce, 1902–21; Ministry of Agriculture and Forestry, Rice Bureau, 1935; Ministry of Finance, Financial Bureau, 1913; 15; 18; Osaka City Government, 1905; 09; Osaka-Dojima Rice Exchange, 1920; 22a; 23a; 25a; 29a; Tokyo Chamber of Commerce, 1921; 24; 27; Tokyo Chamber of Commerce and Industry, 1930a, p. 59; Tokyo City Government, 1924, pp. 500–501; Tokyo Stock Exchange, Investigation Department, 1919–29; 30a; 30b; 31–39

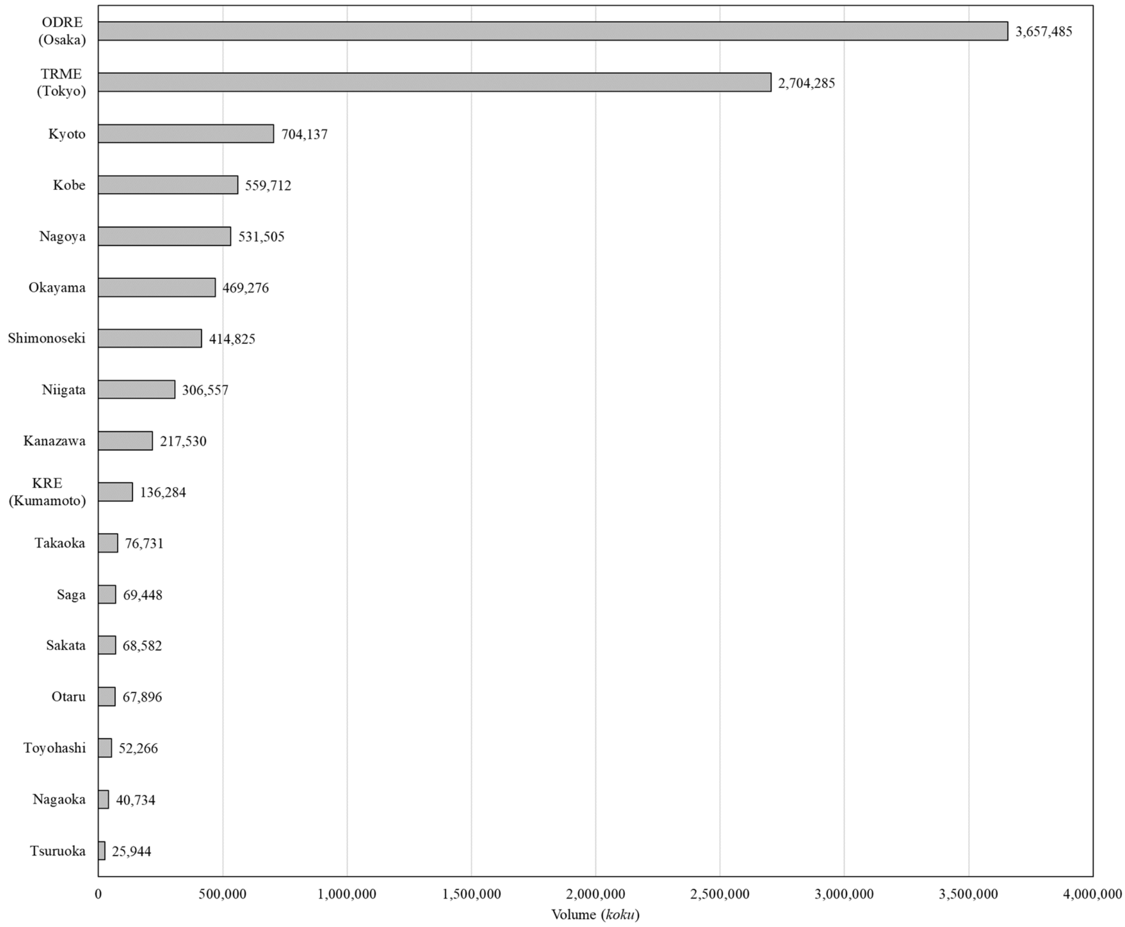


Figure A.8 Monthly average volume of futures trade in rice exchanges (January 1930–August 1939)

Sources) Tokyo Stock Exchange, Investigation Department, 1930a; 30b; 31–39

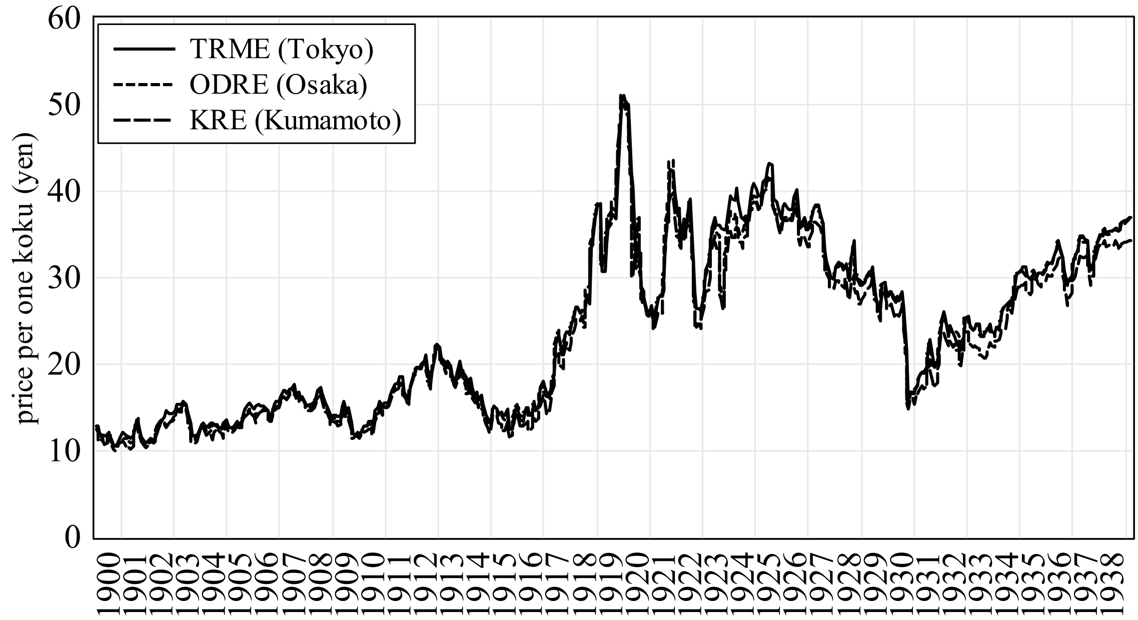
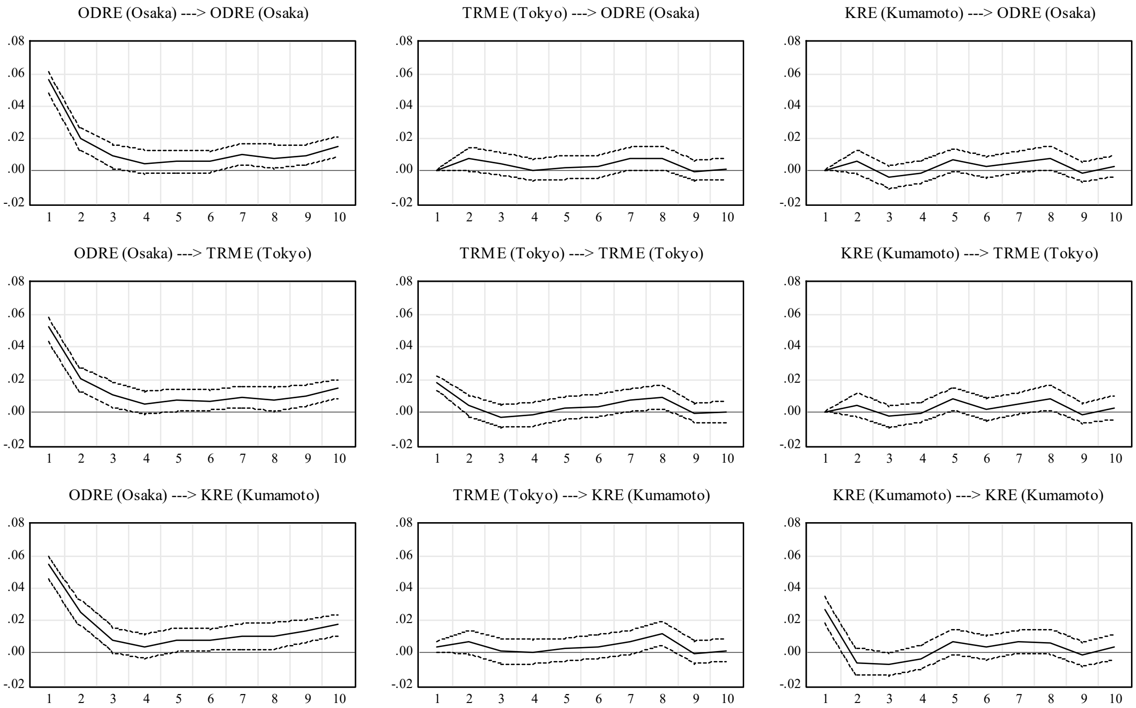


Figure A.9. Rice futures prices in the TRME, the ODRE, and the KRE (January 1900–March 1939)

Notes) This figure demonstrates the rice futures prices of the deferred contract month. The futures trade of the deferred contract month in the KRE was suspended in October 1913 due to the market disruption by soaring prices. All futures trades in the TRME were stopped during the period September–October 1923 because of the Great Kanto Earthquake. Accordingly, we interpolated these breaches by using the Catmull-Rom spline technique.

Sources) Kumamoto City Government, 1904; 09; 14; 18–19; Ministry of Commerce and Industry, 1930–32; Ministry of Agriculture and Commerce, 1920–25; Ministry of Agriculture and Commerce, Commercial Bureau, 1922; 25–26; Ministry of Commerce and Industry, Commercial Bureau, 1927–29; 31–40; Ministry of Finance, Financial Bureau, 1918; Nakazawa, 1933, pp. 382–386; Osaka City Government 1905; 09; Tokyo City Government 1904; 09

(A) Impulse response functions



(B) Relative variance composition

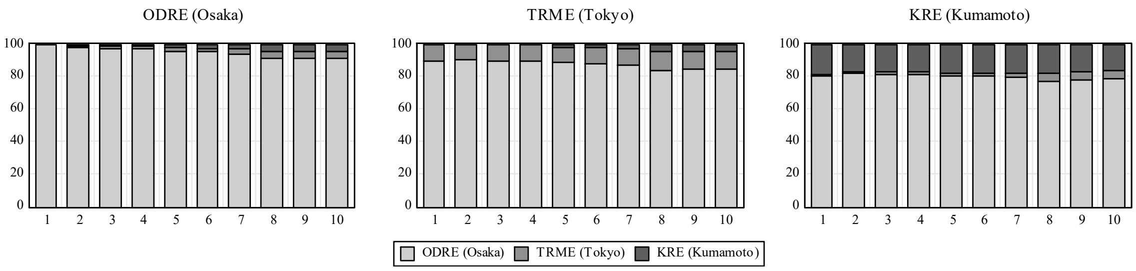
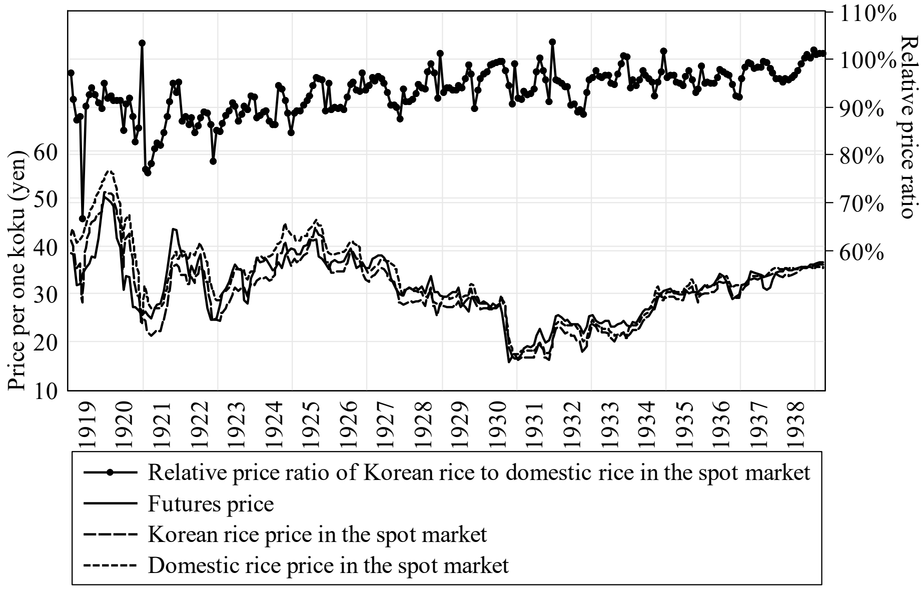


Figure A.10. Results of the innovation accounting approach of rice futures prices

Note) The dashed lines in Panel A represent the 99% confidence band.

(A) Nominal prices (January 1919–March 1939)



(B) Monthly average real prices of Korean and domestic rice in the spot market (1919–38)

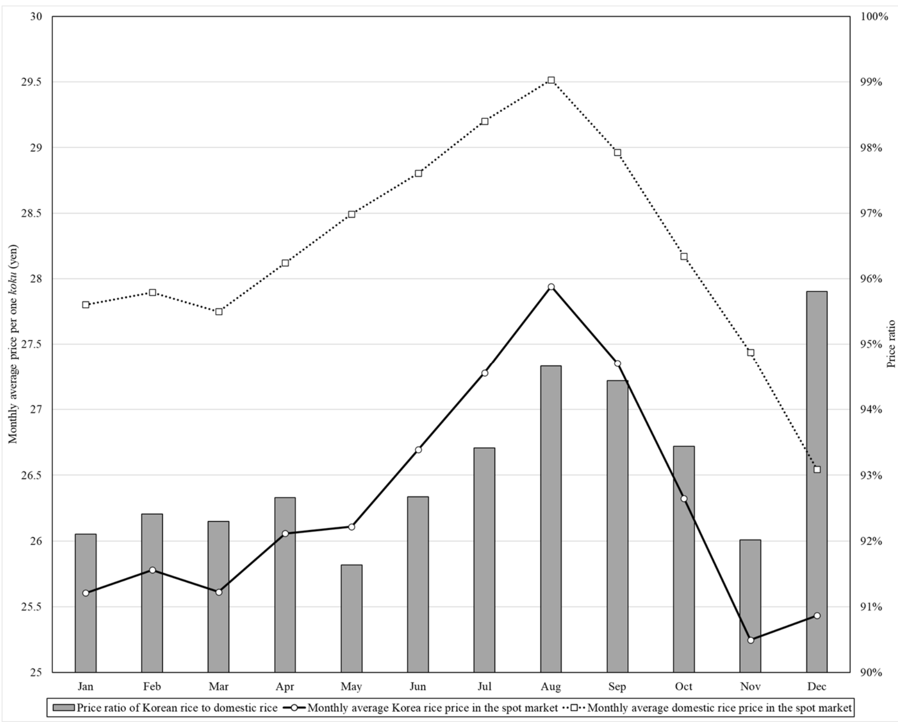
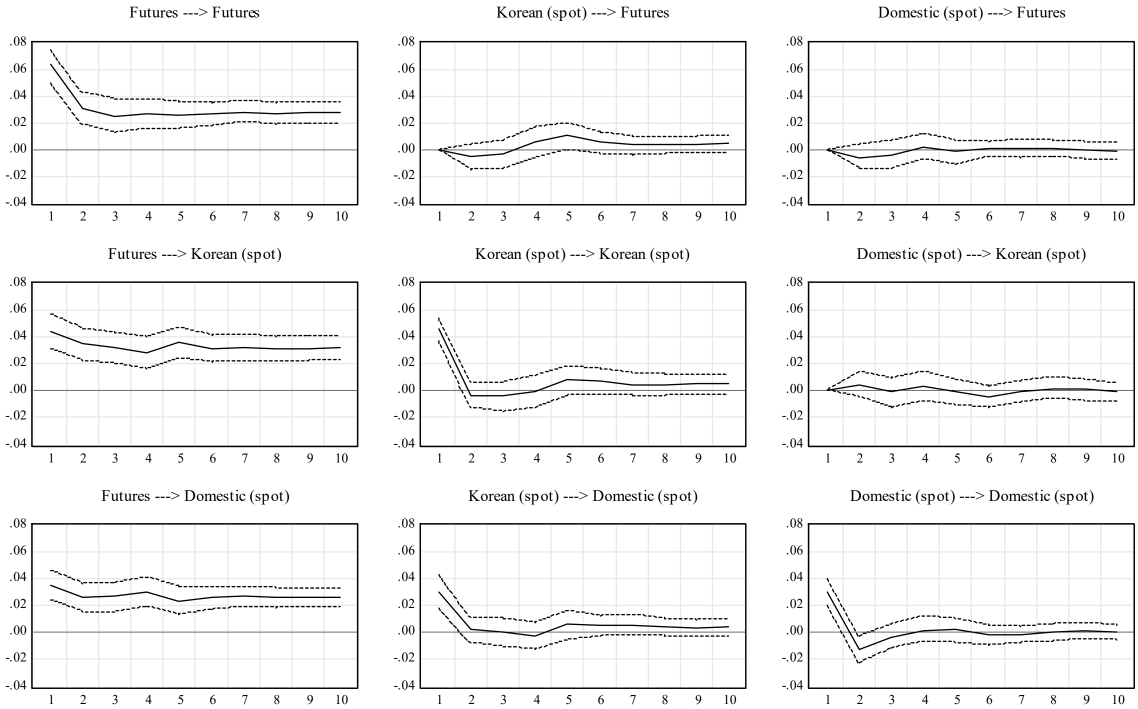


Figure A.11. Rice prices in Osaka

Note) The "Futures price" in Panel A displays the prices of the deferred contract month.

Sources) Bank of Japan, Statistics Department, 1966; Governor-General of Taiwan, Industrial Bureau, 1937; 41; Ministry of Agriculture and Commerce, 1921–25; Ministry of Agriculture and Commerce, Commercial Bureau, 1922; 25–26; Ministry of Commerce and Industry, 1930–32; Ministry of Commerce and Industry, Commercial Bureau, 1927–29; 33–40

(A) Impulse response functions



(B) Relative variance composition

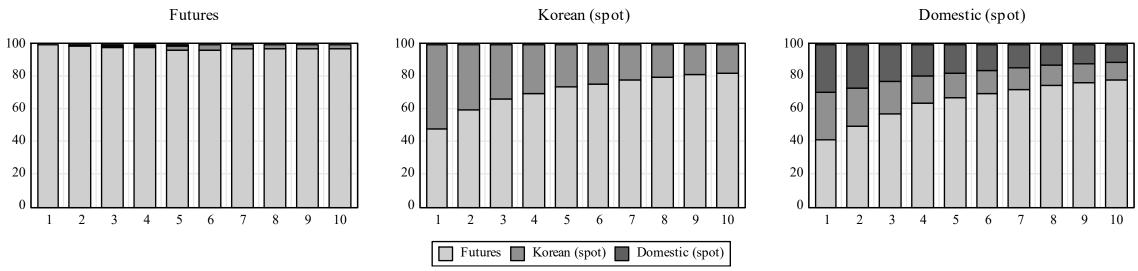


Figure A.12. Results of the innovation accounting approach of rice prices in Osaka

Note) The dashed lines in Panel A represent the 99% confidence band.

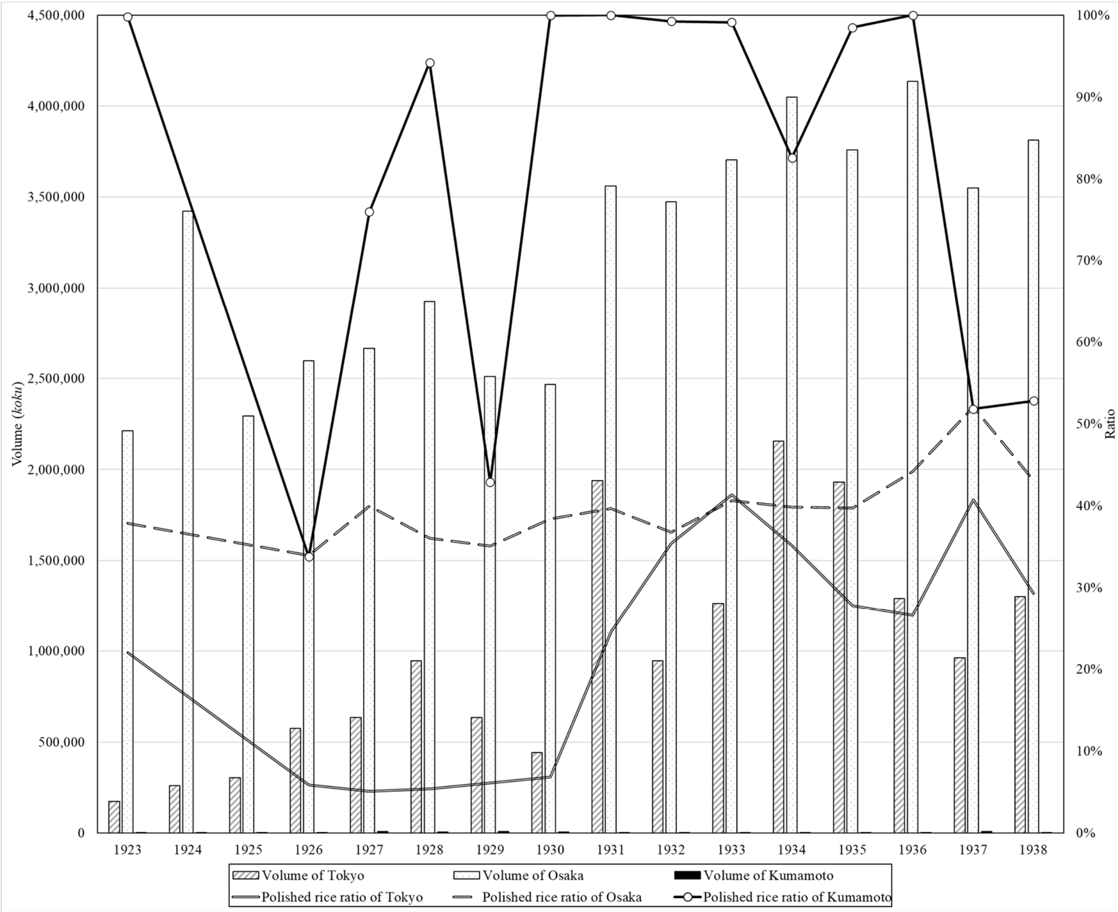


Figure A.13. Volume of Korean rice imports and the polished rice ratio by prefecture (1923–38)

Note) The polished rice ratios are interpolated between 1923 and 1926 because the data on the volume of polished and unpolished rice during the period 1924–1925 are missing.

Sources) Governor-General of Korea, Agriculture and Forestry Bureau, 1935, pp. 60–71; Governor-General of Korea, Agriculture and Forestry Bureau, 1940, pp. 64–69; Governor-General of Korea, Industrial Bureau, 1928, pp. 40–43

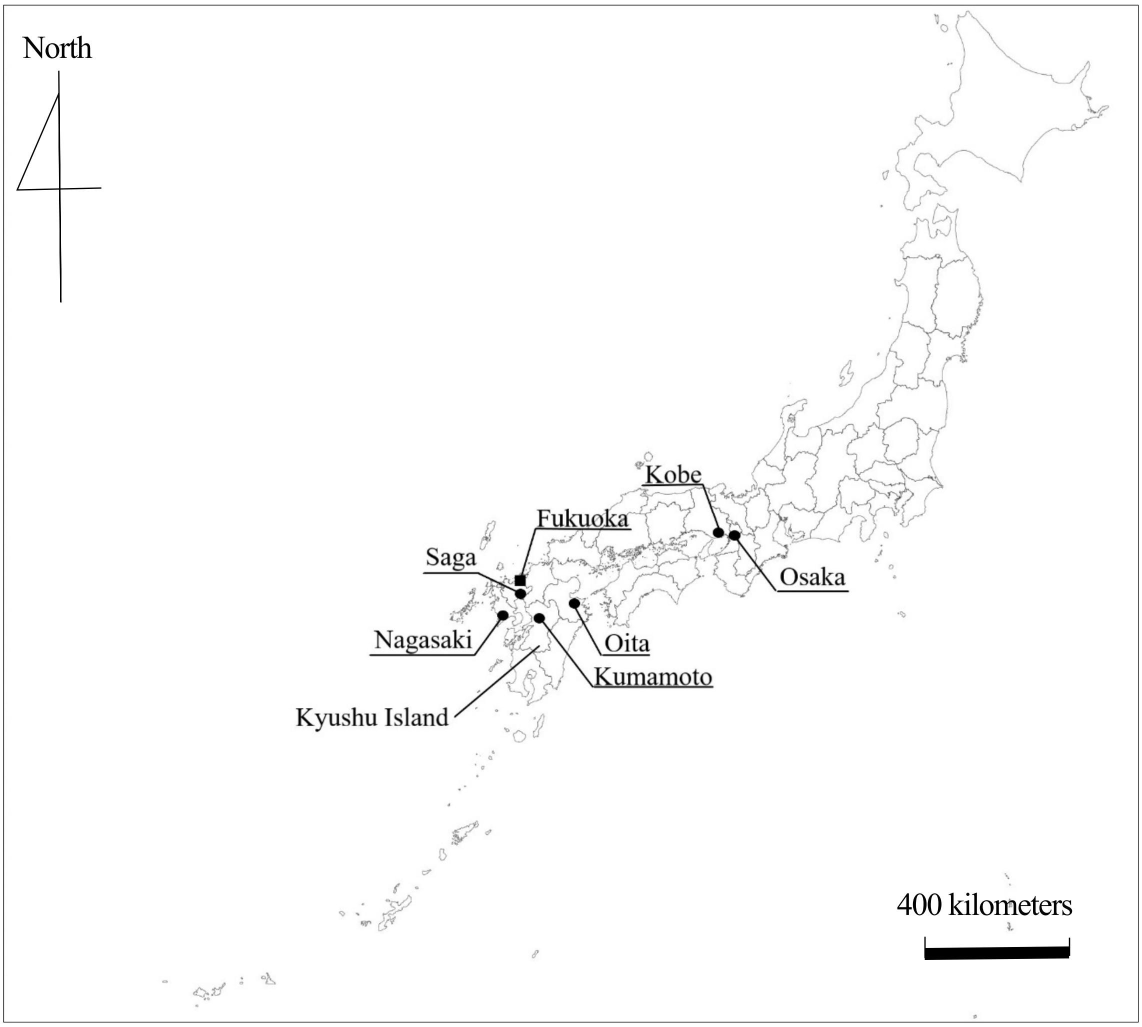


Figure A.14. Destination cities of Korean rice from Fukuoka (1936–37)

Source) Hishimoto, 1938, p. 576

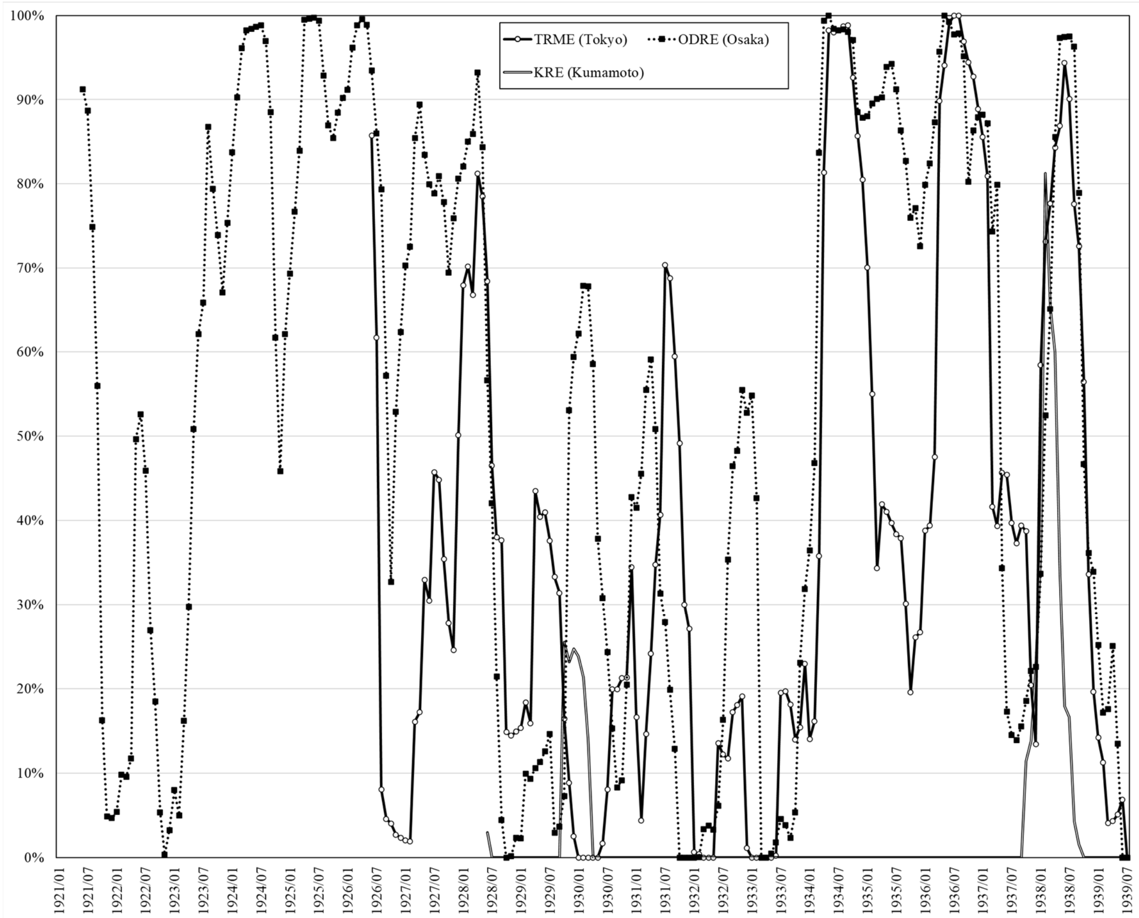


Figure A.15. Six-month average ratio of Korean rice to the delivery volume (January 1921–July 1939)

Note) The breakdowns of delivery volume by origins in the TRME until December 1925 and the KRE until December 1927 are unknown.

Sources) Ministry of Agriculture and Forestry, Agricultural Bureau, 1929; Ministry of Commerce and Industry, Commercial Bureau, 1929–40; Osaka-Dojima Rice Exchange, 1921b; 22b–25b; 26–28