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Taiwanized Rice Prices in Japan During the 1930s

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Abstract

Commodity pricing within empires was complex during the twentieth century, with colonies influencing changes in goods prices in the metropole. However, historical research analysing the mutual relationship between the economies of metropoles and colonies is scarce, while previous studies have tended to overlook the pricing of colonial rice. This study examines the economic ties between metropoles and their colonies within empires after the Great Depression, focusing on the rice price linkage between Japan and Taiwan. During the 1930s, Japan and Taiwan experienced political conflict, as the metropole's market participants regarded colonial products as the cause of the deteriorating market conditions. Japan's reliance on the supply of primary products from its colonies deepened in the bloc economy. This imperial political action conferred the power to alter the prices in the metropole's market to the colonial market. The economic ties within the empire then metamorphosed into a mutual relationship, albeit partially; however, alienation between the governing and economic relationships emerged, leading to conflicts within the empire.

Keywords: colonial trade, rice, seasonal price fluctuation, Taiwan, Japan

JEL classification codes: N25, N55, N75

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1. Introduction

Imperialism characterized the modern world economy during the first half of the twentieth century. Davis and Huttenback emphasize the need for historical research analysing the mutual relationship between the economies of metropoles and colonies.[1] Many economic historians have analysed the concept of price linkage to examine the relationships among multiple economies. Hence, there is a vast literature on market integration and price convergence, notably exploring the driving forces of market integration from the nineteenth century to the early twentieth century against the background of the longstanding issue of 'The Law of One Price'.[2] Scholars analysing commodity markets have paid attention to the improving transportation and communications infrastructure that reduced traders' costs and accelerated trading processes. Federico summarizes the assertions reported by these previous studies and stresses that three factors encouraged commodity markets to integrate from the nineteenth century: an improvement in market efficiency in Fama's sense, the introduction of new means of transportation, and the establishment of telecommunication networks.[3]

The foregoing works primarily examined Europe and North America, where the early introductions of the steam engine and electricity enabled rapid long-haul transportation and allowed telecommunication between distant locations, respectively. These inventions and discoveries brought market integration and economic prosperity to both continents, which in turn led to the emergence of the Great Powers. Finally, from the early twentieth century, the Western Great Powers used their colonies in Africa and Asia as suppliers of primary products such as food and minerals. This fostered the industrialization of their metropoles by allowing them to implement preferential tariffs for colonial trade, which subsequently grew rapidly.[4] The Great Powers consolidated their enclaved economies after the Great Depression, beginning in 1929, and the international commodity market changed in qualitative ways.

Recent research has extended the perspective that the international market underwent a unilinear integration process and broadened its scope to include the interruption of market integration.[5] Hynes, Jacks, and O'Rourke examine the disintegration of the international commodity market during the interwar period.[6] On the contrary, Panza, focusing on the collapse of the Ottoman Empire and incursions of the British and French Empires in the Near East, asserts that colonial market linkages strengthened from the mid-1920s.[7] However, research exploring colonial market linkages remains in its infancy and studies on the commodity market linkages within empires during the interwar period are scant. While advanced countries, including the former Great Powers, established their public archives to reposit historical documents, many former colonies, which later morphed into developing countries, have limited resources for constructing such archives. Hence, investigating colonial markets is harder than analysing metropoles' markets. However, Taiwan, a former Japanese colony, has rapidly built its archives since the 1980s, which now provide rich historical documents.

Based on the foregoing, to bridge the gap in the body of knowledge, this study examines the economic ties between metropoles and their colonies within empires after the Great Depression, focusing on the price linkage between Japan and Taiwan. Throughout the 1930s, the European Great Powers and Japan frequently encountered economic conflicts with their colonies owing to declining commodity prices, which changed the nature of their economic ties in important ways.

The economic relationship between metropoles and colonies was originally unequal and unbalanced. Colonial governments rejected indigenous citizens' suffrage and granted economic privileges to the settlers, who desired superior positions in the colonial economy.[8] After the First World War, the Western Great Powers strengthened their inegalitarian economic relationships with their colonies by improving the transportation and telecommunications infrastructure connecting with the metropoles.[9] Japan laid submarine wires to Korea in 1883 and to Taiwan in 1897, considerably earlier than the Western Great Powers, since Japanese colonies were geographically close to their metropole.[10] These measures increased the speed of transport and information propagation, meaning a metropole and its colonies could exchange commodities and price information expeditiously.[11]

Ten years after the end of the war, however, the beginning of the Great Depression altered empires' colonial relationships. In response to rising protective tariffs globally, the Great

Powers began to use their enormous military power and infrastructure to spawn their bloc economies.[12] However, the conflicts between metropoles and their colonies grew in each empire's bloc. Following the depression, the decline in commodity prices prompted metropoles' market participants to view colonial products with hostility. Taking an example from the British Empire, cotton merchants in Lancashire resisted imports from India.[13] Japan also experienced intense conflicts with its colonies but used its geographical proximity to them to enjoy close trade links. For example, the country's reliance on the colonial supply of rice—a staple food—deepened following the First World War.[14] After the Great Depression, as Japan was consolidating its enclave economy, rice prices tumbled and Japanese farmers regarded the imported colonial rice as the primary cause.[15] In response to farmers' assertions, the Japanese government planned to intervene directly in its rice trade with colonial markets; however, the colonial governments in Taiwan and Korea vigorously opposed the home government's interference.[16] Finally, the Japanese government's direct interventions in colonial markets came to fruition in 1939, when Japan strengthened its wartime economic regimentation in response to the collapse of diplomatic relations with the United States and the United Kingdom.[17]

During the 1930s, the price gaps between the metropole's cities and ports of origin typically expanded and commodity pricing within empires became increasingly complex.[18] In part owing to the enhanced transportation and telecommunications infrastructure, colonies influenced changes in the commodity prices in the metropole by altering their supply volume and prices. Although, theoretically, colonial governments and metropolitan companies oligopolistically controlled colonial exports, exporters who supplied colonial goods to the metropole freely purchased commodities from colonial merchants in the marketplace.[19]

This was especially noticeable for agricultural goods. Japanese colonies had well-organized rice markets in which prices were set through fierce competition between Japanese and indigenous merchants.[20] As the prices in colonial markets differed from those in the metropole's market due to the differences in harvest seasons, colonies experienced different price trends for agricultural goods than the metropole.[21] Further, while Japan only colonized its neighbouring area, the climate conditions in the metropole and colonies still differed. Specifically, although Taiwan is only approximately 2,100 kilometres (1,300 miles) from Tokyo, it is located in tropical and subtropical zones, whereas most of Japan falls within the temperate zone. Taiwan is also more humid than Japan and harvests rice twice a year, as its plant growth is relatively fast.[22] These distinctions in the harvest seasons of agricultural products may have affected price fluctuations in Japan's market, as the prices of agricultural commodities fluctuate seasonally.

Hence, in this study, we specifically examine how Taipei's rice prices affected Tokyo during the 1930s by econometrically analysing the daily rice price data in both cities. Although Japan has a long history of rice futures trading, dating back to the eighteenth century, this study makes an important contribution to the literature.[23] While scholars have investigated Japan's rice prices by conducting time-series analysis from the perspective of market efficiency, as defined by Fama, previous studies have tended to overlook the pricing of colonial rice.[24] Taiwanese historians also have little enthusiasm for rice pricing in colonial Taiwan since the Kuomintang government, which has proclaimed itself as the only legitimate Chinese government, exercised dictatorship over Taiwan and forbade academic research in Taiwanese history until democratization in 1987.[25] Therefore, the literature in Japan and Taiwan fails to examine the relationship between the rice markets in both regions.

The remainder of this paper comprises the following sections. Section 2 presents the historical setting of Taiwanese rice production and export to Japan. Section 3 describes the econometric methodology used in our analysis and explains the original daily price data. Section 4 examines the rice price linkage between Taipei and Tokyo using time-series analysis. Section 5 discusses the impact of Taiwan's rice prices on Tokyo's rice prices. Finally, Section 6 concludes.

2. Taiwanese Rice Production and Export to Japan

The island of Taiwan has an area of approximately 36,000 square kilometres (14,000 square miles) and is situated on the boundary between the East China Sea and South China Sea. Japan colonized Taiwan in 1895 after winning the First Sino-Japanese War and ruled Taiwan as its colony for half a century until its defeat in the Second World War in 1945. At the beginning of the colonial period, Japan established the Governor-General of Taiwan (GGT) in Taipei to govern colonial Taiwan. The GGT developed Taiwan as an agricultural area to produce sugar cane and rice for Japan from the late 1890s.[26]

Taiwan initially cultivated a different breed of rice than Japan did. The former grew an indica breed whose shape and texture are slimline and non-sticky, while the latter has cropped a japonica breed with a round shape and sticky texture. These gaps in quality eroded Japanese consumers' trust in the rice imported from Taiwan.[27] Accordingly, the GGT began researching the development of a new japonica breed that suited Taiwan's climate in the mid-1900s and the Taichung Agricultural Experiment Station succeeded in creating a new breed, Hōrai rice, in the early 1920s.[28] Hōrai rice grows twice a year and has a similar quality to Japanese rice. Therefore, it became a type of rice tailored for export to Japan, leading Taiwanese farmers to actively plant Hōrai rice from the late 1920s.

Hōrai rice production first appeared in the GGT's agricultural statistics in the first harvest season in 1922 (see Figure A. 1). The first and second harvest seasons in Taiwan are from May to July and October to December, respectively.[29] As most of Japan reaped rice once a year from September to October, the first harvest season in Taiwan was about three months before the Japanese harvest season.[30] Taiwanese farmers thus prioritized the production of Hōrai rice in the first harvest season. The production volume of Hōrai rice in the first harvest season increased from 0.9 million *koku*s in 1925 to more than three million *koku*s in 1938.[31] During the first harvest season, Taiwan harvested approximately 60 per cent of the annual production of Hōrai rice. It exported its products before the Japanese harvest season because the rice prices in Japan seasonally hit the ceiling.[32] This helped Taiwanese rice exports flourish in the 1930s. Figure 1 illustrates the

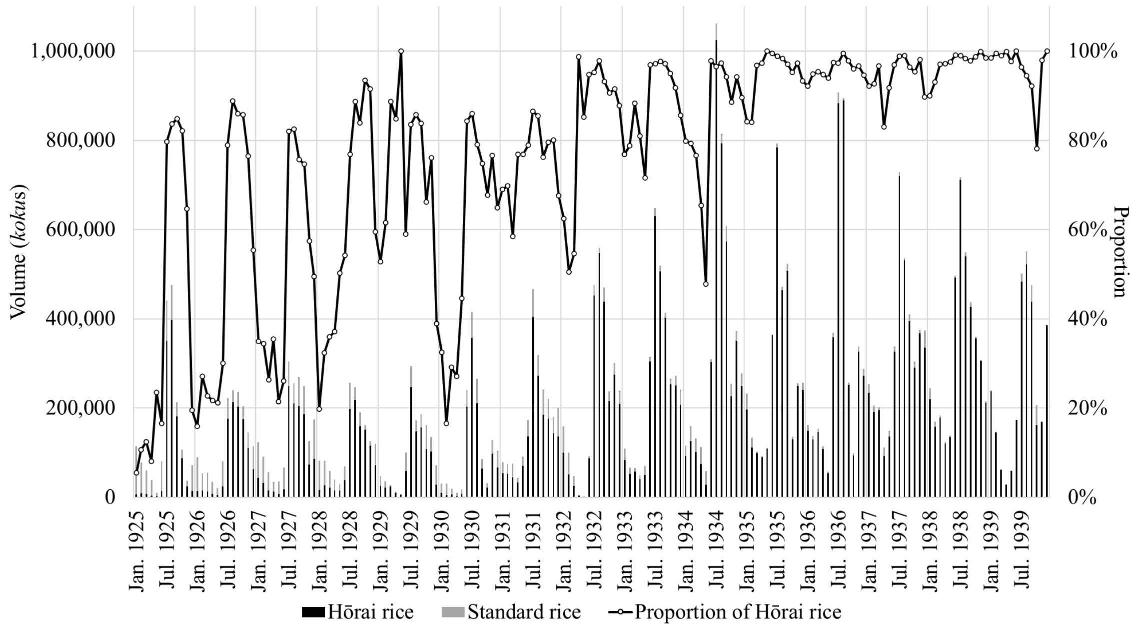


Figure 1. *Monthly volume of rice exported from Taiwan to Japan, January 1925–December 1939*

Sources: Governor-General of Taiwan, Industrial Bureau, Commerce and Industry Division, *Showa 10-nen*, pp. 37–8; Governor-General of Taiwan, Rice Bureau, *Showa 16-nen*, pp. 70–3.

monthly volume of rice exported from Taiwan to Japan from 1925 to 1939.

After the mid-1920s, the rice exported by Taiwan consisted mostly of Hōrai rice and the export volume increased from the 1930s. Throughout the 1930s, Taiwan exported 77 per cent of its harvested Hōrai rice, which accounted for 93 per cent of the rice exported from Taiwan to Japan.[33] Figure 1 illustrates that from June to August, before the Japanese harvest season, Taiwan increased its export volume of Hōrai rice, which was sold at inflated prices, to Japan.

Tokyo was the most significant destination of the Hōrai rice exported from Taiwan. The capital city initially bought rice mainly from eastern Japan, a softer variety of rice than in western Japan. The texture of the rice from eastern Japan was similar to that of Taiwanese rice and Tokyo residents preferred it.[34] Tokyo's two prosperous ports, Tokyo and Yokohama, imported about half of the Hōrai rice exported from Taiwan during the 1930s (see Figure A. 2). The former was the largest destination of Hōrai rice during this period. Figure 2 illustrates the monthly volume of rice

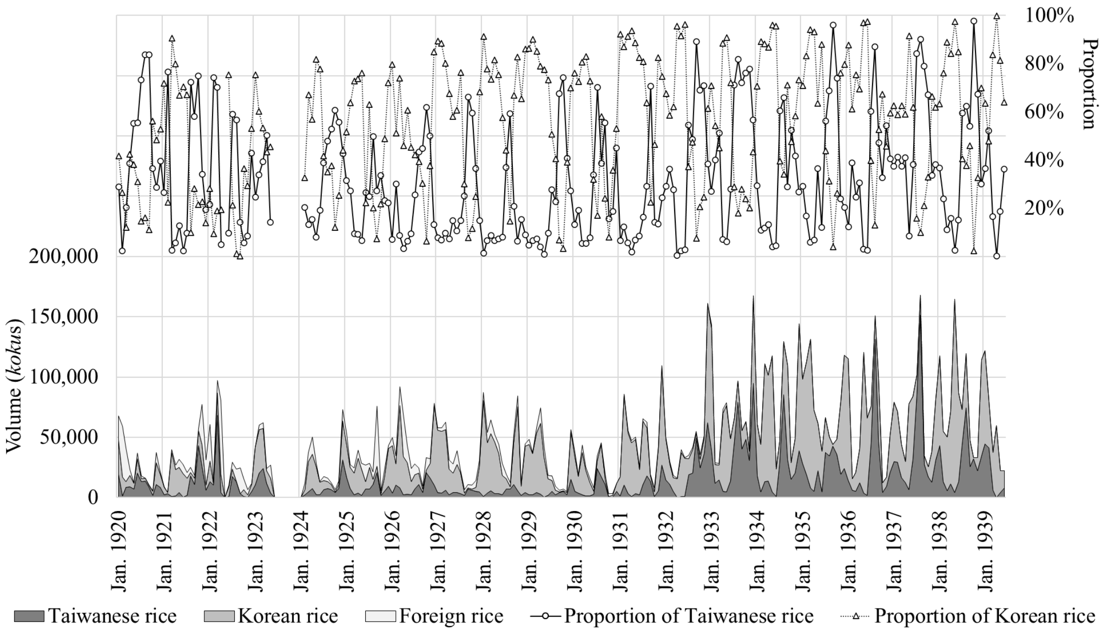


Figure 2. *Monthly volume of imported Taiwanese, Korean, and foreign rice in Tokyo, January 1920–June 1939*

Sources: Tokyo Chamber of Commerce, *Tokyo Shōgyō*, annual series (1921–27); Tokyo Chamber of Commerce and Industry, *Tokyo Shōkō Kaigisho Tōkei*, annual series (1928–39).

imported from Taiwan, Korea, and other countries to Tokyo from 1920 to 1939, showing that Korean rice imports increased after the mid-1920s and outweighed Taiwanese rice imports during the late 1920s.

These two colonial rice varieties showed different seasonal distributions. The distribution of Korean rice increased at the turn of each year and decreased every August. Korea harvested rice from September to October, similar to the Japanese harvest season, and stored large amounts of unhulled rice suitable for extended storage. It hulled rice and shipped unhulled rice when rice prices surged in Japan.[35] Similar to Korea, Taiwan also exported rice, except during the Japanese harvest season. The distribution of Taiwanese rice in Tokyo increased from July to October at the start of the 1930s (see Figure 2). Put simply, these two colonies supplied rice both before and after the Japanese harvest season. Hence, changes in Japan's rice prices were significant for colonial rice exporters.

From the late nineteenth century, Japan's two major cities, Tokyo and Osaka, had enormous futures markets, namely, the Tokyo Rice and Merchandise Exchange and Osaka-Dojima Rice Exchange, respectively.[36] These exchanges dealt with three types of futures contracts: nearby (one month), second-nearest (two months), and deferred (three months). Deferred contracts were the most prosperous and these accounted for approximately 70 per cent of the rice futures trade in Japan at that time.[37] However, the GGT in Taipei refused to establish rice exchanges in Taiwan. Given the wide price disparity between Taiwanese and Japanese rice because of their difference in quality, it was feared that the lower prices of the Taiwanese rice exchange would heavily suppress rice prices in Japan.[38] As a result, Taiwan lacked a well-organized rice market until the 1910s.

During the 1920s, trade and exports in Taiwanese rice expanded but the absence of an institution supplying index prices continued to disrupt trade.[39] In response to this disruption, in April 1925, the GGT permitted the Association for Taiwanese Rice Export Traders to establish the Taiwan Rice Market in Taipei but only for spot trade. After the market initially suffered from a scarcity of trade volume, in June 1928, the GGT also permitted it to trade in forward contracts within 45 days. While this change increased rice trading, the volume of the Taiwan Rice Market remained significantly below that of the rice exchanges in Japan, even during the 1930s. From April 1933 to March 1938, while the monthly average volume of the rice futures trade in Tokyo was 68 million *koku*s, the rice forward trade in Taipei was only 853 thousand kokus, equivalent to 1.3 per cent of the former.[40] However, Taiwan obtained a significant position in the supply of colonial rice before the Japanese harvest season.

Given the difficulty in finding accurate information on the volume of rice distributed to Tokyo, in this study, we use data on the volume of rice transported by train and ship to its stations and ports (see Figure A. 3). According to these statistics, until the beginning of the 1930s, rice exported from Taiwan accounted for less than 10 per cent of the total volume of rice transported from outside the city, which subsequently increased to over 20 per cent after 1933. During the 1930s, Korean rice accounted for about 20 per cent of the total volume. Therefore, Tokyo received approximately 40 per cent of its rice from Japanese colonies, meaning that the colonial rice supply played a crucial role in meeting the growing demand for rice in Tokyo.

3. Methodology and Data

We apply a three-dimensional vector error correction (VEC) model derived from a vector autoregressive model to the following three rice prices: Tokyo's futures prices of Japanese rice (based on deferred contracts at the Tokyo Rice and Merchandise Exchange), Tokyo's spot prices of Japanese rice, and Taipei's forward prices of Taiwanese Hōrai rice. The VEC model is as follows:

$$\boldsymbol{y_t} = \boldsymbol{v} + \sum_{i=1}^{p} \boldsymbol{A_1^i} \boldsymbol{y_{t-i}} + \boldsymbol{\varepsilon_t} \qquad (1)$$

where $\boldsymbol{y_t} = [y_{1t}, y_{2t}, y_{3t}]'$: y_{1t}, y_{2t}, and y_{3t} are Tokyo's futures prices, Tokyo's spot prices, and Taipei's forward prices, respectively; $\boldsymbol{v}$ is a three-dimensional constant vector; $\boldsymbol{A_1^i}$ is a three-by-three parameter vector; and $\boldsymbol{\varepsilon_t} = [\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}]'$ is a three-dimensional white noise vector.

We deduct $\boldsymbol{y_{t-1}}$ from both sides of Equation 1 and express the outcome in Equation 2:

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

where a coefficient matrix $\boldsymbol{\Pi} = \sum_{j=1}^{p} \boldsymbol{A_j} - \boldsymbol{I_m}$ comprises a loading matrix $\boldsymbol{\alpha}$ and a cointegration matrix $\boldsymbol{\beta}$, such that $\boldsymbol{\Pi} = \boldsymbol{\alpha\beta'}$. Both matrices $\boldsymbol{\Pi}$ and $\boldsymbol{\Gamma_i} = -\sum_{j=i+1}^{p} \boldsymbol{A_j}$ include r values below three. This leaves the following VEC model:

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

We apply a historical decomposition (HD) to capture the effect of subsequent shocks on the variables and changes in the market structure over time.[41] An HD can highlight the temporal changes in the market by observing the cumulative impact of subsequent shocks.[42] It is also derived from a VEC model as follows:

$$\boldsymbol{y_{t+j}} = \sum_{i=0}^{j-1} \boldsymbol{\psi_i}\, \boldsymbol{\varepsilon_{t+j-1}} + [\boldsymbol{X_{t+j}\beta} + \sum_{i=j}^{\infty} \boldsymbol{\psi_i \varepsilon_{t+j-i}}] \tag{4}$$

where $\boldsymbol{y_{t+j}}$ is a multivariate stochastic process; $\boldsymbol{\varepsilon}$ is its multivariate noise process; $\boldsymbol{X}$ is the deterministic part of $\boldsymbol{y_{t+j}}$; and i is the number of periods. The first term on the right-hand side shows the proportion of $\boldsymbol{y_{t+j}}$ triggered by the shock. The following term on the same side indicates the prediction of the price series, originating from information available at time t, which corresponds to the event date. This method needs a large sample of price data to enhance its effectiveness. Accordingly, we use historical records issued during the interwar period to build our own high-frequency dataset of rice prices.

As monthly price data complicate the observation of monthly changes in the market's pricing, since they include only one sample per month, we collect daily price data from two historical documents in Taiwan and Japan. The first is the *Taiwan Beihō* (*Taiwan Rice Report*), issued monthly by the Association for Taiwanese Rice Export Traders from May 1930 to October 1939. The Institute of Taiwan History of Academia Sinica holds a series of reports that supply Taipei's daily forward prices of Taiwanese Hōrai rice from 1 April 1930 to 30 September 1939, excluding Sundays. The second is the *Tokyo Beikoku Shōhin Torihikijo Beikoku Geppō* (*Monthly Report of the Tokyo Rice and Merchandise Exchange*). The Tokyo Rice and Merchandise Exchange issued monthly reports from September 1925 to August 1939 to convey their trading conditions to the control authority and its traders. This series of reports records Tokyo's daily futures and spot prices, except Sundays. The Osaka Municipal University and Ritsumeikan University hold these monthly reports. However, no institutions own the report issued in July 1939. Accordingly, we use the *Tokyo Asahi Shimbun* (*Tokyo Asahi Newspaper*) to fill in the missing data in July 1939.

The records of Taipei's forward prices also have some missing data. The seasonal fluctuations in the distribution of Hōrai rice occasionally caused a severe lack of goods to trade, which hindered Taipei's rice forward market. Therefore, we use the Catmull–Rom spline interpolation technique to interpolate the data breaches following three conditions. First, we interpolate the data breaches, in which case the number of breaches is for three continuous days or less. Second, we abandon the interpolation of breaches that last over 14 consecutive days. Third, we apply the interpolation technique if the cases satisfy the following two conditions: some data breaches last for more than four but fewer than 14 consecutive days and the average daily price change during the data breaches is less than 1 per cent. As a result, we obtain four series of interpolated data: from 1 April 1930 to 30 April 1932, 1 July 1932 to 26 May 1934, 2 July 1934 to 30 May 1935, and 28 June 1935 to 31 July 1939. As our dataset, we select the fourth series, which has 1,214 observations and is the most extensive sample, covering approximately four continuous years in the late 1930s. In contrast to Taipei's forward prices, Tokyo's futures and spot prices experienced no breaches from 28 June 1935 to 31 July 1939 (see Figure A. 4). Although our daily price data cover only four years, they highlight the role of Taiwan's rice market in price formation in the Empire of Japan given that Taiwan's rice supply to Tokyo increased during the 1930s.

To meet the stationarity condition, we convert the original data into two types of samples, the natural log and the first difference of the natural log of each price series. We obtain samples of 1,214 and 1,213 observations and apply the augmented Dickey–Fuller and Phillips–Perron tests to these samples as unit root tests. The unit root tests demonstrate that the first difference of the natural log of all the price series satisfies the stationarity condition (see Table A. 1). Finally, we conduct Johansen's trace test on the natural log of all the price series to confirm the number of cointegration relationships among the samples.[43] Johansen's trace test rejects at least one null hypothesis at the 1 per cent significance level: $r = 0$ (no cointegration relationships) (see Table A. 2). This finding suggests that the number of cointegration relationships is one. Accordingly, we estimate the VEC model using one cointegration relationship.

4. Empirical Results

We derive the optimal lag length for the VEC estimation using the lag exclusion Wald test. The test indicates that the optimal lag length is 10 at the 1 per cent significance level (see Table A. 3). Accordingly, we estimate the VEC model with one cointegration relationship and 10 lags (see Table A. 4). Finally, based on the estimated VEC model, we calculate the HD by using the following Cholesky order: Tokyo's futures prices of Japanese rice, Tokyo's spot prices of Japanese rice, and Taipei's forward prices of Taiwanese Hōrai rice. Figure 3 shows the HD and total stochastic values. The HD value shows the extent to which the causal variable affects the outcome variable, while the total stochastic value is the sum of the HD values in the same row.

The HD values illustrate the price formation structure. Each market essentially determined its own prices. Notably, as shown in the first row of Figure 3, Tokyo's futures market had moderate independence in pricing. Tokyo's spot and Taipei's forward markets had less effect on the pricing of Tokyo's futures market, with Taipei's forward market having the greater relative impact. Therefore, Tokyo's futures market partially determined the price fluctuations in the other two markets (i.e. it provided index prices to Tokyo's spot and Taipei's forward markets).

We next explore the price linkage among these three markets by processing the HD values. However, simply observing the HD values has two limitations. First, the HD value is a relative value to the total stochastic value. This characteristic prevents us from comparing more than two HD values in different rows since the total stochastic values vary among rows. Second, the violent fluctuations in the HD values prohibit us from observing the changes in the relationships among the price formations of multiple markets.

To address these limitations, we tailor the HD value in two steps. The first step is to calculate the monthly average ratio of the HD value (RHDV) to the related total stochastic value, which is equal to the sum of the HD values in the same row. The RHDV indicates the relative contribution of a cause variable to the fluctuation in an outcome variable. It enables us to compare the pricing of more than two markets since the sum must be 100 per cent in the same row. The second step is converting the RHDV to the monthly average RHDV. This procedure smooths the

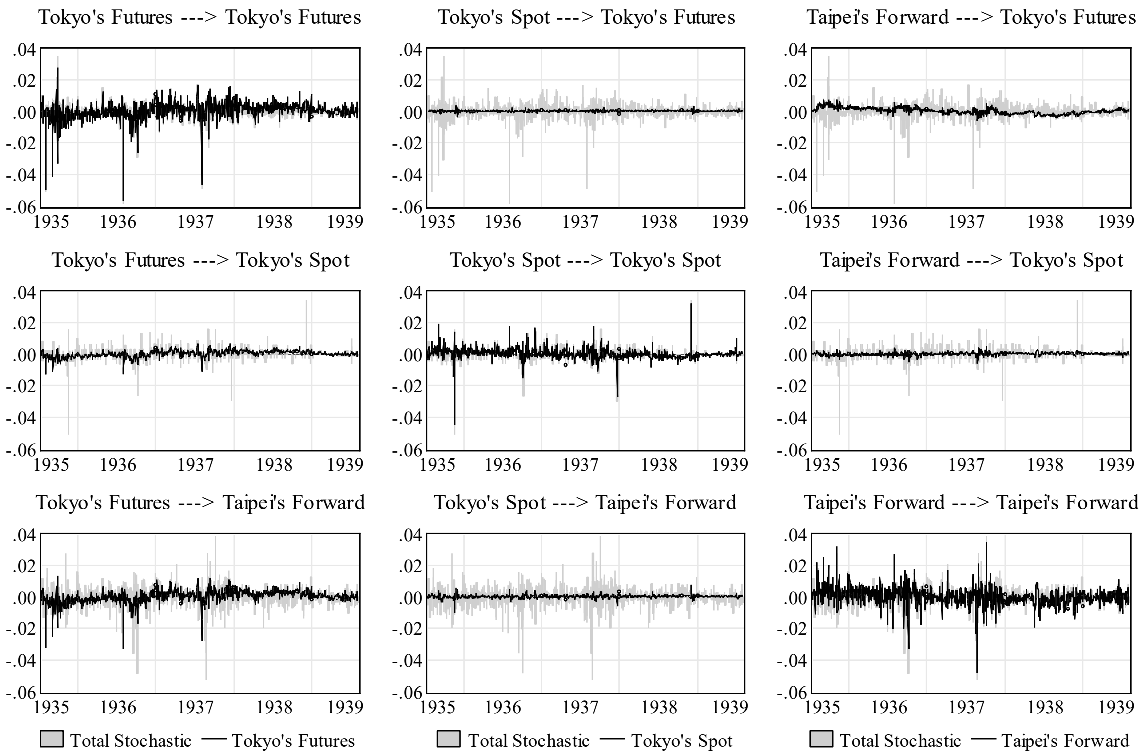


Figure 3. *Historical decomposition of the rice prices in Tokyo and Taipei*

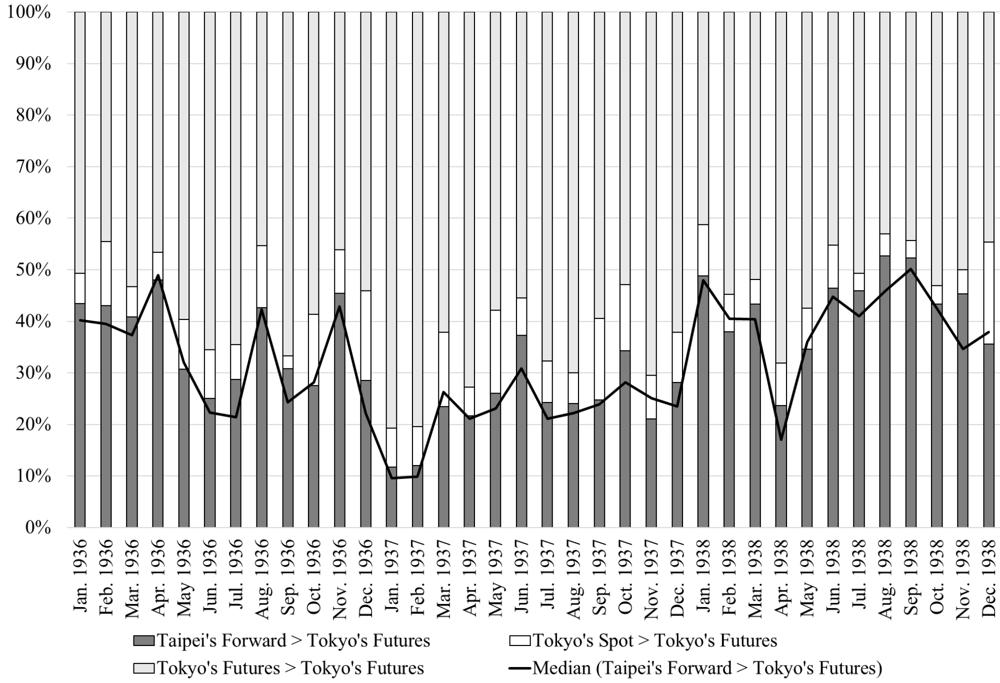
violent fluctuations in the HD value to capture the trend of price changes.

We focus on the monthly average RHDV from January 1936 to December 1938. The HD results are inaccurate at the beginning and end of the sample period due to the burn-in and burn-out effects. Accordingly, we omit the HD values from June to December 1935 and January to July 1939 to augment the accuracy of our analysis. We use these RHDVs to explore the changes in the relationships among the three markets in Tokyo and Taipei.

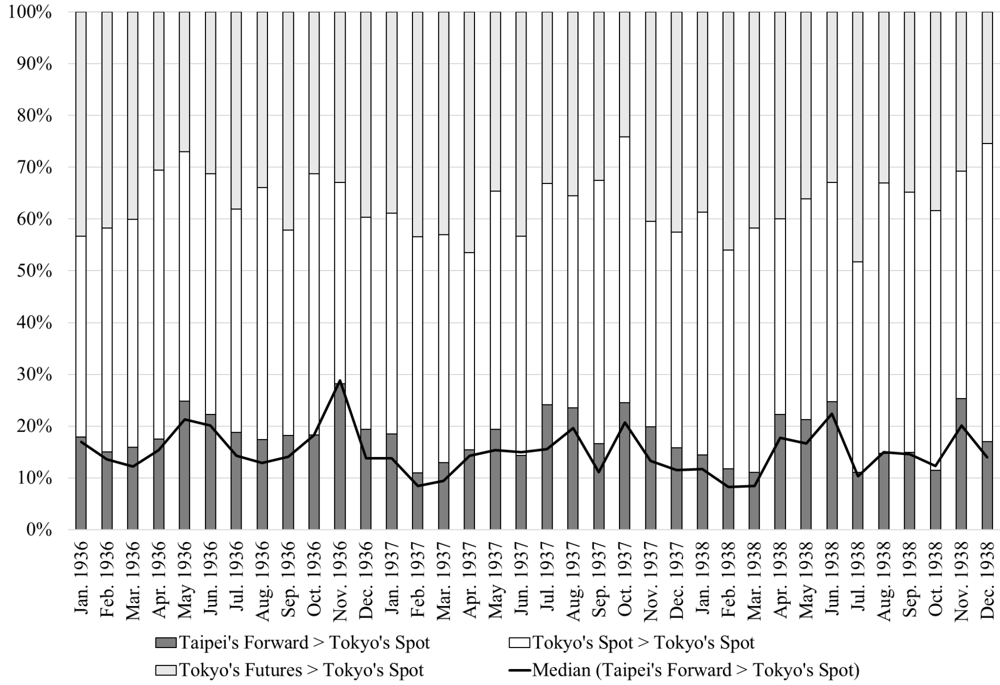
Panels A, B, and C of Figure 4 show the monthly average RHDVs of Tokyo's futures market, Tokyo's spot market, and Taipei's forward market, respectively. Panel A shows that the RHDV of Tokyo's futures market consisted almost entirely of Tokyo's futures and Taipei's forward markets—notably, the former accounted for about 57 per cent of the RHDV on average. Taipei's forward market also had a significant impact on Tokyo's futures market. Its RHDV fluctuated from 11 to 53 per cent; this variation related to the price fluctuations in Tokyo's futures market.

Figure 5 shows the first difference of the natural log of Tokyo's futures prices. The

(A) Tokyo's Futures Market



(B) Tokyo's Spot Market



(C) Taipei's Forward Market

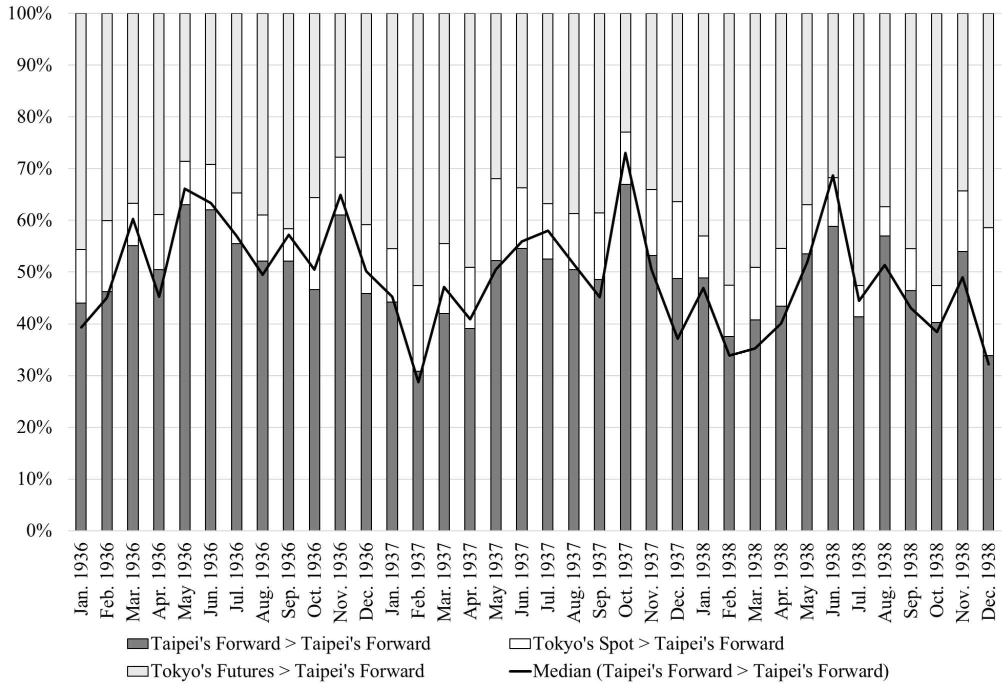


Figure 4. *Monthly average ratios of the historical decomposition value*

Source: Estimated values in Figure 3.

vertical shaded areas denote the periods in which the RHDV of Taipei's forward market was over 40 per cent. During those periods, the first difference of the natural log of Tokyo's futures prices varied from -0.005 to 0.005. This fact means that the influence of the price fluctuations in Taipei's forward market on the pricing in Tokyo's futures market increased when Tokyo's futures prices were relatively stable. On average, the price variations in Taipei's forward market caused about 34 per cent of the price fluctuations in Tokyo's futures market during normal times. By contrast, they had less influence on drastic changes in Tokyo's futures prices. When Tokyo's futures market was volatile, its HD value to and from itself increased (see Figures 3 and 4). Accordingly, the influence of Taipei's forward market declined when Tokyo's futures market faced a volatile situation.

Tokyo's futures market traded only Japanese rice as a standard commodity and physically delivered Japanese and Korean rice.[44] It never dealt with Taiwanese rice, even in the 1930s.

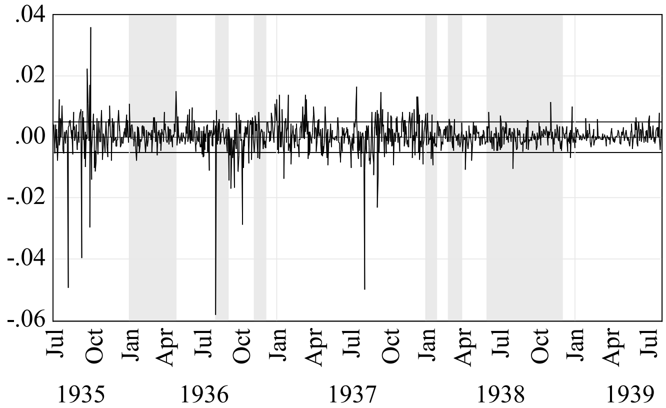


Figure 5. *The first difference of the natural log of Tokyo's futures prices*

Notes: The vertical shaded areas indicate the periods in which the RHDV of Taipei's forward market in Tokyo's futures market was over 40 per cent, from January 1936 to December 1938. The three horizontal lines are 0.005, 0, and -0.005, respectively.

Sources: Tokyo Rice and Merchandise Exchange, *Tokyo Beikoku*; 'Shōkyō [Market trend] in *Tokyo Asahi Shimbun* [*Tokyo Asahi Newspaper*], 2 July–1 August 1939.

Nevertheless, Taipei's forward market had a significant influence on Tokyo's futures prices. Although it had no power to change Tokyo's futures prices drastically, it continuously affected those prices, as Tokyo's futures market considered the fluctuations in Taipei's rice prices and served as the index prices for Tokyo's spot market.

Panel B of Figure 4 illustrates that the price fluctuations in Tokyo's futures and spot markets chiefly affected Tokyo's spot prices. The two markets in Tokyo accounted for about the same ratio and Tokyo's spot prices were less independent than Tokyo's futures prices. Taipei's forward market also accounted for about 18 per cent of the RHDV of Tokyo's spot market. That is, its influence on Tokyo's spot market was about half that of Tokyo's futures market. However, as shown in Panel A, Taipei's forward market had a significant impact on Tokyo's futures market, which was a key cause of the price fluctuations in Tokyo's spot market. Therefore, it had both a direct and an indirect influence on Tokyo's spot market. The pricing in Taipei's forward market played a vital role in determining the price fluctuations in Tokyo. Its impact on Tokyo's spot market varied by season. The RHDV of Taipei's forward market increased twice a year (i.e. from May to July and from October to November) owing to the harvest cycle of Taiwanese Hōrai rice that determined Taipei's forward prices.

Panel C of Figure 4 shows that the RHDV of Taipei's forward market consisted primarily of Taipei's forward and Tokyo's futures markets. These markets accounted for an average of 49 and 40 per cent of the RHDV of Taipei's forward market, respectively. Accordingly, Taipei's forward prices were more independent than Tokyo's spot prices. It fulfilled its price formation function by referencing the price fluctuations in Tokyo's futures market. This fact indicates that Taipei's forward market was not just a subordinate market to Japan. Its RHDV varied by season, increasing from May to July and from October to November. The average RHDVs of Taipei's forward market are 55 and 54 per cent during the former and latter months, respectively, while those in the other months are 46 per cent. The seasonal fluctuation of the RHDV of Taipei's forward market resulted from the seasonality of the rice harvest in Taiwan.

Southern Taiwan, located in the tropical zone, reaps rice a month earlier than northern Taiwan, which is in the subtropical zone. During the first and second harvest seasons, southern Taiwan begins to crop rice from the middle of May to the end of July and from the beginning of September to the middle of December, respectively. Northern Taiwan is ready to harvest rice from mid-June to the start of August and from mid-October to the end of November.[45] Therefore, Taiwan's rice harvest seasons are from June to July and from October to November at their peaks.

We see that during the two harvest seasons in Taiwan, Taipei's forward market set Taiwanese Hōrai rice prices with reference to the harvest conditions in Taiwan. Furthermore, the influence of Taipei's forward market on Tokyo's spot prices increased in both seasons, as shown in Panel B of Figure 4. Consequently, the trend of Tokyo's spot prices boosted its dependency on the price fluctuations in Taipei during the two harvest seasons in Taiwan.

5. Impact of Taiwanese Rice Imports on Tokyo

While we showed above that the changes in Taipei's rice prices affected Tokyo's rice market during the 1930s, we next examine how the fluctuations in Taiwan's rice prices influenced the price formation of Tokyo's rice market. If Taipei's rice market was supportive, it intensified the fluctuations in Tokyo's rice prices. Conversely, if it had an adverse effect, it stabilized the price changes in Tokyo. We use the HD values in Figure 3 to calculate the two ratios of the HD value from Taipei to Tokyo as well as the sum of the two HD values to and from Tokyo's futures and spot markets, respectively.

The first ratio shows the effect of Taipei's forward market on Tokyo's futures market. Its numerator is the HD value from Taipei's forward market to Tokyo's futures market and its denominator is the sum of the HD values to and from Tokyo's futures market and the HD value from Tokyo's spot market to Tokyo's futures market. The second ratio indicates the effect of Taipei's forward market on Tokyo's spot market. Its numerator is the HD value from Taipei's forward market to Tokyo's spot market and its denominator equals the sum of the two HD values: from Tokyo's futures market to Tokyo's spot market and to and from Tokyo's spot market. These two ratios derive from the HD values based on the daily price data and have some outliers, which prevent us from detecting the trend of the ratios. Accordingly, we examine two representative values of the ratios, namely, the median and trimmed mean, which removes the lowest and highest 10 per cent of the values. If these ratios are positive values, Taipei's rice market intensified the fluctuations in Tokyo's rice prices. By contrast, if these ratios are negative values, Taipei's rice market suppressed the fluctuations in Tokyo's rice prices.

The bar and line charts in Figure 6 show the medians and trimmed means of the two ratios, respectively. Most of the values are negative, suggesting that Taipei's forward market suppressed the fluctuations in the rice prices in Tokyo's futures and spot markets. As discussed in the previous section, the effect of Taipei's forward market on Tokyo's rice market resulted from the seasonal cycle of the rice harvest in Taiwan. Hence, to understand the changes in the seasonal price fluctuations in Tokyo, we carry out the seasonal-trend decomposition procedure based on local

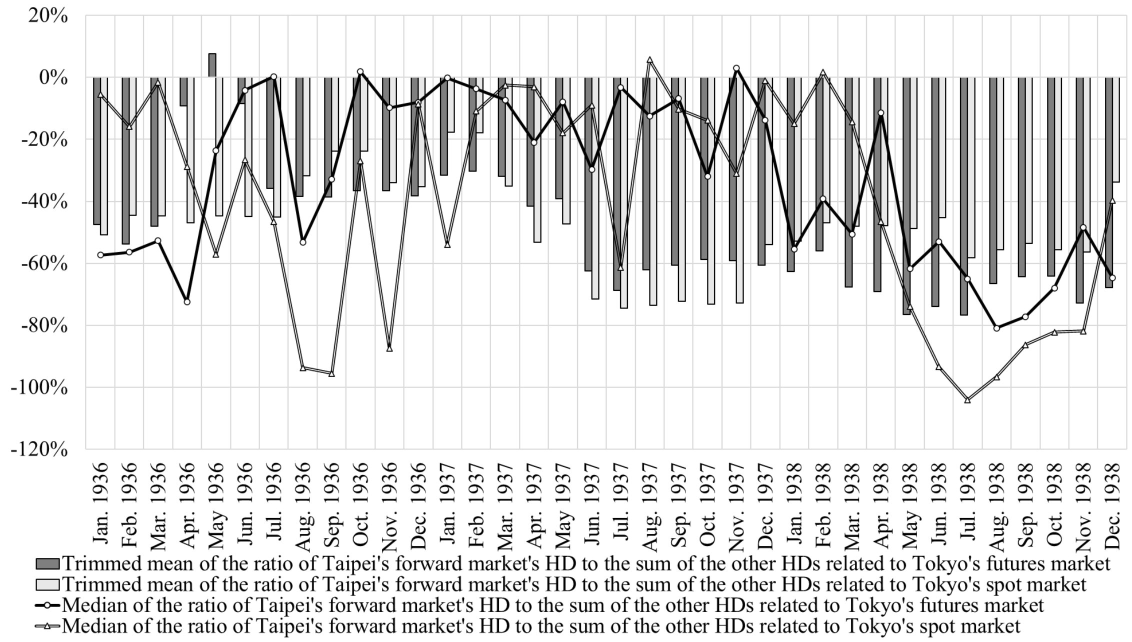


Figure 6. *Monthly medians and trimmed means of the ratio of Taipei's forward market's HD to the sum of the other HDs related to Tokyo's futures and spot markets*

Note: The monthly trimmed means are removed from the lowest and highest 10 per cent of daily values.

Source: Estimated values in Figure 3.

regression (STL) on Tokyo's monthly wholesale rice prices from January 1920 to December 1938. Cleveland and colleagues developed the STL to detect seasonal fluctuations in price data.[46] The STL divides the price series into three components: trend, seasonal, and remainder. Its basic formula is as follows:

$$\boldsymbol{Y_v} = \boldsymbol{T_v} + \boldsymbol{S_v} + \boldsymbol{R_v} \tag{5}$$

where $\boldsymbol{Y_v}$ represents the price series. $\boldsymbol{T_v}$, $\boldsymbol{S_v}$, and $\boldsymbol{R_v}$ mean the trend, seasonal, and remainder components, respectively. The STL has three procedures: the inner loop, outer loop, and local regression (LOESS) estimation. While these require the number of periods per cycle as a periodicity $n_{(p)}$, which serves a significant role in the estimation process, accurately detecting the periodicity of our daily data is impossible since the number of observations per year fluctuates.

Our daily dataset on rice prices has 294, 298, and 297 observations per year for 1936, 1937, and 1938, respectively. The differences in the number of observations results from the overlap between Sundays and national holidays.[47] The markets suspend operations on Sundays and national holidays; an overlap between them thus reduces the number of business closure days. Alternatively, we use the monthly real rice prices in Tokyo's spot market from January 1920 to December 1938. The Annual Reports of the Tokyo Chamber of Commerce and Industry record the monthly nominal rice prices in Tokyo.[48] The Research and Statistics Department of the Bank of Japan published the monthly Prewar Base Overall Wholesale Price Index based on the 1934–36 average.[49] We calculate Tokyo's monthly real rice prices by adjusting the nominal prices using wholesale price indexes. This monthly data enable us to compare the price fluctuations before and after the increase in the distribution of rice exported from Taiwan to Tokyo by extending our scope to the entire interwar period. We set $n_{(p)}$ to 12 since the number of observations per year is 12.

The inner and outer loops estimate the provisional values of the trend, seasonal, and remainder components. The former procedure detects the trend and seasonal components, and the latter calculates the remainder. Finally, the LOESS estimation calculates the smoothed values of the three components. This procedure requires three parameters: the smoothing parameter of the low-pass filter $n_{(l)}$, seasonal smoothing parameter $n_{(s)}$, and trend smoothing parameter $n_{(t)}$. Each parameter should be an odd number and $n_{(l)}$ is an odd value larger than $n_{(p)}$. Therefore, we select 13 as an optimal $n_{(l)}$. By contrast, the setting of $n_{(s)}$ has to be arbitrary, despite Carlin and Dempster's argument that $n_{(s)}$ heavily influences the result of seasonal decomposition.[50] Cleveland and colleagues recommend using a diagnostic method to select an optimal $n_{(s)}$. Accordingly, we draw the seasonal diagnostic display and confirm that $n_{(s)} = 17$ almost smoothens the seasonal lines (see Figure A. 5). In the final step, the optimal $n_{(t)}$ is derived from Equation 6 as follows:

$$n_{(t)} \geq \frac{1.5n_{(p)}}{1-1.5n_{(s)}^{-1}} \tag{6}$$

Equation 6 calculates that $n_{(t)}$ is roughly 19.74. $n_{(t)}$ should be an odd number larger than the calculation result, and we choose 21 as an optimal $n_{(t)}$. By using these parameters, we implement the LOESS estimation procedure to determine $\boldsymbol{T_v}$, $\boldsymbol{S_v}$, and $\boldsymbol{R_v}$. Figure 7 demonstrates the STL results, showing the three elements of the real rice prices in Tokyo's spot market.

Panel A of Figure 7 illustrates the monthly real prices in Tokyo's rice spot market and Panels B, C, and D show the trend, seasonal, and remainder components, respectively. The trend component in Panel B indicates that Tokyo's spot prices were stable during the 1930s, when Tokyo increased rice imports from Taiwan (see Figures 1 and 2). By contrast, Taiwan's rice exports altered the seasonal fluctuations in Tokyo's rice prices from the end of the 1920s.

Panel C shows that the size of seasonal components gradually decreased during the second half of the 1920s, when Taiwan and Korea expanded their rice exports to Japan (see Figure A. 3). These colonies exported rice before and after the Japanese harvest season to maximize their profits, as mentioned in Section 2. The colonial rice trade suppressed the seasonal price fluctuations in Tokyo. Furthermore, these seasonal price fluctuations changed drastically in two key aspects during the 1930s, when the trade in Taiwan's rice flourished in Tokyo.

First, the size of the seasonal components decreased to less than half that of the previous decade. While the gap between the minimum and maximum seasonal components during the first half of the 1920s was 3.5 yen, it more than halved to 1.6 yen during the 1930s. The maximum rice prices before the Japanese harvest season decreased by 0.9 yen from the 1920s to the 1930s, equivalent to approximately 3 per cent of the average real rice price, which was 26 yen. By contrast, during these two decades, the minimum rice prices in the Japanese harvest season increased by 0.8 yen, comparable to about 3 per cent of the average real rice price. Therefore, the shrinkage in seasonal price fluctuations, resulting from the rising distribution of colonial rice, stabilized the fluctuations in rice prices in Japan.

Second, the wave shape of seasonal components changed. The seasonal components

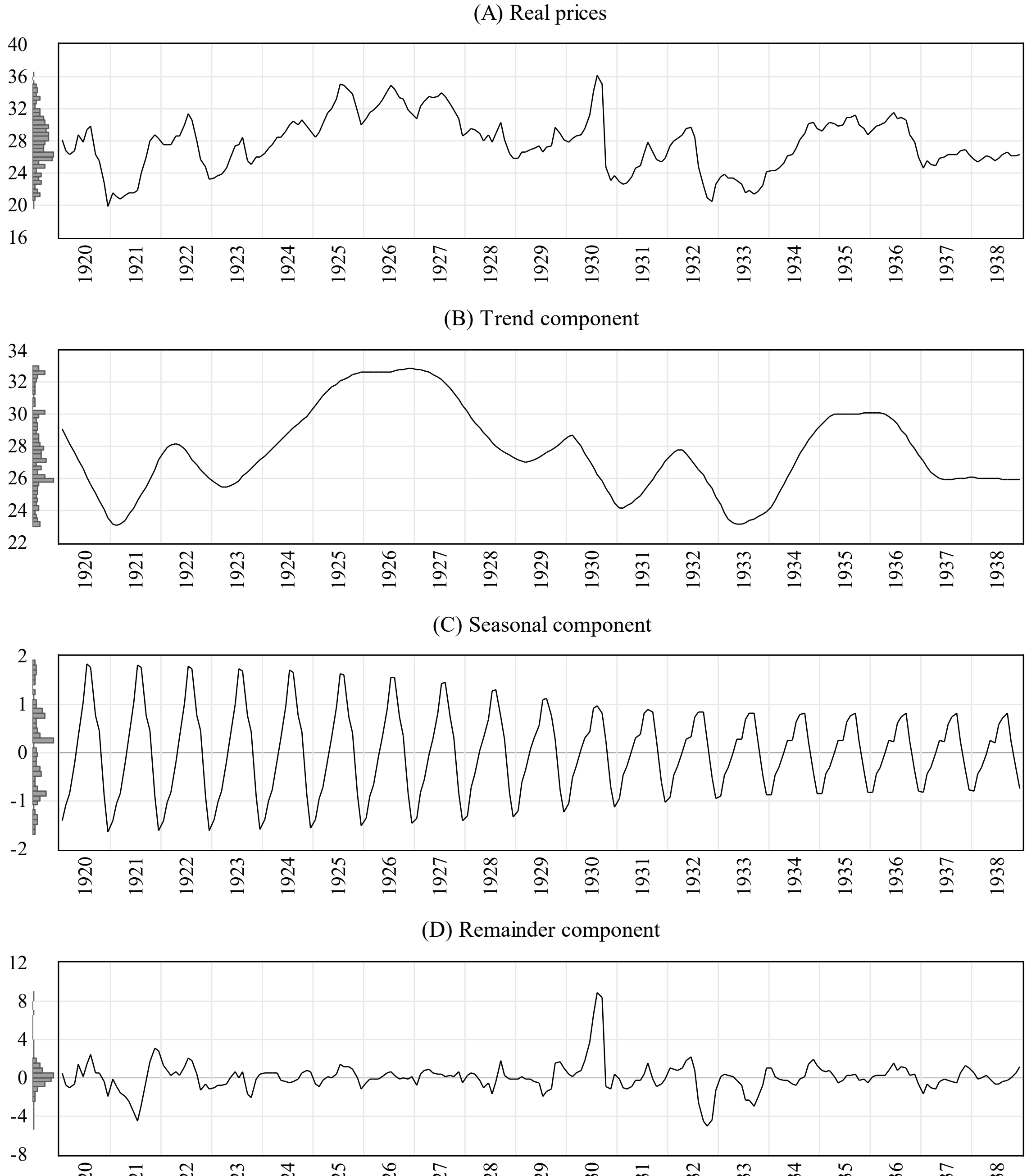


Figure 7. *STL results of Tokyo's real rice spot prices, January 1920–December 1938*

Sources: Tokyo Chamber of Commerce, *Tokyo Shōgyō*, annual series (1921–27); Tokyo Chamber of Commerce and Industry, *Tokyo Shōkō Kaigisho Tōkei*, annual series (1928–39); Bank of Japan, Research and Statistics Department, *Meiji ikō*, pp. 24–5.

soared twice a year during the 1930s, whereas they rose only once a year in the previous decade. During the 1930s, rice prices in Tokyo decreased from the Japanese harvest season and hit their lowest point in December. They began to increase in January but stopped rising from May to June. Rice prices continued to rise in July, peaking in September. From May to June, the price fluctuations in Taiwan prevented Tokyo's rice prices from increasing.

The GGT investigated the monthly prices of Hōrai rice in two Taiwanese cities, Taichung and Keelung. These cities are about 130 and 20 kilometres (81 and 12 miles) from Taipei, respectively. Taichung is a rice distribution centre adjacent to the rice production areas. Keelung is the largest port in Taiwan for exports. During the colonial period, it was the most prosperous port connecting with Japan. Hence, the rice prices in Taichung and Keelung were equivalent to the original and export prices, respectively. Accordingly, we again apply the STL technique to two available price data series—the monthly nominal spot prices in Taichung and Keelung from 1927 to 1938 and from 1925 to 1938, respectively—to observe the seasonal price fluctuations in these cities.

The first step is converting these two nominal price series into real prices. Although Mizoguchi and Wu estimate the annual wholesale price indexes in Taiwan during the colonial period, there are no monthly indexes in Taiwan.[51] Alternatively, we use the monthly Prewar Base Overall Wholesale Price Index based on the 1934–36 average, estimated by the Bank of Japan.[52] The second step is setting the parameters of the STL. We set $n_{(p)}$ and $n_{(l)}$ to 12 and 13, respectively, in the same manner as in the previous subsection. The following procedure is choosing the optimal $n_{(s)}$ by using the diagnostic method. The diagnostic displays indicate $n_{(s)} = 25$ (see Figures A. 6 and A. 7). We assign the optimal $n_{(s)}$ to Equation 6 and obtain $n_{(t)} = 21$. Figures 8 and 9 show the STL results of the real rice spot prices in Taichung and Keelung, respectively.

Panel C of Figure 8 shows that the rice prices in Taichung differed from those in Tokyo in two ways (see Panel C of Figure 7). First, the seasonal component of the prices remained—even in the 1930s. Second, they increased twice every year. Specifically, they declined from June, marking the beginning of the first harvest season in Taiwan, and hit bottom in October. They began

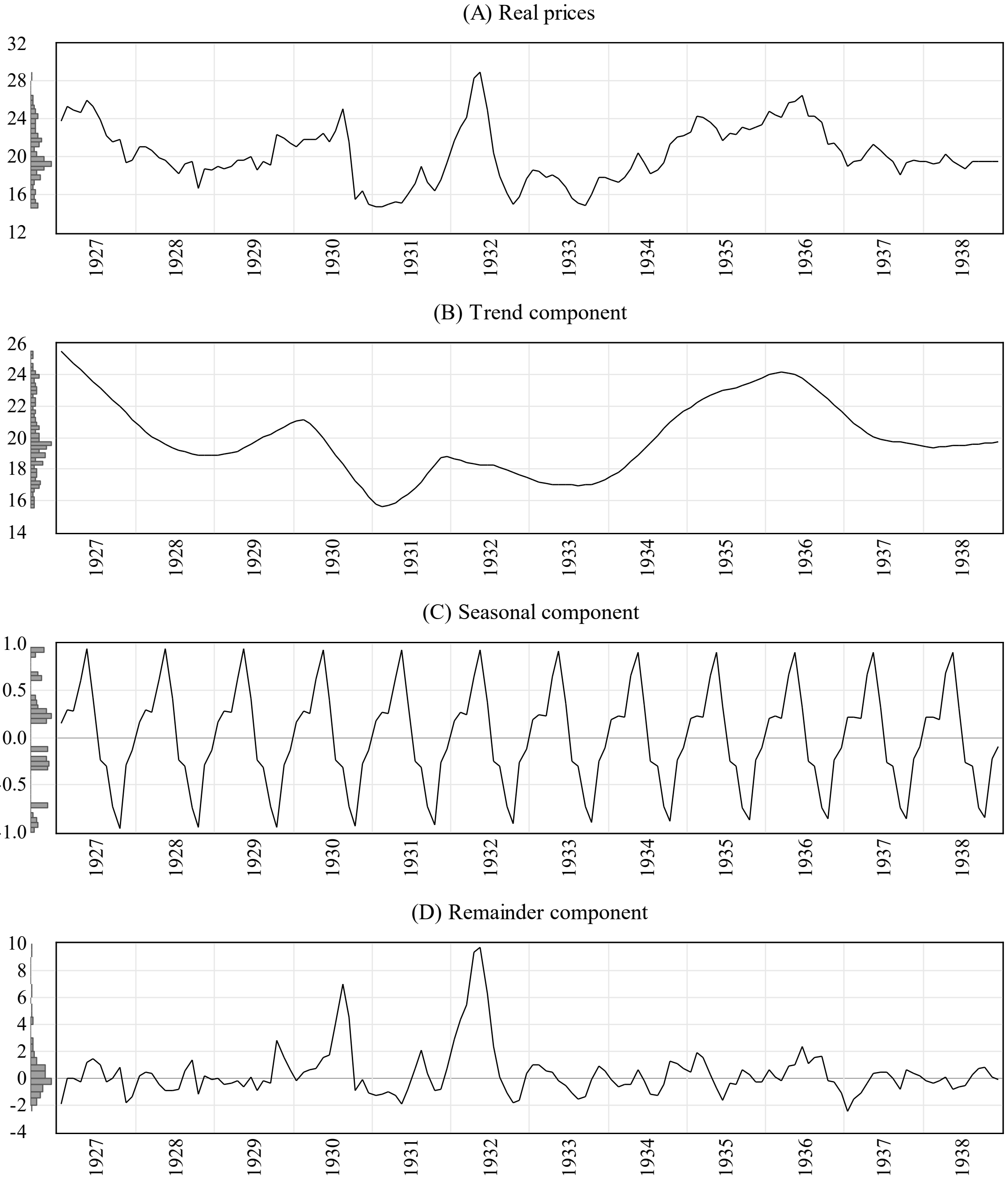


Figure 8. *STL results of the real rice spot prices in Taichung, January 1927–December 1938*

Sources: Bank of Japan, Research and Statistics Department, *Meiji ikō*, pp. 24–5; Governor-General of Taiwan, Rice Bureau, *Showa*, pp. 104–5.

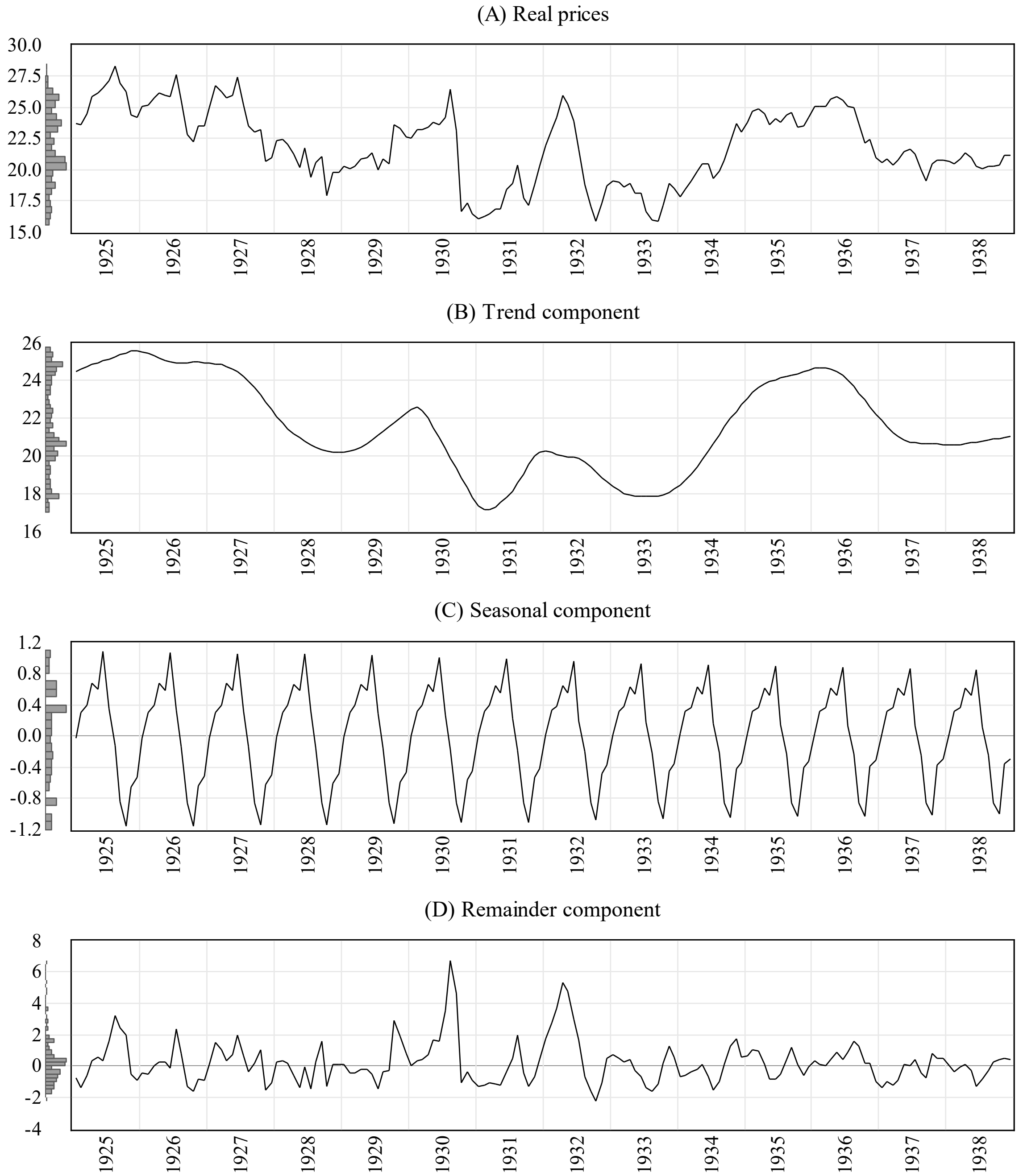


Figure 9. *STL results of the real rice spot prices in Keelung, January 1925–December 1938*

Sources: Bank of Japan, Research and Statistics Department, *Meiji ikō*, pp. 24–5; Governor-General of Taiwan, Rice Bureau, *Showa*, pp. 98–9.

to soar in November, following the end of the second harvest season in Taiwan. However, the rate of price increase gradually diminished in December and prices remained unchanged from February to March. Finally, prices resumed their increase from April to May. These price changes, which resulted from rice brokers' behaviour in Taiwan after the second harvest season, were more complex than the seasonal price fluctuations in Tokyo until the 1920s.

In Taiwan, farmers deposited their unhulled rice with rice brokers, who possessed hulling machines. They closely monitored the price trends and ordered the rice brokers to hull and sell the rice when prices increased.[53] This behaviour reduced the rate of increases in rice prices after the second harvest season, according to the GGT's statistics on the stocked rice volume.

From November 1936, the GGT inspected the volume of Hōrai rice stocked in Taiwan's warehouses six times per year: March, May, July, August, September, and November (see Figure A. 8). According to the GGT's statistics from November 1936 to November 1939, Taiwan's stock volume of Hōrai rice bottomed out in May and November every year. It increased twice after the first and second harvest seasons. After the second harvest season began, Taiwan exported Hōrai rice to Japan but held twice the stock volume in March as it did in May. This was because Taiwanese farmers gradually sold their products after the second harvest season, which coincided closely with the Japanese harvest season. These scrupulous behaviours suppressed the rate of increase in the rice prices in Taichung after the end of the second harvest season. By contrast, after the first harvest season, Taiwanese farmers immediately sold rice to Japan and the prices in Taichung rapidly decreased.

Seasonal price fluctuations also existed in Keelung's prices. Panel C of Figure 9 indicates that the prices in Keelung increased twice a year, similar to those in Taichung. The rice prices in Keelung declined from July, a month after those in Taichung, and reached their lowest point in October. They began to rise in the following month and their rate of increase gradually fell from December. Finally, the prices in Keelung stopped rising from April to May, before increasing again and peaking in June. The seasonal components of Taichung and Keelung exhibited similar wave shapes in the STL results, with the latter trailing the former by a few months. Taichung, located adjacent to the rice production areas, experienced seasonal fluctuations that reflected the two harvest seasons. The seasonal fluctuations in production areas spread to Keelung, an export port, and influenced the prices in Tokyo. Hence, Tokyo's prices fluctuated one month behind those in Keelung during the 1930s, when it relied heavily on Taiwan's rice supply. Consequently, after 1931, Tokyo's rice prices stopped growing from May to June (see Figure 7).

The growth in rice imports from Taiwan after the first harvest season suppressed the increase in Tokyo's rice prices before the Japanese harvest season. The first harvest season in Taiwan was over three months earlier than those in Japan and Korea and the distribution of Taiwanese rice in Tokyo flourished before the Japanese harvest season. By contrast, Taiwan gradually exported rice to Japan after its second harvest season, which coincided closely with the Japanese and Korean harvest seasons. As a result, the growth in the distribution of Taiwanese rice changed the seasonal fluctuations in Tokyo's rice prices.

6. Conclusions

This study examines the economic ties between metropoles and their colonies within empires after the Great Depression, focusing on the price linkage among Japan and its colonial suppliers of rice and adopting two analyses. Both these analyses employ different econometric methods, specifically the HD and STL, as well as use distinct data: the first difference of the natural log of daily prices and real monthly prices. The fact that they lead to the same results ensures the robustness of our findings.

During the 1930s, Japan's reliance on Taiwan's rice supply increased and any fluctuations in Taipei's forward prices thus changed Tokyo's rice prices. One main source of such price fluctuations was seasonality. During every rice harvest season in Taiwan, Taipei's rice prices gained independence from Tokyo's rice prices, reflecting the fact that Taiwanese farmers cropped rice twice a year and that the first harvest season in Taiwan was about three months before the Japanese harvest season. Accordingly, seasonal decreases in Taipei's rice prices dragged Tokyo's rice prices down just before the Japanese harvest season. That is, Taipei's rice market suppressed the seasonal fluctuations in Tokyo's rice prices. Expanding the capacity of Taiwan's rice supply to Japan enhanced the Taiwanese market's autonomy, allowing it to independently set prices from the central market in the rest of the Empire of Japan. Finally, the colonial market's prices partially served as an index for the metropole's market.

Even after Japan transformed into an industrialized region, its colonies remained agricultural regions. While the primary industry accounted for 16 per cent of the net product in Japan, the proportion in Taiwan reached 39 per cent.[54] The metropole's reliance on the supply of primary products from colonies thus deepened during its industrialization process and any changes in the prices of primary products in the colonies had repercussions on Japan. Hence, the rising role of price formation in the colonial markets complicated the price changes across the empire during the 1930s.

However, the colonial markets had two limitations compared with the metropole's market. First, they periodically failed to set prices because their trading volume was significantly less than that of the metropole's market. Second, even when the markets successfully set their prices, the price formation function of the colonial markets fluctuated seasonally. For example, while the colonial markets independently set their own prices during their harvest seasons, they closely reflected Tokyo's price changes at other times. Nonetheless, although the colonial markets failed to perform the same precise function as the metropole's market, they partially provided index prices within the empire.

Similar to the Western Great Powers, Japan used its colonies as suppliers of primary products and achieved industrialization until the Second World War. The Japanese government implemented individual policies in each of its territories to grow the agriculture sector, leading each colony's capacity for agricultural production to alter the price linkage between it and the metropole. Accordingly, while the home government maintained its empire's doctrine, forcing the colonies to remain agricultural regions, it attempted to directly intervene in the colonies' commodity trade to control the prices of primary products. Specifically, after the Great Depression, which caused the prices of primary products to plummet, Japan urgently needed to control commodity prices, as the price changes in the colonial market suppressed the surge in the metropole's prices before the harvest season. This circumstance frustrated Japanese farmers and triggered changes in the Japanese government's agricultural policies for its colonies given the ongoing development of closer economic ties within the empire. Put simply, the economic ties within the empire metamorphosed into a mutual economic relationship, albeit partially. This transformation induced alienation between the governing and economic relationships within the empire. In response, various economic entities demanded superior positions in the metropole's market and pressed the home government to implement political measures. Consequently, the metropole and colonies experienced economic and political conflicts, especially after the Great Depression.

This study has its limitations, as it mainly examines Taiwan as the focal Japanese colony. Accordingly, further research is necessary to broaden its scope to the other Japanese territories such as Korea and Manchuria. This research could also aim to analyse how the home and colonial governments responded after their alienation emerged, since this study only explores the economic aspect. Furthermore, future studies could investigate other empires because the Western Great Powers had different harvest seasons for agricultural products between their metropoles in Europe and colonies in Asia and Africa. This research would enable us to better understand the economic and political ties within all empires during the 1930s.

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[1] Davis and Huttenback, *Mammon*, pp. 1–2.

[2] O'Rourke, 'The European'.

[3] Federico, 'How'; Fama, 'Efficient'.

[4] Aldrich and Stucki, *The colonial*, pp. 69–73.

[5] Pedersen et al., 'Globalization'.

[6] Hynes et al., 'Commodity'.

[7] Panza, 'From'. Li et al. investigate the market linkage between Europe and the Ottoman Empire from the mid-fifteenth century to the early twentieth century.

[8] Cooper and Stoler, *Tensions*, pp. 6–7.

[9] Aldrich and Stucki, *The colonial*, pp. 67–8.

[10] Okubo, ‘Trade’.

[11] The Great Powers and Japan built transportation and telecommunications infrastructure in their colonies before the First World War. Andrabi and Kuehlwein, *Railways*, focusing on British India before the First World War, emphasize that the railroad expansion accelerated the market integration within colonies.

[12] Persson and Sharp, *An economic*, pp. 182–5.

[13] Havinden and Meredith, *Colonialism*, p. 20.

[14] Suh, *Growth*, pp. 122–6.

[15] Myers, ‘Creating’, p. 136; Myers and Yamada, ‘Agricultural’, p. 437.

[16] Totman, *A history*, pp. 402–5.

[17] Bank of Taiwan, Investigation Department, *Taiwan*, pp. 11–12.

[18] Findlay and O’Rourke, *Power*, pp. 461–5.

[19] Hogan, *What*, pp. 74–6.

[20] Yagashiro, *Teikoku*, p. 227–33.

[21] Maeda, *Shio*, pp. 10–11.

[22] Lee and Chen, ‘Agricultural’ provide further information on agricultural production during the interwar period in Taiwan.

[23] Schaede, ‘Forwards’.

[24] Ito et al., ‘Market’; Ito et al., ‘The futures’.

[25] Hsiao, ‘The rise’, p. 210.

[26] Li, *The history*, p. 102.

[27] Ito et al., ‘Market’, p. 332.

[28] Taichung Agricultural Experiment Station, *Taichū*, p. 1.

[29] Governor-General of Taiwan, Industrial Bureau, Agricultural Division, *Taiwan ni okeru Nōka*,

pp. 1–4.

[30] Yamazaki, *Beikai*, p. 131.

[31] The '*koku*' is the Japanese standard unit of measurement in agriculture. One *koku* equals 180.39 litres (39.68 British gallons) and is roughly equivalent to 150 kilograms (331 pounds).

[32] Governor-General of Taiwan, Rice Bureau, *Showa 10-nen*, p. 12.

[33] Governor-General of Taiwan, Rice Bureau, *Showa 16-nen*, pp. 70–73.

[34] Tokyo Rice and Merchandise Exchange, *Taiwan*, p. 154.

[35] Hishimoto, *Chōsen*, pp. 214–5, 533–5.

[36] Tokyo Grain Exchange, *Tokyo*, pp. 30–53.

[37] Ito et al., 'Market', p. 920.

[38] Governor-General of Taiwan, Department of Civil Administration, Industry Division, *Torihikijo*, p. 100.

[39] The description in this paragraph relies on 'Taiwan Shōmai Shijō Kaisetsu no Dōki to sono Shimei [Motivations and Purposes of the Taiwan Rice Market]' in *Jitsugyō Jidai* [*Era of Business*], volume 7, number 1, January 1930, pp. 116–7.

[40] Association for Taiwanese Rice Export Traders, *Taiwan*, pp. 10–11; Tokyo Stock Exchange, Investigation Department, *Tokyo*.

[41] Balcilar et al., 'The renewable'.

[42] Kilan and Helmut, *Structural*, p. 116.

[43] Johansen, 'Estimation'.

[44] Ito et al., 'Market', p. 341–2.

[45] Governor-General of Taiwan, Industrial Bureau, Agricultural Division, *Taiwan ni okeru Nōka*, pp. 1–4.

[46] For more detailed information on the estimation method of the STL, please see Cleveland et al., 'STL'.

[47] In 1973, the Japanese government began to set a substitute holiday on the following Monday if

a national holiday overlapped a Sunday.

[48] The Japanese government enforced the Law of the Chamber of Commerce and Industry in January 1928 and the Tokyo Chamber of Commerce rechristened itself the Tokyo Chamber of Commerce and Industry in the same month (Tokyo Chamber of Commerce and Industry, *Tokyo Shōkō Kaigisho Hyaku-nen*', p. 119).

[49] Bank of Japan, Research and Statistics Department, *Meiji ikō*, pp. 24–5.

[50] Carlin and Dempster, 'Sensitivity', p. 6.

[51] Mizoguchi, *Taiwan*; Wu, 'Taiwan's'; Mizoguchi, *Ajia*.

[52] Bank of Japan, Research and Statistics Department, *Meiji ikō*, pp. 24–5.

[53] Tokyo Rice and Merchandise Exchange, *Taiwan*, p. 146.

[54] Mizoguchi and Umemura, *Kyū-Nihon*, pp. 228, 232.

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Appendices

Table A. 1. *Descriptive statistics and unit root test results*

	Tokyo's futures prices of Japanese rice		Tokyo's spot prices of Japanese rice		Taipei's forward prices of Taiwanese Hōrai rice	
	Log	Diff. Log	Log	Diff. Log	Log	Diff. Log
Descriptive statistics						
Mean	3.511	0.000	3.483	0.000	3.272	0.000
Median	3.525	0.000	3.487	0.000	3.275	0.000
Maximum	3.670	0.036	3.605	0.034	3.460	0.039
Minimum	3.355	-0.058	3.357	-0.050	3.102	-0.053
Std. Dev.	0.074	0.005	0.063	0.004	0.073	0.006
N	1,214	1,213	1,214	1,213	1,214	1,213
Unit root test results						
ADF	-2.225	-32.70***	-3.044	-20.24***	-2.903	-29.44***
Lags	0	0	2	1	1	0
PP	-2.325	-32.67***	-2.904	-30.16***	-2.872	-29.43***
Bandwidth	2	4	10	7	6	2

Notes: 'Log' and 'Diff. Log' denote the natural log and first difference of the natural log of the data series, respectively. 'Std. Dev.', '*N*', 'ADF', 'Lags', 'PP', and 'Bandwidth' indicate the standard deviation, number of observations, augmented Dickey–Fuller test statistics with a time trend and a constant, lag order selected by the Schwartz information criterion, Phillips–Perron test statistics, and Newey–West bandwidth by using the Bartlett kernel, respectively. "***" means significant at the 1 per cent level.

Table A. 2. *Johansen's trace test results*

	Eigenvalue	Trace statistics	Critical value
None	0.0223	45.597	41.081
At most 1	0.0099	18.375	23.152
At most 2	0.0052	6.3172	6.6349

Note: 'Critical value' indicates the critical value at the 1 per cent level.

Table A. 3. *Chi-squared test statistics of the lag exclusion Wald test*

	Tokyo's futures prices of Japanese rice	Tokyo's spot prices of Japanese rice	Taipei's forward prices of Taiwanese Hōrai rice	Combined
Lag 1	480.50 (0.000)	856.39 (0.000)	491.50 (0.000)	1776.5 (0.000)
Lag 2	317.53 (0.000)	321.31 (0.000)	275.90 (0.000)	820.58 (0.000)
Lag 3	170.80 (0.000)	219.58 (0.000)	149.84 (0.000)	504.78 (0.000)
Lag 4	178.03 (0.000)	121.75 (0.000)	139.33 (0.000)	369.30 (0.000)
Lag 5	102.56 (0.000)	76.100 (0.000)	89.546 (0.000)	218.80 (0.000)
Lag 6	96.682 (0.000)	58.003 (0.000)	62.213 (0.000)	172.64 (0.000)
Lag 7	57.604 (0.000)	55.653 (0.000)	50.376 (0.000)	122.42 (0.000)
Lag 8	49.607 (0.000)	48.998 (0.000)	28.125 (0.000)	96.063 (0.000)
Lag 9	14.700 (0.002)	32.346 (0.000)	17.076 (0.001)	52.064 (0.000)
Lag 10	7.6180 (0.055)	15.622 (0.001)	8.9843 (0.030)	27.574 (0.001)
Lag 11	5.6372 (0.131)	8.2104 (0.042)	12.402 (0.006)	19.021 (0.025)

Note: Numbers in parentheses are *p*-values.

Table A. 4. *Results of the VEC estimation*

	Cointegration equation		
	Equation 1		
$y_{1,t-1}$	1.0000		
$y_{2,t-1}$	-0.0409 [0.1186]		
$y_{3,t-1}$	-0.9479 [0.0731]		
Constant	0.0002		
	Error correction		
	$\Delta y_{1,t}$	$\Delta y_{2,t}$	$\Delta y_{3,t}$
Cointegration Equation 1	-0.3761 [0.0890]	0.1655 [0.0595]	0.8447 [0.1072]
$\Delta y_{1,t-1}$	-0.5711 [0.0864]	-0.0463 [0.0577]	-0.7376 [0.1041]
$\Delta y_{1,t-2}$	-0.5540 [0.0836]	-0.0509 [0.0559]	-0.6982 [0.1007]
$\Delta y_{1,t-3}$	-0.4779 [0.0811]	-0.0263 [0.0542]	-0.6755 [0.0977]
$\Delta y_{1,t-4}$	-0.4798 [0.0780]	-0.0360 [0.0521]	-0.6942 [0.0940]
$\Delta y_{1,t-5}$	-0.4034 [0.0753]	-0.0402 [0.0503]	-0.6255 [0.0907]
$\Delta y_{1,t-6}$	-0.2902 [0.0711]	-0.0121 [0.0475]	-0.4740 [0.0856]
$\Delta y_{1,t-7}$	-0.2577 [0.0654]	-0.0392 [0.0437]	-0.4685 [0.0788]
$\Delta y_{1,t-8}$	-0.1726 [0.0586]	-0.0444 [0.0392]	-0.3245 [0.0706]
$\Delta y_{1,t-9}$	-0.1125 [0.0487]	-0.0661 [0.0325]	-0.2488 [0.0586]
$\Delta y_{1,t-10}$	-0.0404 [0.0344]	-0.0446 [0.0230]	-0.1125 [0.0415]
$\Delta y_{2,t-1}$	-0.0296 [0.0471]	-0.9183 [0.0315]	0.0721 [0.0567]
$\Delta y_{2,t-2}$	0.0037 [0.0636]	-0.7491 [0.0425]	0.1280 [0.0767]
$\Delta y_{2,t-3}$	0.0044 [0.0722]	-0.7008 [0.0483]	0.1044 [0.0870]
$\Delta y_{2,t-4}$	-0.0683 [0.0783]	-0.5502 [0.0523]	0.1290 [0.0943]
$\Delta y_{2,t-5}$	-0.0969 [0.0803]	-0.4420 [0.0536]	0.0450 [0.0967]
$\Delta y_{2,t-6}$	-0.1473 [0.0795]	-0.3810 [0.0531]	-0.0139 [0.0957]
$\Delta y_{2,t-7}$	-0.1832 [0.0760]	-0.3335 [0.0508]	-0.0125 [0.0916]
$\Delta y_{2,t-8}$	-0.2334 [0.0689]	-0.2944 [0.0461]	-0.0914 [0.0830]
$\Delta y_{2,t-9}$	-0.1361 [0.0606]	-0.1901 [0.0405]	-0.0342 [0.0730]
$\Delta y_{2,t-10}$	-0.0745 [0.0445]	-0.0826 [0.0297]	-0.0774 [0.0536]
$\Delta y_{3,t-1}$	-0.1963 [0.0805]	0.2839 [0.0538]	-0.0368 [0.0970]
$\Delta y_{3,t-2}$	-0.2251 [0.0768]	0.2657 [0.0513]	-0.0564 [0.0925]
$\Delta y_{3,t-3}$	-0.1791 [0.0733]	0.2884 [0.0490]	0.0344 [0.0883]
$\Delta y_{3,t-4}$	-0.1851 [0.0699]	0.2269 [0.0467]	0.0123 [0.0843]
$\Delta y_{3,t-5}$	-0.1086 [0.0660]	0.1954 [0.0441]	0.0828 [0.0795]
$\Delta y_{3,t-6}$	-0.1542 [0.0615]	0.1428 [0.0411]	0.0457 [0.0741]

Table A. 4. *Results of the VEC estimation* (continued)

	Error correction		
	$\Delta y_{1,t}$	$\Delta y_{2,t}$	$\Delta y_{3,t}$
$\boldsymbol{\Delta y_{3,t-7}}$	-0.0449 [0.0558]	0.1113 [0.0373]	0.0965 [0.0672]
$\boldsymbol{\Delta y_{3,t-8}}$	-0.0348 [0.0491]	0.1145 [0.0328]	0.1128 [0.0592]
$\boldsymbol{\Delta y_{3,t-9}}$	0.0299 [0.0401]	0.1088 [0.0268]	0.1023 [0.0483]
$\boldsymbol{\Delta y_{3,t-10}}$	0.0097 [0.0291]	0.0805 [0.0194]	0.0727 [0.0350]
Constant	0.0000	-0.0000	-0.0000
$\boldsymbol{\bar{R}^2}$	0.4519	0.4527	0.4029

Note: $\boldsymbol{\bar{R}^2}$ denotes the adjusted R-squared value. Standard errors are in parentheses.

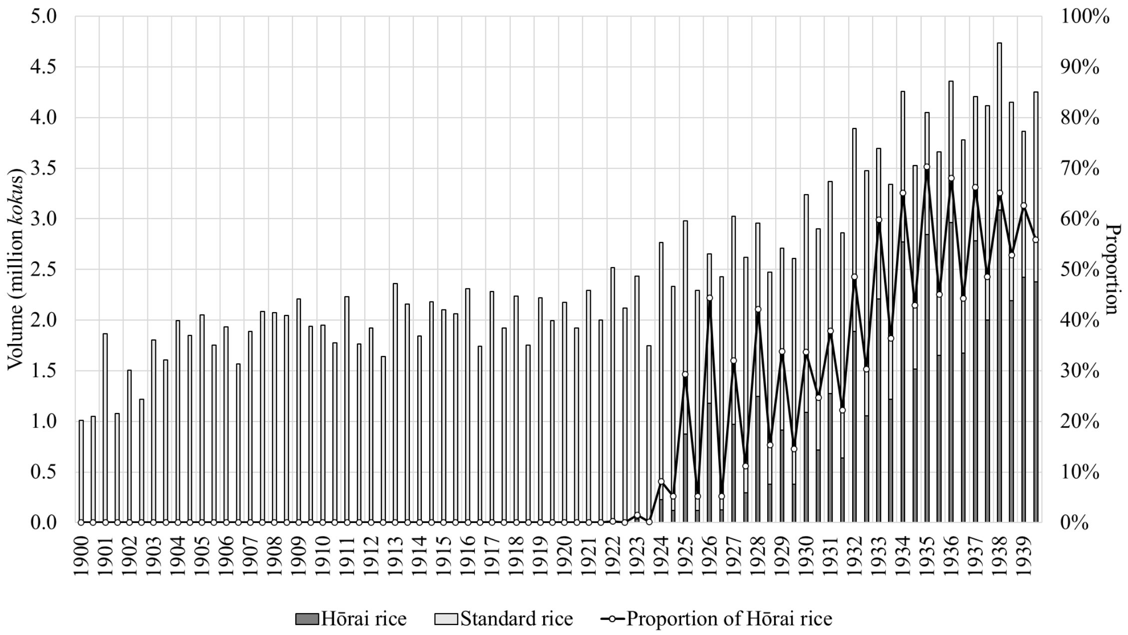

Figure A. 1. *Taiwanese rice production, the first harvest season in 1900–the second harvest season in 1939*

Notes: This figure shows the Taiwanese rice harvest in each year's first and second seasons. The standard rice production volume excludes the production of glutinous rice. Proportion means the ratio of Hōrai rice in the total production volume of Hōrai and standard rice.

Sources: Governor-General of Taiwan, Industrial Bureau, Commerce and Industry Division, *Showa 9-nen*, pp. 5–7; Governor-General of Taiwan, Rice Bureau, *Showa 16-nen*, p. 12.

Figure A. 2. *Taiwanese Hōrai rice exports by Japanese destinations, 1930–39*

Sources: Governor-General of Taiwan, Industrial Bureau, Commerce and Industry Division, *Showa 15-nen*, pp. 89–91.

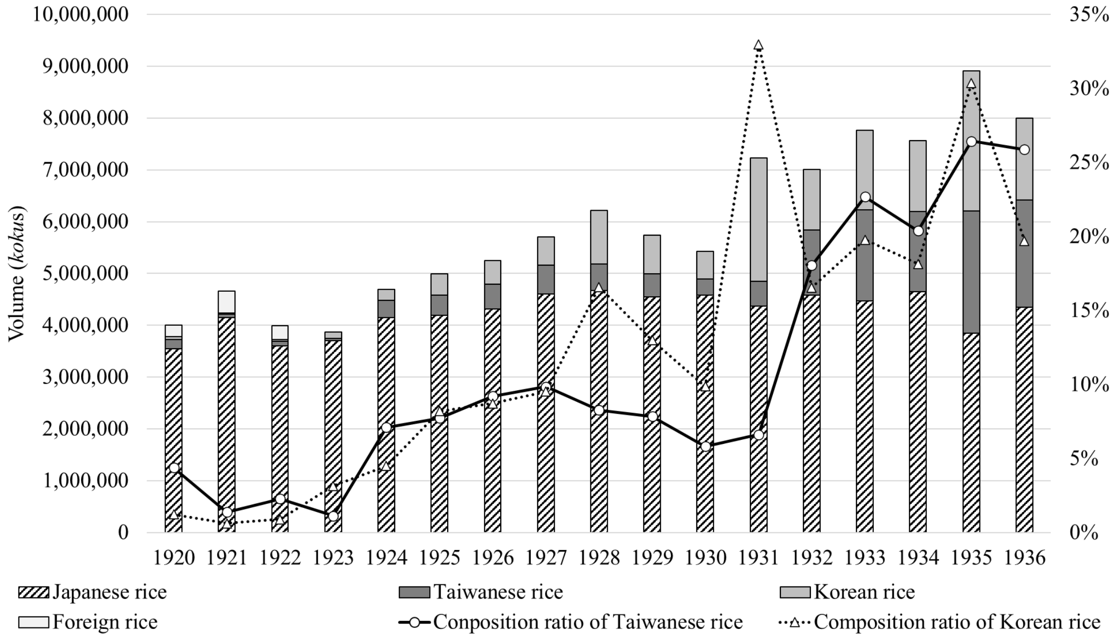

Figure A. 3. *Transport volume of rice to Tokyo, 1920–36*

Note: The Tokyo city government suspended publishing the transport volume of rice in 1937 because of the outbreak of the Second Sino-Japanese War.

Sources: Tokyo City Government, *Tokyo-shi*, annual series (1922–38).

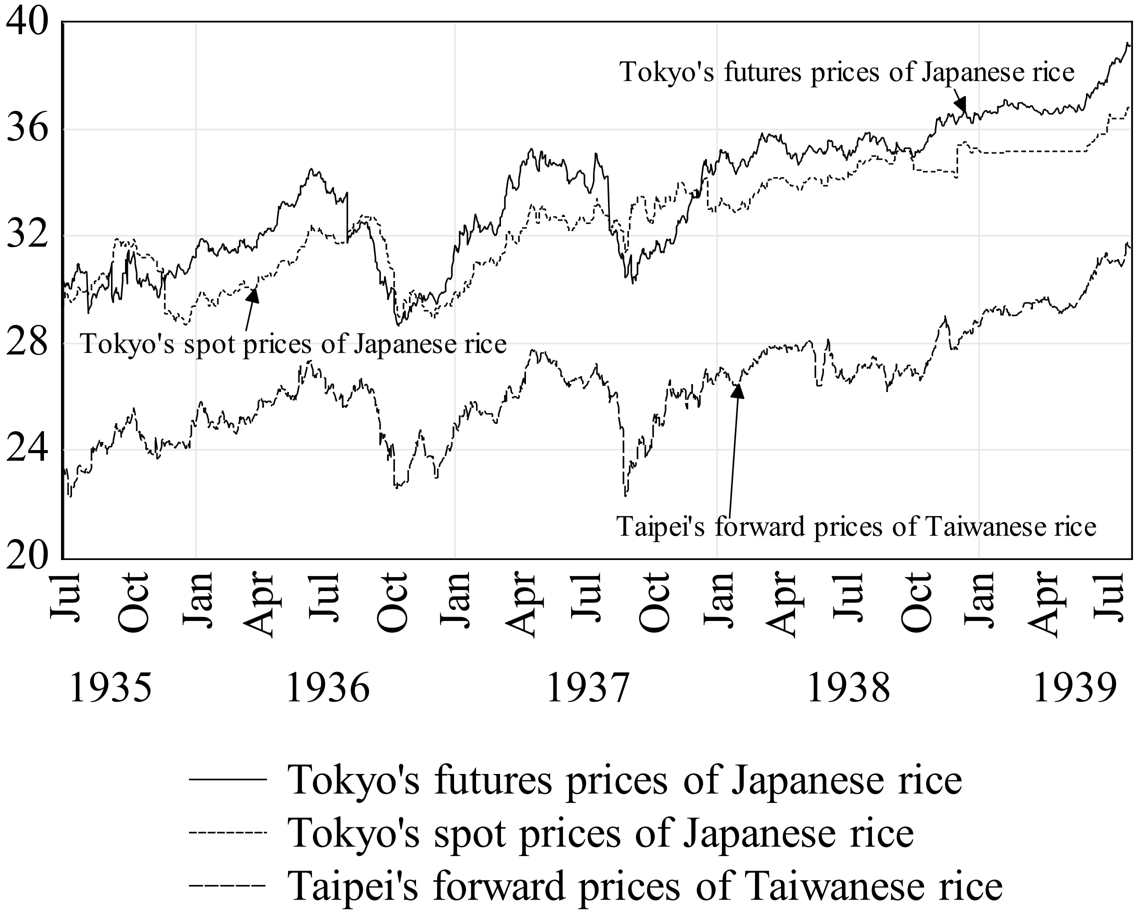

Figure A. 4. *Daily prices of Japanese and Taiwanese rice in Tokyo and Taipei*

Sources: Taiwan Spot Rice Market Association, *Taiwan Beihō*, no. 62–112; Tokyo Rice and Merchandise Exchange, *Tokyo Beikoku*; 'Shōkyō [Market trend] in *Tokyo Asahi Shimbun* [*Tokyo Asahi Newspaper*], 2 July–1 August 1939.

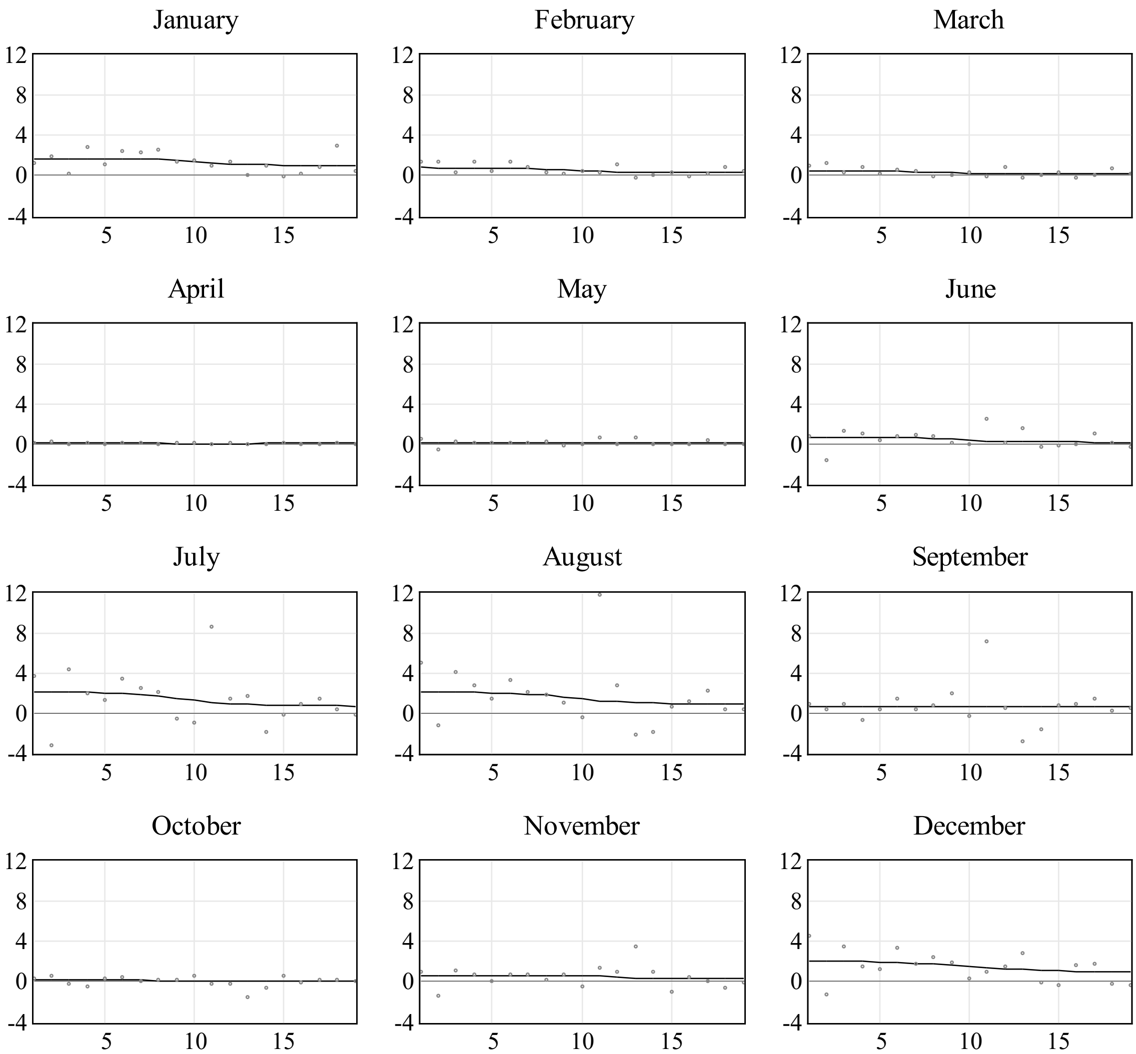

Figure A. 5. *Seasonal diagnostic plot of the monthly real rice prices in Tokyo's spot market, January 1920–December 1938*

Note: We set $n_{(s)}$ to 17.

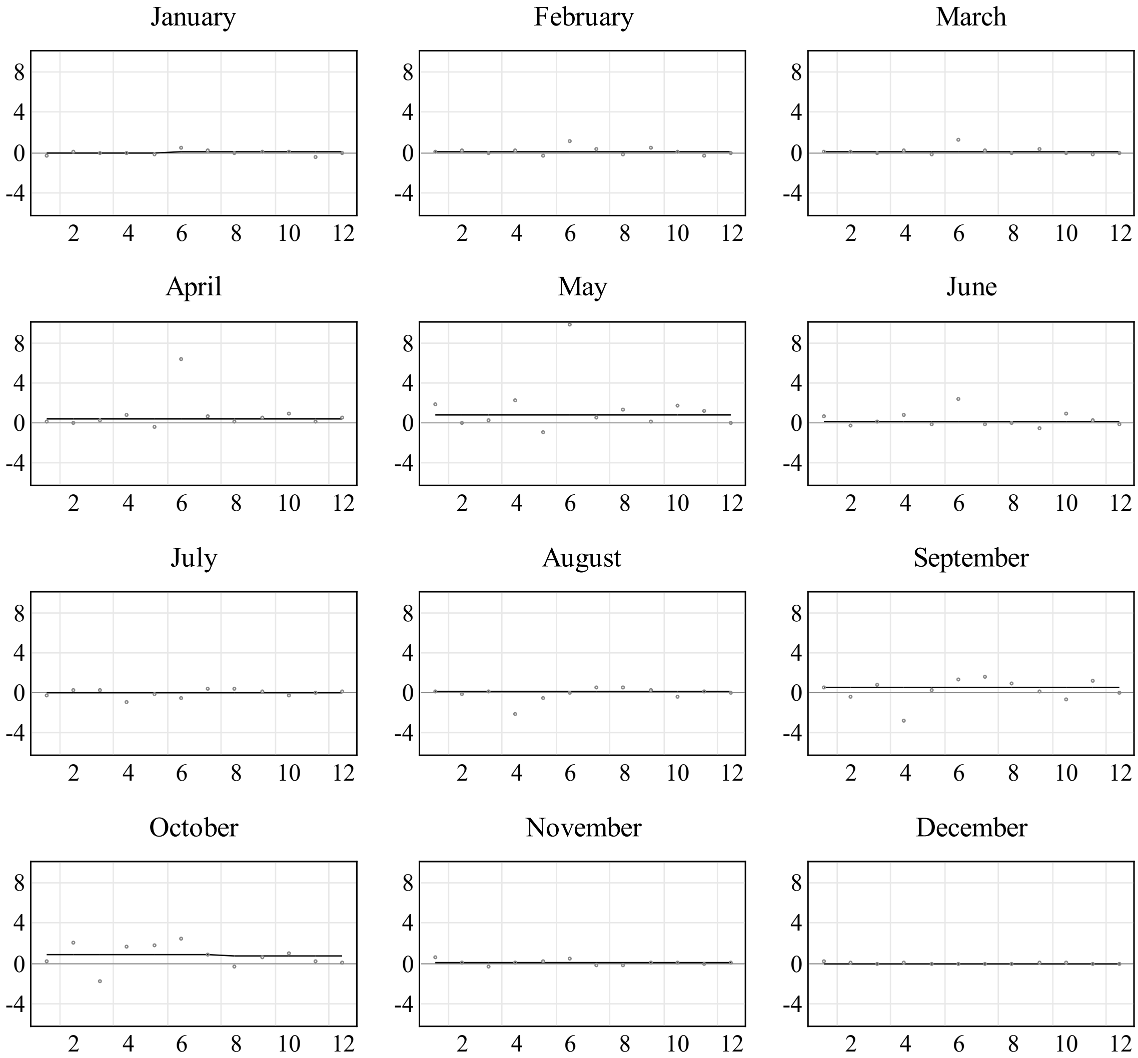

Figure A. 6. *Seasonal diagnostic plot of the monthly real rice prices in Taichung, January 1927–December 1938*

Note: We set $n_{(s)}$ to 25.

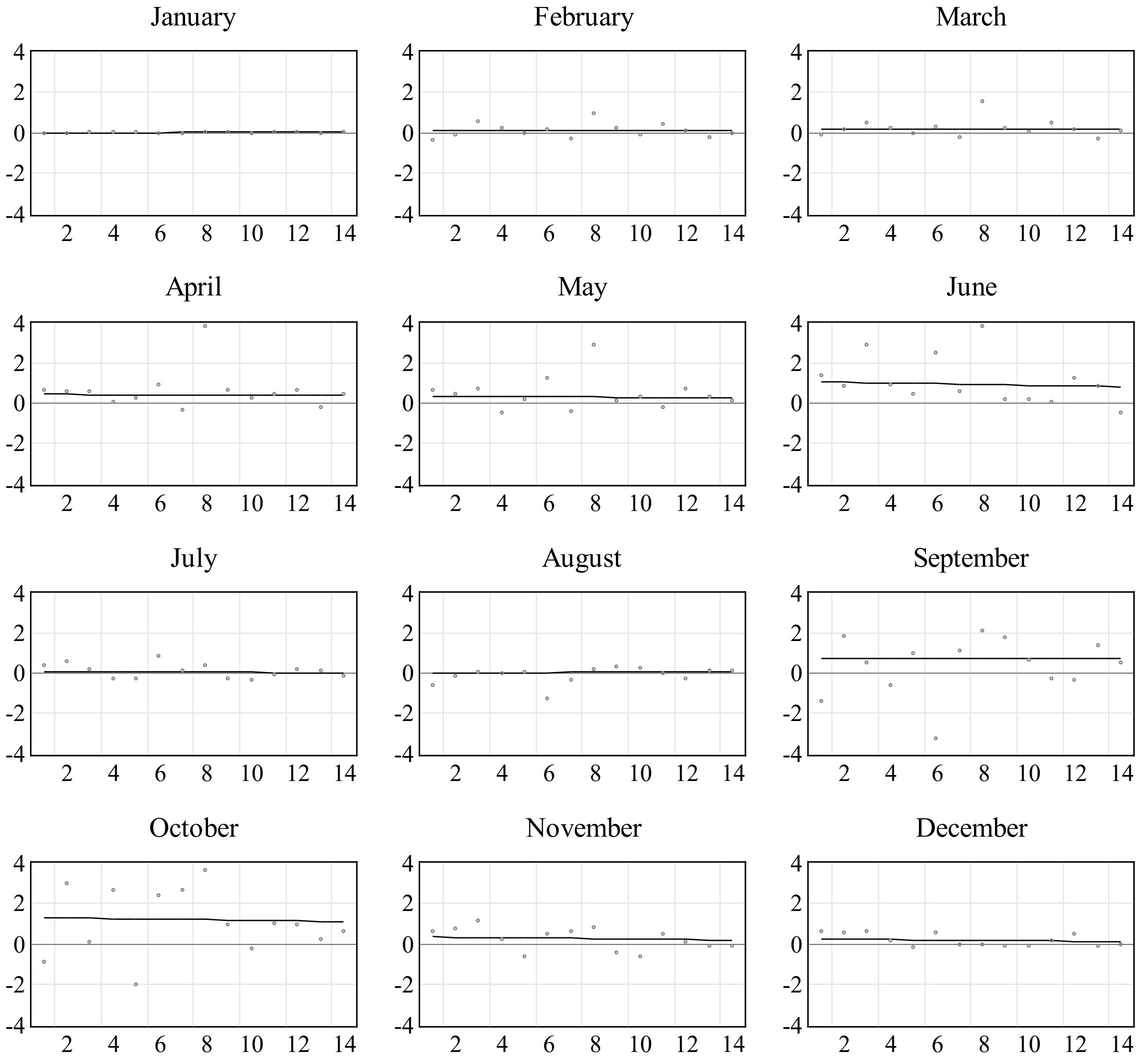

Figure A. 7. *Seasonal diagnostic plot of the monthly real rice prices in Keelung, January 1925–December 1938*

Note: We set $n_{(s)}$ to 25.

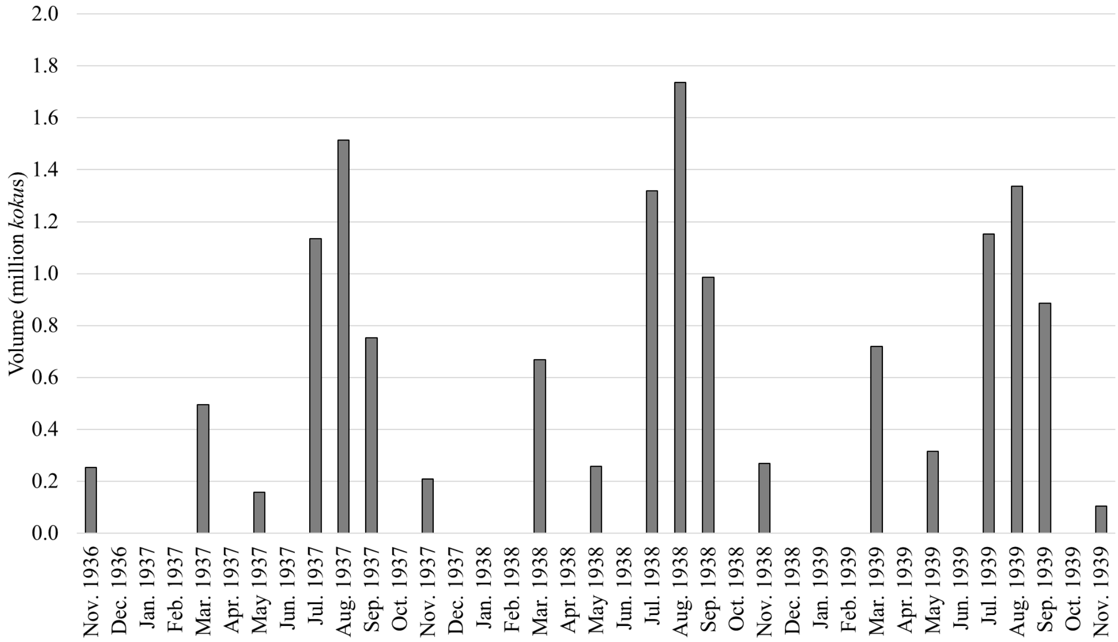

Figure A. 8. *Monthly stock volume of Hōrai rice in Taiwan, November 1936–November 1939*

Notes: The GGT investigated the stock volume of Hōrai rice in March, May, July, August, September, and November after November 1939. The volume in the other months is unknown.

Source: Governor-General of Taiwan, Industrial Bureau, Commerce and Industry Division, *Showa 15-nen*, pp. 59–60.