

# Sorting: The Function of Tea Middlemen in Taiwan during the Japanese Colonial Era

by

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In a case study of Taiwan's tea industry during the Japanese colonial period, we identify an important function of middlemen: sorting. The transaction cost saved by the intermediary due to sorting is shown to be empirically significant. We also study other services provided by tea middlemen, including financing and transportation. These are shown to be by-products of an intermediary's job, rather than his essential contribution to trading. (JEL: D 23, N 75)

## 1 Introduction

What do the *Michelin Red Guide*, *Publishers Weekly*, and school rankings have in common? When there are heterogeneous buyers and sellers in a market, without an independent agent helping to sort traders beforehand, suitable matches may take exhaustingly long to make. We can easily appreciate the service provided by the various consumer reports mentioned above, but when it is offered by middlemen together with other seemingly trifling services, we may overlook its importance and consider the whole package of services lacking in value.

Fair-trade coffee, the producers of which bypass the middlemen (nicknamed coyotes in Central America) by selling directly to fair-trader coffee companies in consuming nations, usually costs consumers more dearly than free-market coffee.<sup>1</sup> Though under a different name, similar fair-trade movements took place before World War II. In the British colonies in Africa, reduction in the number of intermediaries was advocated in the interests of producers and of consumers as well (see BAUER AND YAMEY [1954]). In Taiwan, the Governor-General helped found

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<sup>1</sup> For instance, in New Haven, Connecticut, the usual house-blend coffee beans cost around \$10/lb, while fair-trade coffee beans of similar quality and characteristic cost around \$11/lb. Moreover, except for coffee shops that sell fair-trade coffee beans exclusively, no coffee shops use fair-trade coffee beans to brew the coffee that they sell in store.

a tea auction house (Taiwan Tea Common Market) in 1923 to allow farmers to trade directly with tea refineries with the hope of eliminating tea middlemen. The auction house was closed in 1942 and never brought into operation again, whereas tea middlemen remain active even now. Their survival proves the efficiency of their profession.

The function of middlemen is clearly to lower transaction costs. The question is why a market with one more layer of traders results in lower trading costs. In the literature, RUBINSTEIN AND WOLINSKY [1987] and YAVAS [1994] consider middlemen more efficient in making contacts with traders than ordinary traders themselves. Thus, middlemen help save search costs. BIGLAISER [1993] and LI [1998] consider the case where sellers have private information regarding their goods and this information asymmetry leads to a market dominated by low-quality produce. Middlemen as market experts are shown to help promote the sale of high-quality goods. Lastly, COSIMANO [1996] points out that after a middleman posts a bid and an ask price and guarantees the trade, only sellers with low reservation value and buyers with high willingness to pay choose to trade with the intermediary. In equilibrium, this self-selection leads to a higher probability of a successful match. This paper uses the tea trade in Taiwan as an example to demonstrate another important function of middlemen: to sort heterogeneous goods into limited classes so that when goods are resold to ultimate buyers, matching complexity is greatly reduced. Thus, behind seemingly exploitative behavior, tea middlemen provide the same service as consumer reports do.

In the following, section 2 provides background information about the Taiwanese tea industry and identifies the transaction costs in the tea market. Section 3 explains how tea middlemen help lower transaction costs through sorting. In section 4, the transaction cost previously pinpointed is tested empirically for significance. Section 5 discusses why farmers could not organize themselves to replicate the middlemen's job of making volume sales. Section 6 contemplates the necessity of government intervention to help maintain an exchange house. Section 7 discusses other possible functions of a tea middleman. The final section concludes and discusses other possible applications of this study.

## 2 Background

### 2.1 Tea Middlemen and the Auction House

Tea trees were introduced into Taiwan by the English merchant John Dodd in 1865, and most Formosa tea was exported to the U.S. and Southeast Asia. Tea trees grew on hills, while tea refineries concentrated in Ta-tao-cheng, near the Tamsui River docks, where exporters clustered. Before selling tea leaves to Ta-tao-cheng refineries, farmers did preliminary processing to rid leaves of moisture so as to lessen the transportation cost. Their product was called *crude tea*. In the Ch'ing Dynasty (1662–1911), tea middlemen from China crossed the Strait to Taiwan every tea season to collect crude tea in the hills and resell it to refineries in Ta-

tao-cheng. In the Japanese colonial era (1895–1945) native Taiwanese gradually assumed responsibility for intermediation.

Tea middlemen suffered a bad reputation as exploiters for their practice of buying low and selling high, and critiques of the tea trade suggested a simple direct trade to bypass middlemen. In response to public opinion, in 1923 the Governor-General set up a tea auction house in Ta-tao-cheng. Interested farmers shipped crude tea to the house, where their products were sold to refineries by first-price sealed bidding. The auction house was run like a farmers' cooperative, under the chairmanship of an official appointed by the Governor-General. The operating cost of the auction house was financed by farmers' membership fees, trading charges, and subsidies from the Governor-General. Tea middlemen at that time had to compete with a subsidized auction house for customers.

## 2.2 Refineries Hire Experts to Appraise Crude Tea

Refineries have to carefully appraise crude tea, a highly heterogeneous product, before making their offers. According to SASA [1928, p. 387], in Taiwan there were 28 species of tea trees transplanted from China. His price data helps us to see the wide range of market values for these different varieties of tea. SASA [1928, pp. 387–391] presented a 5-year average of prices for 17 varieties of crude tea. Each variety was subdivided according to whether the crude tea would be made into oolong or pouchong. For crude tea to be refined into oolong, the 5-year average price was 25.83 yuan per 60kg. Among these, the “White-Haired Monkey” variety was the highest priced and “Yu-Che” the lowest, their prices being 40.14 and 18.60 yuan, respectively. On the other hand, the 5-year average price of crude tea for pouchong was 24.35 yuan. The most expensive variety was “Azure-Heart,” with an average price of 33.75 yuan; and the least expensive one was “White-Haired Monkey,” averaging only 14 yuan.<sup>2</sup>

The huge price difference between “White-Haired Monkey” at oolong and pouchong refineries indicates:

(1) Oolong refineries value “White-Haired Monkey” much more highly than pouchong refineries. In general, a variety of crude tea has its own particular way to be refined. Refineries with different know-how thus value the same variety differently. If we take the correlation coefficient between prices at oolong and pouchong refineries for these 17 varieties, we find that it is only 0.16.

(2) “White-Haired Monkey” at oolong refineries must be of a higher grade than that at pouchong refineries, since the same products cannot fetch two different prices.

<sup>2</sup> Besides the variety, the value of the product was also partly determined by climate, soil, and the manner of processing the crude tea. Moreover, according to SASA [1928, pp. 477f., 488f.], in the market, crude tea of the same variety was classified into three grades, and priced accordingly.

This data set shows proper appraisal of crude tea to be essential to refineries. In fact, every refinery hired a specialist for this job. Tea appraisal therefore made up an important part of transaction costs.

2.3 Price Search by Middlemen

To ascertain the best price, a tea middleman would visit each refinery with his sample of crude tea and ask for offers. Before a deal was finally made, the accumulated appraisal cost and search cost became high. Intensive searching was necessary because crude tea of the same variety fetched widely different prices among refineries, as exemplified by the case of “White-Haired Monkey” above. Moreover, the search had to be repeated every season because not only would a given refinery’s offer vary through time, the ranking of refineries’ offers also changed. This was because the value of crude tea at a refinery changed drastically with the refined tea’s export price, and prices of various refined tea moved incoherently.

Table 1 shows that the correlation coefficients between various refined teas are all much less than 1. When prices of refined teas varied, a refinery that formerly made generous offers for crude tea because of the good price of its refined tea might turn stingy with its offers if its product began fetching lower prices than those of other refineries.

The emergence of pouchong in Taiwan’s tea industry also showed how drastically the ranking of offers could change among refineries. At first, oolong was the only refined tea produced in Taiwan. In 1873, the oolong market in North America became depressed, and exporters of Formosa tea sent the oolong in stock to Foochow across the Strait to process it anew into pouchong. Following this episode, pouchong refineries began to emerge in Taiwan. If they had existed before 1873, we would have seen crude tea priced higher at oolong refineries before the North American market crashed and subsequently higher at pouchong refineries.

Table 1  
Correlation Coefficients of Real Tea Prices

	Oolong	Pouchong	Green tea	Black tea
Oolong	1.00	0.41	0.34	0.54
Pouchong		1.00	0.28	0.25
Green tea			1.00	0.49
Black tea				1.00

Note: The data period for oolong and pouchong is 1907–1943; for green tea and black tea, 1911–1943. The nominal prices are quoted from DEPARTMENT OF SPECIAL PRODUCE, PRODUCTION DIVISION, GOVERNOR GENERAL [1929–1940, 1929, p. 16; 1940, pp. 26f.] and STATISTICS OFFICE, COMMITTEE FOR POST-WAR AIDS, TAIWAN BRANCH [1946, p. 28]. The price index used to calculate the real price is quoted from WU AND GAU [1991, pp. 61ff.]

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It is worth mentioning that there are more than the four types of refineries indicated in Table 1. For instance, there is plain pouchong and flavored pouchong. The latter is again classified according to the flowers used to add flavor. When the flower price rises, the demand for crude tea at refineries for flavored pouchong decreases, and offers at refineries for plain pouchong may appear more attractive. The change in the flower market gives one more reason for tea middlemen to search diligently.

### 3 Sorting: The Function of Tea Middlemen

#### 3.1 Direct Trade

Without middlemen, farmers had to search for themselves, and the frequency of appraisals would become very high. According to GUILD OF FORMOSA TEA REFINERIES IN TAIPEI [1921–1929], the guild membership in the 1920s decreased from 105 in 1921 to 68 in 1929, the low being 60 in 1928. Even considering the minimum number of 60 refineries, the search effort for a farmer was still great. On the other hand, DEPARTMENT OF SPECIAL PRODUCE, AGRICULTURE AND FORESTRY DIVISION, TAIWAN PROVINCE GOVERNMENT [1950, p. 2] reports a high number of tea farms: 21,250 in 1928, which remained almost constant until 1945, the most tormenting year of the war, when it dropped to 18,441. In the following analysis, we shall assume there were 20,000 farmers selling their crude tea. If all farmers had traded directly with refineries, the frequency of appraisals would have been as high as 1,200,000 ( $20,000 \times 60$ ).

Consider farmer  $i$  endowed with  $q_i$  units of crude tea. Let  $v_i^j$  denote the marginal revenue product of his tea at refinery  $j$ . After visiting 60 refineries, the farmer will find the value of his product to be  $\max_j v_i^j$ .<sup>3</sup> But no refinery is willing to pay this amount. Let  $c_1$  denote the cost borne by a refinery for one appraisal. For the final buyer, though only  $c_1$  is incurred this time, considering the futile appraisals made for other farmers' tea that falls into competitors's hands, the refinery can only arrange for these other appraisals to be compensated when a deal is successfully reached. To simplify the analysis, we assume that all refineries share an equal chance of  $1/60$  to become the buyer of a given farmer's tea. A refinery's willingness to pay for farmer  $i$ 's product is therefore the production value of crude tea minus the expected appraisal cost to achieve a successful deal,  $60c_1$ . Finally, let  $c_2$  denote the search cost borne by a farmer each time he visits a refinery and waits for the appraisal. The net benefit resulting from a complete search is

$$(1) \quad \max_j v_i^j q_i - 60c_1 - 60c_2.$$

The transaction cost in the whole market reaches  $1,200,000(c_1 + c_2)$  when farmers make the search.

<sup>3</sup> In the model of optimal searching by ROTHSCILD [1974], farmers may not visit all refineries. To simplify the analysis, this paper does not consider such a possibility.

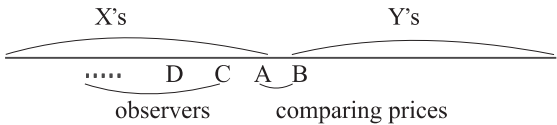
3.2 Indirect Trade

We now turn to explaining why the frequency of appraisals becomes greatly reduced when crude tea is traded through intermediaries. The main job of a tea middleman is to collect crude tea from numerous farmers, sort the collection into a few classes, and then make volume sales to refineries. Two kinds of appraisals take place in this process. First, middlemen have to appraise farmers' tea; then refineries, in turn, have to appraise middlemen's.

When farmers trade with middlemen, the market is perfectly competitive for crude tea of the same kind. According to GUILD OF FORMOSA TEA REFINERIES IN TAIPEI [1921–1929], there were 280 tea middlemen in 1921, and 98 in 1929. This high number meant middlemen had to compete with each other to collect tea and, for a given kind of tea, the same offer would be made by all middlemen. From the farmers' point of view, all middlemen appeared as homogeneous buyers. The following analysis helps illuminate this point.

Consider middlemen X and Y collecting crude tea in adjoining regions as depicted in Figure 1. Suppose X's offer for a given kind is lower than Y's. Farmer A, the resident at the boundary of X's region, will realize this when comparing prices with his neighbor B in Y's region and switch to sell his tea to Y instead. It then follows that C, A's neighbor in X's region, will begin to compare prices with A, and switch to sell to Y, too, etc. At the end of this chain effect, X's region shrinks to null, and X has no other choice but to raise his offer. In equilibrium, it only takes A and B comparing prices to keep middlemen's prices in check.

Figure 1  
Middlemen's Regions



When X and Y make the same offer and maintain their regions as depicted in the figure, farmer C can infer from A's choice to trade with X that X's offer is no worse than Y's, and consequently choose also to trade with X. Farmer D can then infer from C's choice what C knows about what A knows. The reasoning will extend to the other end of X's region. The number of price comparisons made in a region depends on how many different kinds of crude tea there are in this region.<sup>4</sup> Because the cost of comparing prices with a neighbor is trivial and not of the same magnitude as the

<sup>4</sup> Alternatively, tea middlemen could pay each farmer differently according to the individual's tea quality. But this would induce farmers to compare prices extensively and raise transaction costs. For instance, if quality is continuously distributed and no two farmers have tea of exactly the same quality, to ascertain the best offer, each

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search cost  $c_2$  spent in a refinery, we shall ignore it in the following analysis. On the other hand, middlemen still have to appraise farmers' crude tea before a trade. With the assumed 20,000 farmers, the frequency of appraisals in the hills is then 20,000.

We now calculate the frequency of appraisals by refineries. In order not to underestimate the frequency, we shall consider the number of middlemen to be 280, the maximum recorded by GUILD OF FORMOSA TEA REFINERIES IN TAIPEI [1921–1929]. Let  $n$  denote the number of kinds of crude tea an average middleman collects. With 60 refineries assumed, the total number of appraisals in Ta-tao-cheng is then  $60 \times 280 \times n$ .<sup>5</sup> Adding the 20,000 appraisals in the hills, unless  $n$  exceeds 70, we find the total frequency of appraisals to be lower in the indirect trade. When the Governor-General started to enforce wartime price regulations on tea in 1942, the price list of crude tea contained 25 different kinds (see GUILD OF FORMOSA TEA REFINERIES IN TAIPEI [1943, pp. 27f.]), much less than 70. Suppose in each middleman's region, there are only 5 different kinds of crude tea. The total frequency of appraisals in the indirect trade is then 104,000, much less than the frequency of 1,200,000 in the direct trade. The key reason for this result is that crude tea from 20,000 farmers is sorted into limited classes by middlemen. Volume sales greatly lessen refineries' appraisal efforts. SASA [1928, p. 428] criticized middlemen for mixing up crude tea. We consider this very act their main contribution toward saving transaction costs.

The other side of the coin is that allocation efficiency is sacrificed when not fully identical tea is sold in a batch. This is a loss to the tea industry, and in particular, a loss to tea middlemen's revenue. Volume sale is nevertheless worthwhile to middlemen, since having the refinery check on each farmer's product greatly increases the transaction cost.

As the total production value is reduced in the indirect trade, there must be some farmers who will sell their crude tea at lower prices. On the other hand, selling in lots helps save these farmers transaction costs. Let  $c_3$  denote the search cost of a middleman waiting for an appraisal to be completed. Let  $Q$  denote the quantity of a particular kind of crude tea a middleman collects,  $m$  the number of its sellers, and for  $i = 1, \dots, m$ ,  $q_i$  the quantity sold by the  $i$ th farmer, so  $Q = \sum_{i=1}^m q_i$ . When collecting crude tea from  $m$  farmers, it costs the middleman  $mc_3$ ; and when inquiring concerning offers among refineries, he has to further cover appraisal costs of  $60(c_1 + c_3)$ , the cost transferred from refineries included. To complete the exchange of these  $Q$  units, the middleman bears a transaction cost of  $60(c_1 + c_3) + mc_3$  in total. We assume the middleman divides this cost uniformly

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farmer has to ask 280 middlemen for an estimate. Transaction costs then become even higher than that in the direct trade, when farmers only have to search among 60 refineries.

<sup>5</sup> BARZEL [1982] points out that after the seller sorts goods into classes of different quality, buyers may tend to measure goods excessively. However, once tea middlemen establish through repeated transactions that refineries can trust their samples to be representative of each class, no extra measurement will be taken.

among  $Q$  units. In this way, the net profit to farmer  $i$  is

$$(2) \quad \bar{v}q_i - 60(c_1 + c_3)\frac{q_i}{Q} - mc_3\frac{q_i}{Q} - c_2,$$

where  $\bar{v} \equiv (\max_j \sum_{i=1}^m v_i^j q_i)/Q$ . Compared with the net profit in the direct trade calculated in (1), though the production value  $\bar{v}$  in (2) can be lower than the corresponding  $\max_j v_i^j$  in (1), farmer  $i$  should bear less transaction cost in the indirect trade, especially when we consider that in reality no farmer chooses to play the role of a middleman, so that  $c_3$  must be lower than  $c_2$ .

#### 4 An Empirical Study

This paper emphasizes the sorting function of a tea middleman and the reduced requirements for appraisal that result. Whether sorting is nontrivial depends on the magnitude of the associated appraisal and search costs:  $c_1$  for a refinery,  $c_2$  for a farmer, and  $c_3$  for a middleman. When  $c_3 < c_2$ , a middleman is already providing valuable service as a sales agent for farmers. To manifest the importance of his sorting function, we must further demonstrate that  $c_1$  and  $c_3$  are large. There is no bookkeeping for these accounts, so we shall study this problem in an indirect manner.

##### 4.1 Direct Trade versus Indirect Trade: A Choice Model

After the tea auction house was established in 1923, some farmers chose to trade directly with refineries at the auction house while others continued trading through intermediaries. When choosing between these two trading methods, farmers must have taken into account the associated transaction costs. In other words, a farmer's choice as well as the overall market performance was a function of  $c_1$  and  $c_3$ . In what follows, we shall use the very limited aggregate market data to retrieve information regarding  $c_1$  and  $c_3$ .

When farmers choose to sell at the auction house, they have to pay a fee of 0.1 yuan per 60kg sold,<sup>6</sup> denoted as  $c_4$  below. So when farmer  $i$  sells at the auction house, his net profit is

$$(3) \quad \max_j v_i^j q_i - 60c_1 - c_4 q_i.$$

Comparing (2) and (3), the benefit that accrues when switching from indirect to direct trade is

$$(4) \quad \left( \max_j v_i^j - \bar{v} - c_4 \right) q_i - 60c_1 \left( 1 - \frac{q_i}{Q} \right) + (60 + m)c_3 \frac{q_i}{Q} + c_2.$$

Farmer  $i$  will choose direct trade if and only if (4) is positive. This is more likely to happen when farmer  $i$  is of either of the following two types: (A)  $\max_j v_i^j \gg \bar{v}$  and (B)  $q_i/Q \rightarrow 1$ . Intuitively speaking, (A) means the crude tea of farmer  $i$  is

<sup>6</sup> See p. 13 of *Taiwan Tea Common Market*, a handwritten pamphlet.



so much better than others' in the same lot that he is unwilling to mingle his product with others' in an indirect trade. (B) means farmer  $i$  produces in a large quantity, and without joining others in an indirect trade, farmer  $i$  can take advantage of a volume sale by himself. Types A and B are different variants of direct trade.

As in the process of adverse selection described by AKERLOF [1970], when  $c_1$  is very close to 0, farmers will all become type A sooner or later. Because  $c_4$  is very small in reality, when  $c_1 \approx 0$ ,  $\forall i$  such that  $\max_j v_i^j > \bar{v}$ , (4) is positive. After these type A farmers quit indirect trade, the average value of a batch falls. This will trigger the second generation of type A farmers, i.e., those whose crude tea is of higher quality than the new average, to switch to direct trade. The withdrawal proceeds recurrently, and in the end, no farmer stays in indirect trade. Thus, when  $c_1$  is close to 0, we predict: (1) Almost all crude tea is sold at the auction house. (2) Because it is always the better-quality crude tea that is transferred to the auction house, the average price at the auction house is constantly higher than that in the indirect trade.<sup>7</sup>

On average, a farmer's product only accounts for a very small portion (roughly 1%) of his middleman's collection. However, there still exist a few large farmers for whom  $q_i/Q$  is large in (4). For type B farmers, as long as  $c_3$  is large enough, (4) becomes positive even if the value of their crude tea,  $\max_j v_i^j$ , is below the average of the batch,  $\bar{v}$ . The reason these type B farmers switch to direct trade is to save payment of  $(60 + m)c_3 q_i/Q$  to their middleman. Thus when  $c_3$  is significantly large, we expect: (1) Large farmers will sell at the auction house. (2) Because the quality of type B farmers' tea is not necessarily better, the average price at the auction house can be either lower or higher than outside the house.

Lastly, we would like to point out the interplay between these two types of farmers. We shall illustrate this point with an example where  $c_1$  and  $c_3$  are both significantly large. Logically, farmers who are both type A and type B are the most inclined to leave for the auction house. After these farmers withdraw their higher-quality tea from the indirect trade, the average quality of a lot falls, say to  $\bar{v}'$ . This will motivate some purely A-type farmers to follow suit. As a result, the average quality of a lot will fall further, say to  $\bar{v}''$ . As long as  $c_3$  is large enough, some type B farmers with lower-quality tea, i.e., those with  $\max_j v_i^j < \bar{v}'$  and  $q_i/Q$  large, may now find direct trade appealing, and join the auction house too. When their lower-quality tea leaves the middleman's hand, the average quality of a lot increases, and the middleman becomes willing to pay more for crude tea. If  $c_1$  is large enough, it helps discourage more type A farmers from joining the auction house, and an equilibrium between the two kinds of trades is reached.

<sup>7</sup> On the contrary, BIGLAISER [1993, p. 223] predicts the average price and the quality of goods to be higher if sold through middlemen rather than through direct sales. This is because BIGLAISER [1993] considers sellers to possess better information regarding their goods, and only low-quality items are sold directly in equilibrium. In our study, refineries are tea experts and there is no asymmetric information in the tea trade as considered by BIGLAISER [1993].

In summary, farmers join the auction house at different stages. If  $c_1$  is zero, adverse selection will proceed recurrently until all farmers join the auction house. All along, the average price (reflecting the average quality) at the auction house is higher than outside the house. When  $c_1$  and  $c_3$  are both large, though the average price at the auction house is higher at the beginning, it may eventually converge to that outside the house, or even drop lower when type B farmers with lower-quality tea start to join the auction house, and type A farmers stop abandoning indirect trade.

## 4.2 Data

In this section, we shall consider the average price, average trade volume per farmer, and total trade volume at the auction house to figure out the significance of  $c_1$  and  $c_3$ .

Table 2 lists the trade volume and trade value at the auction house along with those in the whole industry. Though the trade volume grew quickly after the opening of the auction house on June 12, 1923, up to 1936 it never exceeded one-quarter of the industry's total. Lacking data on the trade volume after 1936, we turn to consider the trade value afterwards. The trade value at the auction house reached 23.15% of the total sales in 1937, but was reduced to 12.86% in 1940. In summary, the subsidized direct trade reached its peak in 1936–1937. At that time, three-quarters of all crude tea was still traded through the intermediary. The analysis of the previous section shows that if  $c_1$  is zero, all crude tea will eventually be sold at the auction house. Observing the limited business at the auction house, we conclude that  $c_1$ , the appraisal cost of a refinery, must be significantly large.

The price data also points to  $c_1$  being significantly large. In the analysis of the previous section, if  $c_1$  is zero, in the process of adverse selection, the average quality, and so the price, at the auction house is constantly higher than that outside the house. Figure 2 depicts the price of crude tea in the period 1923–1936. Only in the first four years after the auction house opened was the price there higher. From Table 2, in these four years, the sale at the auction house accounted for no more than 6% of the whole industry. According to the previous analysis, this was the beginning stage when farmers with top-quality tea started to join the auction house. When the sale at the auction house increased to 9.38% of the whole industry in 1927, the average price at the auction house fell below that elsewhere. This shows that the adverse selection process became blocked by a high  $c_1$ .

The lower price at the auction house after 1927 indicated that the average quality there was lower than outside. In our model, it can only be that type B farmers with lower-quality tea started to join the auction house. Their movement shows  $c_3$  is not zero. If we take  $c_3$  to be zero, and consider farmer  $i$  to have low-quality tea, such that  $\max_j v_i^j < \bar{v}$ , then (4) cannot be positive without an unreasonably large  $c_2$ , which is the time cost to a farmer waiting for his tea to be appraised by a middleman. From equation (4), the necessary condition for farmers with low-quality tea to sell at the auction house is  $c_2 \geq \min\{60c_1, c_4Q\}$ . Now,  $c_2 \geq 60c_1$  means a farmer's time cost is more than 60 times higher than a refinery tea expert's, which is quite

Table 2  
The Auction House's Business

Year	(1) Auction house		(2) The whole industry		(1)/(2) (%)	
	Volume (60kg)	Value (yuan)	Volume (60kg)	Value (yuan)	Volume	Value
1923	1,396	43,839	212,642	6,291,898	0.66	0.70
1924	3,950	140,519	206,271	6,524,171	1.92	2.15
1925	6,012	246,390	200,944	7,242,592	2.99	3.40
1926	11,107	430,587	198,945	7,541,789	5.58	5.71
1927	18,122	581,331	193,169	6,537,230	9.38	8.89
1928	20,126	688,644	183,427	6,312,220	10.97	10.91
1929	27,619	— <sup>†</sup>	183,402	6,005,009	15.06	—
1930	19,992	423,099	174,069	3,803,615	11.49	11.12
1931	19,095	338,275	160,377	3,228,822	11.91	10.48
1932	27,749	277,735	147,042	2,608,491	18.87	10.65
1933	26,917	622,321	155,449	3,866,536	17.32	16.10
1934	36,795	1,425,974	183,920	7,546,869	20.01	18.89
1935	27,678	931,406	178,028	6,377,093	15.55	14.61
1936	44,311	1,796,912	180,814	7,421,599	24.51	24.21
1937		2,381,601	215,540	10,285,535		23.15
1938		1,392,775	218,371	9,179,285		15.17
1939		1,737,635	233,827	15,324,698		11.34
1940		2,180,000	194,744	16,948,389		12.86

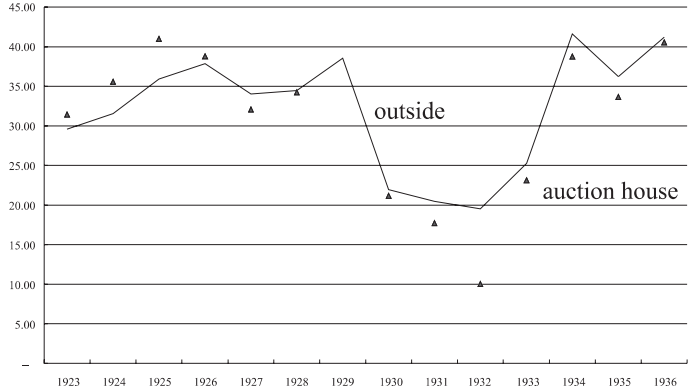
Key: <sup>†</sup> This is recorded to be 3,775 yuan, unreasonably low when compared with trade values in other years. It is also incompatible with the high trade volume in 1929. So we omit it from the table.

Source: For the data at the auction house, the trade volume is quoted from DEPARTMENT OF SPECIAL PRODUCE, PRODUCTION DIVISION, GOVERNOR GENERAL [1929–1940]. The trade value in the period 1923–1927 is quoted from SUZUKI [1928], in 1928 from the ASSEMBLY OF TAIWAN INDUSTRIAL COOPERATIVES, TAIPEI BRANCH [1928], and in 1929–1940 from ASSEMBLY OF TAIWAN INDUSTRIAL COOPERATIVES [1929–1940]. On the other hand, the total output and value of crude tea in 1923–1938 is quoted from DEPARTMENT OF SPECIAL PRODUCE, PRODUCTION DIVISION, GOVERNOR GENERAL [1929–1940], and in 1939–1940 from AGRICULTURE AND FORESTRY DIVISION, TAIWAN PROVINCE GOVERNMENT [1947].

unlikely.  $c_2 \geq c_4 Q$  is also unrealistic. In our study period, the average trade volume of a middleman was lowest in 1925: 221.5 (60kg), which serves as a conservative estimate of  $Q$ . Because  $c_4$  is 0.1 yuan/60kg,  $c_4 Q$  amounts to 22.15 yuan. The estimate of Taiwan's GDP per capita by WU [1991] is 170.81 yuan. Thus, a farmer's time cost for appraisal,  $c_2$ , cannot be higher than  $c_4 Q$ .

The huge trading volume per farmer at the auction house also indicates  $c_3$  is large. Table 3 lists the number of members at the auction house in 1928–1936. When the

Figure 2  
The Average Price of Crude Tea (yuan/60kg)



Source: See Table 2.

number reached 202 in 1936, it still accounted for less than 1% of total tea farms in Taiwan. If they could account for one-quarter of the sales in the whole industry, their individual trade volumes must have been large. Table 3 also lists the average trade volume at the auction house and outside, the former being at least 17 times the latter. This means most traders at the auction house made volume sales.<sup>8</sup>

Table 3  
Average Trade Volume

Year	Members at the auction house	Tea farms in Taiwan	Average trade volume (60kg/person)		
			(1) Auction house	(2) Outside	(1)/(2)
1928	137	20,844	147	7.89	18.6
1929	143	20,873	193	7.51	25.7
1930	145	20,835	138	7.45	18.5
1931	155	20,609	123	6.91	17.8
1932	160	20,627	173	5.83	29.8
1933	165	20,685	163	6.26	26.0
1934	179	20,627	206	7.20	28.6
1935	185	20,925	150	7.25	20.6
1936	202	20,721	219	6.65	33.0

Source: See Table 2.

<sup>8</sup> In this instance, we observed large farmers to have benefited the most from the government support of the auction house. TILLY [1986] wrote about a similar phenomenon with regard to large German enterprises having benefited from banks, and named it “development assistance for the strong.”

In summary, this section uses the trade data to infer the significance of various transaction costs. The findings are consistent with the hypothesis that the appraisal and search costs borne by the refineries and middlemen were both large. So middlemen sorting crude tea indeed helped lower transaction costs.

### 5 Tea Farmers' Cooperatives

If the main function of a tea middleman is to sort crude tea into different kinds for sale, why cannot farmers organize a cooperative to sort their tea and sell directly to refineries? This is the problem we attempt to explore in this section.

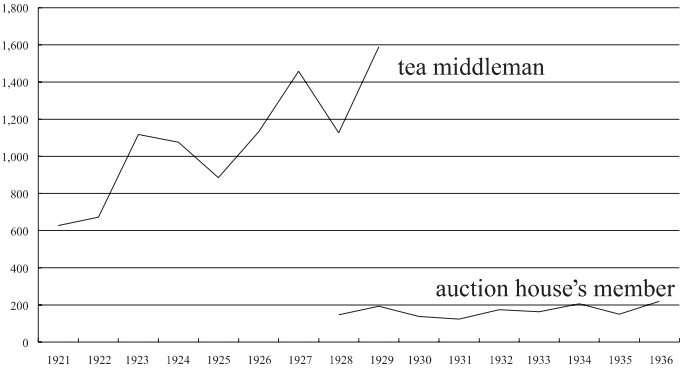
To simplify the discussion, we shall consider a cooperative with only two members:  $H$  and  $L$ . Each of them has one unit of crude tea, and  $H$  holds tea of higher quality than  $L$ . Suppose when the cooperative sells their tea separately, the price for  $H$  is  $\max_j v_j^H = \$20$ , and for  $L$  is  $\max_j v_j^L = \$10$ . If their tea is mixed in a batch to sell, the price becomes  $\max_j v_j^{H+L}$  which cannot be better than the average of  $\max_j v_j^H$  and  $\max_j v_j^L$ . We assume  $\max_j v_j^{H+L} = \$13$ . The revenue of two farmers depends on whether their tea is sold together or separately.  $H$  prefers the latter;  $L$  the former. COASE [1960] sheds light on this problem: so long as the property right of sorting is clearly defined in the cooperative, no matter who owns the right, the products will be sold in an efficient manner; and the assignment of the property right only affects the income distribution between  $H$  and  $L$ .

In our example, no matter whether  $H$  or  $L$  decides how to sell the tea, the tea will be sold separately, and \$30 is earned. How this \$30 is divided between  $H$  and  $L$  depends upon who owns the sorting rights. When discussing problems of externality, COASE [1960] shows that once the government defines the property right related to the object in dispute, the arguers can negotiate for an efficient outcome. The difficulty of our example is that when forming a cooperative,  $H$  and  $L$  themselves, not an independent third party such as the government, have a say in defining the right of sorting. Because the sorting determines income distribution, no one is willing to concede this right to the other party. The right of sorting therefore cannot be defined successfully.

A tea middleman clearly owns the right of sorting his collected tea. When buying crude tea from  $H$  and  $L$ , the middleman does not have to inform them how their tea will be sold to refineries; he only has to propose bid prices. So long as his offers are no worse than peer middlemen's, both  $H$  and  $L$  are willing to sell tea to him. The middleman will then consider whether to sell tea separately in order to maximize his own revenue. In our example, the tea of  $H$  and  $L$  will be sold separately.<sup>9</sup>

<sup>9</sup> The problem of cooperative sorting and property rights is a case of commons. The recent literature shows that commoners often act to avert the tragedy of the commons. In our case, a simple institutional arrangement is to have an elder, who himself produces no crude tea, to perform the cooperative sorting. Such an arrangement can still turn costly, once cooperative members start to bribe the elder. One way to induce

Figure 3  
Average Trade Volume (60kg/person)



Source: For the tea middlemen, see DEPARTMENT OF SPECIAL PRODUCE, PRODUCTION DIVISION, GOVERNOR GENERAL [1929–1940], [1937], and GUILD OF FORMOSA TEA REFINERIES IN TAIPEI [1921–1929]; and for the auction house’s members, see Table 3.

Our discussion above implies that only farmers with tea that is really homogeneous can possibly sell together as a cooperative, because their organization is then free of the sorting problem. This, in turn, implies that the trade volume of a cooperative will be less than that of a middleman, because a cooperative cannot afford to handle tea of different grades as a middleman does. There is no data concerning these cooperatives, but since cooperatives joined the auction house along with big tea farmers (including tea companies), we shall use the average trade volume at the auction house as a proxy for an average cooperative’s business. Figure 3 depicts the average trade volume of a middleman and an auction house’s member. Though the two time series only overlapped for two years, it is clearly seen that a tea middleman’s business was on a much larger scale. If the proxy of cooperatives’ trade volume is reasonable, this observation supports our explanation why farmers cannot organize themselves to replicate their middleman’s function.

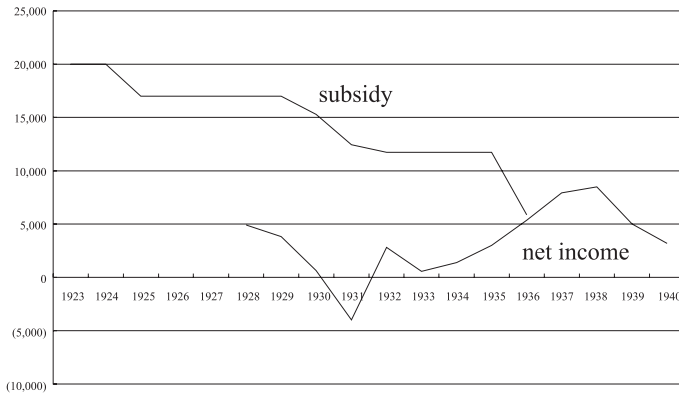
6 Government Intervention

Was the closure of the auction house proof that tea middlemen were efficient? COMMITTEE OF AGRICULTURE PROMOTION, TAIWAN PROVINCIAL GOVERNMENT [1947, p. 31] blamed the depressed market for bringing an end to the auction house. However, the study by KOO [2000] shows large outputs of crude tea and refined

the elder to decline the bribery is to allow him the full receipts of the sorted tea. This is exactly the arrangement farmers have with their middleman.

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Figure 4  
The Auction House's Subsidy and Net Income (yuan)



Source: DEPARTMENT OF SPECIAL PRODUCE, PRODUCTION DIVISION, GOVERNOR GENERAL [1937], ASSEMBLY OF TAIWAN INDUSTRIAL COOPERATIVES, TAIPEI BRANCH [1928], and ASSEMBLY OF TAIWAN INDUSTRIAL COOPERATIVES [1929–1940].

tea in 1942, when the auction house closed. Furthermore, in 1942, the real price of refined tea reached the highest record since 1907. The real price of crude tea was the third highest, and twice as high as that in 1923 when the auction house was open. There was definitely no depressed market to cause the house to close.

It is worth noting that in 1942, the Governor-General started to impose price ceilings on all kinds of crude tea according to a wartime price regulation. The competitive bidding at the auction house could not proceed meaningfully with an upper limit set below the equilibrium price. We conjecture that it was wartime price regulations that caused the auction house to close. However, so long as the direct trade was efficient, we would have expected the auction house to resume business after the war. Conversely, its permanent closure indicates the efficient performance of middlemen.

Or was the auction house a public good in need of governmental support? The Nationalist government that ruled Taiwan after the war did not support the auction house as the Governor-General once did. This also partly explains why the auction house never went into operation again. Figure 4 depicts the net income of the auction house and the subsidy from the Governor-General. Between 1928 and 1936 when these two time series overlap, without subsidy the auction house always suffered a loss. We shall now discuss whether the intervention by the government was justifiable.

The auction house provides a space for people to trade and appears to be a public good like a park. However, when farmers put tea up for auction, the house can easily charge them a fee according to the volume of individual trade, a proxy for the

handling cost. There is no free-rider problem. There is no need for the government to subsidize the auction house.

It is worth noting that trading at the auction house indeed yields some external benefits. In our previous cost-benefit analysis of a direct trade, all refineries are assumed willing to bid at the auction house. It is overlooked that farmers' choices of the trading method may affect refineries' willingness to participate at the auction house. As more farmers sell at the house, more varieties are offered for sale, and more refineries will be attracted. Consequently, the bidding becomes more competitive, and all farmers benefit.

However, COASE [1960] and COASE [1974] show that government intervention is not always necessary when externalities arise. So long as the auction house is an efficient organization, a private party can design ways to collect payment from its beneficiaries to maintain its operation, or even to make a profit. The externality argument also applies to stock exchanges, but in practice stock exchanges do not have to be publicly run. For instance, the London Stock Exchange is a private enterprise. Moreover, if an exchange can truly promote trading, people will compete to set up exchanges. For example, in the art market, Sotheby's and Christie's coexist and compete with each other.

The permanent closure of the Taiwan Tea Common Market indicates its inefficiency. Without subsidies, the auction house would have had to increase its membership and trading fees. This would have discouraged the marginal members, i.e., farmers who had been indifferent to direct trade or indirect trade, from continuing to trade at the house. Their departure had two effects: (1) the financial burden on the remaining members became even heavier and (2) some refineries who found their favored crude tea withdrawn from the auction house turned away. These two effects led to another group of members leaving the auction house. Continuing with this vicious cycle, the business of the auction house degenerated to nothing.

## 7 Other Functions of Tea Middlemen

This article focuses on the tea middlemen's sorting function, whereas contemporary documents emphasized their other functions, such as transportation, finance, and insurance. This section will examine whether it was sorting or other functions that contributed to the prevalence of indirect trade.<sup>10</sup>

<sup>10</sup> If farmers had been uneducated or illiterate, it would have been natural for them to rely on some better-educated middlemen to sell tea. However, the literacy rate in Taiwan was rather high in 1942, when the auction house closed. For children between 6 and 14 years old, the school attendance rate was 76.6% for males and 54.1% for females (TAIWAN PROVINCIAL GOVERNMENT [1946, p. 1241]). Moreover, information also flows by hearsay and comparison of performance. If one educated farmer in the village made abnormal profits from direct trade, other farmers could hire him to read and write contracts for them.



### 7.1 Transportation

In the Ch'ing dynasty, travel in Taiwan was difficult, and crude tea was often transported by ferry boats or shouldered by men. If the middlemen's cost of shipping tea was lower than that of the farmers, transportation must have been one of the main functions of tea middlemen.

When railways and roads became well developed in the Japanese colonial era, crude tea transported in large volume probably enjoyed economies of scale. However, carriers did not need to be involved in the trade. For instance, UPS is by no means a middleman. Since crude tea carriers were not necessarily middlemen, transport could not be the intermediary's main function during the colonial times. On the contrary, once tea middlemen collected crude tea in large quantities, they could well take charge of shipping. Correctly speaking, tea middlemen became carriers of crude tea because of the prevalence of indirect trade.

### 7.2 Finance

A remarkable feature of Taiwan tea middlemen during the Japanese colonial era was their provision of farm credit. They often made loans in the winter for repayment in the next tea season. The auction house also provided loans to farmers, but these could be arranged only when crude tea arrived at the house and was restricted to 60% of the estimated value of the product. In no way was it a perfect substitute for loans provided by tea middlemen, and farmers continued to borrow from tea middlemen in spite of their higher interest rates.

Few trade limits were placed on farmers borrowing from tea middlemen. According to INVESTIGATION COMMITTEE OF OLD LAWS AND CUSTOMS IN FORMOSA [1905], farmers were obliged to sell crude tea to creditors only when their terms were equivalent to those of other tea middlemen. That means farmers could choose lenders and tea buyers separately.

It is worth noting that some later documents, such as DEPARTMENT OF SPECIAL PRODUCE, PRODUCTION DIVISION, GOVERNOR GENERAL [1935a], did report that some middlemen bought crude tea at a lower price from their debtors. However, this does not mean that tea middlemen forced farmers to trade with them by providing loans. The price difference might simply reflect the difference in interest rates or credit terms.

When knowledge about the tea market was costly, inefficient indirect trade may have survived because of the financial services provided. Those willing to borrow from tea middlemen at higher interest rates must have been rejected by lenders elsewhere. At that time most farmers were unable to provide adequate collateral for their loans, and repayment hinged upon sales of crude tea the following year. To avoid bad debts, creditors needed good information about the crude-tea market and local farmers. This was also required knowledge for tea middlemen. If the present value of future earnings from indirect trade exceeded the fixed investment in this knowledge, tea middlemen would acquire the knowledge and trade the tea. Even when the fixed

investment exceeded profits generated from indirect trade, tea middlemen could still exist, if and only if (1) apart from the information cost, the short-term profit from indirect trade was positive, and (2) the present value of short-term profits gained from both indirect trade and credit service exceeded the fixed cost of knowledge. Having acquired knowledge about both the crude-tea market and the individual farmers, tea middlemen did not need to make any additional investment to run their financial business. They naturally dominated the market for financial services to tea farmers.

Nowadays farmers can easily borrow from various credit institutions such as farmers' banks or cooperatives, because the information needed to make farm loans is readily available. Yet the indirect trade in crude tea still prevails. It can be inferred that intermediation is efficient in itself and the farmers' financial needs are no cause for crude tea to trade indirectly.

### 7.3 Insurance

Price fluctuation made crude-tea farming risky. If crude tea was sold to middlemen in the hills, price was a known constant when short-term production decisions – plucking and drying – were made. If instead the tea was sold at the auction house, the price was unknown and subject to change when these decisions were made. Hence farmers bore the risk of price volatility. However, the short-term price fluctuations in the crude-tea market seem to have been moderate. SASA [1928, pp. 477 and 488] calculated the 10-day-average market prices of crude oolong tea and crude pouchong tea, each subdivided into choice, medium, and inferior grades, and found the variations of that average were all smaller than 6% in six markets.

Long-term price risk, on the other hand, was often mitigated by futures trading. However, no documents mention such arrangements between farmers and tea middlemen. In fact, tea middlemen are not in a good position to bear the price risk, which is an aggregate risk and hard to diversify.<sup>11</sup>

## 8 Conclusion and Discussion

The literature of the Japanese colonial period described the intermediation in the crude-tea market as an unnecessary complication to traders, and the Taiwan Tea Common Market was established in expectation that it would simplify transactions and eliminate tea mingling as practiced by middlemen. This paper contests this view and argues that sorting was then the middlemen's main contribution to the trade. It helped save appraisal and search costs, which are shown to be large in our empirical study. Whereas the literature considered the job of a tea middleman to be transportation, finance, and insurance, our analysis shows these services can be provided by specialists as well; but once middlemen are called into service because of their sorting function, transportation and finance become natural by-products of their service.

<sup>11</sup> See KOO AND WANG [1999] for a discussion on insurance against an aggregate risk.

When middlemen pool products of different qualities to sell, allocative efficiency is lost and owners of higher-quality products may choose to sell individually for better prices, and this direct trade is especially likely to occur when quality is widely distributed. For example, in Taiwan, most paintings are sold through galleries and are priced with a standard formula according to paintings' sizes and painters' seniority and award records; while valuable paintings, which are often highly varied in price, are not assorted in this way for sale. They are priced individually in auction houses. In another instance, Kenya's coffee beans, renowned for high quality, are sold through a farmer-friendly auction. According to *Fresh Cup Magazine* (January 18, 2000), Kenya is the only country to employ such a system. KENNEY AND KLEIN [1983] also pointed out that though the Central Selling Organization of the De Beers group sorted diamond stones into more than 2,000 categories for sale, the variance in the value of stones within each category remained substantial. Thanks to a strict rule, buyers were not allowed to negotiate for an alternative offer or a price cut, and oversearching was thus avoided. However, large stones weighing more than 14.8 carats were dealt with differently. They were offered on a negotiated-price basis. How goods in general are separated into different marketing channels to trade is a question awaiting future research.

Lastly, we would like to suggest that the logic of this paper can be used to explain other market phenomena. Chain stores like Starbucks Coffee, and anonymous computer manufacturers working for Intel, are also sorted under one brand name. Without such classification, their individual transactions would incur substantial informational costs.

### References

- AGRICULTURE AND FORESTRY DIVISION, TAIWAN PROVINCE GOVERNMENT [1947], *Taiwan Agriculture Yearly*, Taipei.
- AKERLOF, G. A. [1970], "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism," *Quarterly Journal of Economics*, 84, 488–500.
- ASSEMBLY OF TAIWAN INDUSTRIAL COOPERATIVES [1929–1940], *Taiwan Industrial Cooperative Abstract*, Taipei.
- ASSEMBLY OF TAIWAN INDUSTRIAL COOPERATIVES, TAIPEI BRANCH [1928], *Taipei Chow Industrial Cooperative Abstract*, Taipei.
- BARZEL, Y. [1982], "Measurement Cost and the Organization of Markets," *Journal of Law and Economics*, 25, 27–48.
- BAUER, P., AND B. YAMEY [1954], "The Economics of Marketing Reform," *Journal of Political Economics*, 62, 210–235.
- BIGLAISER, G. [1993], "Middlemen as Experts," *RAND Journal of Economics*, 24, 212–223.
- COASE, R. H. [1960], "The Problem of Social Cost," *Journal of Law and Economics*, 3, 1–44.
- [1974], "The Lighthouse in Economics," *Journal of Law and Economics*, 17, 357–376.
- COMMITTEE OF AGRICULTURE PROMOTION, TAIWAN PROVINCIAL GOVERNMENT [1947], *Taiwan Tea Industry*, Taipei.
- COSIMANO, T. F. [1996], "Intermediation," *Economica*, 63, 131–143.
- DEPARTMENT OF SPECIAL PRODUCE, AGRICULTURE AND FORESTRY DIVISION, TAIWAN PROVINCE GOVERNMENT [1950], *Taiwan Tea Industry Statistics*, Taipei.
- DEPARTMENT OF SPECIAL PRODUCE, PRODUCTION DIVISION, GOVERNOR GENERAL [1929–1940], *Taiwan Tea Industry Statistics*, Taipei.

- [1935a], *A Survey of the Tea Industry by the Tropical Industry Investigation Committee*, Taipei.
- [1935b], *Taiwan Tea Industry*, Taipei.
- [1937], *Taiwan Tea Industry*, Taipei.
- GUILD OF FORMOSA TEA REFINERIES IN TAIPEI [1921–1929], *Business Report*, Taipei.
- [1943], *Formosa Tea Industry*, Taipei.
- INVESTIGATION COMMITTEE OF OLD LAWS AND CUSTOMS IN FORMOSA [1905], *Report of Surveyed Economic Data*, Vol. 1, Taipei.
- KENNEY, R. W., AND B. KLEIN [1983], "The Economics of Block Booking," *Journal of Law and Economics*, 26, 497–540.
- KOO, H. [2000], "The Estimates of Quantities and Product Values of Crude Tea and Refined Tea in Taiwan, 1896–1952," Working Paper, Department of Economics, National Taiwan University, Taipei.
- AND C. WANG [1999], "Indexed Pricing: Sugarcane Price Guarantees in Colonial Taiwan," *Journal of Economic History*, 59, 912–926.
- LI, Y. [1998], "Middlemen and Private Information," *Journal of Monetary Economics*, 42, 131–159.
- ROTHSCHILD, M. [1974], "Searching for the Lowest Price When the Distribution of Prices is Unknown," *Journal of Political Economy*, 82, 689–711.
- RUBINSTEIN, A., AND A. WOLINSKY [1987], "Middlemen," *Quarterly Journal of Economics*, 102, 581–593.
- SASA, H. [1928], *The Industries in Taiwan and their Transactions*, Tainan-New-Papers: Taipei.
- STATISTICS OFFICE, COMMITTEE FOR POST-WAR AIDS, TAIWAN BRANCH [1946], *Main Economic Statistics, Taiwan Province*, Taipei.
- SUZUKI, T. [1928], "The Improvement of the Tea Trading Method in Taiwan," *Literature of Tea Industry in the Japanese Colonial Taiwan (1995)*, 328–374.
- TAIWAN PROVINCIAL GOVERNMENT [1946], *Statistical Abstracts of the Past 51 Years*, Taipei.
- TILLY, R. H. [1986], "German Banking, 1850–1914: Development Assistance for the Strong," *Journal of European Economic History*, 15, 113–152.
- WU, T. [1991], "An Estimation of Taiwan's Gross Domestic Product: 1910–1950," *Taiwan Economic Review*, 19, 127–175.
- AND Y. GAU [1991], "An Empirical Study on Taiwan's Inflation and Money Growth," *Taiwan Economic Review*, 19, 23–71.
- YAVAS, A. [1994], "Middlemen in Bilateral Search Markets," *Journal of Labor Economics*, 12, 406–429.

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