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EXPEDITED RESEARCH ARTICLE

Estimating the degree of market power in the vegetable market in Japan

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Abstract
To adequately capture the market structure of vegetables in Japan, it is necessary to develop an oligopolistic model due to the potential market power of producers vs. retailers. We first estimate the market power between producers and retailers by extending the bilateral oligopoly model. Next, we evaluate the role of the wholesale market and its effect on economic welfare. Our results indicate that the wholesale market benefits both producers and consumers through a reduction in retail margins. This study contributes to the industrial organization literature by developing a bilateral oligopoly model and empirically measuring the wholesale market system in Japan.

Keywords: bilateral oligopoly; Japan; market power; vegetables; wholesale market

Introduction

The food supply change has been increasing in concentration over time. For example, in the European Union, the market share of the top 10 retailers increased from 26 percent in 2000 to 30.7 percent in 2011, while in the United States, the market share of the top 20 retailers has almost doubled since 1990, increasing from 35.0 percent in 1990 to 65.1 percent in 2019 (European Commission 2014; USDA ERS 2021). The downside of this higher market concentration is increasing market power by retailers (e.g., Suzuki and Kaiser 2006; Sexton 2013; OECD 2014; Bonanno, Russo, and Menapace 2018; Sexton and Xia 2018). Specifically, retailers exercise more market power by paying a lower purchase price from farmers and a higher selling price to consumers. This reduces both producer and social welfare (Bonanno, Russo, and Menapace 2018).

One potential solution to this problem is to establish a more vertical integration between retailers and producers through, for example, contract farming. However, in situations where there are only a few retailers, the market power of the retailers remains strong even under a more vertical integration. In such cases, small producers will likely remain at a disadvantage when entering into long-term relationships with retailers (Bonanno, Russo, and Menapace 2018). Furthermore, the empirical evidence shows that vertical integrations have not led to sufficiently higher producer prices (OECD 2014).

Another potential solution to mitigate retailers' market power is to increase reliance on wholesale markets. Wholesale markets are a type of intermediate market defined as "physical places where professional agents congregate to buy and sell products to other professionals" (Cadilhon et al. 2003). It has both physical (gathering the products in one place to help distribute the dispersed flow, storage, grading, and distribution) and economic functions (facilitating communication and competition among stakeholders, banking) (Cadilhon et al. 2003) and is considered to be beneficial especially for small-scale farmers (Dimitri and Gardner 2019; Reid, Simmonds, and Newbold 2019).

Wholesale markets are often established and monitored by public authorities. They exist in many countries such as the United States, France (Cadilhon et al. 2003), Netherlands (Reid, Simmonds, and Newbold 2019), and Japan. However, it is still unclear what effects the wholesale market systems have on economic welfare. The literature on the intermediate markets is often descriptive case studies, and there are few quantitative assessments. This study fills this gap by examining the effects of wholesale markets on market power and economic welfare in Japan, a country with a large presence of wholesale market systems.

More specifically, this study develops a bilateral oligopoly model to quantify Japan's vegetable market structure. The literature on the market power of food sectors typically assumes imperfect competition on either retailers or producers (Bonanno, Russo, and Menapace 2018), and several studies assume monopolies on both the retail and the producer sides. One exception is a study by Kinoshita, Suzuki, and Kaiser (2006, hereafter, KSK), who developed a model that allows monopolistic structures for retailers, manufacturers, and producers for the fluid milk sector. However, empirical studies on modeling bilateral oligopoly have been limited because the bilateral oligopoly model is challenging to estimate due to the difficulty in identifying multiple power parameters, which results in an instability of parameters (Azzam 1996; KSK). In this study, we propose an extended model of the KSK model, which allows us to uniquely identify vertical and horizontal market power parameters. Moreover, we apply a nonlinear programming method that reflects the theoretical constraints to address the parameter instability that still remains with our extended model. We then analyze the relationship between the wholesale market and market power for the vegetable market in Japan.

We find that the market power of producers is significantly smaller (0.293) than that of retailers (0.707). We then estimate the relationship between the vertical market power parameter and the sales share of the wholesale markets. The simulation results show that a higher share of products traded via the wholesale market reduces retailers' margin and increases producers' margin.

The rest of this article is organized as follows. First, we begin with a study of the background on the Japanese vegetable supply chain and a review of the related literature. This is followed by a discussion of the theoretical framework and empirical methods used to estimate the power parameter between producers and retailers. Next, the data used in the study are described, and the results of the study are presented. The final section discusses the implications of the results and offers some concluding remarks.

Background

Vegetable market and wholesale market in Japan

The average farm size in Japan is very small relative to many Western countries at 3.1 ha (MAFF 2021a). As a result, Japanese producers rely on cooperatives to collect and ship agricultural products (OECD 2014). In Japan, collection and shipment are coordinated by the prefecture-level producer cooperatives such as the Japan Agricultural Cooperative.[1] Rather than the producer negotiating on their own, producer cooperatives collect farm commodities at the prefecture level and ship to wholesalers (Higaki, Gunjal, and Coffin 2001), which have the advantage of increasing countervailing market power (Sexton and Xia 2018).

While average farm sizes remain small, production areas are becoming more concentrated in specific prefectures that enable local cooperatives to exercise market power (Matsuda and Kurokawa 1996). Therefore, the high market share of oligopolistic producer cooperatives is a vital policy concern in the vegetable market (MAFF 2021b). Table 1 provides the Hirschman–Herfindahl index (HHI) and the four-firm concentration ratio (CR4).[2] Based on the HHI, the producer side of the market appears to be reasonably competitive. However, both HHI and CR4 have increased over time for most items. Thus, there is a need to examine the possibility of increasing oligopolistic power on the producer side.

On the retail side of the vegetable market, the supermarket is the primary entity that sells to consumers. According to the report by the Organisation for Economic Co-operation and Development (OECD), the 5-firm concentration ratio in terms of sales in the retail food market is about 12 percent at the national level in Japan, which means low concentration at the national level. However, at the regional level, local supermarkets often have significant market shares (50 percent or more, Kojima and Fuchikawa 2010; OECD 2014).

The supply chain of vegetables is summarized in Figure 1. While some fresh vegetables are sold directly from producers to retailers or consumers, most are mainly sold through the wholesale market in Japan. In 2016, the latest data we have, the wholesale market accounted for almost 70 percent of fresh vegetables sold. Imported vegetables accounted for 21 percent of Japan's total vegetable supply in 2019. However, the majority (74 percent, MAFF 2019) of imports are processed vegetables rather than fresh vegetables. Therefore, we ignore imported vegetables in this study.

In the wholesale market in Japan, there are two players: one is the producer (seller), who cosigns their products to the wholesaler. The other is the retailer (buyer), who purchases the products from the wholesaler through the intermediate wholesaler. The Wholesale Market Act regulates vegetable trading in the wholesale market. Generally, the wholesale market in Japan sells vegetables, fruits, and seafood. This wholesale market system was established to increase the efficiency of domestic distribution in vegetables (Higaki, Gunjal, and Coffin 2001) by reducing transaction costs (Ichinose 2018). Vegetables sold at the Ota Market, one of the wholesale markets in Tokyo, creates a reference price for the domestic vegetable market (Byung and Nagaki 2006). At the wholesale market, both pair-wise trading and auction trading take place. Wholesalers approved by the local authority sell vegetables consigned by producers primarily through pair-wise trading. By the principle of prohibition of entrustment refusal in the Wholesale Market Act, wholesalers are restricted from manipulating the price

[1]Japan is divided for administrative purposes into 47 prefectures.

[2]The Japan Fair Trade Commission considers that the possibility as likely to raise competition concerns is low if HHI is less than 2,500 and market share is less than 35 percent based on the Antitrust Law.

Table 1. HHI and CR4 in 1992 and 2014

	1992		2014	
Items	HHI	CR4 (%)	HHI	CR4 (%)
Radish	513	36.35	683.2	43.21
Carrot	1,386	63.24	1548.4	65.04
Chinese cabbage	1,211	57.12	1719.7	63.87
Cabbage	665	43.08	916.3	52.43
Spinach	523	36.92	638.4	42.00
Leek	693	44.95	662.7	44.87
Eggplant	466	30.70	665.9	43.00
Tomato	428	30.85	655.2	40.32
Cucumber	464	35.19	533.3	36.43
Paprika	1,250	63.50	1322.7	64.78
Taro	961	54.83	808.1	49.30
Onion	2,911	77.50	4153.5	85.89
Lettuce	1,659	61.09	1649.0	64.95
Potato	7,070	91.69	7007.6	93.73

Source: MAFF (2014a) and Matsuda and Kurokawa (1996).
Notes: CR4 is the sum of market shares for the four largest producers at the prefecture level. CR4 ∈ (0, 100 percent]; HHI is the sum of the squared percentage shares for all 47 prefectures. HHI ∈ (0, 10, 000].
$\mathrm{HHI} = \sum_{k=1}^{47}\left(\frac{q_k}{\sum_{l=1}^{47} q_l} \times 100\right)^2$; $k,\ l \in \{1, \ldots 47\}$, where q_l is the production volume from the lth prefecture. The HHI in1992 is the Herfindahl index from Matsuda and Kurokawa (1996) multiplied by 1,000.

through quantity adjustments. To participate as a buyer, one must be registered as an intermediate wholesaler and gain approval from the local authority (Tokyo Central Wholesale Market 2021). The registered intermediate wholesalers are allowed to purchase products from the registered wholesaler in the wholesale market and resell them to buyers (retailers).

Previous market power studies

Many economists have examined issues of concentration, competition, and market power in the food supply chain. The New Industrial Organization (NEIO) framework has been widely used to investigate market power issues in agricultural industries (e.g., Schroeter 1988; Suzuki and Kaiser 2006; Lopez, He, and Azzam 2018). To date, several studies have investigated bilateral imperfect competition (e.g., Azzam 1996; Schroeter, Azzam, and Zhang 2000; Raper, Love, and Shumway 2000; Boetel and Liu 2010; Chung and Tostão 2012; Park, Chung, and Raper 2017). Azzam (1996) presents the bilateral oligopoly model to estimate the degree of vertical power balance at two stages.

Sexton and Xia (2018) argue that there are shortcomings in the estimation of market power parameters: (a) the conduct parameters may result in inaccurate market power measurements (Corts 1999), (b) the simplistic estimation of the identification methods

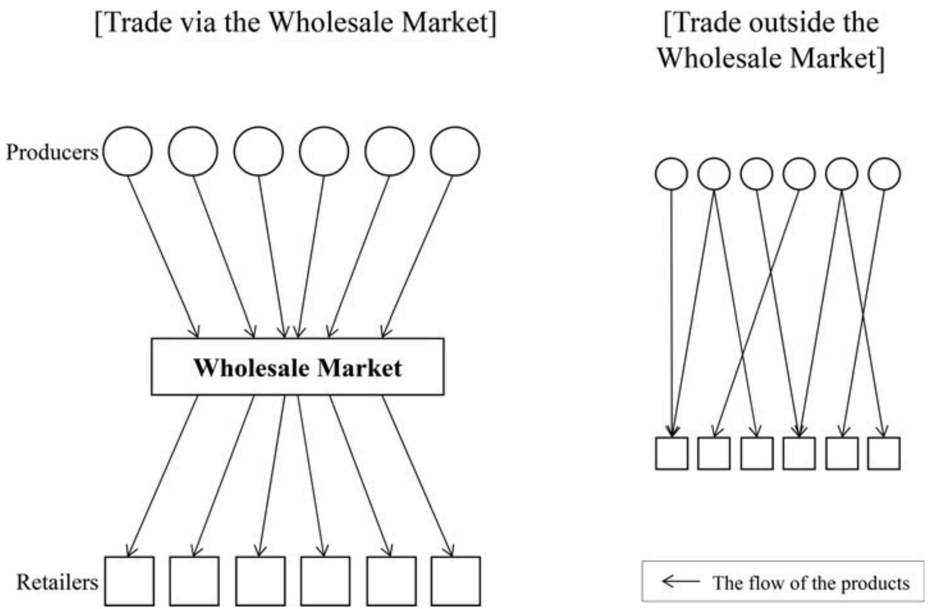

Figure 1. Flow of Vegetables in the Japanese Market.

due to the lack of data (e.g., Perekhozhuk et al. 2017), and (c) a data limitation, especially the lack of retailers' wholesale cost data. However, despite these criticisms, the original model by Azzam (1996) is still advantageous because the model is simple and highly extensible, requiring fewer data. Recently, this model has been applied to the US beef processors and retailers (Chung, Eom, and Yang 2014), the Belgian pork production chain (Maes, Vancauteren, and Van Passel 2019), and international trade of agricultural commodities (Yamaura and Xia 2016). In addition, KSK extended this model to simultaneously estimate the vertical and horizontal competition among three stages in the Japanese milk market.

In the vegetable market in Japan, rising concentration needs to be taken into account for the producer side due to the existence of large producer cooperatives. The oligopoly behavior on the producer side has been empirically estimated in the Japanese onion market (Matsuda and Kurokawa 1996) and potato market (Higaki, Gunjal, and Coffin 2001). Both studies have found that producers do not exert monopolistic power. However, these findings might be biased as the imperfect competition on the retailer side is not considered.

In this study, we develop and extend the bilateral oligopoly approach pioneered by KSK to estimate the market power in the vegetable market in Japan. Specifically, KSK did not take the retailers' marginal variable costs into account, but we do. This study adopts an economic model of a vertical and horizontal relationship between producers and retailers that considers the retailers' marginal cost, which enables the derivation of the unique parameter.

Theoretical framework

Setup

Consider two players in the wholesale market. The sellers are producer cooperatives, while the buyers are retailers (e.g., supermarkets). We assume imperfect competition for both buyers and sellers. In this model, price is determined by the "vertical power balance." Furthermore, the model assumes that there exists an upper limit and lower limit on the price. The upper limit is the maximum price the producer cooperatives can extract from retailers, while the lower limit is the minimum price the retailers can extract from cooperatives. For instance, if cooperatives have market power over retailers, the price should be closer to the upper-limit level.

Here, we define that PW^{U} as the maximum price on the producer side and PW^{L} as the minimum price on the retailer side in terms of the range of price formation. The maximum price and the minimum price denote the limit of the possible value range of the wholesale price. With the introduction of vertical power parameters relative to producers, we can express the actual wholesale price as follows:

$$\mathrm{PW} = \omega \mathrm{PW}^{\mathrm{U}} + (1 - \omega)\mathrm{PW}^{\mathrm{L}}. \tag{1}$$

Consequently, the producers' degree of vertical power parameters relative to the retailers' ω is 1 when the producers possess a completely dominant vertical market power. The formation of the maximum price PW^{U} also considers a horizontal market power parameter, θ, that indicates the producers' degree-of-horizontal-competition parameter, which ranges from zero to one, described in equation (5). The formation of the minimum price PW^{L} takes into account a horizontal market power parameter, λ, that indicates the retailers' degree-of-horizontal-competition parameter, which ranges from zero to one, described in equation (9). Following Azzam (1996), our study defines the maximum price as the seller monopoly price and the minimum price as the buyer monopsony price.

Here, we make the following assumptions:

Assumption 1: This study models vegetable producers at the prefecture level following Higaki, Gunjal, and Coffin (2001). As mentioned in the section "Vegetable market and wholesale market in Japan", the producer cooperatives collect and ship produce consigned by producers at the prefecture level. Following Matsuda and Kurokawa (1996), the degree of horizontal power parameter measures the competition/coordination relationship mainly among prefectures as production units on vegetable pricing. Therefore, this article considers the market power of producers as the producers' collective power, not the market power of individual producers.

Assumption 2: Because of the Wholesale Market Act and the regulation in each market, wholesalers and intermediate wholesalers cannot manipulate the price and the quantity.

Assumption 3: We assume that all vegetables are homogeneous products among the producers at the prefecture level, to focus on not product differentiation but competition in the vegetable market in Japan. Because of the limitation of sellers' and buyers' transaction data, our model estimates the market power parameters using aggregated market data. This differs from the concept of bargaining power, which considers product differentiation (e.g., Bonnet and Bouamra-Mechemache 2016).

Assumption 4: We assume that the degree of oligopolistic power measures the deviation from purely monopolistic and competitive behavior modes (Appelbaum 1982).

Theoretical model

The theoretical model extended from KSK begins with the formulation of price-setting behavior at the producer cooperative level. When producer cooperatives sell vegetables to retailers at the wholesale market, profit for the producer side is given by

$$\max_{Q} \pi_{i,t} = \mathrm{PW}_{i,t} Q_{i,t} - \mathrm{TC}^{\mathrm{P}}_{i,t}, \tag{2}$$

where $\mathrm{PW}_{i,t} = \mathrm{PW}(Q_{i,t})$ is the wholesale price of the product i at the period t, $Q_{i,t}$ is the quantity of the product i to sell, and $\mathrm{TC}^{\mathrm{P}}_{i,t}$ is the total cost of producers.

The first-order condition for profit maximization with the producers who have market power can be rewritten as follows:

$$\mathrm{PW}_{i,t}\left(1 - \frac{1}{\eta^{\mathrm{P}}_{i}}\right) = \mathrm{MC}^{\mathrm{P}}_{i,t}, \tag{3}$$

where $\mathrm{MC}^{\mathrm{P}}_{i,t}$ is the producers' marginal cost, and η^{P}_{i} is the absolute value of the product i's price elasticity of demand faced with producers. This study follows the framework of KSK, Azzam (1996), and Matsuda and Kurokawa (1996); hence, the price elasticity of demand is assumed to be constant.

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By introducing the degree-of-competition parameter $\theta_{i,t}$ with $0 \leq \theta_{i,t} \leq 1$, equation (3) can be generalized as follows:

$$\mathrm{PW}_{i,t}\left(1 - \frac{\theta_{i,t}}{\eta_i^{\mathrm{p}}}\right) = \mathrm{MC}_{i,t}^{\mathrm{p}}, \tag{4}$$

where $\theta_{i,t}$ denotes the producers' degree-of-horizontal-competition parameter following KSK. Equation (4) expresses the oligopoly market between perfect competition and monopoly. If $\theta_{i,t}$ is equal to 1, the producer side acts as a monopolist; if $\theta_{i,t}$ is equal to zero, the market is characterized by perfect competition.

In equation (2), we assume that the vertical power balance between producer cooperatives and retailers is 1:0. Hence, $\mathrm{PW}_{i,t}$, wholesaler price in equation (4), denotes the upper price at which producer cooperatives can sell to retailers. PW^{U} denote the upper price in the wholesale market:

$$\mathrm{PW}_{i,t}^{\mathrm{U}} = \frac{\mathrm{MC}_{i,t}^{\mathrm{p}}}{\left(1 - \frac{\theta_{i,t}}{\eta_i^{\mathrm{p}}}\right)}. \tag{5}$$

Next, consider the retail level. When retailers buy vegetables from producer cooperatives at the wholesale market, the profit of the retailer side is given by

$$\max_{Q} \pi_{i,t} = (\mathrm{PR}_{i,t} - \mathrm{PW}_{i,t})Q_{i,t} - \mathrm{TC}_{i,t}^{\mathrm{r}}, \tag{6}$$

where $\mathrm{PW}_{i,t} = \mathrm{PW}(Q_{i,t})$ is the purchase price of the product i at the period t, $\mathrm{PR}_{i,t} = \mathrm{PR}(Q_{i,t})$ is the retail price, $Q_{i,t}$ is the quantity of the product i to buy, and $\mathrm{TC}_{i,t}^{\mathrm{r}}$ is the total cost of retailers.

The first-order condition for profit maximization with the retailers who have monopsony power can be rewritten as follows:

$$\mathrm{PR}_{i,t}\left(1 - \frac{1}{\eta_i^{\mathrm{r}}}\right) = \mathrm{PW}_{i,t}\left(1 + \frac{1}{\varepsilon_i}\right) + \mathrm{MC}_{i,t}^{\mathrm{r}}, \tag{7}$$

where $\mathrm{MC}_{i,t}^{\mathrm{r}}$ is the retailers' marginal cost for selling and η_i^{r} is the absolute value of the price elasticity of demand faced with retailers. Subsequently, ε_i is the absolute value of the price elasticity of supply faced with retailers. While KSK estimated the range of power parameters, our approach identifies the parameter uniquely by considering both V^{r} and PR in the theoretical model.

Following the framework of KSK, Azzam (1996), and Matsuda and Kurokawa (1996), the price elasticity of supply is also assumed to be constant.

By introducing the degree-of-competition parameter $\lambda_{i,t}$ with $0 \leq \lambda_{i,t} \leq 1$, equation (7) can be generalized as follows:

$$\mathrm{PR}_{i,t}\left(1 - \frac{\lambda_{i,t}}{\eta_i^{\mathrm{r}}}\right) = \mathrm{PW}_{i,t}\left(1 + \frac{\lambda_{i,t}}{\varepsilon_i}\right) + \mathrm{MC}_{i,t}^{\mathrm{r}}, \tag{8}$$

where $\lambda_{i,t}$ is the retailers' horizontal-competition parameter and $0 \leq \lambda_{i,t} \leq 1$. Equation (8) expresses the oligopoly market between perfect competition and monopoly.

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In this study, we assume that the competition intensity in a wholesale market is equal to that in a retail market based on assumption 2.[3]

In equation (6), we assume that the vertical power balance between retailers and producer cooperatives is 1:0. Hence, $PW_{i,t}$, purchase price in equation (8), denotes the lower price at which retailers can buy from producers. PW^{L} denotes the lower price in the wholesale market:

$$PW^{L}_{i,t} = \frac{PR_{i,t}\left(1 - \frac{\lambda_{i,t}}{\eta^{r}_{i}}\right) - MC^{r}_{i,t}}{\left(1 + \frac{\lambda_{i,t}}{\varepsilon_{i}}\right)}. \tag{9}$$

Let the actual price at the wholesale market in Japan be set between the upper price and the lower price by the market power of producers and retailers. Taking into account the above relations of (5) and (9) enables us to rewrite equation (1) into the practical trading price equation at the wholesale market as follows:

$$PW_{i,t} = \omega_{i,t} PW^{U}_{i,t} + (1 - \omega_{i,t}) PW^{L}_{i,t}, \tag{10}$$

where $\omega_{i,t}$ is the product i's vertical power parameter between producers and retailers at the period t ($0 \leq \omega_{i,t} \leq 1$). Equation (10) is consistent with the theoretical consequences of the generalized Nash bargaining model of Prasertsri and Kilmer (2008).

Therefore,

$$PW_{i,t} = \omega_{i,t} \frac{MC^{p}_{i,t}}{\left(1 - \frac{\theta_{i,t}}{\eta^{w}_{i}}\right)} + (1 - \omega_{i,t}) \frac{PR_{i,t}\left(1 - \frac{\lambda_{i,t}}{\eta^{r}_{i}}\right) - MC^{r}_{i,t}}{\left(1 + \frac{\lambda_{i,t}}{\varepsilon_{i}}\right)}. \tag{11}$$

Following KSK, we assume that $TC = VQ + F$, where TC is the total cost, V is the average variable cost, F is the fixed cost, and Q is the quantity of the product. In this case, the producers' marginal cost $MC^{p}_{i,t}$ is equal to V^{p}. For the retailers' marginal cost, KSK assumed that the retailers' marginal cost MC^{r} is equal to zero because most milk retail costs can be considered as fixed costs. In this study, however, MC^{r} is equal to V^{r} due to vegetables' packaging and shipment fees, assuming no economies of scale. Like KSK, we also assume that the demand elasticity in the wholesale markets and the demand elasticity in the retail markets are the same; $\eta^{p}_{i} = \eta^{r}_{i} = \eta_{i}$. It is also assumed that the elasticities of price η_{i} and ε_{i} are constant to simplify the estimation. For instance, if this assumption is relaxed, η_{i} increases or ε_{i} increases, $\omega_{i,t}$ decreases (see Appendix B for more details).

[3]In the Japanese situation, this assumption is reasonable because our data are at the prefecture level, and intermediate wholesalers cannot manipulate the price and the quantity from assumption 2. In Appendix A, the implication of this assumption is investigated. As the wholesale market has fewer participants, the competition intensity in a wholesale market could be larger than that in a retail market. In this case, the producers' market power (ω) will be larger, not affecting our qualitative conclusions.

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Rewriting equation (11) yields

$$\mathrm{PW}_{i,t} = \omega_{i,t}\frac{V^{\mathrm{p}}_{i,t}}{\left(1-\frac{\theta_{i,t}}{\eta_i}\right)} + (1-\omega_{i,t})\frac{\mathrm{PR}_{i,t}\left(1-\frac{\lambda_{i,t}}{\eta_i}\right) - V^{\mathrm{r}}_{i,t}}{\left(1+\frac{\lambda_{i,t}}{\varepsilon_i}\right)}, \tag{12}$$

where

$$0 \le \omega_{i,t} \le 1,\ 0 \le \theta_{i,t} \le 1,\ 0 \le \lambda_{i,t} \le 1. \tag{13}$$

In equation (12), while KSK assumes that $V^{\mathrm{r}}_{i,t} = 0$, we relax this assumption and extend the model to include both V^{r} and PR. This allows us to uniquely obtain market power parameters instead of obtaining a range of parameters as in KSK. However, equation (12) has two theoretically similar parameters, which can lead to multicollinearity problems (see Appendix C for more details). Thus, we use a nonlinear programming method, as described below, instead of regression methods in this study.

With constraints (13), and $\mathrm{PW}^{\mathrm{U}}_{i,t}$ from equation (5) and $\mathrm{PW}^{\mathrm{L}}_{i,t}$ from equation (9) should be positive and $\mathrm{PW}^{\mathrm{U}}_{i,t}$ should be larger than $\mathrm{PW}^{\mathrm{L}}_{i,t}$, a range of values can be examined by adding the following constraints:

$$\begin{gathered} 0 \le \omega_{i,t} \le 1\ ,\ 0 \le \theta_{i,t} \le \eta_i,\ 0 \le \lambda_{i,t} \le \eta_i, \\ \frac{\mathrm{PR}_{i,t}\left(1-\frac{\lambda_{i,t}}{\eta_i}\right) - V^{\mathrm{r}}_{i,t}}{\left(1+\frac{\lambda_{i,t}}{\varepsilon_i}\right)} \le \frac{V^{\mathrm{p}}_{i,t}}{\left(1-\frac{\theta_{i,t}}{\eta_i}\right)}. \end{gathered} \tag{14}$$

Accordingly, this model estimates the degree of vertical power balance between producers and retailers based on the degree of horizontal competition in each stage of the market. The degree of power balance can be obtained as a mean value in the designed period through this method.

Empirical framework

Data

We use annual data for the period 2007–2014 for 14 vegetables: radish, carrot, Chinese cabbage, cabbage, spinach, leek, eggplant, tomato, cucumber, paprika, taro, onion, lettuce, and potato, shown in Table 2. These 14 vegetables are chosen because the producers' and retailers' cost data are available for the 14 vegetables from the MAFF's survey. Annual data are used since seasonal fluctuations are stronger at the daily, weekly, monthly, or even quarterly levels. Further, producers' and retailers' cost data are available only at the annual level. Data on wholesale prices, retail prices, and retail variable costs are aggregated from Tokyo, representing the consumption area. The producer variable costs are at the prefecture-level data.

The wholesale price PW is based on the average wholesale price from the "Market Statistics" (Tokyo Metropolitan Government 2021) collected by the Metropolitan Central Wholesale Market of the Tokyo Metropolitan Government. We use the average wholesale price (yen/kg) each year for the 14 items.

Table 2. Descriptive statistics for prices and variable costs by items

Items	Variable	Mean	St. Dev.	Observations
Total	PR	466.33	228.16	112
	Vr	4.00	2.32	
	PW	220.67	126.95	
	Vp	60.17	32.36	
Radish	PR	154.88	12.71	8
	Vr	1.57	0.16	
	PW	82.13	8.34	
	Vp	25.81	1.06	
Carrot	PR	349.00	25.00	8
	Vr	2.53	0.22	
	PW	128.63	14.94	
	Vp	45.81	1.89	
Chinese cabbage	PR	187.13	11.38	8
	Vr	1.25	0.11	
	PW	62.88	6.10	
	Vp	25.74	1.06	
Cabbage	PR	172.50	15.04	8
	Vr	1.36	0.20	
	PW	87.13	9.34	
	Vp	29.50	1.22	
Spinach	PR	800.75	50.23	8
	Vr	8.03	1.02	
	PW	468.25	41.86	
	Vp	136.87	5.64	
Leek	PR	557.88	39.82	8
	Vr	5.81	0.69	
	PW	272.38	25.20	
	Vp	81.33	3.35	
Eggplant	PR	611.50	27.91	8
	Vr	5.58	0.90	
	PW	326.75	20.25	
	Vp	68.86	2.84	
Tomato	PR	652.75	25.46	8
	Vr	5.56	0.70	

(*Continued*)

Table 2. (*Continued.*)

Items	Variable	Mean	St. Dev.	Observations
	PW	342.25	28.54	
	Vp	89.08	3.67	
Cucumber	PR	547.13	18.07	8
	Vr	4.13	0.67	
	PW	289.13	16.66	
	Vp	56.13	2.31	
Paprika	PR	858.63	37.58	8
	Vr	7.55	0.76	
	PW	382.25	32.17	
	Vp	92.70	3.82	
Taro	PR	630.38	56.95	8
	Vr	5.60	0.64	
	PW	257.38	26.22	
	Vp	70.15	2.89	
Onion	PR	232.00	22.92	8
	Vr	1.79	0.28	
	PW	99.38	16.41	
	Vp	27.98	1.15	
Lettuce	PR	460.38	31.48	8
	Vr	2.76	0.23	
	PW	166.75	13.31	
	Vp	70.77	2.92	
Potato	PR	313.75	26.74	8
	Vr	2.49	0.49	
	PW	124.13	23.03	
	Vp	21.59	0.89	

Note: The unit of dependent variables is JPY per kilogram. 100 yen = 0.92 US dollars in 2007.

The retail price PR is obtained from the "Retail Price Survey" (MIC 2014) from the MIC.

Producer variable costs V^p are based on the "Management Statistics Survey by Item" from the "Agricultural Management Statistics Survey" (MAFF 2013) obtained by the MAFF. Producer variable costs are the average value for several production areas based on this survey[4] and are calculated by dividing the agricultural fluid cost in

[4]The number of production areas for items is as follows: seven prefectures for radish, six prefectures for carrot, three prefectures for Chinese cabbage, eight prefectures for cabbage, five prefectures for spinach, seven prefectures for leek, seven prefectures for eggplant, three prefectures for tomato, three prefectures

each fiscal year by the sales volume (per household). To transform into real values, we use the material price index from the "Statistical Survey on Prices in Agriculture" (MAFF 2014b) in 2007 as the base year.

Retail variable costs V^{r} are taken from the "Price Formation Survey by Food Distribution Stage" (MAFF 2017) from MAFF each year. Retail variable costs are measured as the packaging material costs and payment fare for each vegetable. The MAFF conducts this survey on distributive costs from three market levels: producers, wholesalers, and retailers. To obtain the price per unit of weight, we multiplied the total retail costs by the ratio of retail variable cost per retailer. The total retail cost is based on the retail cost of the "Price Formation Survey by Food Distribution Stage." In the survey, the MAFF conducts preliminary calculations of the distribution expense at three stages on 14 vegetables per 100 kg. The ratio of retail variable cost per retailer is calculated by dividing the sum of packaging material costs and payment fare by retail costs from each year of the "Price Formation Survey by Food Distribution Stage."

The price elasticities of demand and supply come from Nagakubo et al. (2018) and are listed in Table 3.

The sales ratio of products via the wholesale markets is calculated by dividing the wholesale quantity shipped to the wholesale market by the gross domestic product (Table 4). When the value is greater than 1, it is set to 1. The wholesale quantity is based on annual statics of the wholesale quantity of vegetables from the "Fruit and Vegetable Wholesale Market Research" (MAFF 2014c). We use a total quantity for 14 items shipped to all wholesale markets in Japan. We use the gross domestic product data for 14 items from the "Food Balance Sheet" (MAFF 2014d).

The concentration ratio of production is based on the "Crop Survey" (MAFF 2014e). Following Matsuda and Kurokawa (1996), we use the market share of the top four prefectures as the concentration ratio.

Model estimation

Market power in the vegetable market

Although KSK estimates power parameters $\omega_{i,t}$, $\theta_{i,t}$, and $\lambda_{i,t}$ by regressions, we use a nonlinear programming model to reflect parameter constraints explicitly. That is, there should be a constraint on the upper and lower limits of parameters, as shown in Table 5. Another advantage of nonlinear programming is that the model is applicable even when some variables are highly correlated that could cause multicollinearity problems using the conventional regression approach (Judd, Maliar, and Maliar 2011).

The estimated value of PW can be calculated from Equation (12) as follows:

$$\widehat{\mathrm{PW}}_{i,t} = \omega_{i,t}\frac{V^{\mathrm{p}}_{i,t}}{\left(1-\frac{\theta_{i,t}}{\eta_i}\right)} + (1-\omega_{i,t})\frac{\mathrm{PR}_{i,t}\left(1-\frac{\lambda_{i,t}}{\eta_i}\right)-V^{\mathrm{r}}_{i,t}}{\left(1+\frac{\lambda_{i,t}}{\varepsilon_i}\right)}. \tag{12'}$$

for cucumber, three prefectures for paprika, four prefectures for taro, four prefectures for onion, five prefectures for lettuce, and three prefectures for potato.

Table 3. Price elasticity of demand and supply

Items	Price elasticity of supply (ϵ)	Price elasticity of demand (η)
Radish	0.083	0.132
Carrot	0.851	0.169
Chinese cabbage	0.221	0.063
Cabbage	0.061	0.112
Spinach	0.225	0.443
Leek	0.410	0.138
Eggplant	0.558	0.691
Tomato	0.749	0.489
Cucumber	2.686	0.359
Paprika	0.638	0.355
Taro	0.527	0.220
Onion	0.699	0.270
Lettuce	0.215	0.220
Potato	0.177	0.218

Source: Nagakubo et al. (2018)
Note: η is the absolute value.

Similarly, the estimated values of PR, V^{p}, and V^{r} are calculated from equation (12) as follows:

$$\widehat{\mathrm{PR}}_{i,t} = \frac{1}{\left(1-\frac{\lambda_{i,t}}{\eta_i}\right)}\left\{\frac{1}{(1-\omega_{i,t})}\left(1+\frac{\lambda_{i,t}}{\varepsilon_i}\right)\left[\mathrm{PW}_{i,t}-\omega_{i,t}\frac{V^{\mathrm{p}}_{i,t}}{\left(1-\frac{\theta_{i,t}}{\eta_i}\right)}\right]+V^{\mathrm{r}}_{i,t}\right\},$$

$$\widehat{V^{\mathrm{p}}_{i,t}} = \frac{\left(1-\frac{\theta_{i,t}}{\eta_i}\right)}{\omega_{i,t}}\left[\mathrm{PW}_{i,t}-(1-\omega_{i,t})\frac{\mathrm{PR}_{i,t}\left(1-\frac{\lambda_{i,t}}{\eta_i}\right)-V^{\mathrm{r}}_{i,t}}{\left(1+\frac{\lambda_{i,t}}{\varepsilon_i}\right)}\right], \qquad (12'')$$

$$\widehat{V^{\mathrm{r}}_{i,t}} = -\left\{\frac{1}{(1-\omega_{i,t})}\left(1+\frac{\lambda_{i,t}}{\varepsilon_i}\right)\left[\mathrm{PW}_{i,t}-\omega_{i,t}\frac{V^{\mathrm{p}}_{i,t}}{\left(1-\frac{\theta_{i,t}}{\eta_i}\right)}\right]-\mathrm{PR}_{i,t}\left(1-\frac{\lambda_{i,t}}{\eta_i}\right)\right\}.$$

For 14 vegetables within each period, the estimated value of the price and cost was simultaneously calculated from the sets of parameters. As the optimum value for 14 vegetables, respectively, we selected the combination of parameters that had the smallest

Table 4. Descriptive statistics for the sales ratio of products traded via the wholesale markets and concentration ratio of production

	Sales ratio of products traded via wholesale markets		Concentration ratio of production		
Items	Mean	St. Dev.	Mean	St. Dev.	Observations
Total	0.784	0.227	0.561	0.171	112
Radish	0.693	0.016	0.456	0.072	8
Carrot	1.000	0.000	0.653	0.004	8
Chinese cabbage	0.964	0.019	0.627	0.014	8
Cabbage	0.987	0.017	0.527	0.005	8
Spinach	0.508	0.043	0.405	0.012	8
Leek	0.682	0.032	0.453	0.002	8
Eggplant	0.816	0.045	0.407	0.011	8
Tomato	0.680	0.022	0.362	0.024	8
Cucumber	0.892	0.008	0.387	0.009	8
Paprika	1.000	0.000	0.644	0.006	8
Taro	0.478	0.051	0.502	0.016	8
Onion	0.985	0.023	0.856	0.007	8
Lettuce	1.000	0.000	0.638	0.019	8
Potato	0.292	0.014	0.937	0.002	8

sum of the difference between the actual price and cost and the estimated value of the price and cost given as

$$\text{sum of difference} = \left(\frac{\widehat{\mathrm{PW}_{i,t}} - \mathrm{PW}_{i,t}}{\mathrm{PW}_{i,t}}\right)^2 + \left(\frac{\widehat{V^{\mathrm{p}}_{i,t}} - V^{\mathrm{p}}_{i,t}}{V^{\mathrm{p}}_{i,t}}\right)^2 + \left(\frac{\widehat{\mathrm{PR}_{i,t}} - \mathrm{PR}_{i,t}}{\mathrm{PR}_{i,t}}\right)^2 + \left(\frac{\widehat{V^{\mathrm{r}}_{i,t}} - V^{\mathrm{r}}_{i,t}}{V^{\mathrm{r}}_{i,t}}\right)^2. \tag{15}$$

The nonlinear programming solves the following minimization problem for each period t and the product i:

$$\min \text{sum of difference} = \left(\frac{\widehat{\mathrm{PW}_{i,t}} - \mathrm{PW}_{i,t}}{\mathrm{PW}_{i,t}}\right)^2 + \left(\frac{\widehat{V^{\mathrm{p}}_{i,t}} - V^{\mathrm{p}}_{i,t}}{V^{\mathrm{p}}_{i,t}}\right)^2 + \left(\frac{\widehat{\mathrm{PR}_{i,t}} - \mathrm{PR}_{i,t}}{\mathrm{PR}_{i,t}}\right)^2 + \left(\frac{\widehat{V^{\mathrm{r}}_{i,t}} - V^{\mathrm{r}}_{i,t}}{V^{\mathrm{r}}_{i,t}}\right)^2,$$

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Table 5. Lower and upper limits of the parameters

Items	ω		θ		λ	
	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
Radish	0	1	0	0.132	0	0.132
Carrot	0	1	0	0.169	0	0.169
Chinese cabbage	0	1	0	0.063	0	0.063
Cabbage	0	1	0	0.112	0	0.112
Spinach	0	1	0	0.443	0	0.443
Leek	0	1	0	0.138	0	0.138
Eggplant	0	1	0	0.691	0	0.691
Tomato	0	1	0	0.489	0	0.489
Cucumber	0	1	0	0.359	0	0.359
Paprika	0	1	0	0.355	0	0.355
Taro	0	1	0	0.220	0	0.220
Onion	0	1	0	0.270	0	0.270
Lettuce	0	1	0	0.220	0	0.220
Potato	0	1	0	0.218	0	0.218

$$\text{s.t. } 0 \le \theta_{i,t} \le \eta_i,\ \ 0 \le \lambda_{i,t} \le \eta_i,\ \ 0 \le \omega_{i,t} \le 1,$$
$$\frac{\mathrm{PR}_{i,t}\left(1-\dfrac{\lambda_{i,t}}{\eta_i}\right) - V^{\mathrm{r}}_{i,t}}{\left(1+\dfrac{\lambda_{i,t}}{\varepsilon_i}\right)} \le \frac{V^{\mathrm{p}}_{i,t}}{\left(1-\dfrac{\theta_{i,t}}{\eta_i}\right)}, \tag{16}$$

which is derived from equations (14) and (15). The initial values for the power parameters are taken from the range in steps of 0.1. By solving this model, we can derive the power parameters $\omega_{i,t}$, $\theta_{i,t}$, and $\lambda_{i,t}$.

Vertical power parameters

After deriving the vertical power parameter ω through solving the nonlinear programming model, we investigate the determinants of ω using Ordinary Least Squares (OLS). Specifically, we estimate the following equation using OLS:

$$\omega_{i,t} = \beta_0 + \beta_1 \text{via the wholesale markets}_{i,t} + \beta_2 \text{top4}_{i,t} + \beta_3 d_{2011} + \beta_4 d_{2012} + \beta_5 \text{item}_i + u. \tag{17}$$

For equation (17), we identify the following independent variables that are hypothesized to impact the vertical market power parameter for each product i in time period t: *via*

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the wholesale markets is the sales ratio of products traded in the wholesale markets relative to all markets, top4 is the market concentration ratio of the top four producers, d_{2011} and d_{2012} are time dummy variables for the time period of the Tohoku earthquake in 2011 and an emergency demand and supply adjustment performed by the MAFF in 2012 due to the price decline (MAFF 2012), and item$_i$ is the dummy variable for the product i.

Simulation

Finally, we assess the performance of the wholesale market system by simulating two scenarios. In Scenario 1, we simulate the change of the wholesale price when the sales ratio via the wholesale market increases (decreases). In other words, we simulate the wholesale price change if more (less) amounts of products are sold via the wholesale market. In Scenario 1, the retail price, producer variable cost, and retail variable cost are constant. In Scenario 2, we simulate the retail price and margin changes, assuming that the wholesale price changes by a fixed amount. We define the retail margin as a difference between the retail price and the wholesale price. The change in wholesale price in Scenario 2 is based on the result in Scenario 1.

Results

Market power in the vegetable market

Table 6 reports the estimated degree of vertical and horizontal power balance obtained from the nonlinear programming model. The first column of Table 6 suggests that the producer cooperatives have a relatively weaker vertical power balance relative to retailers (ω) for 13 vegetables, except for eggplant. For example, the power balance between producers and retailers is 0.293:0.707 for all 14 items on average. The producer cooperative–retailer power balance ranges from a low of 0.156:0.844 for lettuce to a high of 0.519:0.481 for eggplant. These results coincide with the results of Matsuda and Kurokawa (1996) and Higaki, Gunjal, and Coffin (2001), who find that there is no oligopolistic behavior on the producer cooperative side, even though cooperatives are highly concentrated; for example, potato producers have a CR4 of 93.7 percent (In 2014, the largest prefecture produced around 2 million ton, while the fourth largest 40,000 ton.) and onion producers 85.9 percent (700,000 and 30,000 tons, respectively).

Furthermore, the horizontal power balance of producer cooperatives (θ) and retailers (λ), shown in Table 6, is relatively lower in total, except for eggplant. This shows that the horizontal relationship between cooperatives and retailers is relatively competitive. However, the result from this model does not tell us why this is the case but rather quantifies the power balance outcome in terms of its position within the price range.

Vertical power parameters

Table 7 provides the results of the OLS regression. None of the variables in equation (17) are statistically significant except for the sales ratio of products traded via the wholesale level, which is positive and statistically significant at 10 percent level. Interestingly, the vertical power parameter decreases by 0.091 as the sales ratio of products traded via the wholesale markets drops by 10 percent. This result indicates that the cooperatives' market power is strengthened by selling via the wholesale market.

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Table 6. Estimation result of producers' market power (2007–2014)

	ω		θ		λ		
Items	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Observations
Total	0.293	0.153	0.241	0.146	0.184	0.119	112
Radish	0.396	0.083	0.114	0.002	0.101	0.008	8
Carrot	0.300	0.200	0.137	0.013	0.130	0.017	8
Chinese cabbage	0.190	0.019	0.053	0.007	0.051	0.006	8
Cabbage	0.214	0.065	0.098	0.013	0.089	0.025	8
Spinach	0.241	0.107	0.376	0.032	0.176	0.100	8
Leek	0.301	0.199	0.118	0.009	0.099	0.022	8
Eggplant	0.519	0.116	0.602	0.005	0.505	0.127	8
Tomato	0.328	0.216	0.415	0.009	0.279	0.097	8
Cucumber	0.296	0.083	0.314	0.005	0.199	0.009	8
Paprika	0.245	0.147	0.315	0.005	0.226	0.059	8
Taro	0.276	0.073	0.199	0.006	0.194	0.014	8
Onion	0.375	0.170	0.227	0.010	0.187	0.022	8
Lettuce	0.156	0.066	0.201	0.010	0.186	0.018	8
Potato	0.265	0.120	0.203	0.004	0.151	0.045	8

Table 7: Estimation results of the vertical power parameter

Variable	OLS
Via the wholesale markets	0.910*
	[−0.513]
top 4	−0.274
	[−0.637]
d2011	0.039
	[0.038]
d2012	0.033
	[0.041]
Constant	−0.119
	[−0.468]
Item Dummy	Yes
Observations	112
adj. R^2	0.259

Notes: Standard errors in parentheses.
* $p < 0.1$.

Simulation

Two scenarios are simulated to understand how the sales ratio of products traded via the wholesale markets affects the price change. First, we simulate the average price change for 14 vegetables using the result of ω, as the vertical power parameter from Table 6.

The first step in the simulation process is to find the link between the wholesale price and the sales ratio of products traded via the wholesale market, while the other price and variable cost data and the value of θ and λ are fixed (Scenario 1). The second step is to identify the change in retail price and retail margin, based on the first simulation result, while the other data are fixed (Scenario 2). We assume that a 10 percent reduction in the sales ratio of products traded via the wholesale markets equals a 0.09 decrease in ω, which is based on the result from the regression presented in Table 7. The 14 vegetables' mean prices and mean costs in total described in Table 2 and 14 vegetables' mean values of θ and λ in total described in Table 6 were used in the simulations.

(1) Scenario 1

Figure 2 shows the change in the wholesale price when the sales ratio of products traded via the wholesale market changes. The results suggest that the wholesale price decreases and retail margin increases for every ten percentage point decrease in the sales ratio of products traded via the wholesale markets. For the entire range, when the sales ratio of products traded in the wholesale market declines from 78.4 percent to 48.4 percent, the wholesale price falls by 42.9 percent, which averages to 1.4 percent for every one percentage point decrease. The retail margin rises by 37.5 percent or 1.2 percent for every one percentage point decrease.

(2) Scenario 2

Next, we simulate the retail margin on the condition that the wholesale price decreases when the sales ratio of products traded via the wholesale markets decreases

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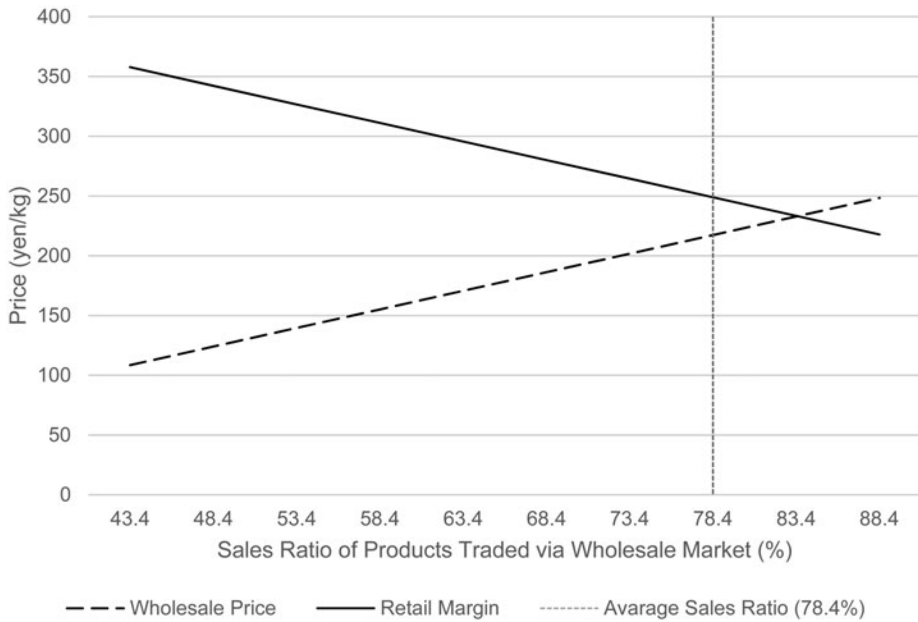

Figure 2. Simulation Results of Price and Retail Margin Change (Scenario 1).
Notes: The unit of dependent variables is JPY per kilogram. A 10 percent reduction in the sales ratio of products traded via the wholesale markets equals a 0.09 decrease in ω. The average sales ratio (78.4 percent) is the mean value of the sales ratio of products traded via wholesale markets for a total of 14 vegetables shown in Table 4.

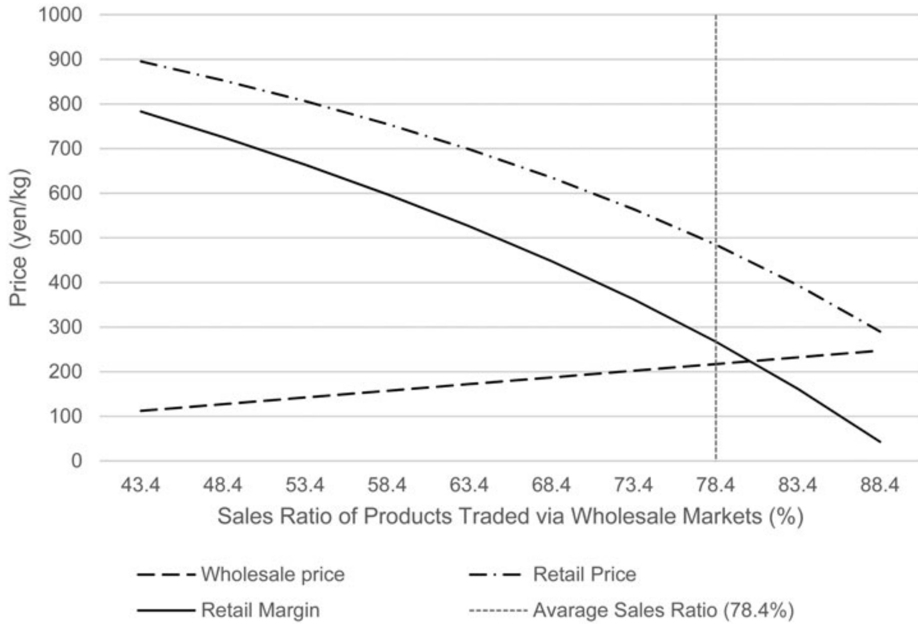

Figure 3. Simulation Results of Price and Retail Margin Change (Scenario 2).

Notes: The unit of dependent variables is JPY per kilogram. A 10 percent reduction in the sales ratio of products traded via the wholesale markets equals a 0.09 decrease in ω. The average sales ratio (78.4 percent) is the mean value of the sales ratio of products traded via wholesale markets for a total of 14 vegetables shown in Table 4.

based on the simulation result in Scenario 1. We assume the condition that the wholesale price decreases by 31 yen/kg when the sales ratio of products traded via the wholesale markets decreases by 10 percent. Figure 3 shows that the retail price rises as the sales ratio of products via the wholesale markets decreases. Figure 3 also suggests that the retail margin increases for the above condition. The most interesting aspect of the simulation results is that selling vegetables via the wholesale market reduces the retail margin and increases the producer cooperative margin due to the wholesale price rise. This means that retailers are less likely to exercise market power in their transactions conducted through the wholesale market, as reflected by the lower retail margin than retailers' direct transactions.

Discussion and conclusion

This study presented a bilateral oligopoly model for measuring the degree of vertical power balance in the vegetable market in Japan. We extended the bilateral oligopoly model by Azzam (1996) and KSK. The extended model uniquely obtains the horizontal and vertical competition parameters of producers and retailers. However, using that model with regression methods can lead to multicollinearity problems by estimating theoretically similar parameters with a limited data set. Thus, we applied a nonlinear programming method instead of regression analysis to derive the optimal parameters that fulfill the constraints of the theory. We then estimated the relationship between the vertical power parameters, ω, and the sales ratio of products traded via the wholesale markets to consider the effect of the wholesale markets on the retail price and wholesale price.

Under the four assumptions we made based on previous research and the current vegetable market state in Japan, this study had the following findings. The first major finding is that the producer cooperatives' market power is relatively weaker (0.293) than the retailers' position (0.707) in the vegetable supply chain in Japan. This is true even though producers have fairly large cooperatives marketing their products.

The second major finding is that the retail price and retail margin increase, and the wholesale price declines when the sales ratio of products traded via the wholesale markets decreases. This finding suggests that producer cooperatives and consumers benefit from the existence of the wholesale market to prevent the surplus transfer to retailers in the vegetable market in Japan. The quantitative estimation has provided deeper insights into the impact of changes in the sales ratio of products traded via wholesale markets. The empirical findings in this study provide a new understanding that the wholesale market decreases retailers' power even though they possess stronger market power than producers. Furthermore, the wholesale market benefits both the producers and the consumers by raising producer prices and lowering retail prices. Therefore, reducing the deadweight loss when the wholesale market functions effectively can enhance economic welfare unless the market's operating costs exceed the reduction in deadweight loss. This approach could be applied to determine if similar conclusions hold.

However, several issues were not addressed in this study. Because this study used aggregated data at the prefecture level, we assumed all vegetables were homogeneous. In Japan, since most vegetables are collected and shipped as homogeneous products via producer cooperatives at the prefecture level, this assumption is reasonable, as described in the Section "Vegetable market and wholesale market in Japan". Also, due to the multicollinearity problem with limited samples, we used the nonlinear programming method to obtain the power parameters. If individual transaction data were available, we could relax the homogeneity assumption and develop a bargaining model that explicitly considers the potential endogenous problem. Another caveat is our strong assumption of the competition intensity in retail. Further econometric work with individual transaction data will be essential to consider the market dynamics in both producers and retailers. Finally, our simulation assumed either a change in the wholesale price or a change in the retail price. More research is needed to simulate the market equilibrium while considering both price changes simultaneously.

Although the current study is based on a small sample of data, the findings suggest that the public pricing system, such as the wholesale market system in Japan, may help lessen retailers' market power in the food industry. Under the four assumptions that we made, the wholesale market can benefit both producers and consumers by raising wholesale prices and lowering retail prices. Sexton and Xia (2018) argue that the developments of vertical coordination have been controversial: "With vertical coordination and contract production, farmers may be 'locked in' to a particular buyer and possibly vulnerable to opportunistic behavior, or 'locked out' if they are unable to secure a contract". A wholesale market system like Japan could prevent these issues, thereby accomplishing efficiency and eliminating costs from the food supply chain.

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