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Abstract

We propose a method to measure the efficiency of the retail industry. In the case of the manufacturing industry, we can define its efficiency by total factor productivity (TFP) based on the production function. Since retailers do not produce specific objects, we cannot observe their output with the exception of monetary observations such as sales or profit. TFP could be computed as in the manufacturing industry using such data, however, increased TFP does not necessarily indicate efficiency gain for retailers because it also includes the effects from the demand side. If demand increases, the TFP of retailers will increase. Therefore, we look at retailers' cost function rather than production function to study their efficiency. Assuming that the retail industry is competitive, we construct a cost model and identify the cost efficiency. In standard economic theory, duality holds for productivity and cost efficiency, though it is not clear in the present case. This paper deals with the retailers of goods with an inelastic supply function which include agricultural and marine products. We propose and apply a new empirical method to measure the retail industry efficiency of agricultural products using Japanese regional panel data of wholesale and market prices and traded quantity for a variety of vegetables from 2008 to 2014. The marginal cost efficiency was stable during this period.

Keywords: Retail industry, Agricultural products, Cost function, Marginal cost efficiency, Prefectural level data

JEL classification: L81, D24, Q11

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1 Introduction

Productivity/efficiency is an important issue in economics because it is considered a source of economic growth. In the case of manufacturing industry, there exist a large body of literature, most of which estimates the production function and computes total factor productivity (TFP) as a measure of productivity. However, relatively little research has been conducted that studies the productivity of the service or non-manufacturing industries. There are two essential difficulties relative to manufacturing industry if we take the TFP-type approach to this problem. First, it is not clear what the service sector produces. For example, the sales quantity may be considered as the production output, but it also could be regarded as the input. Therefore, the definition of the production function of the service industry is not a straightforward issue. One possibility is considering the sales or value-added as the outcome of service industries. However, this output depends also on the demand. Second, the consumption of service industry is realized only when demand arrives. For example, a hairdresser serves only when a customer visits the hair salon. Manufactures can produce goods without demand arrival. If the production quantity exceeds the demand, the stock simply increases. Productivity is a characteristic of suppliers, and in principle, should not depend on demand.

The purpose of this paper is to measure efficiency of the retail industry. One possible approach, as stated above, is to compute TFP taking sales, margin, or profit as the outcome. This is, needless to say, an important measure of industry performance. However, this measure is affected by consumers' demand shocks, producers' supply shocks, retailers' efficiency shocks, and input market shocks. This means that it is unclear what kind of policy should be implemented—demand side, supply side, or retailer efficiency improving—in response to a decline in TFP in the retail industry. In order to identify the retailers' efficiency based on the TFP, we adopt the cost function approach for the efficiency measure related to the role of retailers. They operate if there is a difference between the market-clearing price and the price at which they buy goods from suppliers. If the retail industry is competitive, which is likely, their profit must be zero. We estimate the cost function and cost efficiency of retailers by using this relationship. The retail industry is a part of the service industry. There are some empirical results of productivity measures for the service industry. We refer to a limited number of results in this field. Foster et al. (2006) compute the labor productivity of the retail industry in USA. Kainou (2009) computes labor productivity using Japanese data. Fukao (2010) computes TFP for various service sectors in Japan by focusing on the effect of ICT investment. Jorgenson, Nomura and Samules (2015) compare TFP of Japanese and US wholesale/retail industries to conclude that the former attains only 70% productivity of the latter. Kwon and Kim (2008) calculate the TFP of the wholesale and retail industry using Japanese panel data to examine the source of changes in the productivity of the Japanese wholesale and retail industry. Mas and Moretti (2009) investigate the efficiency of cashier workers using high frequency data. Morikawa (2011, 2012, 2014) studies the productivity of a variety of service industries by TFP analysis. Fukao et al. (2016) discuss the results in connection with the choice of deflator in several service sectors for the UK, US, and Japan. Konishi and Nishiyama (2010) estimate efficiency of hairdressers using microdata by a hedonic approach.

In modern microeconometrics, we often apply structural econometric modeling. There, we construct an economic model of behavior of agency as well as the constitution and market regulations. In constructing the econometric model, we add shocks and errors, clearly specifying who can observe which components, which in turn determines how the solutions are affected. This addresses any problems of endogeneity that may arise. Based on this model, we study how we can identify quantities of interest and estimate them. This approach is called structural econometric modeling (see Reiss and Wolak (2007) and Ackerberg, Benkard, Berry and Pakes (2007) for overviews). In terms of efficiency analysis, Marshack and Andrews (1944) first identified the endogeneity problem in the production function estimation. Taking this problem into account, Levinsohn and Petrin (1999, 2003) and Olley and Pakes (1996) proposed new identification and estimation methods for measuring productivity. Ichimura, Konishi and Nishiyama (2011), Ackerberg, Caves and Frazer (2015) and many other papers are related to this problem. See the references in these articles. We also refer to Ackerberg et al. (2007) and Syverson (2010) for a brief survey of this field. We follow this approach to handle the problem of endogeneity, define, and estimate the efficiency of retailers. The following section provides a simple economic model of retailer behavior when the supply function is inelastic. Using this framework, we add shocks and errors to determine the endogeneity structure in Section 3. Section 4 presents an econometric model and its estimation method. Section 5 explains the data and provides results of the empirical analysis using prices and quantity of Japanese agricultural products. Section 6 concludes.

2 A simple economic model of retailer and producer behavior

We propose an economic model of retailer behavior based on the key observation that their profit depends on the price gap between the wholesale and retail markets. There are three participants in this setup: consumers, producers, and retailers. Retailers exist because consumers cannot purchase goods directly from the producers for several reasons. The retailers purchase goods from the producers in the wholesale market and sell them to consumers observing their demand function. Needless to say, retailers seek to earn a profit from the price gap. They have to pay labor and capital costs out of the income from the price gap, which includes wages and rent for the store and/or warehouse. Retailers are willing to work only when their costs do not exceed the earnings from the price gap. If the retail industry is competitive, retailers earn no profit. Then the equilibrium price in the wholesale market will be set at the level at which the revenue equals the total cost.

In this paper, we consider retailers trading goods with inelastic supply curves, such as agricultural products. The products, like fresh food, cannot be stocked. Producers supply a fixed amount of their product to a wholesale market. The supply amount is initially fixed; thereafter the wholesale price is determined such that the entire supply is sold out. The fixed supply level, the consumers demand function, and the retailers' cost determine the wholesale market price. Producers will determine their optimal supply in the wholesale market such that their revenue is maximized, given the behavior of the retailers. We do not consider the profit maximization by the producers as the production quantity was already determined in the past. For example, farmers decide how much cabbage they plant several months before they sell their crop in the market. They can only adjust how much cabbage they ship in a day or a month. They cannot ship more than they have, but can choose to dispose a part of the crop. Under this setup, we obtain a Nash equilibrium in the market.

In the real economy, retailers vary in terms of their scale or other attributes, such as department stores, supermarkets, and local shops. Obviously, they operate on different principles and perhaps face different customers. We should carefully construct an economic model that considers such aspects, especially when we consider commodities with product differentiation. In this paper, we ignore these issues by using data of ordinary agricultural products. We only briefly look at the scale effect in the empirical section later.

2.1 Decision of retailers

We present a basic formal model in the above-mentioned framework. See Figure 1.

Suppose producer supply is fixed at q^+. The supply function is, units of their products in the wholesale market, which means that the supply curve is inelastic. For example, farmers dispatch a certain amount of agricultural products to the wholesale market that must be sold within the day. The supply function is,

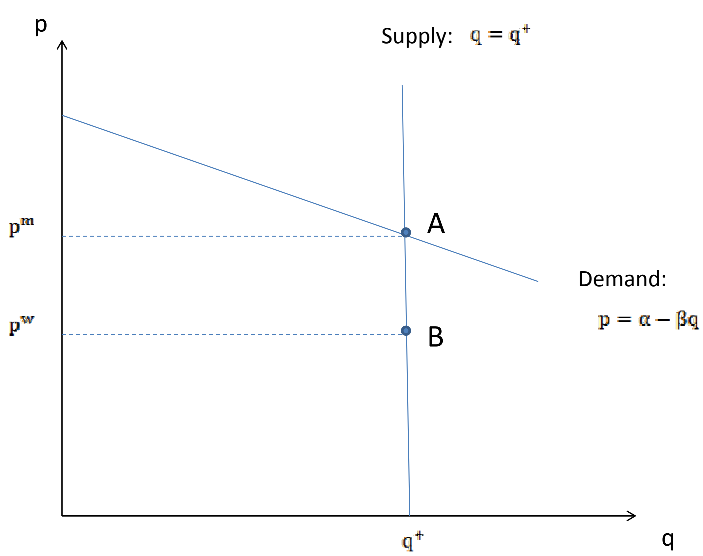
$$q = q^+$$

as shown in the figure. Let the consumer demand function be

$$p = \alpha - \beta q,\ \ \alpha > 0,\ \ \beta > 0.$$

If consumers can directly buy goods from the producers, A is the equilibrium point and the equilibrium price is p^m. Since this is impossible in the present setting, retailers purchase the

Figure 1: Equilibrium



products at a certain price p^w that is lower than p^m and sell them to consumers at p^m. p^w is determined by the game played by producers and retailers where producers move first and supply q^+ units of the good. Thereafter, each retailer offers a price. If there is only one monopolistic retailer, s/he can offer $p^w = 0$. On the other hand, if the retail industry is competitive, p^w will be determined such that the revenue $p^m q^+$ equals the total cost of the retailers, thereby implying zero retailers' profit. It seems likely that retailers compete with each other, as the barriers to entry in the retail industry are not significant, except in case of some special commodities. Let the cost of retailers exclusive of purchase cost be

$$C(q) = c^0 + c^1 q.$$

Retailers need to pay $C(q)$ to sell the quantity q of the commodity. This consists of labor costs, capital costs, and other costs like transportation costs. c^0, c^1 depend on such input prices, but we do not explicitly outline this relationship now. The total cost including the purchase cost is $C(q) + p^w q$.

Retailers operate only when

$$(p^m - p^w)q^+ \geq c^0 + c^1 q^+$$

and the retailers' purchase price must satisfy

$$\begin{aligned} p^w &\leq (p^m - c^1) - \frac{c^0}{q^+} \\ &= (\alpha - \beta q^+ - c^1) - \frac{c^0}{q^+}. \end{aligned}$$

The equality uses the equilibrium condition of retail market.

2.2 Nash Equilibrium under perfect competition in retail industry

If the retail industry is competitive, or the no profit condition holds, the retailers offer the price

$$p^w = (\alpha - \beta q^+ - c^1) - \frac{c^0}{q^+}.$$

Based on this retailer behavior, rational suppliers determine the supply quantity q^+ such that $p^w q^+$ is maximized. Let Q be the maximum quantity that they can supply. Their optimization problem is

$$\max_{q^+} p^w q^+ \ s.t. \ q^+ \leq Q, \, p^w \leq (\alpha - \beta q^+ - c^1) - \frac{c^0}{q^+}.$$

Q depends on factors such as the farmers' ex-ante demand expectation and weather. When $Q \geq \frac{\alpha - c^1}{2\beta}$, the supply constraint $q^+ \leq Q$ is not binding. If the market is competitive, the solution is

$$q^* = \frac{\alpha - c^1}{2\beta}$$

which gives the equilibrium prices

$$p^{m*} = \alpha - \frac{\alpha - c^1}{2} = \frac{\alpha + c^1}{2},$$

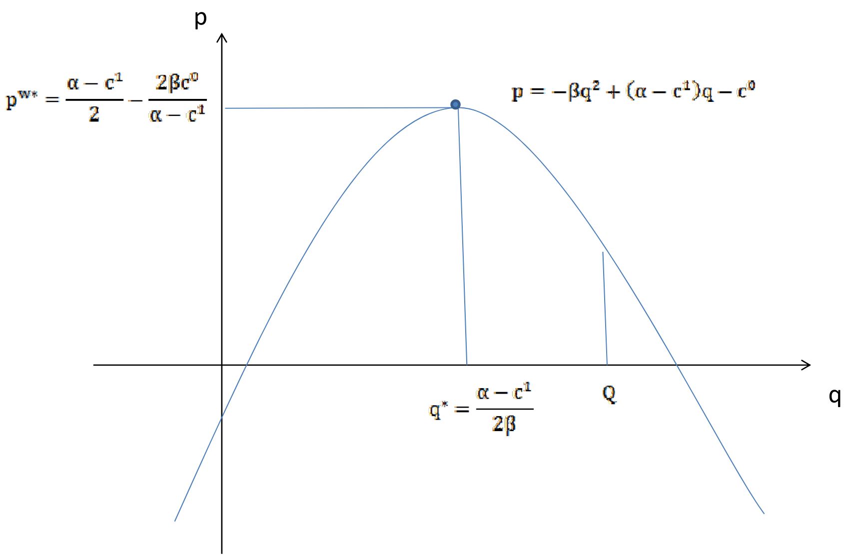
$$p^{w*} = \frac{\alpha - c^1}{2} - \frac{2\beta c^0}{\alpha - c^1}$$

and the revenue for the producers is

$$R^* = p^{w*} q^* = \frac{(\alpha - c^1)^2}{4\beta} - c^0 \tag{1}$$

If suppliers behave rationally, they control q^+ as above. Thereafter, suppliers dispose the amount $Q - \frac{\alpha - c^1}{2\beta}$ and sell only $\frac{\alpha - c^1}{2\beta}$ units of the product. Thus the amount traded in the market is endogenous. However, the amount traded can be exogenous in some cases, such

Figure 2: Internal solution



as when there are a number of suppliers, none of which know how much other suppliers are willing to provide in the market.

When $Q < \frac{\alpha - c^1}{2\beta}$, the supply quantity constraint is binding. Then the equilibrium turns out

$$q^* = Q$$

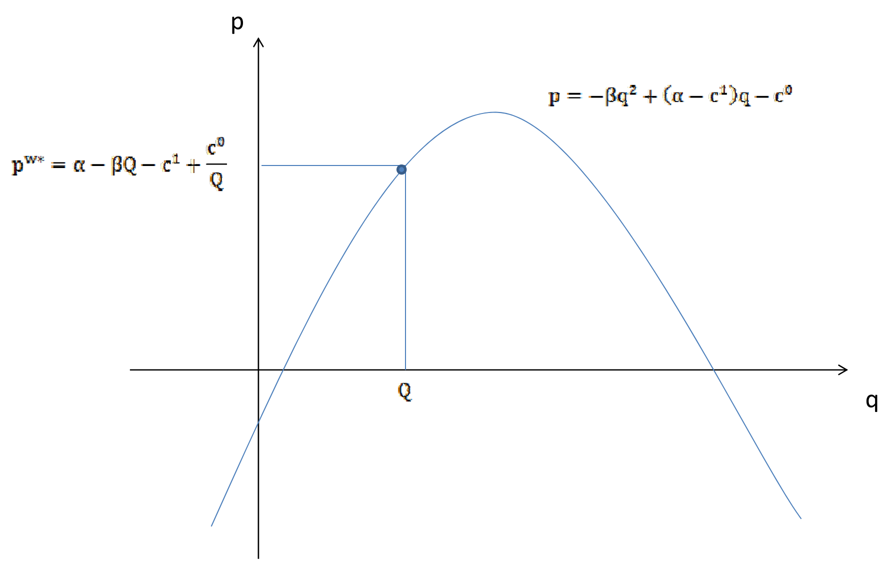
and

$$p^{m*} = \alpha - \beta Q$$

$$p^{w*} = (\alpha - \beta Q - c^1) - \frac{c^0}{Q}.$$

This does not result in the realization of the optimal revenue for the producers, but they do not have more products to sell. For example, this situation may arise when weather negatively

Figure 3: Corner solution



affects the crop. Figures 2 and 3 show the cases where the supply quantity constraint is binding, and is not binding, respectively.

If the retail industry is not competitive, p^w can be smaller than p^{w*} depending on the possibility of competitiveness and collusion.

2.3 Subsidy to product disposal

Government subsidizes product disposal due to abundant crop to keep the price in a certain range and protect producers. This could affect the optimization behavior of producers. More specifically, producers could earn more by disposing more than the optimal amount of product if the subsidy is too high. We briefly see the effect of such a scheme. We consider the case when $Q > q^*$ so that producers provide q^* in the market and dispose amount $Q - q^*$ if there is no subsidy. Suppose government subsidizes τ per unit of disposed product when p^w is too small, say $p^w < \bar{p}$. When producers provide q unit of products in the market and dispose $Q-q$, the revenue is

$$R = p^w q + \tau(Q-q)1(p^w < \bar{p})$$

where

$$p^w = (\alpha - \beta q - c^1) - \frac{c^0}{q}.$$

The producers will choose q such that

$$\max_q R = \begin{cases} -\beta q^2 + (\alpha - c^1)q - c^0 & if\ -\beta q^2 + (\alpha - c^1 - \bar{p})q - c^0 > 0 \\ -\beta q^2 + (\alpha - c^1 - \tau)q - c^0 + \tau Q & otherwise \end{cases}$$

When producers can earn more by disposing more than the optimal amount of product, consumer utility falls. The supply is insufficient when

$$R^* < (\bar{p} - \tau)q_1 + \tau Q$$

where $q_1 = \{(\alpha - c^1 - \bar{p}) - \sqrt{(\alpha - c^1 - \bar{p})^2 - 4\beta c^0}\}/2\beta$. If Q is bounded, which is likely, it is possible to set $\bar{p}$ and τ such that the above inequality holds. Therefore, the government can provide a subsidy scheme such that the supplied quantity remains q^* and thus, the price does not unnecessarily rise.

3 Shocks, endogeneity and efficiency

We construct an econometric model based on the economic model presented in the previous section. We need to make explicit assumptions about shocks and errors in the equations. This step clarifies the kind of endogeneity, heterogeneity, heteroscedasticity, and other econometric aspects being considered. We also define efficiency measures in this setup.

3.1 Shocks and endogeneity

We specify the market demand function as

$$p = \alpha - \beta q + u^S + u^R + u^{SR} + u \tag{2}$$

where u^S and u^R are shocks that can only be observed by the suppliers and the retailers, respectively. u^{SR} is the shock that can be observed by both suppliers and retailers and u is the unobservable error. We assume the retailers cost function to be

$$C = c^0 + (c^1 + v^{1S} + v^{1R} + v^{1SR} + v^1)q + v^{0S} + v^{0R} + v^{0SR} + v^0 \tag{3}$$

where the superscripts S, R, SR indicate the same as described in the case of the shocks. The superscripts 0 and 1 mean that the shocks correspond to the constant and the slope, respectively. v^0, v^1 are external errors. c^0 and c^1 are components which depend on input prices so that, if the relationship is linear,

$$c^0 = \gamma_0 + \gamma_1 r + \gamma_2 w + \gamma_3 g$$

$$c^1 = \delta_0 + \delta_1 r + \delta_2 w + \delta_3 g$$

where r is the price of capital, w is wage per hour and g is the petrol price.

Taking the same line as in section 2 with a special attention to who can observe which shocks, we determine the optimizing behaviors. We first look at the decision of retailers. Retailers can only observe part of (2) and (3), or the demand function

$$p = \alpha - \beta q + u^R + u^{SR}$$

and the cost function

$$C = c^0 + (c^1 + v^{1R} + v^{1SR})q + v^{0R} + v^{0SR}. \tag{4}$$

Therefore, assuming that the supplied quantity is q^+, retailers operate only when

$$(p^m - p^w)q^+ \geq c^0 + (c^1 + v^{1R} + v^{1SR})q^+ + v^{0R} + v^{0SR}$$

with

$$p^m = \alpha - \beta q^+ + u^R + u^{SR}$$

which yields

$$p^w \leq \alpha - \beta q^+ + u^R + u^{SR} - (c^1 + v^{1R} + v^{1SR}) - \frac{c^0 + v^{0R} + v^{0SR}}{q^+}.$$

Assuming a competitive retail industry, the wholesale price should be set at

$$p^w = \alpha - \beta q^+ + u^R + u^{SR} - (c^1 + v^{1R} + v^{1SR}) - \frac{c^0 + v^{0R} + v^{0SR}}{q^+}. \tag{5}$$

Given this price setting behavior, suppliers maximize their revenue based on the following observation of the demand function and the cost function

$$p = \alpha - \beta q + u^S + u^{SR}$$

and

$$C = c^0 + (c^1 + v^{1S} + v^{1SR})q + v^{0S} + v^{0SR}.$$

Suppliers cannot observe (5) but they recognize that retailers determine p^w as follows. Assuming that Q is sufficiently large and the constraint $q^+ \leq Q$ is not binding, supplier behavior is characterized by

$$\max_{q^+} p^w q^+ \ s.t. \ p^w = \alpha - \beta q^+ + u^S + u^{SR} - (c^1 + v^{1S} + v^{1SR}) - \frac{c^0 + v^{0S} + v^{0SR}}{q^+}.$$

This gives

$$q^* = \frac{\alpha + u^S + u^{SR} - c^1 - v^{1S} - v^{1SR}}{2\beta}.$$

Based on the above results, the realized quantity and prices are

$$\tilde{q} = \min(q^*, Q)$$

$$\tilde{p}^m = \alpha - \beta\tilde{q} + u^S + u^R + u^{SR} + u$$

$$\tilde{p}^w = \alpha - \beta\tilde{q} + u^R + u^{SR} - (c^1 + v^{1R} + v^{1SR}) - \frac{c^0 + v^{0R} + v^{0SR}}{\tilde{q}}.$$

Therefore, in terms of observed quantity and prices, we have

$$\begin{aligned} (\tilde{p}^m - \tilde{p}^w)\tilde{q} &= (c^1 + u^S + u + v^{1R} + v^{1SR})\tilde{q} + (c^0 + v^{0R} + v^{0SR}) \\ &= c^0 + c^1\tilde{q} + \epsilon \end{aligned} \tag{6}$$

where

$$\epsilon = (u^S + u + v^{1R} + v^{1SR})\tilde{q} + (v^{0R} + v^{0SR}).$$

3.2 Efficiency of retailers

In the above model, the demand function is determined by consumers and the supply level is determined by the producers based on revenue maximization. All retailers can do is to determine the wholesale price based on the cost function. If a retailer is a monopolist, s/he can set the wholesale price to be arbitrarily small. If the industry is competitive, the wholesale price must be set at (5). In the case of oligopoly, the wholesale price must be somewhere between

0 and (5) depending on the degree of collusion. We assume that retailers are competitive because there is no barrier to entry.

Given the above structure of retail industry, the efficiency of retailers should be defined based on their cost function (3). $c^0 + v^{0S} + v^{0R} + v^{0SR} + v^0$ is the fixed cost and $c^1 + v^{1S} + v^{1R} + v^{1SR} + v^1$ are the marginal cost. If they are reduced, we say the retailers make an efficiency gain. However, we should carefully look at the elements that constitute retailers' cost. As is usually the case, the main components of the cost must be capital and labor cost. Additionally, transportation cost is a reasonably important factor in the retail industry. When wage declines due to, say, macroeconomic fluctuation, the cost goes down because of this exogenous macroeconomic state. However, this reduction in cost is not a result of an efficiency improvement in the retail industry. The same story applies to capital cost reduction and/or fuel cost reduction. In defining efficiency, we would like to exclude such effects from price change in outside but related markets. These effects are included in c^0, c^1. Therefore, we define efficiency measures as

$$e^0 = v^{0S} + v^{0R} + v^{0SR}$$

$$e^1 = v^{1S} + v^{1R} + v^{1SR}.$$

e^0 is the fixed cost efficiency and e^1 is the marginal cost efficiency. We do not include v^0 and v^1 because they are external errors. The reduction in either leads to a reduction in cost. In empirical examinations, we can also use their rate of growth.

4 Econometric model and Identification of Retailer's Efficiency

Based on the economic model introduced in the previous section, we estimate the cost function in order to measure the efficiency of retailers using spatio-temporal data of Japan from 2008 to 2014 in section 5. In this section, we specify a feasible econometric model for our empirical study and identify an efficiency measure based on the econometric model.

4.1 Econometric model

We estimate the model using the data in the next section. For this purpose, we construct an empirical model based on a simplified model. As stated above, we have spatio-temporal data of months*prefectures*items. Let subscripts t, m, i denote time (month*year), location (prefecture) and item (vegetables). The model considers all possible shocks observable for each agent. However, it may be reasonable to assume that, say, producers cannot observe shocks in the retailers' cost function. Therefore, we can remove $v^{0S}, v^{1S}, v^{0SR}, v^{1SR}$ from the estimation model. Thus, the retailers' efficiency is simplified to v^{0R}, v^{1R}. This simplification substantially mitigates the problem of endogeneity. Without this assumption, these shocks would be present in both q and the disturbances. We shall identify and estimate these quantities from the data.

We specify the empirical model of cost and demand functions. The cost function of retailer for item i, in prefecture m, time t is assumed to be

$$C_{imt} = C^0_{mt} + C^1_{mt} q_{imt}, \;\; i = 1, \cdots, n, \; m = 1, \cdots, M, \; t = 1, \cdots, T.$$

The parameters C^0, C^1 can be different across markets and time, but can be the same for different items. This means that the cost for selling, say carrot and potato, are the same as far as the quantity is the same. As in the previous section, we introduce shocks as follows.

$$\begin{aligned} C^0_{mt} &= c^0_{mt} + v^{0R}_{mt} + v^0_{mt} \\ &= \gamma_{0m} + \gamma_{1m} r_{mt} + \gamma_{2m} w_{mt} + \gamma_{3m} g_{mt} + v^{0R}_{mt} + v^0_{mt} \end{aligned}$$

$$\begin{aligned} C^1_{mt} &= c^1_{mt} + v^{1R}_{mt} + v^1_{mt} \\ &= \delta_0 + \delta_1 r_{mt} + \delta_2 w_{mt} + \delta_3 g_{mt} + v^{1R}_{mt} + v^1_{mt}. \end{aligned}$$

We allow the coefficients in C^0_{mt} to depend on m because fixed cost can be different based on the market size. For each market and time, we can define the retailers' efficiency by

$$e^0_{mt} = \gamma_{0m} + v^{0R}_{mt}, \;\; e^1_{mt} = \delta_0 + v^{1R}_{mt} \tag{7}$$

.

Given this specification, we estimate the model

$$\begin{aligned}(\tilde{p}^m_{imt} - \tilde{p}^w_{imt})\tilde{q}_{imt} &= C^0_{mt} + C^1_{mt}\tilde{q}_{imt} \\ &= c^0_{mt} + (c^1_{mt} + u^S_{imt} + u_{imt} + v^{1R}_{mt})\tilde{q}_{imt} + v^{0R}_{mt} + v^0_{mt} \\ &= c^0_{mt} + c^1_{mt}\tilde{q}_{imt} + \epsilon_{imt} \end{aligned} \tag{8}$$

where

$$c^0_{mt} = \gamma_{0m} + \gamma_{1m} r_{mt} + \gamma_{2m} w_{mt} + \gamma_{3m} g_{mt}$$

$$c^1_{mt} = \delta_0 + \delta_1 r_{mt} + \delta_2 w_{mt} + \delta_3 g_{mt}$$

$$\epsilon_{imt} = (u^S_{imt} + u_{imt} + v^{1R}_{mt})\tilde{q}_{imt} + v^{0R}_{mt} + v^0_{mt} \tag{9}$$

$$\tilde{q}_{imt} = \min(q^*_{imt}, Q_{imt})$$

$$q^*_{imt} = \frac{\alpha + u^S_{imt} + u^{SR}_{imt} - c^1_{mt}}{2\beta}.$$

The demand function of item i, in prefecture m, time t is

$$\tilde{p}^m_{imt} = \alpha_{mt} - \beta_{mt}\tilde{q}_{imt} + \kappa_i I_{mt} + u^S_{imt} + u^R_{imt} + u^{SR}_{imt} + u_{imt} \tag{10}$$

where I_{mt} is the income of prefecture m at time t. We assume that its coefficient depends on only the product; this implies that the utility function does not change over time.

4.2 Estimation of Efficiency

Our main target is to extract the efficiency measures in (7). For this purpose, we use equations (8) and (10) in the previous section with suitable instruments. In view of $\tilde{q}$ and the disturbance structure, $u_{imt}^S + u_{imt}^{SR}$ turns out the source of endogeneity. As it is a part of the demand shock, we can use climate variable Z as the instrument to consistently estimate the parameters. Z consists of the average temperature, average rainfall, and average hours of sunlight. Formally, we assume that

$$E\{(v_{mt}^{1R} + v_{mt}^1)\tilde{q}_{imt} + v_{mt}^{0R} + v_{mt}^0 | Z_{mt}\} = 0$$

$$E(u_{imt}^S + u_{imt}^R + u_{imt}^{SR} + u_{imt} | Z_{mt}) = 0$$

We estimate the model by the Generalized Method of Moments (GMM) to obtain $\hat{\gamma}_{0m}$, $\hat{\gamma}_{1m}$, $\hat{\gamma}_{2m}$, $\hat{\gamma}_{3m}$, $\hat{\delta}_0$, $\hat{\delta}_1$, $\hat{\delta}_2$, $\hat{\delta}_3$, $\hat{\alpha}_{mt}$, $\hat{\beta}_{mt}$, $\hat{\kappa}_i$ and the residuals

$$\hat{\epsilon}_{imt} = (\tilde{p}_{imt}^m - \tilde{p}_{imt}^w)\tilde{q}_{imt} - (\hat{c}_{mt}^0 + \hat{c}_{mt}^1 \tilde{q}_{imt})$$

where

$$\hat{c}_{mt}^0 = \hat{\gamma}_{0m} + \hat{\gamma}_{1m} r_{mt} + \hat{\gamma}_{2m} w_{mt} + \hat{\gamma}_{3m} g_{mt}$$

$$\hat{c}_{mt}^1 = \hat{\delta}_0 + \hat{\delta}_1 r_{mt} + \hat{\delta}_2 w_{mt} + \hat{\delta}_3 g_{mt}.$$

Based on (9), $\hat{\epsilon}_{imt}$ estimates $(u_{imt}^S + u_{imt} + v_{mt}^{1R})\tilde{q}_{imt} + v_{mt}^{0R} + v_{mt}^0$. Assuming demand shocks u_{imt}^S, u_{imt} are independent of lagged quantity $\tilde{q}_{im,t-1}$, we propose to estimate v_{mt}^{1R} by

$$\hat{v}_{mt}^{1R} = (\sum_{i=1}^{n} \tilde{q}_{im,t-1}\tilde{q}_{imt})^{-1} \sum_{i=1}^{n} \tilde{q}_{im,t-1}\hat{\epsilon}_{imt}.$$

We need some other information to identify v_{mt}^{0R}.

5 Data and Empirical results

Our research objective is the examination of the efficiency of retailers that sell goods with inelastic supply such as agricultural products. For this purpose, we estimate eq. (8) with suitable instruments for quantities ($\tilde{q}_{imt}$). Using the estimation results, we identify efficiency by eq. (7). Due to the restriction of data, some shocks are removed from the model as noted in section 4. Therefore, our analysis is limited to being based on a simplified model. In this section, we present variable descriptions, summary statistics of variables, and the estimation results.

5.1 Data

We collect spatio-temporal data of months*prefectures*items conducted by Japanese ministries that are available online. Let subscripts t, m, i denote time (month*year), location (prefecture) and item (vegetables) in (8); the subscript y denotes year in Table 1. Table 1 describes the variables used in the empirical analysis and the sources from which the data for the variables is obtained. The dataset is composed of 47 prefectures, 27 vegetables, 12 months, and 7 years (2008–2014), which accounts for more than 100,000 observations. The selected vegetables are Japanese radish, carrot, burdock lotus root, Chinese cabbage, cabbage, spinach, Welsh onion, asparagus, broccoli, lettuce, cucumber, pumpkin, eggplant, tomato, green pepper, string bean, green soybean, sweet potato, potato, taro, Japanese yam, onion, ginger, shiitake mushroom, enoki mushroom, and shimeji mushroom. Table 2 shows the summary statistics of the dependent variable ($(\tilde{p}^m_{imt} - \tilde{p}^w_{imt})\tilde{q}_{imt}$), the explanatory variables (w_{my}, r_{my}, g_{mt}) and the instrumental variables (Z: $temp_{mt}$, $sunny_{mt}$, $rain_{mt}$) for $\tilde{q}_{imt}$ in (8). We deflate monetary base data by using a consumer price index ($deflator1_{mt}$) and a consumer prices index ($deflator2_{my}$) of regional difference.

Table 1: Variable Descriptions and Sources of Data

variable (unit)	Description	Sources
$\tilde{p}^{w}_{imt}$ (yen)	Wholesale price	Wholesale price Survey on Vegetables and Fruits Wholesale Market, Ministry of Agriculture, Forestry and Fisheries
$\tilde{q}_{imt}$ (kg)	Wholesale quantity	Wholesale price Survey on Vegetables and Fruits Wholesale Market, Ministry of Agriculture, Forestry and Fisheries
$\tilde{p}^{m}_{imt}$(yen)	Retail price	Retail Price Survey (Structural Survey), Ministry of Internal Affairs and Communications
w_{my}(yen)	Average wage rate of retail industry	Basic Survey on Wage Structure, Ministry of Health, Labour and Welfare
r_{my}(yen/m^2)	the value of commercial districts	Ministry of Land, Infrastructure, Transport and Tourism
g_{mt}(yen)	Lighter fluid's average price	Petroleum Products Price Statistics, Ministry of Economy, Trade and Industry
$temp_{mt}$(C)	Average temperature	Japan Meteorological Agency, Ministry of Land, Infrastructure, Transport and Tourism
$sunny_{mt}$(hours)	Sunshine duration (Total amount)	
$rain_{mt}$ (mm)	Rainfall (Total amount)	
$field_{yt}$ (ha)	area of field for vegetables	Statistics on Crop, Ministry of Agriculture, Forestry and Fisheries
$deflator1_{mt}$ All items	price index base year=2010	Consumer Price Indices, Ministry of Internal Affairs and Communications
$deflatr2_{my}$ All items	regional difference price index	The Regional Difference Index of Consumer Prices, Ministry of Internal Affairs and Communications

Table 2: Summary Statistics (2008-2014)

variable (unit)	unit	mean	median	S.D.	min.	max.	N
$(\tilde{p}^m_{imt} - \tilde{p}^w_{imt})\tilde{q}_{imt}$	yen	95220	34567	218780.3	5.9	4619603	102277
$\tilde{p}^w_{imt}$	yen	347.1	280.6	270.1	18.3	2395.4	102279
$\tilde{q}_{imt}$	ton	496.5	135	1288.9	1	25600	102279
$\tilde{p}^m_{imt}$	yen	695.3	564.5	511.7	60.3	4345.9	102279
$field_{yt}$	ha	24838.7	9190	59697.6	1370	414900	102279
w_{my}	yen	261470.6	261157.2	26811.2	193124.1	373870.6	102279
r_{my}	yen/m^2	144371.3	85018.6	203512.4	27569.05	1602426	102279
g_{mt}	yen	125.6	128.1	15.0	87.6	172.6	102279
$temp_{mt}$	C	15.6	15.9	8.5	-4.7	30.5	102279
$sunny_{mt}$	hours	161.5	163.2	45.8	17.6	294.4	102279
$rain_{mt}$	mm	142.9	114.5	113.3	0	1561	102279

5.2 Empirical Results

In order to observe the efficiency of retailers, we estimate eq. (8) considering the problems of endogeneity and heterogeneity, as stated in section 3. We implement 2SLS regression to handle the problem of endogeneity in $\tilde{q}_{imt}$ by using the prefecture level monthly climate data, such as average temperature, duration of sunshine, and total amount of rainfall, as instrumental variables. Figure 4 shows the aggregated quantities by prefectures in 2014 and the cumulative curves. Ten prefectures (from Rank 1 to 10) occupied more than 60% of the sum of quantities of 47 prefectures, which indicates to the existence of heterogeneity in the quantities. We consider to control the differences of market scale among prefectures. Therefore, we adopted $(\tilde{q}_{imt}/field_{yt})$ as the dependent variable in the first stage regression, and regressed $\tilde{q}_{imt}/field_{yt}$ on climate variables. Table 3 shows the result of first stage regression; we obtained adjusted $R^2 = 0.498$ and found that coefficients of average temperature, lag of average temperature, and duration of sunny hours are positive and significant. The coefficient of the square of average temperature is negative and significant. Due to limited data availability, we simplify eq. (8) for estimation to

$$(\tilde{p}^m_{imt} - \tilde{p}^w_{imt})\tilde{q}_{imt} = C^0_m + C^1_y \tilde{q}_{imt} + \epsilon_{imt}. \tag{11}$$

We examine the fitted values of $\tilde{q}_{imt}$ that are calculated by $\hat{\tilde{q}}_{imt} = \widehat{\tilde{q}_{imt}/field}_{yt} \times field_{yt}$ using the estimation results of first step. We allow the coefficients in C_m^0 to depend on each prefecture. Therefore, C_m^0 captures the difference in market size between prefectures. In eq. (8), C_{mt}^1 that stands for marginal cost has subscripts time*prefectures. However, we assume that C^1depends only on year in eq. (11). Due to the serious multicollinearity problem, we choosed a subscriot y as the better expression of marginal cost. Both C_m^0 and C_y^1 do not have a subscript i in eq. (11). This is because we assume that the cost for selling the same quantity of, say carrots and potatoes, are the same. As a second step, we estimate the cost function for 100,670 observations and obtain the adjusted R^2=0.70. In the interest of saving space, we only check the signs of the fitted values of eq. (11) and do not present the estimation results of all coefficients. As $C_m^0 + C_y^1\tilde{q}_{imt}$ denotes the total cost, we expect that estimation results of $C_m^0 + C_y^1\hat{\tilde{q}}_{imt}$ to be positive value. In figure 5, we calculated average of $\hat{C}_m^0 + \hat{C}_y^1\hat{\tilde{q}}_{imt}$ in terms of year and items for each prefecture and the averages are positive. Additionally, we observed that the retailers in big cities tend to spend higher expenses to sell vegetables.

Using estimation results of eq. (11), we obtain residuals $\hat{\epsilon}_{imt} = (\tilde{p}^m_{imt} - \tilde{p}^w_{imt})\tilde{q}_{imt} - (\hat{c}^0_{mt} + \hat{c}^1_{mt}\tilde{q}_{imt})$. According to eq. (9), we can rewrite the residuals as $\hat{\epsilon}_{imt} = (u^S_{imt} + u_{imt} + v^{1R}_{mt})\tilde{q}_{imt} + v^{0R}_{mt} + v^0_{mt}$. v^0_{mt} and v^{1R}_{mt} are components of fix cost efficiency (e^0) and marginal cost efficiency (e^1) in eq. (7), respectively. Assuming that the demand shocks of u^S_{imt} and u_{imt} are independent of lagged quantity$\tilde{q}_{im,t-1}$, we proposed to estimation of v^{1R}_{mt} by

$$\hat{v}^{1R}_{mt} = (\sum_{i=1}^{n} \tilde{q}_{im,t-1}\tilde{q}_{imt})^{-1} \sum_{i=1}^{n} \tilde{q}_{im,t-1}\hat{\epsilon}_{imt}.$$

We can obtain $\hat{v}^{1R}_{mt}$ by implementing GMM estimation of $\hat{\epsilon}_{imt}$ on $\tilde{q}_{imt}$, the instrumental variables of $\tilde{q}_{imt}$ are $\tilde{q}_{im,t-1}$. However, it is not able to be identify v^{0R}_{mt} without additional information. Figure 6 shows the average marginal cost efficiency every year, and the bar graph of each year indicates the cost of selling an additional 1 kg of vegetables. When the cost decreases, the marginal cost efficiency improves (and vice versa). The solid and dotted line plots represent $mean \pm 1\sigma$ and $mean \pm 2\sigma$; these lines tell us whether the average of each year changes or not. As a result, each bar is located in the confidence intervals, which suggests that the marginal cost efficiency was stable for these seven years in Japan. Finally, we observe the relation between the marginal cost efficiency and the regional features of retailers in the "Yearbook of the Current Survey of Commerce, 2014" conducted by the Ministry of Economy, Trade, and Industry. We aggregate $\hat{v}_{mt}^{1R}$ in each prefecture and examine the correlation coefficients with each index. We found that prefectures that have a high establishment ratio of small and medium size establishments have lower marginal cost efficiency. On the other hand, when the share of large business is higher in a prefecture, the efficiency tends to be higher. When shopping floor per person is larger, the efficiency is lower. The shop floor productivity is defined by total amount sales over number of employees, and the correlation between productivity and efficiency is positive. Moreover, the labor productivity is defined by total amount sales over number of employees, and the correlation between labor productivity and efficiency is insignificant. It suggests that measuring labor productivity is not enough to know the efficiency of selling vegetables.

Figure 4: $\tilde{q}_{imt}$(Right), Cumulative curve of $\tilde{q}_{imt}$(Left), 2014

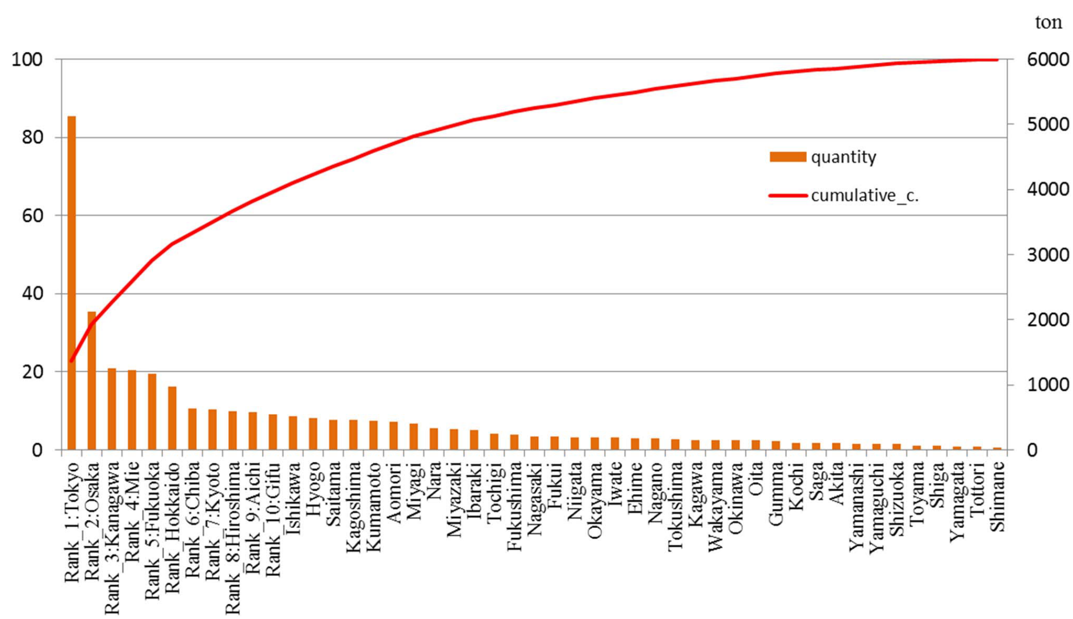


Figure 5: Estimation results of $C_m^0 + C_y^1 \hat{\hat{q}}_{imt}$

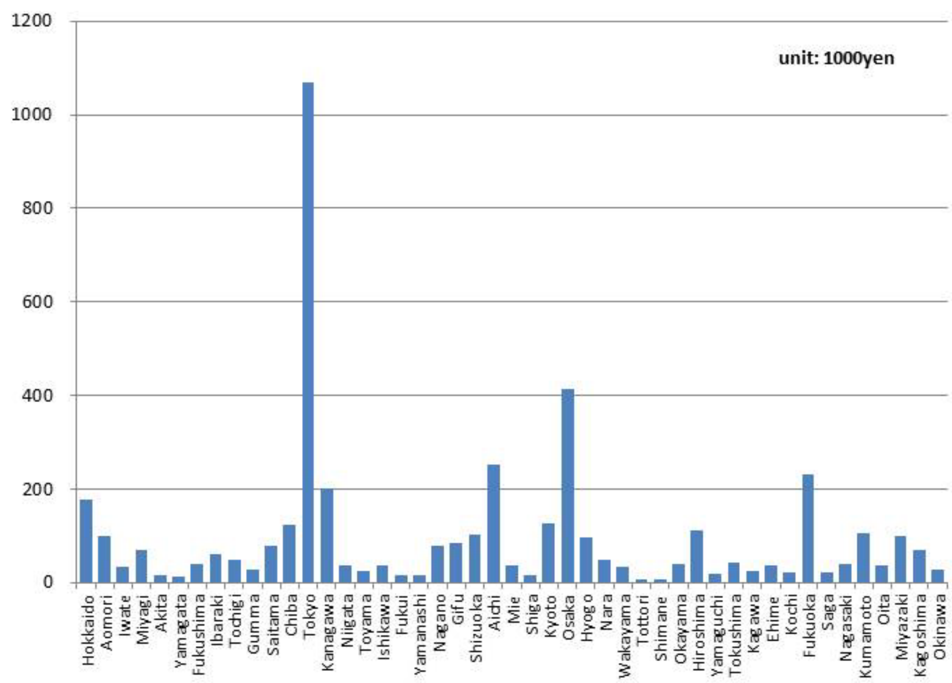


Table 3: Estimation Result: First Stage

	$\tilde{q}_{imt}/field$
$temp_{mt}$	1.241***
	(0.451)
$sunny_{mt}$	0.045*
	(0.024)
$rain_{mt}$	0.014
	(0.016)
$temp_{mt}^2$	-0.061***
	(0.013)
$rain_{mt}^2$	-0.000
	(0.000)
$temp_{mt-1}$	0.550***
	(0.193)
$sunny_{mt-1}$	-0.020
	(0.024)
$rain_{mt-1}$	0.001
	(0.009)
constant	-46.366***
	(9.287)
N	100670
R^2	0.498

1. 1. Prefecture dummy and year dummy are included.
2. 2. Vegetables dummy are included.
3. 3. Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure 6: Marginal Cost Efficiency $\hat{v}_{mt}^{1R}$: 2008-2014

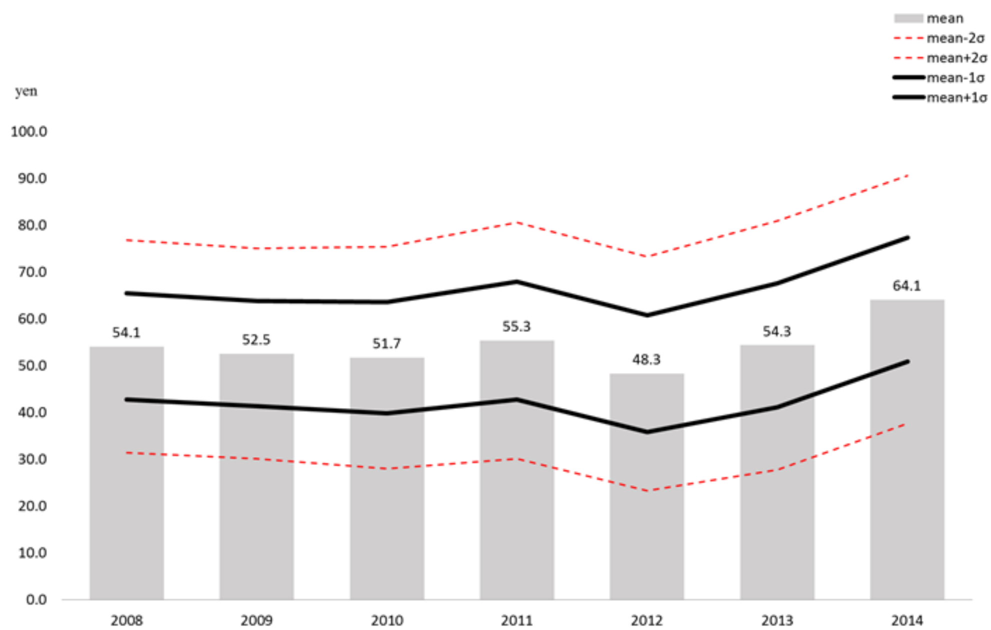


Table 4: The Correlation between $\hat{v}_{mt}^{1R}$ and Retailer's Indices

Indices	Retail Industry (all) ** p< 0.05	Efficiency (when each index is higher)
the Share of small business ($\leqq$ 4 employees)	0.31**	lower
the Share of small business ($\leqq$ 10 employees)	0.37**	lower
the Share of large business (50 $\leqq$ employees $<$100)	-0.46**	higher
the Share of large business ($\geqq$ 100 employees)	-0.33**	higher
Floor space per person	0.41**	lower
Shop floor productivity	-0.28**	higher
Labor Productivity	-0.04	no relation

Source of indices: "Yearbook of the Current Survey of Commerce (2014)" conducted by Ministory of Economy, Trade and Industry.

6 Concluding remarks

We proposed an economic model of retailers and constructed an econometric model based on it. The basic idea is to describe retailers' behavior as buying goods at a price and then selling them at a higher price. They do not operate if the cost of their business cannot be recovered. In this paper, we look at goods with an inelastic supply, such as agricultural and marine products. Market price is determined by consumer demand and quantity supplied; thus there is no room for retailers to affect the price in principle. Retailers can only decide the price to offer to suppliers, or wholesale price. If the retail industry is competitive, the wholesale price will be set such that revenue from the price difference equals the retailers' cost. Based on such behavior of retailers, suppliers will optimize the amount of supply in the market. Such interaction determines the market price, the wholesale price, and the quantity traded. We add shocks to the demand function and retailers' cost function to define the retailers' cost efficiency and determine the structure of endogeneity. We estimate this econometric model by the IV method to obtain the parameters and the retailers' efficiency using agricultural products transaction data in Japan.

Our method is novel in that we define the efficiency carefully such that the measure is not contaminated by demand and supply shocks. It is obvious that the efficiency measure will be affected by such shocks if we compute TFP using sales or profit data to estimate the production function. In our empirical analysis, we compute the trend of retailers' efficiency for each prefecture and we aggregate them to determine retailers' efficiency in Japan.

It may be interesting to measure efficiency of each retailer, unlike aggregated efficiency that is calculated in this paper. The proposed method does not directly apply in the estimation of efficiency of a retailer who sells multiple goods. If we have a detailed microdata of market and wholesale prices and quantities of each item, it can be similarly determined. The measurement of the efficiency of different kinds of retailers, such as department stores, supermarkets, and local shops is important. These problems will be handled in future research. Moreover, most goods have elastic supply functions; therefore, methods that are applicable to such goods need to be developed. Research that does this is currently underway.

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