Measuring Oligopsony Power in Thai Jasmine Rice Market; Re-evaluating the Paddy Pledging Program

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Abstract

In this paper, we develop a model that consists of a system of equations that allows the estimation of the degree of imperfect competition in Thai Jasmine rice market. Using an annual panel data running from crop marketing year 2001/02-20015/16 and exploiting the institutional feature of the government price support policy, we find strong evidence of some oligopsony power and a moderate level of oligopsony price distortion. Therefore, the society is worst off without intervention in Jasmine rice market. We also find that the paddy pledging program is inefficient. However, when we account for the income redistribution effect, the benefit of the program is higher than the net social cost. In addition, we also find that the oligopsony power of rice millers is lower under the program than under free market. Furthermore, both farmers and consumers benefit from the program, and the program can be efficient by setting a suitable support price. Hence, in contrast to generally accepted "wisdom" regarding government agricultural policies, our results show that less government and more market (deregulation) are not always the right policy prescription, and price support policy can benefit not only farmers but also consumers.

Introduction

Agricultural price support policy is among economists' favorite examples of costly and inefficiently way to help farmers. In a world of perfect competition, such market intervention benefits farmers, hurts consumers, and imposes a net welfare loss on society. Therefore, it will be much more efficient for the government to give money directly to farmers rather than through government intervention. These assessments and policy recommendations are not only appeared in microeconomic textbooks (Pindyck and Rubinfeld 2009, Perloff 2004), they have become conventional "wisdom" in contemporary policy discussions(OECD 2001, 2017).

In the past, the Thai government had used price support policy, locally known as the paddy pledging program, to increase rice price and farmers' income. Prior studies reveal several drawbacks of the paddy pledging program. First, it imposes the deadweight loss on the society (Duangbootsee and Myers 2015, Permani and Vanzetti 2016, Siamwalla, Poapongsakorn, and Pantakua 2014). Second, this program is costly and fiscally unsustainable (Poapongsakorn 2010, The World Bank. 2012). Lastly, it does little to help poor farmers (Poapongsakorn 2013). These criticisms are in line with generally accepted "wisdom" about agricultural price support policy. Hence, earlier studies have recommended Thailand to eliminate the paddy pledging program. The Thai government did so in mid-2014. However, such policy prescription may be inaccurate in the presence of imperfect competition (Russo, Goodhue, and Sexton 2011).

In Jasmine rice market, there is a high possibility that the market is imperfectly competitive. Thailand is the world's largest Jasmine rice exporters and the United States is the major export market of high quality Thai Jasmine rice (Ministry of Commerce. 2017). Currently, 1.9 million farmer households produce Jasmine rice, which only around 457 rice millers or processers purchase (Rice Department. 2016b). Moreover, Jasmine rice farmers have few, usually no, choices among buyers because of high transportation cost. Besides, the switching cost from growing Jasmine rice to other crops is high. As a result, buyers have more bargaining power than farmers do, and they can use this buyer market power or oligopsony power to depress farm-level prices below those that would prevail in a competitive market. In the presence of oligopsony power, the society suffers welfare loss from market failure, and the wealth is unfairly transferred from farmers to rice millers. This transferred wealth, in turn, limits farmers' profitability. More importantly, policy analysis which assumes perfect competition in imperfect competition market may yield unreliable conclusions and recommendations which can hurt millions of Jasmine rice farmers. Therefore, in this paper, we investigate the presence of buyer market power and reevaluate the paddy pledging program with imperfect competition model in Thai Jasmine rice market. We address three questions: How much oligopsony power do rice millers have and exercise? Does society better off without market intervention? And, what are the market and welfare effects of the paddy pledging program under imperfect competition model?

Prior researches on competition in Thai rice market indicates that rice millers do not exercise market power (Chaowagul 2011, Titapiwatanakun 2012, Srisompun 2014). The drawback of these studies is that they are based on Structure-Conduct-Performance (SCP) framework. SCP framework assumes that the degree of market power (conduct) can be implied from market structure. However, this framework has been subjected to extensive criticism regarding their conceptual foundation and interpretation of the result (Church and Ware 2000, Jeffrey, Larry, and Amos 2007). Indeed, since the 1980s the focus of industrial organization studies has shifted from SCP framework to New Empirical Industrial Organization (NEIO) frameworks that directly measure the degree of market power (Kaiser and Suzuki 2006).

Although there is a high potential for imperfect competition in rice market in developing world, it has not been subjected to standard NEIO imperfect competition analysis. This is because data limitation prevents researchers from estimating the degree of imperfect competition in the rice market. Most of rice supply data in developing countries are available on a yearly basis. However, this annual data cannot be used to estimate the degree of imperfect competition under NEIO approaches.

Nevertheless, we can employ NEIO models in our study by exploiting the institutional features of price support policy to identify the degree of imperfect competition.

Our paper contributes to the empirical literature on competition in developing countries. Extensive researches exist regarding estimating oligopsony power in the developed country food industry (Anders, 2008; Azzam and Schroeter, 1995; Evans and H. Ballen, 2016; Morrison Paul, 2001; Muth and Wohlgenant, 1999). However, to the best of our knowledge, there are only a few empirical studies about oligopsony in developing countries that have been delivered to agricultural economics literature (Perekhozhuk et al. 2015, Lopez and You 1993, Scalco and Braga 2014). Indeed, Sheldon and Sperling (2003) point out that "we know very little about the extent of market power outside of the US food manufacturing sector". This study attempts to fill this gap.

In addition, our research contributes to the studies that incorporate imperfect competition parameter to evaluate agricultural policy (Suzuki, Lenz, and Forker 1993, Suzuki et al. 1994, Suzuki and Kaiser 1997, Lanclos and Hertel 1995, McCorriston and Sheldon 1996a, b, Alston, Sexton, and Zhang 1997, Hamilton and Sunding 1998, Lence 2016). For example, Suzuki et al. (1994b) examine the impact of generic milk promotion in Japan and find that perfect competition model underestimate marginal promotion benefit by 23-27 percent. Overall, most of these studies indicate that a failure to incorporate imperfect competition parameter in agricultural policy evaluation can lead to serious bias results.

Our research also relates to emerging research on the effect of market structure on oligopsony power. Lopez and You (1993) show that the creation of the coffee exporter board association in Haiti does not have any significant impact on oligopsony power. Liu, San, and Kaiser (1995) find that price support policy in the United States increases the oligopsony power of dairy manufacturers and fluid processors. More recently, Boyer and Brorsen (2013), in contrast with Cai et al. (2011), show that mandatory price reporting policy in the United State decrease meatpacker's oligopsony power.

The remainder of the paper is structured as follows. The next section describes the Jasmine rice market structure and the government intervention. The section following explains how we measure the degree of imperfect competition and the welfare implication of price support policy. We then illustrate the empirical model and data used in the analysis, followed by estimation results and the policy implication of these results. The last section concludes.

Thai Jasmine Rice Market and The Paddy Pledging Program

Brief Overview of Jasmine Rice Industry

Jasmine rice farmers are small-scale farmers. In 2016, 1.9 million farmer households with average farm size around 2.15 hectares per household grew Jasmine rice (Rice Department. 2016b). In 2013, around half of Jasmine rice production was marketed internationally (Srisompun 2014). Rice millers play a significant role in buying the Jasmine rice from farmers. In 2015, there are 457 rice millers in the main Jasmine rice growing area, the Northeastern (Department of Internal Trade. 2017a). As can be seen from Figure 1 , the spatial competition among the rice millers in Jasmine rice growing area is relatively low compared to other rice growing area. Moreover, if we zoom in on the main Jasmine rice growing areas, we will find that spatial competition among the rice millers is concentrated only in some areas.

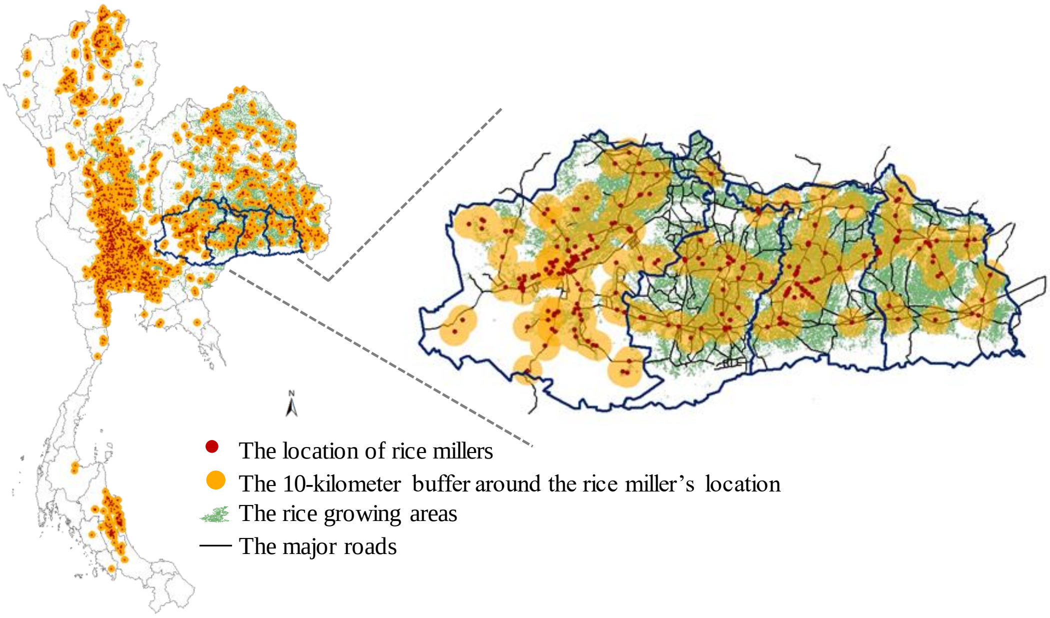

Figure 1 The spatial competition among the rice millers in Thailand in 2014

Source: Created by the authors based on data from Geo-Informatics and Space Technology Development Agency.(2016), Rice Department (2016a), and DIVA-GIS (2016)

The Paddy Pledging Program

The paddy pledging program[1] was a key instrument that government use to support rice price and increase farmer's income. This program was implemented between crop marketing year (MY) 2001/02[2]- MY2008/09 and MY2011/12- MY2013/14[3]. Under this program, the government offers loans to farmers at harvest time (November to February) with their paddy pledge as collateral. Farmers can borrow by either bring paddy to participating rice mills (warehouse deposit slip pledging) or keep it on the farm (on-farm pledging). The loan values equal the support price times the quantity of the farmer's paddy put under the loans. The loans are made for four months. If the paddy market price increase sufficiently during the period of the loan, the farmer may pay off the loan plus interest and regain control of his rice. If the paddy market price is not sufficiently above the support price when the loan comes due, the farmer can then freely default. The government agrees to accept paddy as full reimbursement. The government also hires the rice millers to process rice and deliver it to the government's warehouse. After that, the government releases rice to domestic and international market via auction or government-to-government deal.

As the support price was much higher than the market price, most Jasmine rice farmers sold their paddy to the government. Figure 2 shows that the support price of Jasmine paddy was relatively high compared to market price. On average, the government set support price around 20.1% higher than the market price. As a result, the government purchased a significant amount of paddy from farmers (see Table 1).

Since mid-2014, the Jasmine rice market has been deregulated. Given the high cost of an overall program and the management problems (particularly, corruptions), the government replaced

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[1] The program covered not only Jasmine paddy but also non-glutinous paddy and glutinous paddy. Jasmine paddy accounted for only 20.2% of total pledged paddy.

[2] Note: we define MY2001/02 as November 1, 2001 – October 31, 2002.

[3] In 2010, the government replaced the paddy pledging program with price insurance program. Under this program, the government provided a direct payment to farmers based on the difference between a a benchmark price and guaranteed prices. However, in 2012, the new government resumed the paddy pledging program.

the paddy pledging program with less-market distorting policy. For example, the government directly paid $174.5 per hectare to farmers in MY2014/15 and MY2016/17 (Sloop and Welcher 2017).

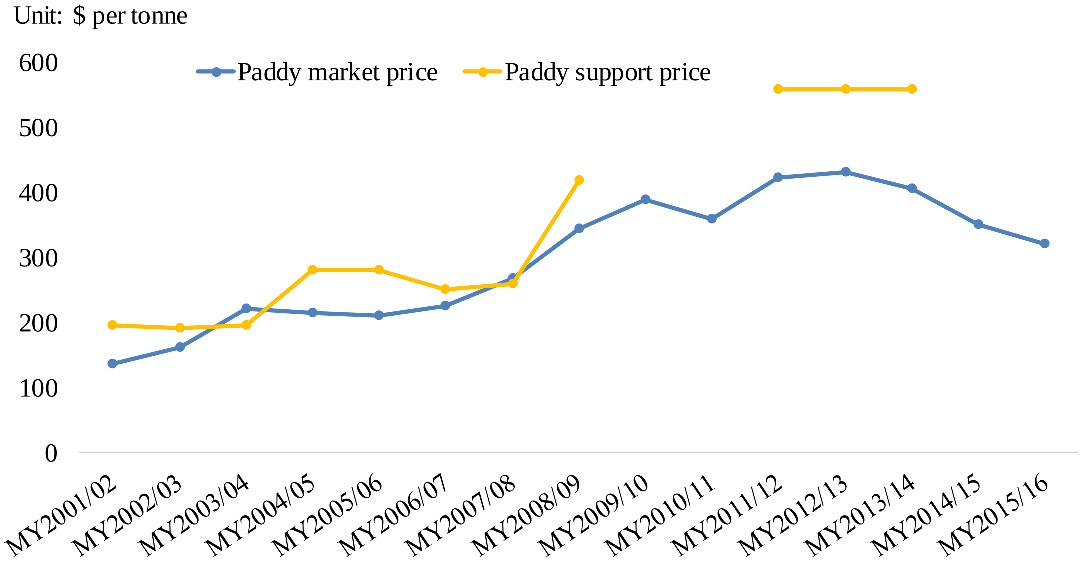

Figure 2 The Jasmine paddy market price and the Jasmine paddy support price

Source: Department of Internal Trade (2016), Isvilanonda (2010), Poapongsakorn (2010), and Office of Agricultural Economics (2017c)

Table 1 The Jasmine paddy production and the volume of paddy under the paddy pledging program

Marketing year	Jasmine paddy production (1,000 tonnes)	Jasmine paddy under the pledging program (1,000 tonnes)	Jasmine paddy under the pledging program (%)
2001/02	6,222	1,480	23.8
2002/03	5,989	611	10.2
2003/04	6,127	192	3.1
2004/05	6,319	2,176	34.4
2005/06	6,486	2,738	42.2
2006/07	6,569	653	9.9
2007/08	6,604	114	1.7
2008/09	6,692	1,327	19.8
2011/12	8,840	3,076	34.8
2012/13	8,653	3,403	39.3
2013/14	8,608	3,701	43.0

Source: Department of Internal Trade (2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2012, 2013, 2014) and Office of Agricultural Economics (2015)

A Theory Framework

A Theoretical Model of Thai Jasmine Rice Market

We build a theoretical model of Thai Jasmine rice market based on NEIO approach (Muth and Wohlgenant 1999). Suppose that the rice millers or the processors have an oligopsony power. They buy paddy (input) from farmers and sell milled rice (output) to consumers. Assume that the inverse Jasmine supply equation is

$$P^f = G(Q, Z) \qquad (1)$$

where P^f is the farm gate price, Q is the rice supply, and Z is a vector of supply sifters. Rice milling is assumed to utilize a fixed proportion and constant return technology. This assumption is reasonable because the conversion rate from paddy to milled rice is very stable and the interview with the rice millers has confirmed this assumption. In this case, we can denote both paddy and milled rice by the same variable, Q.

Let π_i be the rice miller's profit function for rice miller i.

$$\pi_i = P^w \cdot q - P^f q - C(q, V) - T(q, L) \qquad (2)$$

for $i = 1, \ldots, n$

where $P^f = G(Q, Z)$ as in Equation (1), $P^w$is wholesale price, $C(q, V)$ is constant processing costs per unit of paddy rice processed, $T(q, L)$ is transportation cost, V and L are a cost shifter. Assume that the output market is competitive. The first-order condition for a maximum profit takes the form

$$\frac{\partial \pi_i}{\partial q} = P^w - P^f - \frac{\partial G(Q, Z)}{\partial Q} \cdot \frac{\partial Q}{\partial q} q - \frac{\partial C(q, V)}{\partial q} - \frac{\partial T(q, L)}{\partial q} \qquad (3)$$

Rearranging terms in Equation (3), we have

$$P^f + \theta \frac{\partial G(Q,Z)}{\partial Q} Q = P^w - \frac{\partial C(q,V)}{\partial q} - \frac{\partial T(q,L)}{\partial q} \quad (4)$$

where the conduct parameter (θ) indexes the degree of imperfect competition or oligopsony power. θ has the value between 0 and 1. When firms are perfectly collusive or monopsony, θ = 1 and when firms are perfectly competitive, θ = 0. The right-hand side of Equation 4 is the value of marginal product (VMP), this is the case by fix-proportion assumption (Azzam and Park 1993), and the left-hand side is the marginal factor cost (MFC).

Solving for P^f give the derived demand equation.

$$P^f = -\theta \frac{\partial G(Q,Z)}{\partial Q} Q + P^w - \frac{\partial C(q,V)}{\partial q} - \frac{\partial T(q,L)}{\partial q} \quad (5)$$

Equation (4) can be written in elasticity form as

$$P^f (1 + \frac{\theta}{\epsilon}) = P^w - \frac{\partial C(q,V)}{\partial q} - \frac{\partial T(q,L)}{\partial q} \quad (6)$$

where θ measures the degree of oligopsony power and $\varepsilon = \frac{\partial Q}{\partial P^f} \frac{P^f}{Q}$ is price elasticity of Jasmine paddy supply.

Since the value of marginal product and the farm gate price would be equal if the market were competitive, the different between VMP and P^f is an index of the relative oligopsony price distortion. Rearranging Equation (6), we have

$$M = \frac{\theta}{\varepsilon} \quad (7)$$

where M measures the oligopsony power distortion of the rice millers.

A Welfare Analysis of Price Support Policy

An Analytical Framework

We develop an analytical framework based on the theoretical work of Russo, Goodhue, and Sexton (2011) to evaluate the efficiency and the equity effect of price support policy. Unlike Russo, Goodhue, and Sexton (2011), we assume processers to exert market power only in procurement market. Moreover, we relax the assumption that government stock has no value to reflect the reality of the price support policy in Thailand. In addition, we include income redistribution effect in the model.

Suppose that the government intervenes the market and set support price at P_S. Figure 3 presents three possible cases for market equilibrium under price support policy.

In (*a*), the government set support price higher than competitive price ($P_S > P_C$). The support price makes the supply curve, as viewed by the oligopsonists, flat in the range where the support price is above the original supply curve. The new MFC_2 is flat where the supply curve is flat and is the same as MFC_1 where the supply curve is upward sloping. The intersection of MFC_2 and the derived demand curve determines the new oligopsony equilibrium where processors purchase Q_R tons at price P_R. The floor price reduces a welfare loss to triangle EFG. Therefore, the price floor increases welfare by trapezoid Y+J+Z. Moreover, as the government buys a quantity Q_S, the producer surplus increase by the speckled triangle I+K. Thus, total change in welfare or efficiency effect is

$$(Y + J + Z + I + K) - Net\ \ cost\ \ to\ \ government$$

The net cost to government is purchasing cost (P_S*(Q_S - Q_R)) + processing cost + sack cost + transportation cost + storage cost + operating cost + interest cost + quality depreciation cost – revenue from selling milled rice.

Next, we consider the equity effect. The price floor transfers the welfare from processors to farmers and consumers equal area A and C, respectively. In addition, the government transfers income from taxpayers to farmers equal area F. Hence, total income redistribution effect is A+C+F.

In (b), the government set support price equal competitive price ($P_S = P_C$). In this case, the efficiency gain is N+M, and equity gain is R+L. Since the support price does not induce supply surplus, the cost to government is only the management cost of the program.

In (c), the government set support price lower than competitive price ($P_S < P_C$). In this case, the efficiency gain is Q and equity gain in O+P. Since this support price also does not induce supply surplus, the cost to government is only the management cost of the program.

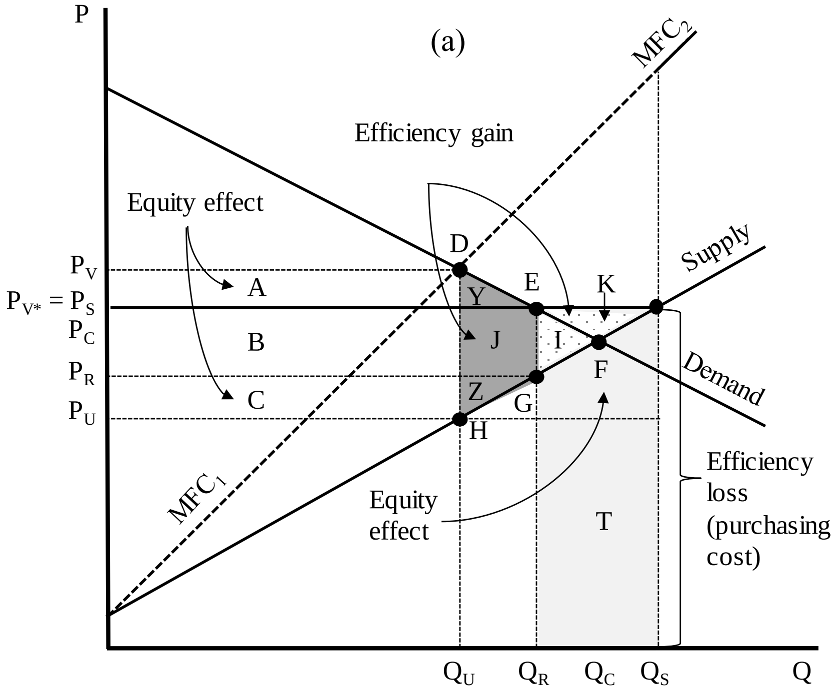

Figure 3 The efficiency and equity effects of the price support policy

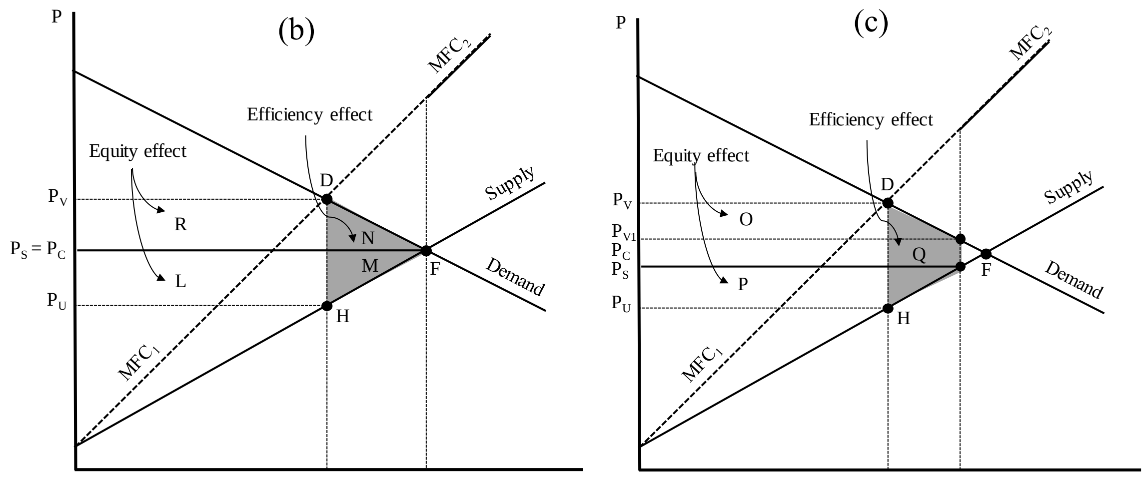

Figure 3 (Continued)

A Calculation Procedure

We observe P_S, P_R, Q_R, and Q_S in the Jasmine rice market. Therefore, we need to estimate P_C, Q_C, P_U, Q_U, P_V, P_{V^*}, and P_{S^*}. Since our estimation results are in the first difference form (Δderived demand equation, Δsupply equation), we have to convert them into level form (derived demand equation, supply equation). After that, we can find competitive equilibrium from derived demand equation and supply equation.

First, we need to estimate P_{V^*}, P_V, P_U, Q_U, and P_{S^*} by the following step (see Figure 4).

1. Estimate P_{V^*} from below formula

$$P_{V^*} \ or \ VMP_R = P_R\left(1 + \frac{\theta_R}{\varepsilon}\right)$$

where θ_R and ε are oligopsony power under regulated market and price supply elasticity, respectively.

2. Estimate P_V and P_U from below formula

$$P_U\left(1 + \frac{\theta_U}{\varepsilon}\right) = P_V \ or \ VMP_U$$

where θ_U and ε are oligopsony power under unregulated market and price supply elasticity, respectively.

Since we have $\left(1 + \frac{\theta_U}{\varepsilon}\right)$, P_{V^*}, and P_R, we can obtain P_V and P_U by decreasing P_R by 1 unit and increasing P_{V^*} by 1 unit (see Figure 4) until we find the gap between P_R and P_{V^*} that equal $\left(1 + \frac{\theta_U}{\varepsilon}\right)$.

3. To get Q_U,

   3.1 Solve for predicted Δsupply equation by substituting average value of each variable into estimated supply equation (10), we have

$$\widehat{\Delta Q} = d\widehat{\Delta P} + e \qquad (8)$$

   where d and e are a number.

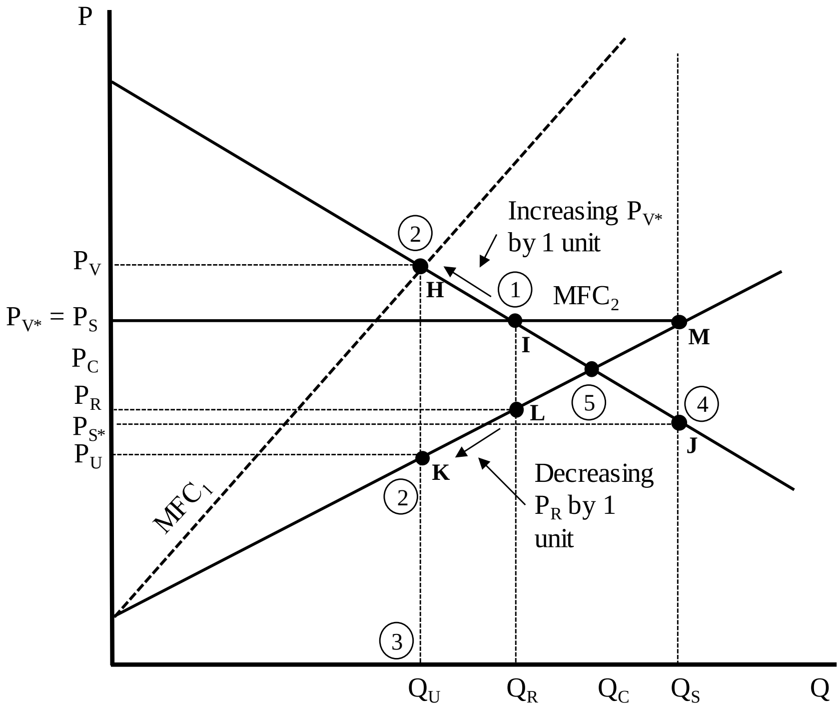

Figure 4 A calculation procedure for welfare analysis

3.2 Calculate change in price (ΔP) from unregulated market (P_U) to regulated market (P_R), $\Delta P = P_U - P_R$

3.3 Plug ΔP into predicted Δsupply equation (8), we get the estimated change in supply under unregulated market ($\widehat{\Delta Q_U}$).

3.4 Since we know the actual supply (Q_R) and actual supply change (ΔQ_R) under regulated market, we can estimate Q_U from

$$Q_U = Q_R + (\widehat{\Delta Q_U} - \widehat{\Delta Q_R})$$

4. To get P_{S*},

4.1 Solve for predicted Δderived demand equation that based on change in rice supply (ΔQ) by,

4.1.1 Our estimated predicted derived demand equation is

$$\widehat{\Delta P} = -\theta \widehat{\Delta Q}^* + c$$

where θ is oligopsony power, c is a number and $\widehat{\Delta Q}^* = \frac{\widehat{\Delta Q}}{\alpha_1 + \alpha_3 * ferp_{t-1}}$

Multiply above equation by $h = \alpha_2 + \alpha_3 * ferpy,$ we have

$$h\widehat{\Delta P} = -\theta\widehat{\Delta Q} + hc$$

4.1.2 Plug average value of each variable into estimated derived demand equation (13), we have predicted change in price ($\widehat{\Delta P}$)

4.1.3 Since we know *h*, $\Delta P, -\theta,$ and ΔQ, we can get *c* from

$$c = (h\widehat{\Delta P} - (-\theta\widehat{\Delta Q}))/h$$

4.1.4 Now we have *c* value; we can plug *c* value into the predicted derived demand equation

$$h\widehat{\Delta P} = -\theta\widehat{\Delta Q} + hc \qquad (9)$$

4.2 As we observed Q_R , we can estimate the change of supply at point P_{S*} from

$$\Delta Q_s = Q_S - Q_R$$

Since Q_S equal Q_R + the amount of government rice purchase, we have

ΔQ_s = the amount of government rice purchase

4.3 Plug ΔQ_s in predicted Δderived demand equation (9), we get the estimated change in price ($\widehat{\Delta P_{S*}}$)

4.4 Since we have estimated price (P_{V*}) and estimated change in price (ΔP_{V*}) in predicted demand equation, we can estimate P_{S*} from

$$P_{S*} = P_{V*} + (\widehat{\Delta P_{S*}} - \widehat{\Delta P_{V*}})$$

5. So far, we have point H, I, and J on derived demand curve and point K, L, and M in supply curve (see Figure 4). To get competitive equilibrium (P_C, Q_C),

5.1 Solve for linear approximation of derived demand and supply based on point H, I, J and K,L,M, we have

$Q_{de} = gP + n$ … Derived demand equation

$Q_{su} = mP + v$ ………….. Supply equation

Where *g, m, n,* and *v* are number.

5.2 Solve derived demand equation and supply equation; we have P_C and Q_C

An Empirical Model of Thai Jasmine Rice Market

we specify the Jasmine paddy supply equation (1) as follow:

$$Q_{nt} = \alpha_0 + \alpha_1 P^f_{nt} + \alpha_2 ferp_{t-1} + \alpha_3 P^f_{nt} * ferp_{t-1} + \alpha_4 dgovp_{nt} + \alpha_5 rainq3_{nt-1} + \alpha_6 (rainq3_{nt-1})^2 + \alpha_7 rain10_{nt-1} + \alpha_8 (rain10_{nt-1})^2 + \alpha_9 sugap_{t-1} + \alpha_{10} casap_{t-1} + \alpha_{11} miniw_{nt-1} + \alpha_{12} q2p_{nt-1} + \alpha_{13} ttrend + u_{1nt} \quad (10)$$

where

Q_{nt}	= the quantity of Jasmine paddy supply
P^f_{nt}	= average Jasmine farm gate price
$ferp_{t-1}$	= lagged fertilizer price
$P^f_{nt} * ferp_{t-1}$	= interaction term that allow supply curve to rotate
$dgovp_{nt}$	= dummy variable $dgovp_{nt}$ = 1 if government support price is 20% higher than the market price during harvesting period and 0 otherwise
$rainq3_{nt-1}$	= lagged rain in quarter 3[4]
$(rainq3_{nt-1})^2$	= the square term of lagged rain in quarter 3
$rain10_{nt-1}$	= lagged rain in October
$(rain10_{nt-1})^2$	= the square term of lagged rain in October
$sugap_{t-1}$	= lagged sugarcane farm gate price
$casap_{t-1}$	= lagged cassava farm gate price
$miniw_{nt-1}$	= lagged minimum wage
$q2p_{nt-1}$	= lagged farm gate rice price in quarter 2 (3 months before planting)
$ttrend$	= a liner time trend to account for technological change
u_{1nt}	= error term

n denotes province (1,…,15), *t* denotes marketing year

[4] Figure 5 shows how we define quarter in the marketing year of Jasmine rice

In unregulated market, the current marketing year rice price (P_{nt}^{f}) will not affect the current marketing year rice supply as it has been already fixed by planting decision made in the previous marketing year (see Figure 5). However, under the paddy pledging program, the current marketing year price can affect the current marketing year rice supply. Figure 6 shows the current farm gate rice price and the current Jasmine rice supply. As can be seen, the supply of Jasmine rice in the market increase (decrease) when the farm gate rice price increase (decrease). This shows that there is a competition between the rice millers and the government to buy rice from the farmers.

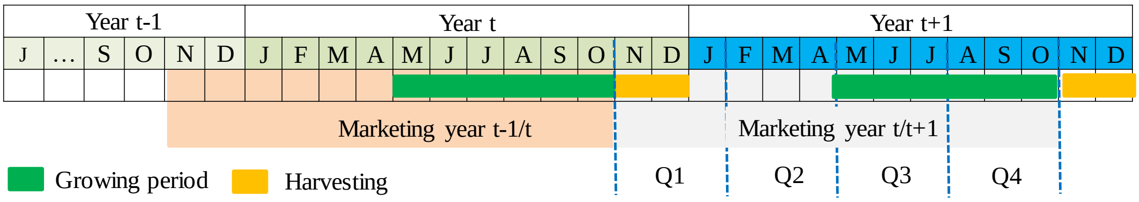

Figure 5 The crop marketing year of the Jasmine rice
Note: The supply of Jasmine rice in marketing year t/t+1 has been fixed by plating decision made in marketing year t-1/t

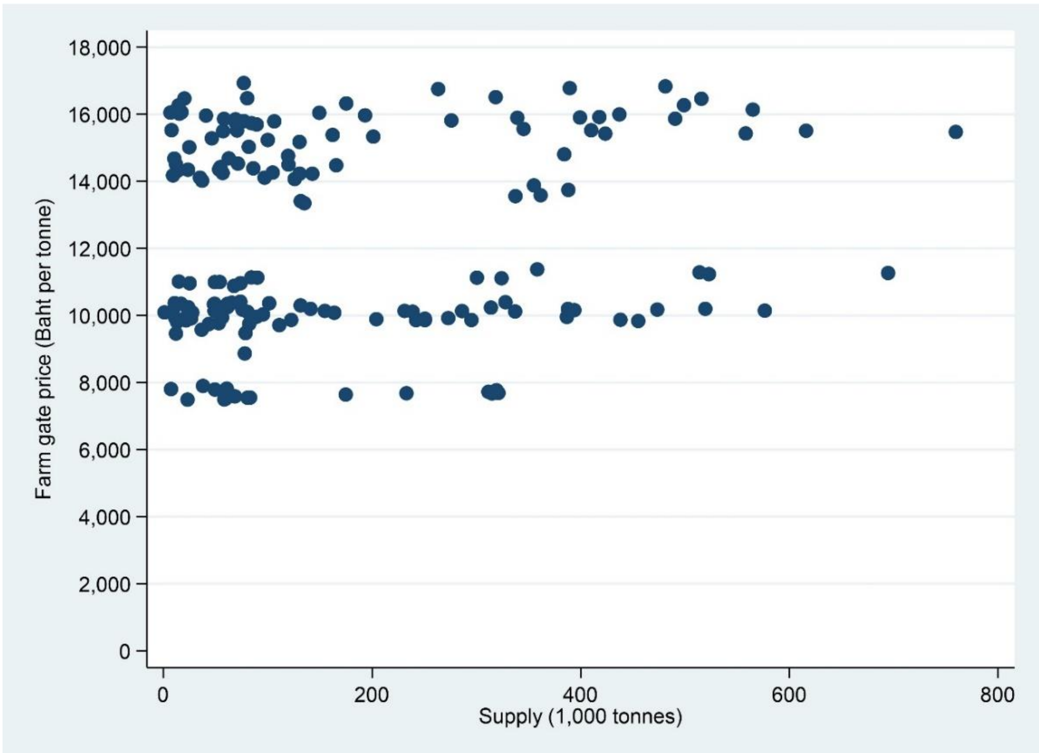

Figure 6 The farm gate rice price and the Jasmine rice supply during the implementation of the paddy pledging program.

To complete the model, we must specify a reduced-form of the value of the marginal product. As can be seen from Equation (4), the value of marginal product is a function of wholesale price and cost shifter. In the case of the rice millers, the cost-shifters are a wage, a price of electricity, and a diesel price. Thus, we specified a reduced-form of the value of the marginal product as follow.

$$VMP = \beta_0 + \beta_1 diesp_t + \beta_2 miniw_{nt} + \beta_3 electrip_t + \beta_4 P_t^w + u_{2nt} \qquad (11)$$

where

$diesp_t$	= diesel price
$miniw_{nt}$	= minimum wage
$electrip_t$	= electricity price
P_t^w	= wholesale Jasmine rice price index
u_{2nt}	= error term

n denotes province (1,…,15), *t* denotes marketing year

Substituting VMP into Equation (5), we have

$$P_{nt}^f = -\theta \frac{\partial G(Q,Z)}{\partial Q} Q + \beta_0 + \beta_1 diesp_t + \beta_2 miniw_{nt} + \beta_3 electrip_t + \beta_4 P_t^w + u_{2nt} \qquad (12)$$

Solving for $\frac{\partial G(Q,Z)}{\partial Q}$ from supply Equation (10), we have

$$\frac{\partial G(Q,Z)}{\partial Q} = \frac{1}{\alpha_1 + \alpha_3 ferp_{t-1}}$$

Substituting $\frac{\partial G(Q,Z)}{\partial Q}$ into Equation (12) yields the final empirical specification of derived demand relation.

$$P_{nt}^{f} = \beta_0 - \theta Q^{*} + \beta_1 diesp_t + \beta_2 miniw_{nt} + \beta_3 electrip_t + \beta_4 P_t^{w} + \mu \qquad (13)$$

where $\mu = u_{2nt} - u_{1nt}$ and $Q^{*} = \frac{Q}{\alpha_1 + \alpha_3 ferp_{t-1}}$

Since the government support price may have an impact on oligopsony power, we specify oligopsony power as a linear function of the difference between market price and government support price. We also specify oligopsony power as a linear function of time since oligopsony power may change over time. We have

$$\theta = \theta_I + \theta_G pdifgovmar_{nt} + \theta_T ttrend \qquad (14)$$

where $pdifgovmar_{nt}$ is the price difference between government support price and market price during the harvesting period, and $ttrend$ is time trend.

Substituting θ into Equation (13), we have

$$\begin{aligned} P_{nt}^{f} = \beta_0 - (\theta_I + \theta_G pdifgovmar_{nt} + \theta_T ttrend) Q^{*} \\ + \beta_1 diesp_t + \beta_2 miniw_{nt} + \beta_3 electrip_t + \beta_4 P_t^{w} + \mu \end{aligned} \qquad (15)$$

Equation (10) and (15) make up the system of equations that allow us to determine the degree of oligopsony power in the Jasmine rice market.

The Data

Data Set

We construct, using 9 data sources, a provincial-level balanced panel data set that includes information on Jasmine crop production, Jasmine farm gate price, wholesale price, climate, wage, fertilizer price, diesel price, government support price, Thai population, and exchange rate. The data are annual[5], 15 provincial level observations, running from marketing year 2001/02-2015/16, providing 225 observations before taking first differences[6]. All price and income variables were deflated using the consumer price index from Bureau of Trade and Economic Indices (2017). Details on variable definitions and data sources are provided in the Appendix A1. Here we describe the critical variables in the empirical analysis.

The Jasmine paddy supplied variable used in the estimation is constructed by subtracting Jasmine paddy production by the amount of Jasmine paddy purchased by the government, the amount of household consumption and the amount of seed used. The amount of household consumption is estimated by multiplying the number of Jasmine rice farming household by household size and per capita rice consumption. The amount of seed used is calculated by multiplying the planted area by seed rate used per unit of area. The government Jasmine paddy purchased data are from Department of Internal Trade (2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2012, 2013, 2014), Ministry of Commerce. The Jasmine paddy rice production, Jasmine rice farming household, household size, planted area and seed rate data are from Agricultural Data Operation Center by Office of Agricultural Economics (2015, 2017a, b), Ministry of Agriculture and Cooperatives, which complies crop production data, farm gate price data and agricultural farm household socio-economic data from relevant government agencies. The per capita rice consumption is drawn from Production,

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[5] Ideally, one would like to have monthly data. Unfortunately, such data are unavailable, specifically for Jasmine paddy rice supplied variable.

[6] Due to the unit root problem, we must do the first different before estimation. If we estimate when we have a unit root problem, the result will be invalid.

Supply and Distribution Database by United States Department of Agriculture (USDA)[7].

In considering the effect of government support price policy on oligopsony power, we construct the price difference variable by subtracting the government support price by the market price during the harvesting time. Moreover, to capture the effect of government support price on rice supply, we construct the dummy variable of government support price by comparing the government support price with the market price. This variable equals 1 if government support price is 20%[8] higher than market price and 0 otherwise. The government Jasmine paddy support price data are from Department of Internal Trade. The data of Jasmine farm gate price are from Office of Agricultural Economics (2017c).

Rainfall variables are constructed by multiplying rainfall data with the percentage of Jasmine rice planted area to total rice planted area[9]. Rainfall data are from Climatic Data Service Center by the Thai Meteorological Department (2017), Ministry of Digital Economy and Society. Rice planted area data are from Office of Agricultural Economics. Fertilizer price variable is constructed by dividing fertilizer imported value by imported quantity[10]. The data on import is from Thailand's Trading Database by Ministry of Commerce (2017).

Ideally, one would like to use actual electricity price data to reflect the energy cost of rice milling. However, unfortunately, this data is unavailable. Thus, we use the fuel oil price as a proxy variable for electricity price. Fuel oil price is a good proxy since it is used as a reference price for natural gas which accounts for 69% of total supply resources used to generate electricity in Thailand in 2015 (Electricity Generating Authority of Thailand. 2015). Besides, electricity price is generally set on a cost-plus basis. Therefore, fuel oil price is correlated with electricity price. Fuel oil price data are

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7 Available at https://apps.fas.usda.gov/psdonline/app/index.html#/app/advQuery

8 The mean value of the percentage price difference between government support price and market price in the sample

9 Weight is used to make the effect of rain variable on Jasmine rice production more precise.

10 This fertilizer price is a reasonable choice because 95% of fertilizer used in Thailand is imported fertilizer.

from Real Sector Statistics by Bank of Thailand[11].

The wholesale Jasmine rice price index variable is calculated based on Jasmine rice milling conversion rate and wholesale Jasmine milled rice price and its by product price in Bangkok. These data are from Department of Internal Trade (2017b, c, d, e). Thai population variable and exchange rate variable are used as instrumental variables for the endogenously determined wholesale Jasmine rice price index. Thai population data are from Department of Provincial Administration (2017), and the exchange rate is from Bank of Thailand[12].

Descriptive Statistics of Sample

Table 2 presents descriptive statistic for the full sample, the main growing areas sample, and the minor growing areas sample (see Figure 7) Overall, the jasmine rice production increase around 15,000 tonnes per year per province during the sample period. However, the production in the main growing area increases more than in the minor growing area. In the main growing area, the production increase around 30,000 tonnes per year per province whereas it increases only 4,500 tonnes per year per province in the minor growing area. The farm gate price and wholesale price increase around 219 and 342 baht per tonne per year, respectively. Rain is quite stable during our sample period since the average change is close to 0.

[11] Available at http://www2.bot.or.th/statistics/BOTWEBSTAT.aspx?reportID=90&language=ENG

[12] Available at http://www2.bot.or.th/statistics/BOTWEBSTAT.aspx?reportID=123&language=ENG

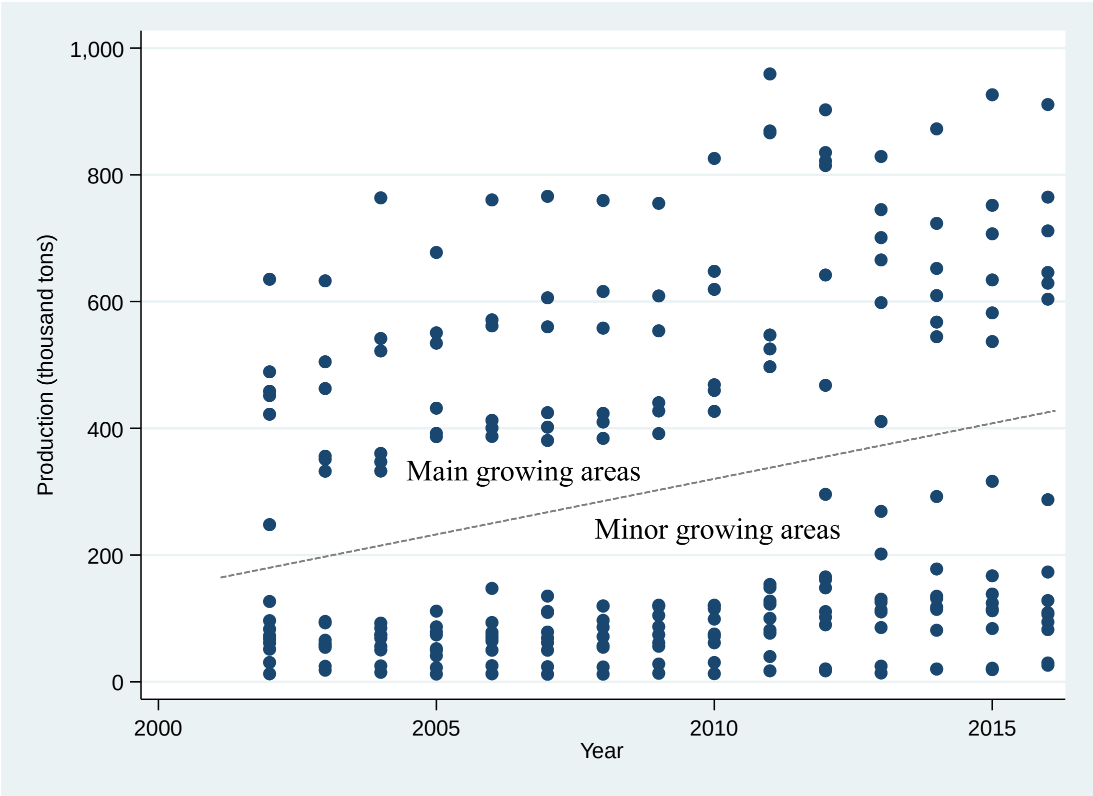

Figure 7 Jasmine rice production in each province

Table 2 Summary statistic

Variable	Full sample		Main growing area		Minor growing area		Unit
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	
Δjasmine paddy production	15.1	133.1	30.9	207.0	4.5	30.1	1,000 tonnes
Δfarm gate price	219.8	1,792.7	197.2	1,944.6	235.0	1,691.6	Baht per tonne
Δfertilizer price	9.0	486.8	9.0	488.6	9.0	487.6	Baht per 50 kilograms
Δfarm gate price*fertilizer price	204,003	8,194,318	190,437	8,705,802	213,047	7,870,458	-
Δprice support dummy	-0.1	0.7	-0.1	0.6	-0.1	0.7	-
Δlagged rain in quarter 3	-0.0	35.7	-0.8	46.9	0.4	25.9	Millimeter
Δ(lagged rain in quarter 3)^2	-55.8	11,052.6	-217.6	15,845.1	52.1	6,124.8	Millimeter
Δlagged rain in October	0.5	57.7	-0.7	81.9	1.2	33.5	Millimeter
Δ(lagged rain in October)^2	13.7	15,305.5	-212.3	22,293.8	164.3	7,848.7	Millimeter
Δlagged sugarcane farm gate price	6.3	100.5	6.3	100.9	6.3	100.7	Baht per tonne
Δlagged cassava farm gate price	75.5	444.4	75.5	446.0	75.5	445.1	Baht per tonne
Δlagged minimum wage	8.0	22.7	7.9	22.8	8.0	22.7	Baht per day
Δlagged farm gate price in quarter 2	350.4	2,143.3	352.4	2,315.6	349.1	2,029.7	Baht per tonne
Δdiesel price	0.4	4.4	0.4	4.4	0.4	4.4	Baht per liter
Δminimum wage	8.1	22.7	8.0	22.8	8.1	22.7	Baht per day
Δfuel oil price	0.4	3.5	0.4	3.5	0.4	3.5	Baht per liter
Δwholesale price index	342.1	1,825.4	342.1	1,831.9	342.1	1,828.3	Baht per tonne
Observations	210		84		126		

Estimation Results and Policy Implication

Oligopsony power (*θ*)

We simultaneously estimate supply and derived demand equation using system estimation methods. These methods are more efficient than estimate each equation separately (Wooldridge 2010). Table 3 shows that regardless of model specification, estimates of the oligopsony power component (θ) is mostly statistically different from zero at the 1% significance level. Column 1 specifies oligopsony power components as a linear function of the difference between market price and government support price (θ_G) and a linear function of time (θ_T). As expected, there is a negative relationship between government support price and oligopsony power. The coefficient on θ_G is negative and highly statistically significant ($p < .001$). It means that 2,500 baht[13] spread between support price and market price is predicted, holding other oligopsony power components fixed, to decrease oligopsony power by 0.23. On the contrary, if the government set the price lower than the market price, the negative price gap will increase oligopsony power. Therefore, oligopsony power decrease (increase) when the government set support price higher (lower) than the market price. The θ_T is also statistically significant, and its coefficient implies an approximate 0.034 decrease in oligopsony power per year, on average. In addition, the coefficient on constant oligopsony power (θ_I) is positive and highly statistically significant.

The remaining results of the perceived demand equation have the reasonable effects. For example, an increase in output price (wholesale price index) has a strongly positive effect on the price of input (farm gate price). Controlling for other variables, one bath increase in wholesale price increases farm gate price by around 0.78 bath. As Breusch-Pagan test for heteroscedasticity

[13] The mean value of the price difference between government support price and market price in the sample

and Wooldridge test for autocorrelation result in high p-value, our derived demand equation has no heteroskedasticity and autocorrelation problem[14]

The results of supply equation also have the expected effects. For instance, the farm gate price variable, the fertilizer price variable, and their interaction are statistically significant at the 1% significance level. From the mean value of Δfertilizer price, one bath increase in farm gate price[15] increases rice supply by 50 tonnes, an expected relationship. Like derived demand equation, our supply equation has no heteroskedasticity and autocorrelation problem.

Column 2 uses nonlinear three-stage least square (N3SLS) to estimate supply and derived demand equation. The results are similar to column 1 where we use iterative three-stage least square (I3SLS). Thus, imposing the nonlinear coefficient restrictions does not make any difference in our regression model. Column 3 drops θ_T from oligopsony power components. Dropping θ_T reduce the coefficient on other oligopsony power components, yet they remain highly statistically significant. Column 4 drops θ_G from oligopsony power components. The results are similar to dropping θ_T.

Column 5-8 estimate parallel specification but with the main growing area sample. The results are generally similar, except that the coefficient on θ_T become statistically insignificant in column 5 and 6. In addition, in column 8, the coefficient on θ_I and θ_T turn statistically insignificant. These misleading results may arise from the autocorrelation problem. We suspect that we have autocorrelation in derived demand equation since the Wooldridge test for autocorrelation shows small p-value (0.03).

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[14] If we have heteroskedasticity and autocorrelation problem, the conclusion we draw from test statistic will be invalid (Wooldridge 2012)

[15] The partial effect of farm gate price on rice supply is $\frac{\Delta\text{rice supply}}{\Delta\text{farm gat price}} = \alpha_1 + \alpha_3 \Delta fertilizer\ price$

Table 3 I3SLS and N3SLS estimations of perceived demand equation and supply equation

Variables	Full sample				Main growing area			
	I3SLS (1)	N3SLS (2)	I3SLS (3)	I3SLS (4)	I3SLS (5)	N3SLS (6)	I3SLS (7)	I3SLS (8)
Perceived demand equation, dependent variable: farm gate price (ΔP)								
Δdiesel price	-70.5**	-70.0**	-112.0***	-82.1***	-66.8	-68.2	-102.5***	-123.261***
	[27.697]	[27.412]	[20.536]	[20.747]	[47.098]	[47.613]	[36.950]	[41.139]
Δminimum wage	-1.023	-0.874	1.913	4.191	-5.11	-5.64	-3.410	-1.546
	[3.659]	[3.622]	[2.835]	[2.562]	[4.788]	[4.844]	[4.443]	[4.456]
Δfuel oil price	150.8***	151.2***	201.6***	158.4***	137.5***	140.1***	167.3***	156.560***
	[36.461]	[36.082]	[27.072]	[27.411]	[45.073]	[45.621]	[36.830]	[42.243]
Δwholesale price index	0.785***	0.785***	0.837***	0.841***	0.902***	0.897***	0.949***	1.006***
	[0.041]	[0.041]	[0.031]	[0.030]	[0.065]	[0.065]	[0.053]	[0.053]
θ_I	0.603***	0.601***	0.212***	0.198***	0.380**	0.396**	0.168**	-0.050
	[0.131]	[0.130]	[0.051]	[0.066]	[0.167]	[0.170]	[0.070]	[0.090]
θ_G	-.00009***	-.00009***	-.00006***		-.00009***	-.00009***	-.00006***	
	[0.00002]	[0.00002]	[0.00001]		[0.00002]	[0.00002]	[0.00002]	
θ_T	-0.034***	-0.034***		-0.015**	-0.017	-0.018		0.004
	[0.010]	[0.010]		[0.007]	[0.012]	[0.012]		[0.009]
Δconstant	-381.1***	-381.8***	-334.9***	-177.8***	-445.8***	-451.3***	-379.4***	-147.110
	[86.426]	[85.511]	[69.863]	[54.712]	[139.979]	[141.482]	[126.413]	[99.302]
Observations	210	210	210	210	84	84	84	84
R-squared	0.79	0.81	0.86	0.88	0.89	0.89	0.90	0.90
Breusch-Pagan test for heteroscedasticity	0.74		0.77	0.60	0.28		0.29	0.22
Wooldridge test for autocorrelation	0.70		0.54	0.59	0.19		0.22	0.03
Durbin-Watson		1.74				2.21		

Table 3 (continued)

Variables	Full sample				Main growing area			
	I3SLS (1)	N3SLS (2)	I3SLS (3)	I3SLS (4)	I3SLS (5)	N3SLS (6)	I3SLS (7)	I3SLS (8)
Supply equation, dependent variable: jasmine rice supply (ΔQ)								
Δfarm gate price	0.051***	0.054***	0.056***	0.055***	0.071***	0.090***	0.062***	0.050**
	[0.014]	[0.014]	[0.014]	[0.014]	[0.021]	[0.022]	[0.022]	[0.023]
Δfertilizer price	0.865***	0.913***	0.676**	0.677**	1.448**	1.476**	1.640***	2.030***
	[0.289]	[0.291]	[0.286]	[0.287]	[0.587]	[0.600]	[0.585]	[0.594]
Δfarm gate price*fertilizer price	-.00005***	-.00006***	-.00005***	-.00005***	-.00009***	-.0001***	-.00009***	-.000***
	[0.00001]	[0.00001]	[0.00001]	[0.00001]	[0.00003]	[0.00003]	[0.00003]	[0.000]
Δprice support dummy	-55.618***	-55.063***	-42.381**	-38.354**	-212.3***	-192.6***	-233.1***	-283.2***
	[18.790]	[18.940]	[18.661]	[18.725]	[27.808]	[28.219]	[27.971]	[27.695]
Δlagged rain in quarter 3	2.000***	1.987***	2.050***	1.967***	2.060*	2.164*	2.033*	2.137**
	[0.693]	[0.699]	[0.681]	[0.687]	[1.074]	[1.115]	[1.059]	[1.038]
Δlagged rain in quarter 3^2	-0.007***	-0.007***	-0.007***	-0.007***	-0.007**	-0.007**	-0.007**	-0.007**
	[0.002]	[0.002]	[0.002]	[0.002]	[0.003]	[0.003]	[0.003]	[0.003]
Δlagged rain in October	1.273***	1.278***	1.161***	1.186***	2.508***	2.513***	2.518***	2.482***
	[0.406]	[0.409]	[0.401]	[0.404]	[0.497]	[0.515]	[0.491]	[0.484]
Δlagged rain in $October^2$	-0.003**	-0.003**	-0.003**	-0.003**	-0.007***	-0.007***	-0.007***	-0.007***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.002]	[0.002]	[0.002]
Δlagged sugarcane farm gate price	0.194	-0.026	0.356**	0.319*	-0.363	-0.092	-0.583**	-0.910***
	[0.178]	[0.053]	[0.175]	[0.177]	[0.285]	[0.080]	[0.281]	[0.286]
Δlagged cassava farm gate price	-0.021	0.188	0.003	-0.008	-0.125	-0.177	-0.160**	-0.206***
	[0.052]	[0.179]	[0.052]	[0.052]	[0.078]	[0.292]	[0.077]	[0.079]
Δlagged minimum wage	-0.383	-0.346	-0.338	-0.422	-0.868	-0.668	-0.982*	-0.984*
	[0.386]	[0.389]	[0.380]	[0.383]	[0.565]	[0.585]	[0.559]	[0.555]
Δlagged farm gate price in quarter 2	0.016*	0.015	0.023**	0.021**	0.017	0.029**	0.006	-0.011
	[0.009]	[0.009]	[0.009]	[0.009]	[0.013]	[0.013]	[0.013]	[0.013]

Table 3 (continued)

Variables	Full sample				Main growing area			
	I3SLS (1)	N3SLS (2)	I3SLS (3)	I3SLS (4)	I3SLS (5)	N3SLS (6)	I3SLS (7)	I3SLS (8)
Year 2010	-23.754	-19.916	-116.545	-105.569	156.619	13.979	285.048**	477.742***
	[76.517]	[77.167]	[75.409]	[76.025]	[119.698]	[122.893]	[119.128]	[121.048]
Year 2011	56.160	64.018	-10.873	13.396	306.317**	246.826**	390.373***	500.115***
	[85.744]	[86.453]	[84.771]	[85.364]	[132.735]	[135.899]	[131.520]	[135.652]
Year 2015	247.0***	248.3***	279.4***	298.2***	256.314***	326.307***	198.077**	46.156
	[63.799]	[64.310]	[63.264]	[63.596]	[86.710]	[88.223]	[87.753]	[87.525]
Year 2016	78.023	79.946	127.0***	117.518**	44.017	108.970	-10.739	-87.987
	[49.351]	[49.772]	[48.588]	[49.021]	[70.435]	[72.575]	[69.694]	[70.263]
Δconstant	-24.570*	-25.593*	-24.702*	-25.258*	-35.348*	-41.137**	-33.909*	-29.503
	[13.259]	[13.365]	[13.162]	[13.235]	[18.150]	[18.527]	[18.332]	[19.046]
R-squared	0.45	0.45	0.44	0.44	0.81	0.82	0.80	0.80
Breusch-Pagan test for heteroskedasticity	0.29		0.29	0.29	0.12		0.12	0.12
Wooldridge test for autocorrelation	0.08		0.08	0.08	0.45		0.45	0.45
Durbin-Watson		2.18				2.56		

Note: The quantities in blankets below the estimates are the standard errors. *, **, *** indicate significance at the 0.1, 0.05, 0.01 levels, respectively. We use TSP 5.1 for N3SLS. Standard error of N3SLS estimators are robust to heteroskedasticity.

Table 4 summarizes the estimates of oligopsony power in each specification. The estimates of θ in full sample and main growing area sample range from -0.39 to 0.65 and -0.21 to 0.55, respectively[16]. Overall, the results in Table 3 and 4 show the evidence of some oligopsony power and pro-competitive effect of price support policy in Thailand's Jasmine rice market.

Table 4 Estimates of oligopsony power (θ) for selected marketing year

	Full sample				Main growing area		
	Oligopsony power model						
Marketing year	$\theta = \theta_I+(\theta_G*a_t)+(\theta_T*b_t)$	$\theta = \theta_I+(\theta_G*a_t)+(\theta_T*b_t)$	$\theta = \theta_I+(\theta_G*a_t)$	$\theta = \theta_I+(\theta_T*b_t)$	$\theta = \theta_I+(\theta_G*a_t)+(\theta_T*b_t)$	$\theta = \theta_I+(\theta_G*a_t)+(\theta_T*b_t)$	$\theta = \theta_I+(\theta_G*a_t)$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
2002/03	0.40	0.40	0.13	0.17	0.25	0.27	0.08
2003/04	0.65	0.65	0.31	0.15	0.53	0.55	0.28
2004/05	0.16	0.16	0.02	0.14	0.12	0.13	-0.02
2005/06	0.12	0.12	0.02	0.12	0.13	0.14	-0.01
2006/07	0.28	0.28	0.14	0.11	0.27	0.29	0.09
2007/08	0.40	0.40	0.24	0.10	0.42	0.43	0.20
2008/09	0.04	0.04	0.03	0.08	0.18	0.20	0.02
2009/10	0.29	0.29	0.21	0.07	0.38	0.40	0.17
2010/11	0.26	0.26	0.21	0.05	0.38	0.40	0.17
2011/12	-0.25	-0.25	-0.09	0.04	-0.04	-0.03	-0.14
2012/13	-0.29	-0.29	-0.09	0.02	-0.03	-0.03	-0.14
2013/14	-0.39	-0.39	-0.13	0.01	-0.13	-0.13	-0.21
2014/15	0.12	0.12	0.21	-0.01	0.38	0.40	0.17
2015/16	0.09	0.09	0.21	-0.02	0.38	0.40	0.17

Note: a_t = the price difference between government support price and market price during the harvesting period ($pdifgovmar_{nt}$), b_t = time trend ($ttrend$), see the value of a_t and b_t at Appendix A2

[16] Although the negative values of θ are not theoretically possible, they arise because the simple specification (15) which does not constrain θ to be nonnegative. Our interpretation is that in this period there is no collusion among rice millers.

Oligopsony Price Distortion (*θ/ε*)

We need to estimate the price elasticity of rice supply (ε) so that we can estimate oligopsony price distortion. Table 5 shows that Jasmine rice supply is price elastic. The coefficient of Δlog(farm gate price) is the estimated elasticity of rice supply with respect to price. The estimated results in column 1 imply that a 1% increase in the farm gate price increases the rice supply by about 1.18%. Column 2 drops rain variables. This causes the coefficient on Δlog(farm gate price) to slightly decrease. Column 3 and 4 estimate parallel specification but with main growing area sample. The results are generally similar. Overall, the results in Table 5 shows that our estimated price elasticity of rice supply is elastic and robust across model specifications.

Table 5 2SLS estimations of supply equation. Dependent variable: Log (Jasmine rice supply)

Variables	Full sample		Main growing area	
	(1)	(2)	(3)	(4)
Δlog (farm gate price)	1.183***	1.128***	1.164***	1.139***
	[0.265]	[0.249]	[0.333]	[0.340]
Δfertilizer price	0.000	-0.000	-0.000	-0.000
	[0.000]	[0.000]	[0.000]	[0.000]
Δgovernment support price	-0.000**	-0.000*	-0.000***	-0.000***
	[0.000]	[0.000]	[0.000]	[0.000]
Δlagged rain in quarter 3	0.004		-0.000	
	[0.003]		[0.006]	
Δlagged rain in quarter 3^2	-0.000		0.000	
	[0.000]		[0.000]	
Δlagged rain in October	0.005**		0.006***	
	[0.002]		[0.002]	
Δlagged rain in October^2	-0.000*		-0.000**	
	[0.000]		[0.000]	
Observations	210	210	84	84
R-square	0.391	0.362	0.647	0.602

Note: The quantities in blankets below the estimates are the robust standard errors. *, **, *** indicate significance at the 0.1, 0.05, 0.01 levels, respectively. Each regression also includes lagged farm gate price of competitive crop, lagged minimum wage, and year dummy variables when there is no rice pledging policy.

Table 6 presents the estimates of oligopsony price distortion according to the specification of oligopsony power component. As the price elasticity of rice supply is around 1, the oligopsony price distortion is close to the estimated oligopsony power. The estimate of oligopsony price distortion in full sample and main growing area sample range from -33% to 55% and -18% to 47%, respectively.

Table 6 Estimates of oligopsony price distortion for selected marketing year

	Full sample				Main growing area		
	Oligopsony power model						
Marketing year	$\theta = \theta_I+(\theta_G*a_t)+(\theta_T*b_t)$	$\theta = \theta_I+(\theta_G*a_t)+(\theta_T*b_t)$	$\theta = \theta_I+(\theta_G*a_t)$	$\theta = \theta_I+(\theta_T*b_t)$	$\theta = \theta_I+(\theta_G*a_t)+(\theta_T*b_t)$	$\theta = \theta_I+(\theta_G*a_t)+(\theta_T*b_t)$	$\theta = \theta_I+(\theta_G*a_t)$
	(1)	(2)	(3)	(4)	(5)	()	(7)
2002/03	0.34	0.34	0.11	0.14	0.21	0.23	0.07
2003/04	0.55	0.55	0.26	0.13	0.46	0.47	0.24
2004/05	0.14	0.14	0.02	0.12	0.10	0.11	-0.02
2005/06	0.10	0.10	0.02	0.10	0.11	0.12	-0.01
2006/07	0.24	0.24	0.12	0.09	0.23	0.25	0.08
2007/08	0.34	0.34	0.20	0.08	0.36	0.37	0.17
2008/09	0.03	0.03	0.03	0.07	0.15	0.17	0.02
2009/10	0.25	0.25	0.18	0.06	0.33	0.34	0.15
2010/11	0.22	0.22	0.18	0.04	0.33	0.34	0.15
2011/12	-0.21	-0.21	-0.08	0.03	-0.03	-0.03	-0.12
2012/13	-0.25	-0.25	-0.08	0.02	-0.03	-0.03	-0.12
2013/14	-0.33	-0.33	-0.11	0.01	-0.11	-0.11	-0.18
2014/15	0.10	0.10	0.18	-0.01	0.33	0.34	0.15
2015/16	0.08	0.08	0.18	-0.02	0.33	0.34	0.15

Policy Implication

To use the results of the previous section in evaluating the paddy pledging policy, estimates of the management costs of the paddy pledging program are required. The estimates of Siamwalla, Poapongsakorn, and Pantakua (2014) and Poapongsakorn and Charuphong (2010) are used for that purpose. Those studies comprehensively estimate the management cost of the program. Table 7 shows the estimated management cost from those studies. Column 1 and 2 show that the average management cost per tonne of the paddy pledging program in MY2005/06 and MY2011/12-MY2013/14 is $44.9 and $67.5, respectively. Based on these numbers, we calculate weighted average management cost of the paddy pledging program during our study period[17]. The weighted average management cost is $57.4 per tonne (column 3). We use this management cost for our cost estimation. In addition, we also need release rice price data to estimate government's revenue. Poapongsakorn and Wichitaksorn (2016) show that the lowest released rice price of Jasmine milled rice in MY2011/12-MY2013/14 through government to government and auction is 31% and 17% lower than the market price, respectively. In our study, we assume the release rice price is 17% lower than the market price. Table 8 shows that average acquisition and release price of Jasmine rice are $406.0 and $361.9 per tonne, respectively.

Another consideration is the accuracy of model prediction. Figure 8 presents that even though our full sample regression model can precisely predict Jasmine rice supply in minor Jasmine rice-producing area (7-15), it cannot accurately estimate Jasmine rice supply in top six Jasmine rice-producing provinces. In these provinces, most of actual ΔSupply are not close to predicted ΔSupply and are outside a 95% confidence interval for the predicted ΔSupply.

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[17] The weighted average cost is equal [column 1*the proportion of Jasmine paddy bought by the government between MY2002/03-MY2008/09 + column 2* the proportion of Jasmine paddy bought by the government between MY2011/12-MY2013/14]

This is problematic since our policy analysis will be inaccurate.

Table 7 Management cost of the paddy pledging program

Cost items Unit: $ per tonne	MY2005/06[a]	MY2011/12 – MY2013/14[b]	MY2002/03-MY2008/09 and MY2011/12-MY2013/14
Processing cost + Sack cost + Transportation cost	16.9	24.5	21.1
Storage cost	6.7	5.8	6.2
Operating cost	4.0	9.4	7.0
Interest cost	13.1	18.5	16.1
Quality depreciation cost	4.3	9.3	7.1
Total cost	44.9	67.5	57.4

Source: [a]Poapongsakorn and Charuphong (2010) [b]Siamwalla, Poapongsakorn, and Pantakua (2014)
Note: all costs are deflated using CPI.

Table 8 Acquisition and release price of Jasmine rice

Marketing year	Acquisition price* ($ per tonne of paddy)	Release price** ($ per tonne of paddy)
2002/03	262.7	301.3
2003/04	266.0	309.2
2004/05	369.8	279.3
2005/06	349.2	285.2
2006/07	304.0	297.2
2007/08	303.6	415.1
2008/09	486.3	438.2
2011/12	588.5	439.9
2012/13	570.0	449.2
2013/14	559.6	404.6
Average	406.0	361.9

Source: * Department of Internal Trade (2016), Isvilanonda (2010), Poapongsakorn (2010); **Authors' calculation based on data from Department of Internal Trade (2017b, c, d, e) and Poapongsakorn and Wichitaksorn (2016)

On the contrary, Figure 9 and 10 show that our main growing area sample regression model can precisely predict the Jasmine rice supply and the farm gate price. Most of actual ΔSupply

(ΔPrice) are close to predicted ΔSupply (ΔPrice) and are inside a 95% confidence interval for the predicted ΔSupply (ΔPrice). The predicted ΔSupply and actual ΔSupply are -36.02 and -34.76, respectively. Moreover, the predicted Δprice and actual Δprice are \$24.78 and \$22.51, respectively. This slight difference between actual and predicted value shows that, based on the factors including in the regression, we can accurately predict Jasmine rice supply and farmgate price. This is desirable as we now can precisely evaluate welfare effect of price support policy. Therefore, we evaluate the welfare effect of price supply policy using regression model from main growing area sample which accounts for around 68% of total government rice purchase.

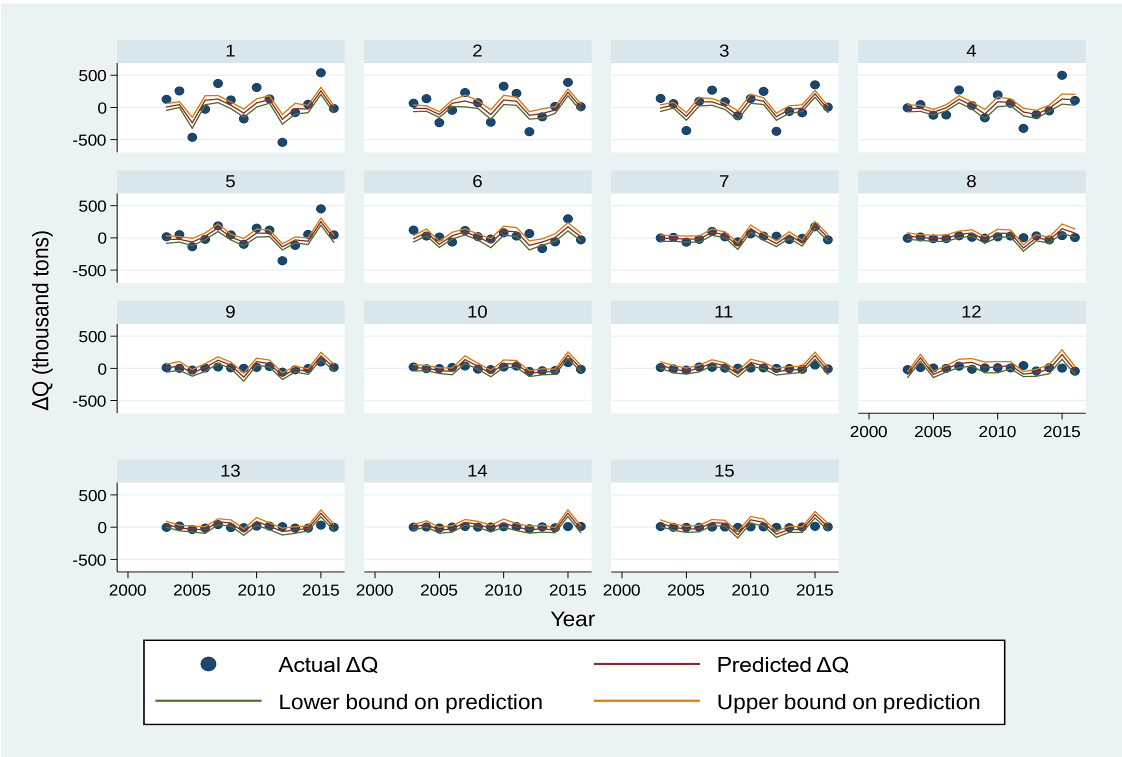

Figure 8 The comparison of actual and predicted value of ΔSupply in full sample model

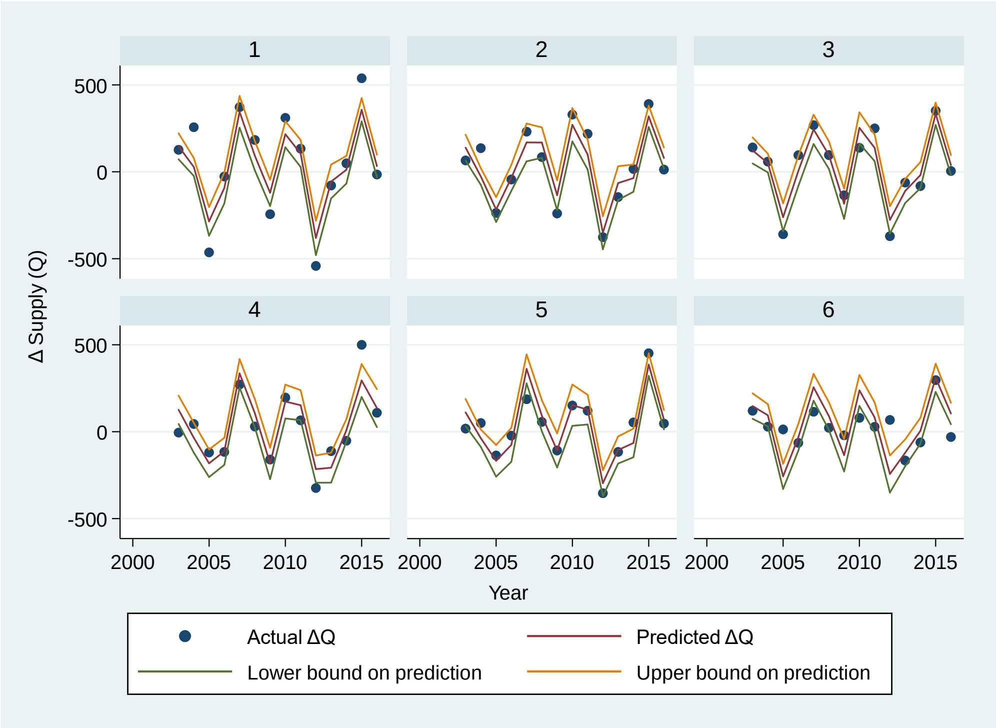

Figure 9 The comparison of actual and predicted value of ΔSupply in the main growing area sample model

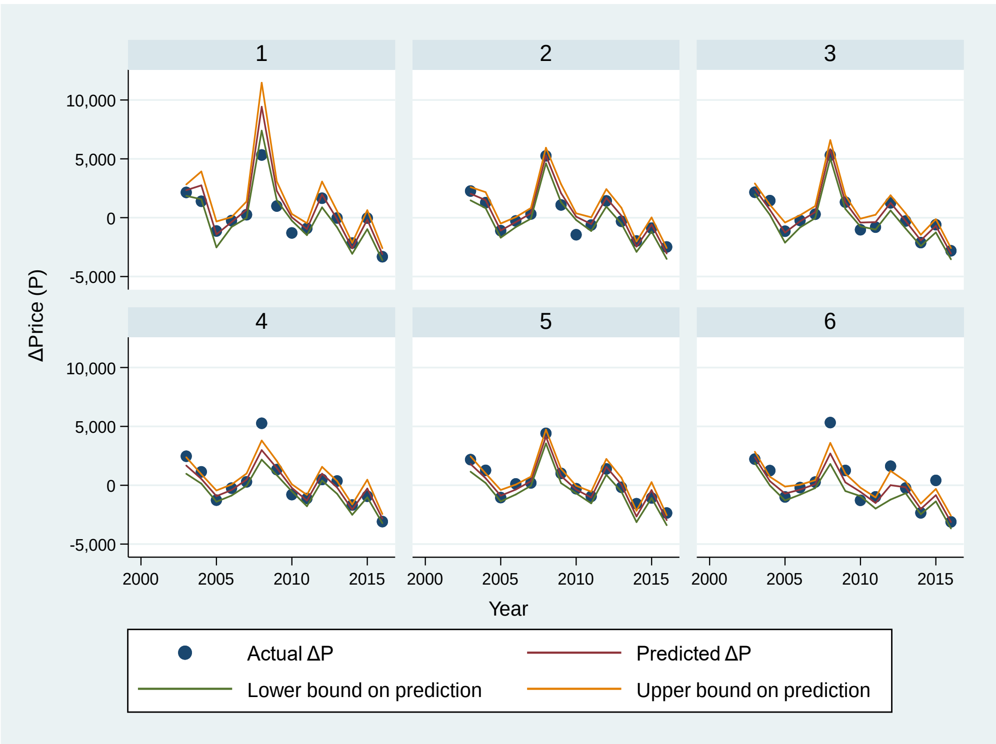

Figure 10 The comparison of actual and predicted value of Δprice in main growing area sample model

Does Society Better Off without Intervention in Jasmine Rice Market?

We find that farmers are worst off without market intervention. Figure 11 shows Thai Jasmine rice market under complete deregulation. We estimate the values in Figure 11 using the sample mean value[18] and calculation procedure presented at a theory framework section. As rice millers have oligopsony power, they use this power to depress farm gate price by almost 33% below the value of marginal product. They purchase 1.3 million tonnes at $329 price. However, If the market were competitive, rice millers will purchase 3.1 million tonnes at $397 price. With oligopsony, the farm gate price is lower and less is sold. Because of the lower price, farmers lose surplus $88.7 million per year (L). Moreover, farmers lose surplus $60.5 million per year (M) because of the reduced sales. Therefore, the total loss of farmer surplus is $149.2 million per year (L+M).

In addition, consumers are also worst off under the free market. Under oligopsony, the rice price is higher, and consumers buy less. Because of the higher price, consumers lose surplus $52.3 million per year (R). Furthermore, consumers lose surplus $24.4 million per year (N) because of the reduced purchase. The total loss of consumer surplus is, therefore, $76.7 million per year (R+N).

In contrast, processors are better off. If the market were competitive, processors would receive no benefits. Nonetheless, since processors have oligopsony power, they gain surplus $141.1 million per year (R+L) by transferring it from farmers and consumers.

Overall, the society is worst off without intervention. If society views that oligopsonist's profits are not a social problem[19] (a standard economic efficiency point of view),

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[18] The average value of each variable during the implementation of the paddy pledging program

[19] Neoclassical economics assumes that we value the welfare of consumers, farmers, and processors equally. Therefore, oligopsonist's profits is not a social problem because the wealth transfer from farmers and consumers to processors does not affect the market's total wealth. In other words, the oligopsonist's

the society suffers efficiency loss or deadweight loss $84.9 million per year. On the contrary, if society views that oligopsonist's profits are a social problem, the society suffers from efficiency loss and equity loss $225.9 million per year (R+L+N+M).

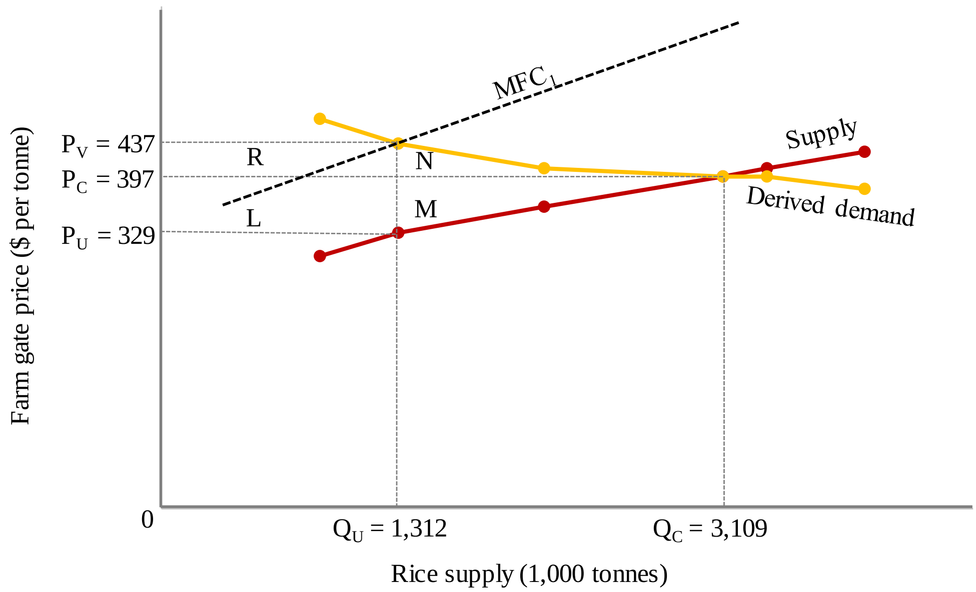

Figure 11 Thailand's Jasmine rice market without the government intervention

Note: *the original values are computed in Thai Baht, but to facilitate interpretation they are converted into U.S. dollars at the fixed exchange rate of 35.8 baht per dollar.

Market and Welfare Effects of the Paddy Pledging Program

Figure 12 presents Thailand's Jasmine rice market during the implementation of price support policy. We estimate the values in Figure 12 using the sample mean value and calculation procedure presented at a theory framework section. In theory, the estimated value of marginal product (VMP) of processors must equal the observed support price. However, our VMP estimation is higher than the observed support price around 1.7% or $7 per tonne. This slight difference indicates the validity of our model. Since the estimated value and observed value are

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profit does not represent a shrinkage in the size of the economic pie; it merely represents a bigger slice for processers and a smaller slice for farmers and consumers (Mankiw 2012).

only slight difference, we set VMP equal observed support price.

We find that the paddy pledging program increases both farmers' and consumers' gains by cutting the oligopsony margins of middlemen. If there were no government intervention, rice millers buy 1.3 million tonnes of paddy and use their oligopsony power to depress farm gate price by almost 33% below the value of the marginal product to pay at $329 price. On the contrary, with government intervention, the rice millers depresses farm gate price by only 11% and buys 2.1 million tonnes of paddy at $360 price. Moreover, the rice millers sells rice at $406 per tonne under market intervention whereas they sell $437 per tonne under deregulated market. Therefore, the program decreases the margin of rice millers from $108 per tonne to $46 per tonnes. Consequently, consumers and farmers equally gain $12.4 million per year (area Y and Z). These results are at odds with the common belief that agricultural policies can increase farmer gains, but the consumer will lose.

However, we find that the paddy pledging program is inefficient as, partly, the government set support price too high compared to unregulated market price. The program increases consumer surplus (Y), producer surplus (Z+I+K), and processor surplus (J) around $12.4 million, $40.7 million, and $37.2 million, respectively. At the same time, the government pays for the buying cost and management cost $449.6 million and $70.6 million, respectively. As the revenue from rice releasing is $445.3 million, the net cost of the program is $124.9 million. Since the program increases surplus only $90.4 million (Y+Z+I+K+J), it imposes the deadweight loss to society about $34.5 million per year. This inefficiency partly arises because the government set support price 23.3% higher than unregulated market price and 2.3% higher than optimal support price.

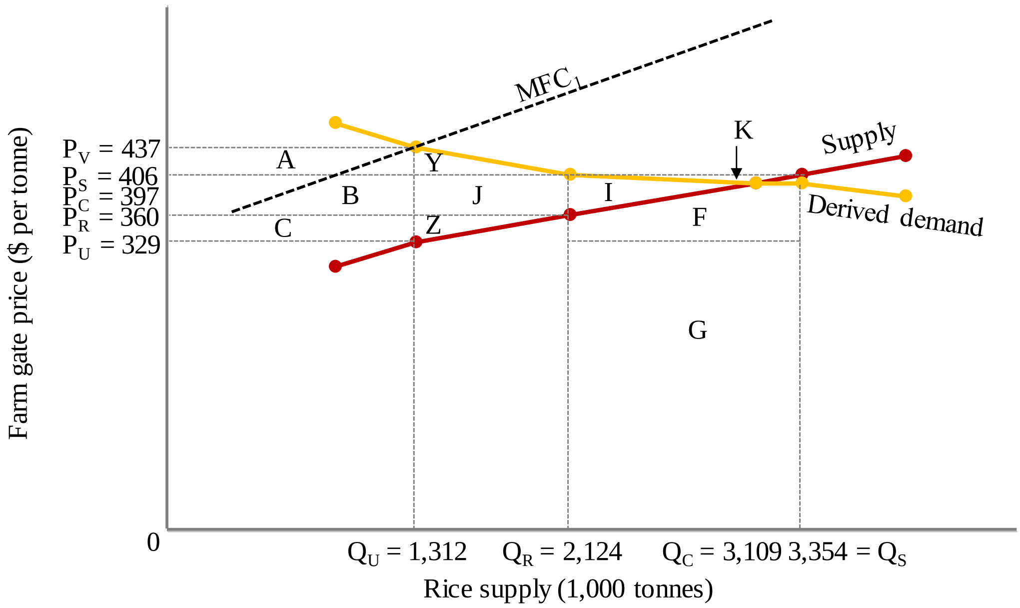

Figure 12 Predicted Supply, Demand, and Equilibrium in Thailand's Jasmine Rice Market

Note: *the original values are computed in Thai Baht, but to facilitate interpretation they are converted into U.S. dollars at the fixed exchange rate of 35.8 baht per dollar.

Next, we consider the equity effect of the program. We find that the program is effective in income redistribution. Under the program, consumer's surplus (A) and producer's surplus (C) equally increase $40.4 million. Thus, a total surplus transfer from processors to consumers and producers is $80.8 million. This transfer does not affect the total social surplus or the size of the economic pie. It represents a bigger slice for consumers and producers and a smaller slice for processors. In addition, the government also transfer income from taxpayers to farmers about $66.1 million (F). Therefore, the program redistributes income from rice millers and taxpayers to farmers and consumers around $146.9 million per year.

When we combine efficiency and equity effect, the benefit of the program is greater than the net social cost. The benefit of the program is $237.3 million while net social cost is $124.9 million. Hence, the total social benefit of the program is around $112.4 million per year.

Nevertheless, the total social benefit might reduce if the government's administrative costs and costs of surplus stock dispositions are larger than decreases in deadweight losses and increases in income redistribution. For example, if the release rice price is 30% lower than the market price, the total social benefit will reduce to $62.8 million per year. Moreover, the society will suffer loss around $13.7 million per year, if the release rice price is 50% lower than the market price.

In sum, the paddy pledging program benefits not only farmers but also consumers. However, the program is inefficient as it imposes the deadweight loss on society. Nonetheless, when we account for the income redistribution effect, the program benefits are larger than the net social cost. Moreover, the program can be efficient by setting a suitable support price.

Policy Recommendations

The model shows that society is worst off without any intervention in the Jasmine rice market because the market does not generate efficiency price. Therefore, the government intervention is needed to solve market failure and improve market outcome. Ideally, the best policy instrument should be the one that creates the largest efficiency gain. In this section, we consider two policy instruments; price support policy, and institutional policy such as organizing farmer's cooperatives to increase farmer bargaining power.

We find that both price support policy and institutional policy can increase total social welfare. Figure 13 shows that if there were no market intervention, oligopsony processors buy rice from farmers at $0.33 per kilograms and sell rice to consumers at $0.44 per kilograms[20]. The government can improve the market outcome by setting the minimum support price between $0.33 per kilogram and $0.39 kilogram or by increasing farmer bargaining power. Both policies might increase farmers' price to $0.37[21] per kilogram and reduce consumers' price to $0.42 per kilogram. As a result, total social welfare will increase if decreases in deadweight

[20] This price is the selling price for consumers minus the transaction cost of the rice millers.

[21] In this case, the government set support price at $0.37 per kilogram.

losses are larger than administrative costs. Ideally, the optimal market outcome will be the point where both prices are $0.39 per kilogram when processor's profits are zero.

However, in the long term, the institutional policy is better than the price support policy. The government price support policy cannot maximize social welfare as the government has to pay annual management cost of the program[22]. In contrast, the government only needs short-term investments for institutional policy. For example, in theory, when farmer cooperatives supported by the government policies gain enough bargaining power to counter with buyer power, the government does not need to continue spending budget to intervene the market. Farmers themselves will bear the cost of collective bargaining.

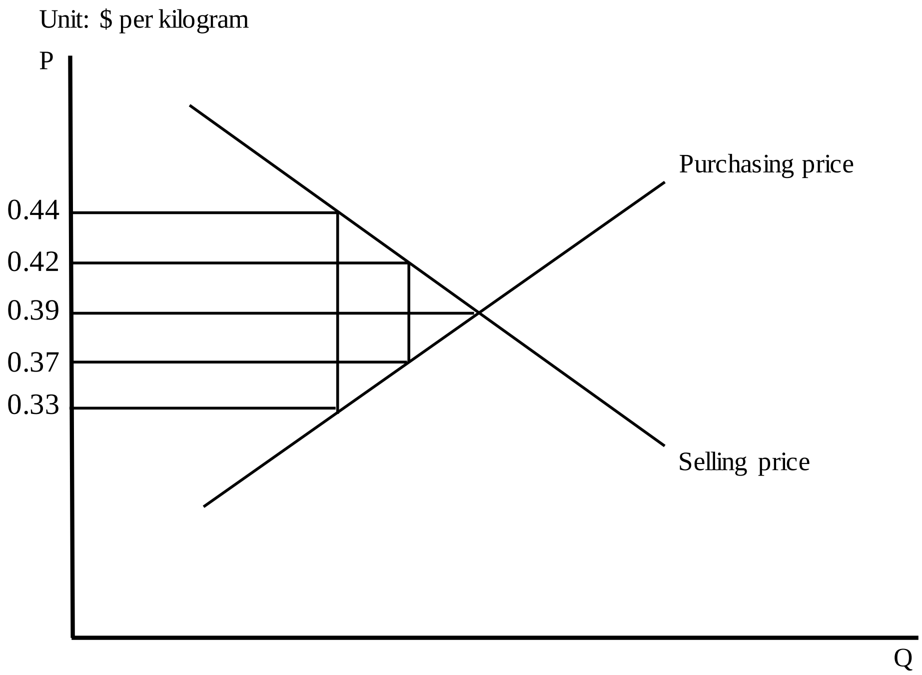

Figure 13 A simple model of Thai Jasmine rice market

Therefore, we recommend the government of Thailand to use institutional policy to tackle market failure in Jasmine rice market. Nonetheless, since it takes some time for institutional policy to take effect, we suggest Thai policymakers to reconsider using the price

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[22] In MY2011/12, the management cost was around $14.1 million.

support policy in the short term. With better policy making decision, Thai government can improve its abandoned paddy pledging program by setting support price at optimal support price. In the long term, when farmers gain enough bargaining power, the government should abolish price support policy.

An important caveat concerning the application of these results to public policy is that the benefit of price support policy is likely to be well below the estimates presented here. On farmers side, our model does not consider the interaction between farmers and input providers. This implies that we assume farmers buy input from a competitive market. Nonetheless, there is a high possibility that input providers may exercise oligopoly power. If this is the case, the welfare benefit from price support policy will be transferred to input providers. As a result, farmers gain little from the policy. On the consumer side, we assume that retailers and exporters who buy rice from the wholesale market do not exercise oligopoly power. If they do, the consumer gains will be transferred to retailers and exporters. Consequently, consumers also benefit little from price support policy.

Moreover, we may underestimate the oligopsony price distortion of the rice millers. Oligopsony price distortion depends on the elasticity of supply. The less elastic the supply curve, the more oligopsony price distortion the buyers enjoys. As our model estimate the elasticity of supply under the government support policy, the rice supply is elastic because farmers can choose between selling to the government and selling to the rice millers. However, farmers have fewer choices in the deregulated market than in the regulated market. As a result, the supply curve in the deregulated market may be less elastic than the supply curve in the regulated market. Consequently, rice millers may be able to exercise more oligopsony price distortion.

Conclusion

We have investigated the degree of imperfect competition in the Thai Jasmine rice market by exploiting the institutional feature of the government price support policy to identify oligopsony power under NEIO framework. We find strong evidence of some oligopsony power over MY2002/03 – MY2013/14 sample period. We also find a moderate degree of oligopsony price distortion. Hence, society is worst off without intervention in Jasmine rice market. Besides, we have examined the impact of price support policy on oligopsony power. We find strong evidence that price support policy decreases the oligopsony power of the rice millers.

We also have evaluated the market and welfare effect of paddy pledging program by incorporating the degree of imperfect competition into Jasmine rice market model. While any market and welfare effect analysis is dependent on many questionable assumptions, the estimates presented in this paper suggest that the paddy pledging program is inefficient. However, when we account for income redistribution effect, the benefits of the program are greater than the net social cost. Moreover, the program can be improved to be efficient by setting a suitable support price. Furthermore, our findings have challenged several accepted "wisdom" regarding government agricultural policies. First, in oligopsony market, it is not true that government policies distort the markets and deregulation mitigate market distortion. Second, in oligopsony market, it is not true that price support policy benefits farmers but hurts consumers. Lastly, it is also not always true that total social welfare is larger in deregulated markets than in regulated markets.

In addition, we have investigated policy options to correct market failure and enhance market outcome. We find that both price support policy and institutional policy can increase total social welfare when administrative costs are smaller than decreases in deadweight losses. Nevertheless, in the long term, we find that institutional policy such as organizing farmers' cooperatives to increase farmers' countervailing power is better than the price support policy. Since the idea about farmers' organization is not new, a logical next step for future research is to understand the environments and conditions for the cooperatives to flourish or fail to flourish. Moreover, the role of the cooperatives in increasing equity, reducing inequality, and enhancing inclusive economic growth represents an important avenue for future investigation.

Our paper extends the existing studies about the competition and the government policy in Thai rice market in two ways. First, we utilize a more advanced and more modern method to investigate the degree of imperfect competition than prior studies do. Second, we apply the imperfect competition model to evaluate the impact of the paddy pledging program in specific rice market. Prior studies ignore the difference of market structure among rice varieties and assume perfect competition in policy evaluation. These assumptions can lead to serious bias results.

Last, our research also contributes to the growing evidence of buyer market power and its implication on agricultural policy analysis. There has been a great deal of interest in recent years in buyer market power and its interaction with government regulation, both theoretically and empirically (Russo, Goodhue, and Sexton 2011, Lence 2016, Boyer and Brorsen 2013). However, the lack of data has hampered attempts to investigate oligopsony power in rice industry in developing countries. Our results thus add the evidence of oligopsony power and its interaction with price support policy in rice market in advance developing country to agricultural economic literature.

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Appendix

A1 Variable description

Variable	Description	Sources
P_{nt}^{f}	Jasmine farmgate paddy price	OAE
Q_{nt}	The quantity of Jasmine paddy rice supplied in the market	Constructed
$rain10_{nt-1}$	Weighted lag rain in October	Constructed
$rainq3_{nt-1}$	Weighted lag rain in quarter 3	Constructed
$q2p_{nt-1}$	Lagged Jasmine farmgate paddy price in quarter 2	OAE
$ferp_{t-1}$	Lagged fertilizer price	MOC
$miniw_{nt-1}$	Lagged minimum wage	MOL
$miniw_{nt}$	Minimum wage	MOL
$diesp_{t}$	Lagged diesel price	BOT
$electrip_{t}$	Fuel oils price	BOT
$sugap_{t-1}$	Lagged sugarcane farm gate price	OAE
$casap_{t-1}$	Lagged cassava farm gate price	OAE
thaipop	Thai population	DOPA
exrate	Exchange rate Thai baht to Dollar	BOT
P_{t}^{w}	Whole sale Jasmine milled rice price index	Constructed
Trend	Time trend	Constructed

Note: OAE: Office of Agricultural Economics, MOC: Ministry of Commerce, MOL: Ministry of Labor, BOT: Bank of Thailand, DOPA: Department of Provincial Administration, NESDB: Office of The National Economic and Social Development Board

A2 The value for calculating the oligopsony power

Marketing year	$pdifgovmar$ (unit: baht)	$ttrend$
2002/03	1,403	2
2003/04	-1,695	3
2004/05	2,874	4
2005/06	2,728	5
2006/07	1,169	6
2007/08	-412	7
2008/09	2,163	8
2009/10	0	9
2010/11	0	10
2011/12	4,594	11
2012/13	4,578	12
2013/14	5,667	13
2014/15	0	14
2015/16	0	15