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Increasing profit by rice export reduction among union members

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ในช่วงเวลาที่ผ่านมาองค์กร OPEC ซึ่งจัดการด้านนโยบายน้ำมันให้กับประเทศสมาชิกมีการตกลงลดกำลังการผลิตเพื่อเพิ่มราคาน้ำมันขึ้น และด้วยค่าความยืดหยุ่นที่ -0.13 น้ำมันจึงเป็นสินค้าโภคภัณฑ์ที่ไม่ยืดหยุ่น จึงทำให้การลดอุปทานนี้เพิ่มราคาน้ำมันโลกขึ้นอย่างมาก เป็นที่น่าสังเกตว่าเพราะ OPEC ได้รวมกลุ่มกันจึงมีอำนาจการควบคุมราคาน้ำมันได้เนื่องจากสมาชิกเมื่อรวมกันนั้นถือครองสัดส่วนการผลิตน้ำมันของโลกไว้มาก จึงนำมาสู่ความน่าสนใจว่าหากมีการรวมกลุ่มระหว่างประเทศสมาชิกเพื่อเพิ่มราคาข้าวบ้างแล้ว จะสามารถสร้างระบบเพิ่มราคาข้าวด้วยการลดอุปทาน ได้หรือไม่ เนื่องด้วยค่าความยืดหยุ่นของข้าวนั้นอยู่ประมาณ -0.51 ถึง -0.13 จึงทำให้ข้าวก็เป็นสินค้าไม่ยืดหยุ่นเช่นกัน แม้ว่าข้าวกับน้ำมันจะมีข้อแตกต่างกันบ้าง การจำลองการตกลงลดปริมาณการส่งออกข้าวระหว่างประเทศสมาชิกจึงเกิดขึ้นในการศึกษานี้เพื่อดูผลกระทบต่างๆทั้งต่อระบบข้าว ชาวนาและรวมถึงผลกำไรจากประเทศต่างๆ โดยการสร้างแบบจำลองนี้ได้ใช้ทฤษฎีต่างๆมารวมกันเป็นหนึ่งนั่นคือการใช้การวิเคราะห์การถดถอย เส้นอุปสงค์ ดัชนีเงินเฟ้อผู้บริโภค การคำนวณหาค่าความยืดหยุ่นของข้าวระดับโลก การเลือกสมาชิกภาพ การคำนวณต้นทุนและรายได้ โดยทำให้เป็นมูลค่าปัจจุบัน การใช้ autoregressive time-series model รวมถึงการป้องกันไม่ให้ราคาข้าวสูงจนคนหันไปใช้สินค้าทดแทน โดยผลลัพธ์ที่ได้จะเน้นกับประเทศไทยเป็นหลัก พบว่าหากลดปริมาณการส่งออก 10% ระหว่างสมาชิกนั้นจะสามารถสร้างกำไรที่เพิ่มขึ้นให้ประเทศต่อปีได้ประมาณ 141.72 ล้านดอลลาร์สหรัฐเทียบกับหากไม่มีการลดการส่งออก โดยไทยมีโอกาสได้รายได้เพิ่ม 6.64% หากมองเฉพาะการส่งออก และ 11.08% หากมองการผลิตข้าวโดยรวม

ภาควิชา วิศวกรรมอุตสาหการ	ลายมือชื่อนิสิต ....
สาขาวิชา วิศวกรรมอุตสาหการ	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
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NARABHATRA SANGMANACHAROEN: Increasing profit by rice export reduction among union members. ADVISOR: ASST. PROF. DARICHA SUTIVONG, Ph.D., CO-ADVISOR: ASST. PROF. CHONAWEE SUPATGIAT, Ph.D., 115 pp.

Over the past decades, OPEC which coordinates petroleum policies among members has agreed to cut supply to raise oil price. With a consensus elasticity of -0.13, oil is an inelastic commodity, a reduction in production results in a huge increase in price. It is noticeable that OPEC can increase oil price because they altogether possess a large amount of global oil supply. It is interesting whether this strategy can be used with rice to increase its price by reducing its supply. Because rice elasticity ranges between -0.51 and -0.13, rice is also an inelastic commodity. Although rice and oil have some differences, a rice export reduction agreement among union members is investigated in this study to see the possibility of price movement of rice and the potential profit generated among countries given various percentages of rice export reductions among members as well as the effect to farmers in Thailand if implemented. This study creates a model for the relationship between rice export quantity reduction and corresponding profits. This model construction includes the integration of regression, demand curve, consumer price index inflation adjustment, elasticity determination, union member selection, autoregressive time-series model, revenue and cost calculation with discounted present value, and substitution price limit. The study mainly focuses on effects to Thailand. It is found from the model that an export reduction of 10% among members would increase an average annual profit of Thailand by 141.72 million USD compared to the current export level. Thailand may experience an additional revenue gain of 6.64% from export only and 11.08% for the total production of rice.

Department:	Industrial Engineering	Student's Signature	....
Field of Study:	Industrial Engineering	Advisor's Signature	....
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Chapter 1

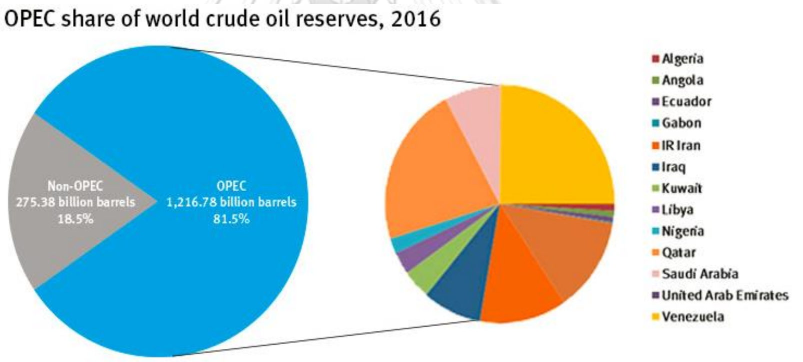
Introduction

1.1 Background of the research

Rice is a valuable commodity to Thai farmers, government, and consumers. It drives export and increases trade surplus in annual trade current account. Thailand had been producing and exporting a large amount of rice for a long time, until year 2014 where rice pledging policy became unsuccessful and ultimately reduced overall rice production. Rice pledging policy on that time was believed to benefit the country by increasing income of farmers while consumer’s payment would not be affected much as world rice price might increase by a little. (Ongchaiwattana, 2013) believed that rice pledging policy intervenes nature of rice market which he suffered the consequence from this policy that his rice market was ultimately shut down. (Ongchaiwattana, 2017) Both Thai Rice Price Insurance and Pledging Scheme formerly increased supply of rice because schemes motivated farmers to produce rice and sell it at a guaranteed price.

It is interesting to reduce supply of rice instead of increasing it like previous policies. However, reducing supply of rice would require alliance to be formed to affect global quantity reduction that will increase price. Therefore, this study will use rice global export reduction agreement with other countries to achieve supply reduction. This study investigates previous successful commodity supply reduction, which occurred in oil by OPEC.

The mechanism of commodity pricing was studied to analyze opportunities for alternative rice pricing policy. Crude oil is brought into interest. In the past, crude oil price once peaked and stayed about 130 USD/Barrel from OPEC price collusion by cutting production output. (BP, 2017) Because OPEC consists of many countries, it is difficult to ensure that every member would honor an agreement. Figure 1 shows members of OPEC and share of world crude oil reserves as of 2016. (OPEC, 2017) Source of this figure is from OPEC 2016 annual report.



OPEC proven crude oil reserves , at end 2016 *(billion barrels, OPEC share)*

Venezuela	302.25	24.8%	Kuwait	101.50	8.3%	Qatar	25.24	2.1%	Gabon	2.00	0.2
Saudi Arabia	266.21	21.9%	United Arab Emirates	97.80	8.0%	Algeria	12.20	1.0%			
IR Iran	157.20	12.9%	Libya	48.36	4.0%	Angola	9.52	0.8%			
Iraq	148.77	12.2%	Nigeria	37.45	3.1%	Ecuador	8.27	0.7%			

Source: OPEC Annual Statistical Bulletin 2017.

Figure 1: Members of OPEC and share of world crude oil reserves as of 2016

When OPEC members reduce oil production, crude oil price shifts. Figure 2 shows oil production allocations among members.

OPEC Members' crude oil production allocations *(1,000 b/d)*

	Oct 93–Jun 96	Jul 96–Dec 97	Jan 98–Mar 98	Apr 98–Jun 98	Jul 98–Mar 99	Apr 99–Mar 00	Apr 00–Jun 00	Jul 00–Sep 00	Oct 1, 00–Oct 30, 00	Oct 31, 00–Jan 01	Feb 01–Mar 01
	21/	22/	23/	24/	25/	26/	27/	28/	29/	30/	31/
Algeria	750	750	909	50	788	731	788	811	837	853	805
Indonesia	1,330	1,330	1,456	70	1,280	1,187	1,280	1,317	1,359	1,385	1,307
IR Iran	3,600	3,600	3,942	140	3,318	3,359	––	3,727	3,844	3,917	3,698
Iraq	400	1,200	1,314	––	––	––	––	––	––	––	––
Kuwait	2,000	2,000	2,190	125	1,980	1,836	1,980	2,037	2,101	2,141	2,021
Libya	1,390	1,390	1,522	80	1,323	1,227	1,323	1,361	1,404	1,431	1,350
Nigeria	1,865	1,865	2,042	125	2,033	1,885	2,033	2,091	2,157	2,198	2,075
Qatar	378	378	414	30	640	593	640	658	679	692	653
Saudi Arabia	8,000	8,000	8,761	300	8,023	7,438	8,023	8,253	8,512	8,674	8,189
United Arab Emirates	2,161	2,161	2,366	125	2,157	2,000	2,157	2,219	2,289	2,333	2,201
Venezuela	2,359	2,359	2,583	200	2,845	2,720	2,845	2,926	3,019	3,077	2,902
OPEC	**24,233**	**25,033**	**27,500**								
OPEC excl Iraq				**1,245**	**24,387**	**22,976**	**21,069##**	**25,400**	**26,200**	**26,700**	**25,201**
Target				**25,742**							

Figure 2: Members' crude oil production allocations

While figure 3 and 4 show values of petroleum exports gained compared to total exports of that country. Source of two figures are from OPEC 2016 annual report.

OPEC Members' values of petroleum exports *(m $)*

	2011	2012	2013	2014	2015
Algeria	51,409	48,271	44,462	40,628	21,751
Angola	65,215	69,386	66,299	57,017	31,696
Ecuador	12,925	13,792	14,107	13,276	6,660
Indonesia	18,606	16,457	14,504	12,839	6,397
IR Iran	114,751	101,468	61,923	53,652	27,308
Iraq	83,006	94,103	89,402	83,561	54,394
Kuwait	96,721	112,933	108,548	97,554	48,782
Libya	18,615	60,188	44,445	10,424	4,975
Nigeria	88,449	95,131	89,930	77,489	41,818
Qatar	62,680	65,065	62,519	56,406	28,303
Saudi Arabia	317,614	337,480	321,888	284,424	157,962
United Arab Emirates	79,573	86,016	85,640	97,165	52,369
Venezuela	88,131	93,569	85,603	71,731	35,802
OPEC	**1,097,695**	**1,193,858**	**1,089,270**	**956,164**	**518,216**

Notes:
Where applicable, petroleum product exports are included. Data for some countries may include condensates, as well as other NGLs. Some countries import substantial amounts of crude and products, resulting in lower net revenue from petroleum operations.

Figure 3: OPEC members' values of petroleum exports

OPEC Members' values of exports *(m $)*

	2011	2012	2013	2014	2015
Algeria	77,668	77,123	69,659	62,886	37,787
Angola	67,310	71,093	68,247	59,170	32,637
Ecuador	22,322	23,765	24,848	25,732	18,366
Indonesia	203,497	190,032	182,552	175,981	150,283
IR Iran	144,874	107,409	91,793	85,235	77,974
Iraq	83,226	94,392	89,742	83,981	54,667
Kuwait	102,052	118,917	115,096	103,891	54,959
Libya	19,060	61,026	46,018	13,806	10,861
Nigeria	99,878	96,905	97,818	82,586	45,365
Qatar	112,912	132,985	136,767	126,702	77,294
Saudi Arabia	364,698	388,401	375,873	342,324	205,447
United Arab Emirates	302,036	359,728	371,028	367,597	333,370
Venezuela	93,747	97,877	88,753	74,714	38,010
OPEC	**1,693,281**	**1,819,651**	**1,758,194**	**1,604,606**	**1,137,020**

Notes:
All figures fob.

Figure 4: OPEC members' values of exports

It is seen that petroleum exports contribute high value for total exports in each country. By implementing oil price increase, OPEC can gain additional revenue while produce less due to law of demand and supply. Oil elasticity of demand ranges between -0.90 to -0.03 while its consensus is -0.13. (Caldara, 2016) Due to its inelastic property, quantity removed from market would increase price of oil. If rice has inelastic demand, it is possible that it would behave the way OPEC did to oil. Thailand has abundant resources of rice but could not sell at high price globally while OPEC has limited oil resources but can sell at a designated higher price. Farmers and stakeholders can obtain more profit than their current earns when resources are allocated and utilized efficiently.

Crude oil price was considered too high for various countries. As non-OPEC countries, especially U.S., suffered from this collusion, they began inventing something that might substitute crude oil and have minor difference in effect to engines. (Plumer, 2016) stated that increase in prices pressured drillers in the United States to use innovative drilling techniques to reach large quantities of oil from shale formations in places like North Dakota and Texas. Later, they successfully obtained large amount of shale oil and put it into the market. Then, supply caught up with demand and surpassed it. This made oil price fell dramatically. It is believed that shale oil invention occurs because inventors thought that developing shale oil, though incurred high cost for R&D, would benefit everyone more than cost of crude oil managed by OPEC. This resulted in a dramatic decline in crude oil price that declined more than 50% of its highest peak shown in Figure 5. (BP, 2017)

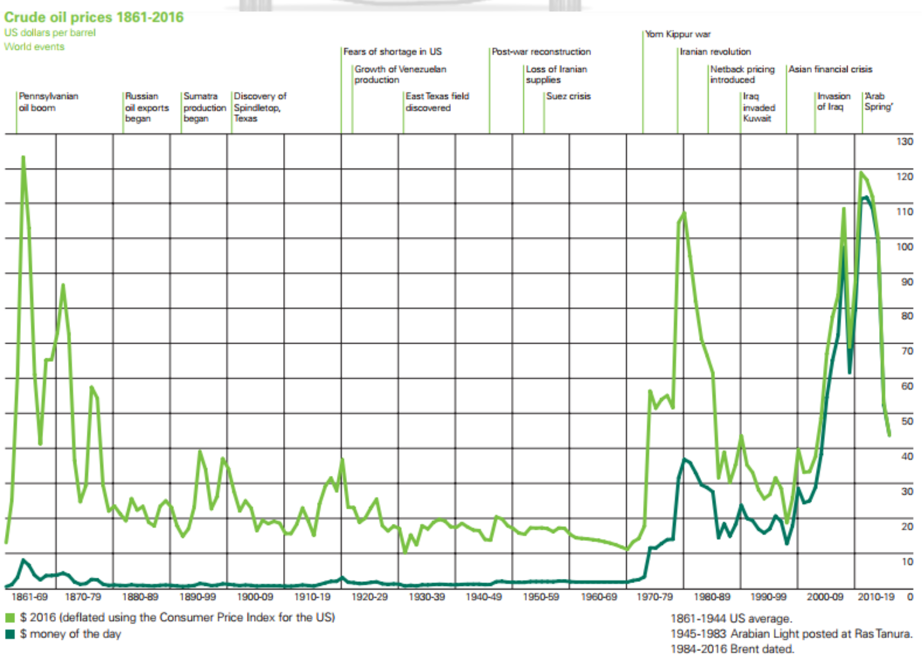


Figure 5: Oil price historical graph

This shale oil case becomes an interesting example to apply to any commodities. It shows that when there is a collusion of non-consumable commodity, it is likely that others will invent substitute and encourage users to use substitute instead.

It is not appropriate to stock rice because rice is a perishable product unlike oil which can be stored, for example. It is interesting that rice, when compared to crude oil, is difficult to find an exact substitute. One might be able to claim that if rice is too expensive, with price exceed his or her willingness to pay, he or she will eat salad, steak, potato, or any product that does not come from rice instead. However, this is not comparable because it is not an exact substitute like shale oil when used instead of oil to drive engines. (Kesseli, 2016) stated that there are several alternatives of rice to white rice. However, those are mostly for healthy purpose and considered premium thus will be always more expensive than plain white rice. One of interesting type of rice is brown rice, which is type of rice gained before processing into white rice. However, it is more expensive due to the lower demand for brown rice. (Ministry of Communications and Information, 2017) wrote that it is produced at a less economic scale compared to white rice. This makes brown rice considered a premium product and more expensive. (Cheney, 1994) added that oil in brown rice makes it vulnerable to spoilage. Each food has its own properties such as elasticity of demand, income, and cross-price. Some food maybe indirect substitute to rice, but some maybe complement to rice. This makes comparison inappropriate. In this study, wheat is assumed to be a substitute for rice if price of rice is increased over final product price of wheat including shipping cost. This is to cap the ceiling of maximum price of rice set each year theoretically when assume that wheat is a sole substitute.

It is believed that later, oil pricing control by strategy such as collusion will never be effective like previous one anymore. (Beattie, 2018) stated that cost of conventional crude oil is around 30 to 40 USD/Barrel while shale oil is around 60 USD/Barrel. Altogether, (Gaffen, 2017) stated that amount of conventional and shale oil can be viewed as oversupply. This may indicate that if applied to rice, collusion strategy may last only a period, which after that price will never be controllable anymore if substitution dominates because agreement of rice price raise price too much. This is one interesting point that price of rice set should never exceed that of substitute such as wheat.

This unique property of rice then becomes an interesting factor to adopt a new policy like what OPEC previously did. This policy has less probability to result in an absolute loss to consumers due to an increasing price of rice and an increasing profit of governments, mills, and farmers that would be more than rice quantity reduction. An unused area owned by farmers occurred from this study can be used to generate other type source of income. Moreover, farmers may see benefit of not overproducing rice, which will increase price of rice and gain revenue more efficiently. This will be explained by the mechanism of rice production which is believed to behave as follows. Rice trading in each country consists of two markets: domestic and international. Generally, farmers produce rice and bring them to mills, which mills later bring to either for domestic trading or international trading. Government should set price to sell in an international market more expensive than that of domestic in account of profit from export. With a higher selling price in an international market, farmers will sell to a mill that sells to government for export purpose. With a limited quantity of export available, farmers who possess excess rice will have to sell in domestic market, which has a lower price. This will discourage farmers to overproduce and therefore farmers will produce to extent of export only. This then creates shortage of rice in domestic market where demand is more than supply. (Dreger, Kholodilin, Lommatzsch, Slacalek, & Wozniak, 2007) stated that there is some evidence showing price convergence in competitions in internal market may occur but should take long period of time to observe for a definitive conclusion. With this shortage, domestic price will gradually converge to international price. (Naik, 2016) Scope of this study is therefore based on only international price due to prior explanation. As farmers begin to reduce overproduction of rice, it means that there must be unused lands. These unused lands may be beneficial when farmers produce other types of grain. Not only overall rice price increases which gives farmers more marginal revenue, but farmers also enjoy additional gain from planting other grains in their lands. Eventually, there is a chance that consumers will get more diversified type of grain grown exploited from free areas not producing rice and thus more choices to choose and consume.

Although it is difficult to find a perfect replacement for rice and this is an advantage of rice over oil, this does not mean that collusion can increase price to any unlimited ceiling. There is still possibility that if price exceeds some threshold, rice importers will start to perform R&D to find an exact substitute like what happened to crude oil. This means the raised price by collusion should not exceed willingness to pay, or utility, of consumers. The possibility to achieve this is to make members in rice collusion reduce export by percentage of their previous year export, or by limiting the maximum price that rice can reach to its potential substitute, for example, wheat. In this study, the maximum allowable price set will be the reference of final product of wheat such as bread with included transportation cost to same country to fairly compare price between these two commodities. As a result, a numerical value of profit maximized will be analyzed. In addition, an agreement within OPEC members and between them and non-OPEC members were often seen to default a collusion agreement. (Beattie, 2018) stated that cheating among these signatories may prevent OPEC from reaching its goal. This might be caused from number of members that has been large and thus difficult to manage agreement control and monitoring as seen from Figure 1.

However, for simplicity this study assumes that there will be no cheating among agreement on export reduction and the more countries that can join membership, the more power that this union would have. Hence, it is interesting to visualize impacts obtained by this implementation such as an increase in expected income of each country. Though non-members, freeloader, will get the same price as members collude to reduce production, it is still worthwhile to visualize the effect of volume reduction to price effect.

Another interesting point from this model design is that this study is a design of model for rice export reduction which involves elasticity. An involvement in elasticity means that this model may be usable on other commodities if appropriate adjustments from rice are done. Moreover, further studies from this model may develop an extensive model for commodity export reduction sensitivity.

1.2 Problem statement

This study focuses on profit generated among rice collusion members from reducing quantity of export. This study would like to know the amount of export reduced that can maximize profit among members in each year given there will be shock effect on price from year to year by reducing quantity of export. This is to simulate the additional wealth of members that may gain. Compositions of profit are revenue and cost from selling and producing rice, discounted with risk-free interest rate to current year interested. The reduction of export cannot raise the shocked price of rice exceeding price of wheat or consumers will shift from consuming rice to wheat. The statement is explained further in notational form. Additional explanation regarding these notational forms will be in chapter 3.

Profit maximization model is

$$\text{Max Profit } \pi = \sum_{i=1}^{n} PV(Revenue_i - Cost_i) \tag{1}$$

Where i is index of each year and, n is number of years, and PV means present value of both revenue and cost.

Revenue and cost each year is discounted by discounted cash flow formula denoted as:

$$PV(Revenue_i - Cost_i) = \frac{Revenue_i - Cost_i}{(1+r)^i} + \frac{Revenue_{i+1} - Cost_{i+1}}{(1+r)^{i+1}} + \cdots + \frac{Revenue_n - Cost_n}{(1+r)^n} \tag{2}$$

Which

$$Revenue_i = P_{riceadj\ i} \times Q_{shocked\ i} \tag{3}$$

Where

$$P_{riceadj\ i} = P_{rice'i} \times \frac{CPI_i}{CPI_{i-1}} \tag{4}$$

From

$$P_{rice'i} = P_{rice\ i} + \Delta P_{shocked\ i} \qquad (5)$$

Which rice price is limited by a substitute price, wheat:

$$P_{wheat\ i} = P_{rice\ i-1} \times \frac{CPI_i}{CPI_{i-1}} \times PC \qquad (6)$$

And $Q_{shocked\ i}$ is found using relationship of

$$\varepsilon = \frac{\Delta Q}{\Delta P} \times \frac{P}{Q} = b \times \frac{P}{Q} \qquad (7)$$

While

$$Cost_i = Variable\ Cost_i + Fixed\ Cost_i \qquad (8)$$

x_i is the amount of export left after reduction in unit of percentage range from zero to one hundred percent from total export quantity among members on each year. Decision variable among years i are independent. Decision variable will affect export controlled by members only. Overall, quantity in each year is denoted as:

$$(x_i \times Q_{member2017}) + Q_{nonmember2017} = Q_i \qquad (9)$$

Subject to:

$\mathrm{I} = index\ set\ of\ years = \{1, 2, 3, \dots, n\};$

$x_i \geq 0, \forall i \in I;$

$x_i \leq 1, \forall i \in I;$

$Revenue_i \geq 0, \forall i \in I;$

$Cost_i \geq 0, \forall i \in I;$

$$P_{riceadj\,i} - P_{wheat\,i} \leq 0, \forall i \in I;$$

1.3 Objective of this study

Objectives of this study are to:

Develop a model that simulates effect of reduction in quantity of a commodity to its price from agreement among countries.

Determine the amount of global export quantity reduced by coordination among members to reach achieving maximum profit among members with realistic action while non-members still export at the same growth rate.

Determine additional profit obtained among members.

Determine implementation of export reduction and its effect to Thailand farmer households.

1.4 Scope of this study

Data used are secondary data related to rice. The study focuses on quantity and value of rice. Quality of rice is not in a consideration. Data on amount of rice on activities such as export, production for each country are from United States Department of Agriculture (USDA) website and are collected from year 1998 to September of year 2017 as this study began in this month. (United States

Department of Agriculture, 2017) Data on rice price are from Thai Rice Exporters website. Prices are needed for inflation adjustment to be fair when compared and are normalized by using Consumer Price Index from World Bank website. Future possible Consumer Price Index is obtained from PwC website. Export quantity reduced from members action will shock current and future prices based on autoregressive time-series model. This study concerns on rice collusion and does not consider effect of price movement effect gained from producing other grains when farmers do not overproduce rice. Wheat is a sole substitute for rice. As rice is considered as one of important commodities globally, movements of price are not cyclical. Hence, there is no uncertainty in this study.

1.5 Assumptions of this study

1. The study uses an F.O.B. (free-on-board) price of white rice 5% broken because it has the most available data in years compare to global rice price from other sources. A study from ADB Technical Assistance, 2009, showed that white rice 5% has the most share when calculate with the export; comprising 26% of the total. Moreover in 2017, Bangkok Post published an article stating that white rice 5% was also doing exceptionally well and competitive globally. It is assumed that price of all rice is equal to F.O.B. price of white rice 5%. An F.O.B. indicates that the sale is considered

complete at the seller's shipping dock, and thus the buyer of the goods is responsible for freight costs and liability during transport.

2. Only wheat is a potential substitute of rice due to same consumer behavior is possible. Other types of consumables such as tapioca starch, flour, are not suitable to compare with rice because consumption purpose is different. The reduction of export cannot raise the price of rice exceeding price of wheat or consumers will shift from consuming rice to wheat.
3. World rice market is under perfect competition, but with strong export quantity reduction agreement from large exporters, the market will behave more oligopoly.
4. This study is based on a partial equilibrium analysis where only rice market is in scope of consideration. Effects generated from this collusion on other types of grains are not in the scope.
5. Due to possible economic and lawful collusion, this study does not consider enforcement difficulties and feasibility of an agreement. This study assumes that members can reduce export quantity by agreement when they want to.
6. Rice in all countries has same quality; quality is not in consideration.
7. Rice is considered as one of important commodities globally, movements of price are not cyclical. Hence, there is no uncertainty in this study which means this study uses a deterministic approach.

8. This study assumes that selected members in export reduction will not cheat. They will always reduce export to extent of the agreement of each year.

1.6 Brief methodology

Most of this study involves with quantitative approach. Data of rice in all aspects essential for this study is collected. Price of rice is deflated with consumer price index. Rice elasticity is determined from linear regression and economics theory to be used in deterministic approach. Members to be put in agreement are filtered by amount of its export compared to import, or net export. The amount of shift in quantity and price will be based on total export reduction agreement from these members. A shift, for example, of 5% reduction in all members' export will affect price of rice by its elasticity, deflated price, and autoregressive time-series shock. This shift is a deterministic-based sensitivity analysis. Profit maximization is then found from an objective function using discounted cash flow of differences between annual revenue and cost with risk-free interest rate to make calculation realistic. Price of rice cannot exceed its substitute when compare together as final product view. Profits among members are then compared with previous profit before agreement to analyze changes in monetary value. With value of export reduction known, implementation to farmers will be analyzed with respect to degree of this value. The conceptual design flowchart of system of this model is shown as:

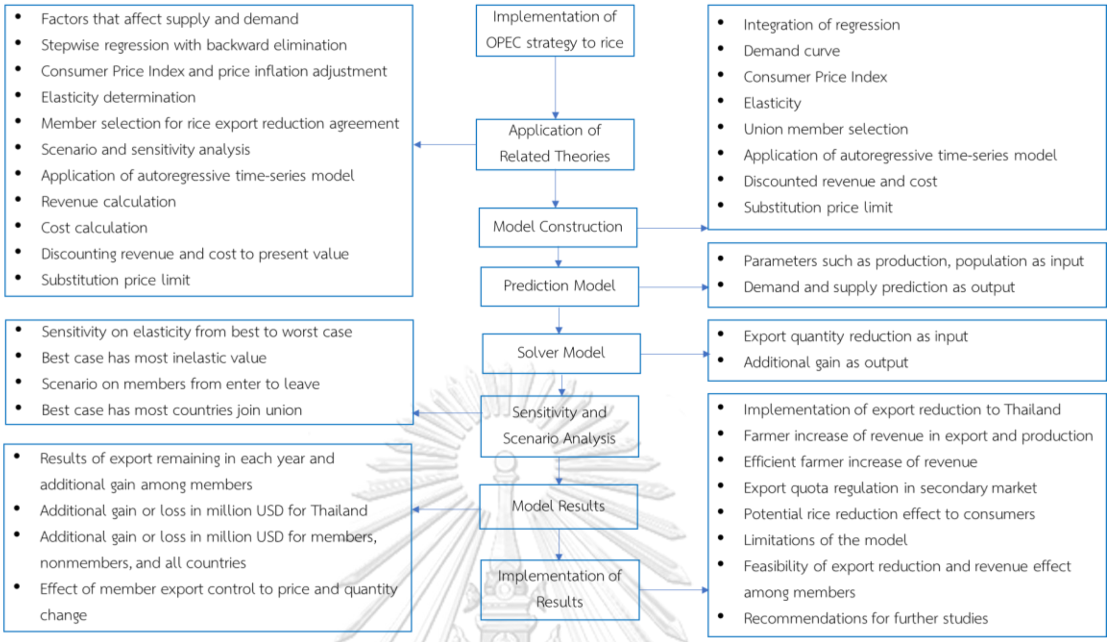


Figure 6: Conceptual design flowchart of a rice export reduction model

1.7 Potential benefits from this study

1. Data from analysis can interpret current position of Thailand compared to other countries and can be used to plan other policies related to rice according to its position at the time this study is made.
2. Result from analysis can determine value created from export reduction agreement and raise awareness to involved parties to take this into consideration.
3. Related parties enjoy additional profit from a designated agreement.

4. Related parties can implement or improve strategy from results of this study to rice or other commodities in the future.
5. In future this study can be further developed with other type of commodities or products from determining its elasticity and scope such as global or regional. Hence, benefit of this study is to create a model to use with rice and can be applied and developed by further studies with this model.

Chapter 2

Theory and Literature Review

2.1 Factors that affect supply and demand

There are several factors that can affect supply and demand. (Morgan, 2017) stated that these factors are price fluctuations, income and credit, availability of substitutes and competition, trends, advertisement, and seasons. Start with price fluctuations; this is a strong factor that contributes to a change in supply or demand. Next, changes in income and credit can affect supply and demand. A healthy trend may reduce customers to eat fried potatoes and turn to baked potatoes instead. Advertisements also help influence people to buy things and this help make changes in supply and demand. Seasonality can affect supply and demand dramatically. For example, water guns will be heavily demanded during Songkran festival. In reality, demand and supply would face an effect from natural disaster, famine, which affects import and export among countries. This model uses all data which includes all market anomalies during year 1998 to 2017 which when used with regression analysis, it can be implied that model can be used when market does not behave normally.

In rice market, only some factors specified above affect rice market due to its market characteristic. (ทิพรัตน์ วีระวัฒน์, 1996) studied rice quantity movement relative to several factors and found that price is a main factor that affect quantity significantly.

Also, as rice is an important commodity used to consume and substitutes are not easy to be found when discussed in chapter 1, effect of advertisement, seasonality, income, trends, and competition are minimal and negligible. This also supports one of assumptions use in this study that quality of rice is not concerned and brought into consideration. Therefore, supply and demand of rice are affected mostly by price fluctuations among the world markets. In deriving supply and demand function, partial differentiation between quantity and price on overall equation will show relationship between these two while setting other parameters derived in regression constant. The increase in price motivates producers to produce more rice. With an increase in production, total volume of rice exported will eventually reach the amount that would bring price back to equilibrium due to sufficient supply.

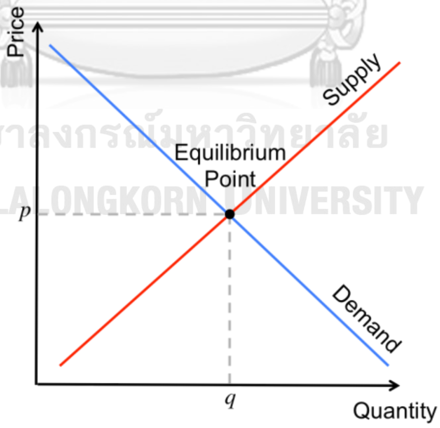


Figure 7: Equilibrium is a long-term intersection between supply and demand curve

Previous study defined and used import as a demand and export as a supply for rice quantity. (พงศ์กรณ์ ลาภชีวะสิทธิ์, สิรวิชญ์ หวังวิทยากุล, & อริสา ไพศาขมาศ, 2014; วรรณวิภางค์ มานะโชติพงษ์, 2013) This study will continue previous studies and use import as demand while use export as supply. The reason that global import quantity and global export quantity are not equal is due to the lag in direction of trade (DOT) dataset recording. (International Monetary Fund, 2017)

2.2 Regression with backward elimination

Backward elimination procedure is a method of regression where a variable that has largest p-value is considered as least significant and is removed. After that, model is refitted. This refitting continues removing least significant variable in the model on each run until all variables have each p-value is less than a specified value. This study uses a p-value of 0.05 as a criterion on eliminating variables. (Dallal, 2007) The full explanation of regression method to is found in appendix exhibit 1 and 2. Data used are all linearly plotted from raw data to fit in regression like previous study method. (พงศ์กรณ์ ลาภชีวะสิทธิ์, สิรวิชญ์ หวังวิทยากุล, & อริสา ไพศาขมาศ, 2014; วรรณวิภางค์ มานะโชติพงษ์, 2013)

2.3 Consumer Price Index and price inflation adjustment

(Appelbaum, 2004) wrote an online journal in Mathematical Association of America that price in different years should be adjusted to same value by using Consumer Price Index. Also, a study from (Koo, Karmana, & Erlandson, 1985) used deflated price from CPI along years to fairly compare prices. This hence becomes an interesting point and a point where CPI comes into an additional consideration to determine elasticity.

Consumer Price Index shows the weighted average of prices of a basket of consumer goods and services. It is calculated by using current price divided by base price in base year for each item in the basket of goods and then averages them. (Öner, 2017) wrote an article about inflation on an International Monetary Fund and commented that CPI is the most frequently used measure of inflation. The formula of CPI is show below.

$$CPI = \frac{Current\ Price}{Base\ Price} \times 100 \quad (10)$$

Consumer Price Index can be useful in comparing price among different periods. An increase in value shows inflation occurs between periods, while a decrease shows deflation. With this knowledge, rice price can be compared fairly among different years by setting a base year to have CPI of 100 and other years will have value relative to that base year. In another word, it is used to deflate price. In this study, CPI information was from World Bank where base year started from 1998 as data used started from 1998. Future inflation projections are from PwC website which forecast inflation rate. (PwC, 2017) Afterwards, each price is divided by CPI in that year to deflate all prices and reasonably comparable between years when regression analysis is performed.

2.4 Elasticity determination

In rice export reduction, elasticity of demand is a main thing to concern because shifts in supply moves along a demand curve. (Koo et al., 1985) also assumed that consumers' behavior will not change, and hence fix a demand curve. There are several literatures that have already determined the value of demand and supply elasticity for rice. However, these values are domestic values and cannot be used to explain price movement from shifts in global export reduction interested by this study. Therefore, several values of elasticity are found from previous literatures in purpose of comparison for validity of elasticity found in this study. Several previous studies were domestic demand elasticity for rice. (Flordeliza A. Lantican, Mercedita A. Sombilla, & Quilloy, 2013; Koo et al., 1985; สมพร อิศวิลานนท์ & วีระศักดิ์ คงฤทธิ์, 2006) Value found ranges between -0.51 and -0.13. This study finds global rice elasticity by means of comparison to previous value found. This range will later be used on sensitivity analysis of the model.

(Black, Hashimzade, & Myles, 2009) explained that elasticity is a measure of a sensitivity to a change in one variable to another variable proportionally. Elasticity concept is derived from Economics theory and comprises of three types of elasticity.

Price Elasticity measures the responsiveness of the quantity demanded of a product to a change in its price given else are equal. A value of elasticity is greater than 1 suggests that demand for product is affected by the price. A value that is less than 1 suggests that the demand is insensitive to price. Equation below shows price elasticity relationship with quantity and price. (Frank, 2008)

$$\varepsilon = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta P}{P}} = \frac{\%Change\ in\ Q}{\%Change\ in\ P} \tag{11}$$

Where Q is quantity and P is price of the same good.

Income Elasticity measures the responsiveness of the quantity demanded for a product to a change in people's income given else are equal. A negative value shows the good is inferior while a positive value shows the good is normal. Equation below shows income elasticity relations with quantity and income. (Frank, 2008)

$$\varepsilon = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta I}{I}} = \frac{\%Change\ in\ Q}{\%Change\ in\ I} \tag{12}$$

Where Q is quantity and I is income of people demanding that good.

Cross-Price Elasticity measures the responsiveness of the quantity demanded for a product to a change in the price another given else are equal. A negative value means two goods are complements, and a positive value means they are substitutes. Equation below shows cross-price elasticity relations with quantity and price of different goods. (Frank, 2008)

$$\varepsilon = \frac{\frac{\Delta Q_x}{Q_x}}{\frac{\Delta P_y}{P_y}} = \frac{\%Change\ in\ Q_x}{\%Change\ in\ P_y} \tag{13}$$

Where Q_x is quantity of good x and P_y is price of good y.

In this study, price elasticity is the main interest and used solely for analysis because value of price elasticity measures quantity of rice export changes compared to that of price and this is the only value that is related to its changes in quantity and price. As global rice export is used along with Thai 5% white rice price, it is assumed that this derived price elasticity is a value that can be used globally because data used in determining this were from global supply and demand.

To fairly compare prices along years interested, additional parameter is put into the equation. (Appelbaum, 2004) mentioned that price in different years should be adjusted to same value by using Consumer Price Index. Also, a study from (Koo et al., 1985) used deflated price from CPI along years to fairly compare prices.

Therefore, in this study, a rice price is deflated along the period to make comparison fair by dividing them with Consumer Price Index. Regression analysis from collected data will automatically account the appropriate unit for this value. Equation below shows price elasticity relations with quantity and deflated price with CPI.

$$\varepsilon = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta P}{P}} = \frac{\%Change\ in\ QuantityExport}{\%Change\ in\ PriceOverCPI} \tag{14}$$

Rearranging terms also yields equation below where b is defined as a slope of elasticity;

$$\varepsilon = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta P}{P}} = \frac{\Delta Q}{\Delta P} \times \frac{P}{Q} = b \times \frac{P}{Q} \tag{15}$$

2.5 Principle of collusion and application to rice trading collusion

This study considers rice market with sufficient collusion to be oligopoly instead of a generally viewed rice market as a perfect competitive market; therefore, like crude oil industry, principle of collusion is needed to be studied. (Harrington, 2017) stated in his book, The Theory of Collusion, and Competition Policy about explicit and tacit collusion. Explicit or overt collusion involves an observable proof that members will pursue a common course of action. Tacit collusion is different. When one firm raises price, other follows without further communication. He also wrote that not all collusion is illegal. Economic collusion and unlawful collusion are different. Economic collusion can be lawful. This study uses an economic, overt collusion, or an explicit collusion with formal agreement, as OPEC did and because tacit collusion, a price leadership, may be found illegal.

(Harrington, 2017) also wrote that not all collusion is illegal. If firms in industry would like to shift from competition to collusion, they would require communications to make collusion effective. However, this is controversial because communication is useful only when messages are truthful and creates right set of incentives for firms to correctly communicate. This argument is also supported by (Robert C. Marshall, 2012) on their book, The Economics of Collusion: Cartels and Bidding Rings that there are some factors that made collusion difficult, which includes communications.

Due to possible economic and lawful collusion, this study does not consider enforcement difficulties and feasibility of an agreement. This study assumes that countries can collude whenever they want to.

Rice export agreement in this study is based on OPEC crude oil production cut. Amount of rice that members altogether hold will affect global price. OPEC increases oil price by reducing production. Rice collusion can increase price by methods such as reducing production or export. This study uses export reduction as production is assumed to be reduced for export only. Internal consumption is assumed not to be affected by export reduction agreement. Even though non-members may potentially benefit from this collusion because only members reduce export while non-members maintain export at the same growth rate, this collusion should continue. It is like doing a group work where there may be some freeloaders, but a work still needs to be done for a greater good.

2.6 Nash equilibrium

(Guha, 2008) wrote in a published journal that Nash equilibrium is a fundamental concept in game theory and is the most widely used method for prediction of an outcome of an interaction such as collusion. Table 1 shows payoff diagram based on each action from each company.

Table 1: Payoff diagram

Company	B honors	B cheats
A honors	(2,2)	(0,3)
A cheats	(3,0)	(1,1)

The table above illustrates Nash equilibrium example by giving simple payoff diagram in different circumstances in terms of (payoff to A, payoff to B). It is seen that regardless of what B will do, firm A should always cheat because A could gain 3 or 1 compared to honor which could gain 2 or 0. Firm B would also think like this. This explains mostly in real situation all firms would eventually cheat because they hope to gain more benefit. Solutions to this can be vary depend on that circumstance. In real situations, one of recommendations to prevent cheat is that in agreement, members should create a penalty for cheating members. To simplify and focus on effect of export quantity reduction to price of rice and revenue gain, cost incurred among members, this study assumes that selected members will not cheat.

2.7 Member selection for rice export reduction agreement

A full methodology is shown in the next chapter. In selection of the colluding countries, there must be reasonable criteria to choose countries that will become members like what OPEC did. The rice collusion model is based on OPEC previous actions because OPEC is considered to make commodities that should behave like perfect competition to behave like oligopoly. Countries to join as members will have significant amount of rice net export altogether to the world. This amount will also be used in scenario analysis to see changes in impact to rice price given number of net export from members to world increases or decreases.

A consideration for candidate countries is found from weighting amount of its export minus by its import, and its production. Reason behind this is that countries are required to produce and import rice for its own population too. Having net trade (export – import) can see its available resources excluding domestic consumption of each country. By subtracting these values between countries yields net export, it is an appropriate measurement according to usage in calculation of aggregate expenditures. A positive value of net export means that country has trade surplus while a negative value means trade deficit.

Having production is also considered interesting because ability to produce rice among countries can scale to export bargaining power. However, a study from (ทิพรัตน์ วีระวัฒน์, 1996) wrote in conclusion of his study that China loses a large amount of production for domestic consumption. For example, China produces a lot of rice but has negative value of net trade. Therefore, production of rice should not be included in selection of members. OPEC increases oil price by reducing production. Rice export reduction agreement can increase price by methods such as reducing production or export.

2.8 Comparing parameters among countries using percentage ranking

Data from USDA contains both export and import. By subtracting these values between countries yields net export, it is an appropriate measurement according to usage in calculation of aggregate expenditures. A positive value of net export means that country has trade surplus while a negative value means trade deficit.

By arranging all countries by rank percentage from most to least value of net export, when total amount of net export from countries are summed up to one value, this is total number of countries that are members. The formula used to find percentage to be used in ranking is:

$$\%country\ net\ export = \frac{net\ export\ of\ that\ country}{total\ global\ net\ export} \quad (16)$$

2.9 Application of autoregressive time-series model

The amount of export reduction will theoretically affect rice price only for one year, and afterwards price will go back to its equilibrium at next export quantity. However, in actual case consideration price will not go to its equilibrium suddenly when next year arrives. There is a lag between price movement to equilibrium and time. (Mills, 1990) has described a model that can be used to explain this as an autoregressive time-series model. This model accounts for an intertemporal effect of shocks. In autoregressive process, a one-time shock affects values of following variable far into the future. This is consistent to what an export reduction, treated as a shock, will result in following shocks for export and prices in the future. An application of an autoregressive time-series model can be shown as the amount of years that price will be affected by shock and the intensity of that shock. This can be found using equation:

$$P_{actual} - P_{theoretical} = u\Delta P_y + v\Delta P_{y-1} + w\Delta P_{y-2} + \epsilon \quad (17)$$

Where P_{actual} is an actual historical price of rice

$P_{theoretical}$ is an estimated annual price obtained from equation using regression

u is coefficient for ΔP_y as a factor contributor to actual price difference (LHS)

v is coefficient for ΔP_{y-1} as a factor contributor to actual price difference (LHS)

w is coefficient for ΔP_{y-2} as a factor contributor to actual price difference (LHS)

ΔP_y is difference of theoretical price at current year y

ΔP_{y-1} is difference of theoretical price at previous year y-1

ΔP_{y-2} is difference of theoretical price at previous two years y-2

ϵ is residual between variables at left-hand side and right-hand side

A deviation of raw data is used to detrend raw data and is used to determine value of $\Delta P_y, \Delta P_{y-1}, \Delta P_{y-2}$. Method starts from plotting raw data with x as a trend variable along the timeline. After plotting, plot a linear trendline. Trendlines gained from the plot are:

$$P = 15.711x + 209.4 \quad (18)$$

$$Pro = 5.7934x + 375.94 \quad (19)$$

$$Ex = 1.1848x + 20.899 \quad (20)$$

$$Im = 0.9831x + 22.435 \quad (21)$$

$$WP = 77.919x + 5853.1 \quad (22)$$

$$ES = -0.3325x + 110.82 \quad (23)$$

Raw data on each variable is then subtracted with values of trendline on each year. Deviations are denoted as a variable with prime sign. For example, P'. This dataset is a deviation between actual and trendline. Regression analysis with backward elimination is then used to analyze relationship between deviation of variables. Price deviation is set to be Y while other variables are X. After backward elimination is done, equation obtained is:

$$P' = 3.092 + 5.989Pro' - 21.047Ex - 1' \quad (24)$$

Where $Ex - 1$ is previous year export.

Equation 15 is then added back to equation 9 to include trend effect and obtain theoretical price used for ΔP_y calculation. This value is subtracted by $P_{theoretical}$. $\Delta P_{y-1}, \Delta P_{y-2}$ are similar to ΔP_y in values but different in time. ΔP_{y-1} is value of ΔP_y that is lagged by one year while ΔP_{y-2} is that of two years.

This model assumes that amount of shock will affect future prices by u, v, w times difference in prices on each year. Solver in excel is used to minimize sum of square of ∈ to minimize error occurred by lagged prices. In this method, u, v, w are variables to be solved by solver to be used in real optimization model. These coefficients will be multiplied with $\Delta P_y, \Delta P_{y-1}, \Delta P_{y-2}$ in real model to find shock lag effect among years of price movement. It is noticeable whether shock model can be applied with quantity reduction to see its shock directly. For example, left hand side would become $Q_{actual} - Q_{theoretical}$ instead. However, price change occurs from an action to reduce quantity and that is the reason of shock. Therefore, using quantity as a shock may not be appropriate.

2.10 Revenue calculation

Revenue gained by all countries including non-members are calculated from shocked, or lagged, price and shocked quantity. When shocked values are used, revenue recognition is the most realistic. Starting with lagged price, price on each year is affected by previous actions from members such as status quo or reduces export. A shocked price is then adjusted with expected inflation in form of CPI to reflect the most possible price. This adjusted price is then used to calculate lagged quantity by means of elasticity formula. With an annual elasticity on each different year, lagged quantity can be calculated from adjusted shocked price recalled in equation (3).

$$Revenue_i = P_{riceadj\ i} \times Q_{shocked\ i}$$

2.11 Cost calculation

Producing rice requires cost to produce. Cost consists of two parts: fixed and variable. Costs are referred from paper of Asian Development Bank, 2012 and Characteristics and production costs of USDA report, 2004. ADB paper (Boonjit Titapiwatanakun, 2012) shows margin for main crop rice, rice grown outside central plains, and for secondary rice, minor production from central plains. This can be used with rule of three to compare what cost should be given revenue and average margin. USDA paper (Janet Livezey, 2004) shows details of fixed and variable cost of rice. It is seen from Table 2 that cost composes of operating and ownership costs. Ownership cost is assumed to be fixed cost while operating cost is variable cost. It is seen that fixed cost composes of 26.7% of total cost. Costs and value of production are in USD per ton.

Table 2: Composition of costs from Asian Development Bank, 2012

Operating and ownership costs/cwt:	
Costs/actual yield	3.99
Costs/expected yield	4.01
Costs and returns per planted acre:	
Gross value of production	385.45
Operating costs	204.17
Seed	20.68
Fertilizer and soil conditioners	34.7
Chemicals	32.73
Custom operations	34.26
Fuel, lube, and elasticity	43.53
Repairs	14.59
Purchased irrigation water	3.68
Interest on operating capital	5.16
Hired labor	14.86
Ownership costs	74.64
Capital recovery of machinery and equipment	62.62
Taxes and insurance	12.02
Total operating and ownership costs	278.81
Value of production less operating costs	181.28
Value of production less operating and ownersl	106.64

A high percentage of fixed cost to total cost may imply that export occurred by production should be increased instead of reduced because fixed cost is high. Increased export will decrease percentage of fixed cost incurred.

Another interesting and plausible method to calculate cost of rice is found in a research paper from Thanyaburi University (สุขใจ ตอนปัญญา, 2011). This research has clear details on fixed and variable costs of rice in currency of Thai baht per rai. Details are shown in a table below.

Table 3: Composition of costs from USDA report, 2004

Variable Cost	THB	Fixed Cost	THB
Rice species	654.98	Depreciation	142.85
Rice growing labor	41.19	Land Rent	842.03
Fertilizer labor	123.57		
Insecticides labor	68.81		
Area labor	22.80		
Self-labor	986.78		
Crop labor	380		
Fertilizer	998.19		
Primary insecticides	73.33		
Secondary Insecticides	56		
Hormones	26		
Fuel	216.74		
Tractor labor	450		
Total	4098.39		

Moreover, this paper stated that costs of rice are 13% from raw material, 24% from labor, and 63% from labor. Which when fixed and variable costs are calculated to find a breakeven quantity for revenue, that quantity is shown on next table.

Table 4: Breakeven quantity for revenue

Breakeven Analysis	THB
Fixed cost	984.88
Sell per unit	5,903.08
Variable cost per unit	4,098.39
	kgs
Breakeven quantity	**550.00**

Means that this paper suggested farmers to grow 0.55 tons of rice per rai to breakeven cost. From Table 3, It is seen that fixed cost in second paper composes of 19.4% of total cost. From comparison between first and second paper, this paper has more detail in analyzing sources and classification of cost types. Therefore, cost of rice on this study is referred from this paper.

2.12 Discounting revenue and cost to present value

In finance, future cash flows are discounted to current year at a specified discount rate. (Berk & DeMarzo, 2014) The formula for discounting cash flows to a present value is:

$$DCF = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \cdots + \frac{CF_n}{(1+r)^n} \tag{25}$$

Where CF is cash flow of that year, DCF is sum of all future cash flows discounted to the same period specified, r is discount rate, and n is number of years that this amount of cash flow reaches.

(Berk & DeMarzo, 2014) define risk-free interest rate as the interest rate at which money can be borrowed or lent without risk over that period. (Berk & DeMarzo, 2014) also commented that this interest rate can be used to evaluate other decisions in which costs and benefits are separated in time without knowing investor's preferences. This case, preference on investors is unknown. Also, a risk-free rate is a unique risk that is not a market rate. It means this rate has zero correlation to the market. If assume beta of commodities to be zero, risk-free rate can be used. Hence, it is appropriate to apply a widely used risk-free interest rate as a discount rate for discounting these cash flows. However, note that by discounting with a low rate like in this case, value of money obtained in terms of additional gain will be biased towards higher value. This use of risk-free rate is widely used, but with a limitation. In this case, an average rate of three-month U.S. Treasury bill is universally used as risk-free interest rate in this study.

Future values of revenues and costs are discounted at risk-free interest rate of 1.67% from average rate of three-month U.S. Treasury bill and are discounted based on number of years from current year. (YCharts, 2018) This can be applied to both revenue and cost of rice.

2.13 Substitution price limit

In this study, wheat is the only substitute of rice. Consumers that eat rice may shift to wheat product when price of final product of rice is more expensive than that of wheat. This is because wheat can be a meal for consumers unlike tapioca starch or corn starch final products. Unlike rice, wheat is mainly produced in USA. An article from The U.S. Department of Commerce’s International Trade Administration website published in 2017 supports that Thailand’s wheat production is marginal due to unfavorable climatic conditions, the lack of seed development, and unattractive returns compared to other field crops. (U.S. Commercial Service of the U.S. Department of Commerce, 2017) 90 percent of domestic flour products come from locally milled imported wheat. Wheat price is also an initial product which is not consumable unlike rice which is a price of its final product. The claim of price of rice is being final product is confirmed when compare price of white rice 5% in THB from Thai Rice Millers with Thai Rice Exporters Association. (สมาคมโรงสีข้าวไทย, 2017) (Thai Rice Exporters Association, 2017b) Data of rice from Millers are per 1 rice sack, which is equivalent to 100 kilograms. A multiplication with ten yields an equivalent trade volume with USDA price. Table 3 shows the relationship of rice final product in different currency.

Table 5: Relationship of rice final product in different currency.

Average Thai Annual White Rice 5% Price		Average USDA Annual White Rice 5% Price	
12,020	THB	399	USD
Exchange Rate		**30.16**	THB/USD

It is seen that these are milled rice with equivalent value at exchange rate of 1 USD per 30.16 THB. Then, adjustments of price for wheat must be done to make it comparable with rice final product in same place. First, shipment cost from USA to Thailand with weight over 1,000 kg is 577 THB per kilogram. (FedEx, 2018) Next, historical price of wheat is used to find final product value. (Macrotrends) Its trading unit is in cents per bushel, this must be converted into USD/ton to compare with rice. 1 USD equals 100 cents and 1 ton equals 36.7437 bushels. Raw data of wheat is available monthly from 2010 onwards. Prices are averaged yearly like rice. Then, (Wech, 2017) stated that the value of wheat in that loaf was about 12% of total value. Other factors (milling, baking, packaging, shipping, etc.) made up the rest of purchase price. This number of 12% is then used with original wheat price to see its final value. Next, rice price and final wheat price are brought to find average difference from 2010 to 2017. Average of these values is the price deviation limit, which rice price in the model cannot exceed. It is found that price limit is 286.6%. Future wheat price from 2017 is determined from a forecast by using rice price with a forecast CPI growth from PwC multiply with percentage of price limit gained. This ceiling is limited with constraint function on solver of excel. A formula for determining wheat price referred in (6):

$$P_{wheat} = P_{rice\ y-1} \times \frac{CPI_y}{CPI_{y-1}} \times PC$$

Where $P_{rice\ y-1}$ is a price of rice in previous year with assumption that no export reduction agreement is done to simulate wheat price movement at normal condition.

PC is price deviation limit between rice and wheat. From derivation of statistical data, this study uses 286.6% as a value of price limit.

2.14 Scenario analysis

Number of countries joining members can vary from year to year and this would change amount of export reduction agreement. It is interesting to see amount of changes of profit among countries or a differed shocked price of rice given number of members are different. There are several scenarios that can be implemented through this study. Selected scenarios will be: the largest net exporter exits membership, the smallest member exits, and the country that has net export less than smallest member joins membership. (Appelbaum, 2004)

2.15 Sensitivity analysis

Elasticity of rice is important in this model. Shocked price of rice varies on slope b and elasticity when export quantity is reduced. A calculated slope of elasticity is used with model and yields a shocked price in each year. This study will use the lowest and highest value of elasticity of local rice found from previous research to see the amount of changes in price of rice, export reduction when solver is executed, and profit changes comparison. Value of slope determined in this study is base case while the lowest is determined as worst case because it is more elastic, and price would not change on quantity that much. The highest is determined as best case which is more inelastic.

2.16 Implementation of export reduction to Thailand

There are about 3.7 million farmer households in Thailand. (Thamrongthanyawong, 2015) Using data from USDA in 2015 shows that export in Thailand was 9.87 million metric tons. Milled production was 15.8 million metric tons. Domestic consumption was 9.1 million metric tons. Ending stock was 8.4 million metric tons, changed from year 2014 of 11.27 million metric tons by 2.87 million metric tons decrease. The relationship of rice parameter can be possibly estimated from known information as:

$$Milled\ Production \approx Export + Domestic\ Consumption + Change\ of\ Ending\ Stocks \quad (26)$$

While these values from left hand side and right hand side are unequal, it is believed that residual is an import of Thailand. Import was not shown in USDA report because Thailand imported small amount of rice compared to those countries globally. Import may occur due to taxes and trading benefits when pass to Thailand and export to other countries.

If assume that production for domestic consumption will be sufficient and domestic consumption is stable, it is possible to use export per household to analyze how many households will be affected by export reduction. This means that domestic consumption of 9.1 million tons and 3.7 million households are divided together to see necessity of farmers to produce rice. It is seen that 2.46 tons per a household is necessary to cover domestic consumption. And with export of 9.87 million tons, 2.67 tons per household now is used with export.

With export amount decreased in Thailand when this execution occurs, this export reduction will affect revenue, cost, and profit of farmer households. Focusing on export, a reduction in export means farmers may obtain revenue less than by selling 2.67 tons per household to a miller because new quota is applied. However, statistics shows that lack of farmers in this country tends to increase. (กรวิทย์ ตันศรี, 2014) The study mentioned reason that young age labors tend to move from farmers to other occupations. This increases average age of labor throughout previous years.

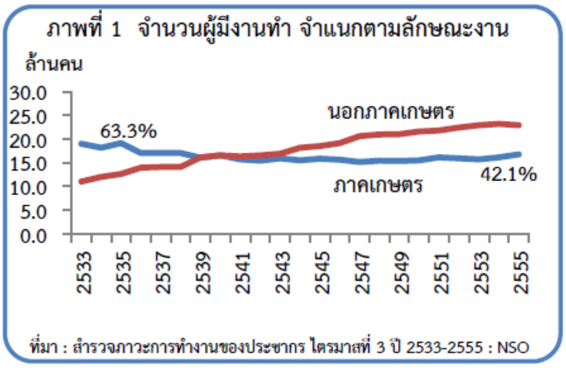


Figure 8: Statistics showing decline of farmers in overall labor force

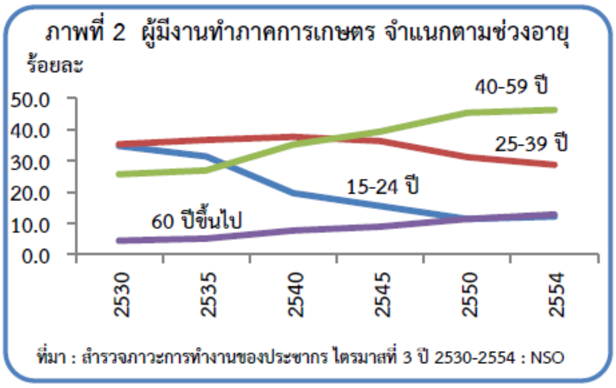


Figure 9: Downtrend of young farmers and uptrend of aged farmers

This could be a benefit to farmers because it means that households are also decreasing while export quota is reduced. Future reduced farmer households may obtain more revenue to serve domestic consumption and export because there are less total revenue sharers. This is based on assumption that farmers have sufficient land to produce rice at designated capacity. However, farmers may experience an additional gain instead if price raised by export reduction agreement makes revenue that comes from price times quantity larger than that of no agreement applied.

Another possible implementation to limit export from country to a preferred value is to create a limited export quota. For example, this year agreement is to export 2,000 metric tons. An export contract of 1 kg per contract in total of 2 million units are then placed in a secondary market such as TFEX. Pricing in secondary market is fair because it has bid-ask system that can match buyers with sellers.

Chapter 3

Methodology

3.1 Data collection

Data collection is done through various sources. Most of data collected are global values to ensure that data, methods, and results are consistent to global reduction of export quantity and an increase of price in the model.

3.1.1 Rice data from USDA

Rice data from USDA are collected such as global supply or demand, export, import, production, and year to be used in part of regression analysis and determining elasticity. These global activities obtained from USDA ranged from year 1988 to 2017. However, due to rice price data constraint that only is available from 1998, USDA data are used in analysis from 1998 to 2017. Data are collected until the end of September 2017 because this was the time that this study initiated. (United States Department of Agriculture, 2017)

3.1.2 Rice data from Thai Rice Exporters

Rice price data from Thai Rice Exporters are collected to be used in part of regression analysis and determining elasticity. This will require deflating price with CPI later to fairly compare prices along the timeline. The chosen price is Thai 5% broken white rice because it has high popularity among consumers and traders as discussed in chapter 1. Data are collected monthly from January 1998 to September 2017 in USD per metric ton of milled rice basis. (Thai Rice Exporters Association, 2017b) Prices from twelve months on each year are then averaged to find yearly price. The reason of data selection to be yearly is because collusion policy should not be changed frequently, or it will not be realistic. Rice in Thailand has unlimited export quota which means no ceiling in export agreement. (Thai Rice Exporters Association, 2017a)

3.1.3 Estimated annual population data from United States Census Bureau

An estimated annual population data is obtained from United States Census Bureau in purpose of running a regression to find whether population has impact on demand and supply and data are collected from year 1998 to 2017. This data set is then divided by one million to make data set easier to visualize and easily comparable to other variables in a regression.

3.1.4 Additional variable definitions

Deflated price

Past CPI data are collected from World Bank from year 1998 to 2017 to reflect inflation along years and are used to deflate price for appropriate comparison along years. (The World Bank, 2017)

Trend variable

(Koo et al., 1985) shows that time trend variable is required to be used in analysis to see whether demand or supply function depends on time. If p-value is more than 0.05, it means that coefficient in front of time trend is zero at the end of regression and hence that demand or supply with that run does not have time trend effect.

3.2 Linear regression analysis

Linear regression with backward elimination is used to analyze possible relationships between export or import quantities versus other parameters. In this study, all parameters that can be potentially involved are all put into analysis and eliminate non-significant variables one-at-a-time. (Koo et al., 1985) used x as a time trend variable and detrend all values. The full explanation of regression method and the use of linearity are found in appendix exhibit 1 to 4. Import and export prediction from plot can be implied with linear pattern from trendline plot. This study continues this usage of time detrending. Parameters are notated as abbreviations and illustrate the following in terms of annual measurement:

x is a time trend where x equals to 1 starting from 1998 and increases by 1 annually

WP is annually recorded total world population in unit of person divided by 1 million

Pro is an annual world rice production in unit of millions of metric tons per hectares

ES is an annual world rice ending stocks in unit of millions of metric tons per hectares

Ex is annual total world rice export in unit of millions of metric tons per hectares

Im is annual total world rice import in unit of millions of metric tons per hectares

Ex-1 is annual total world rice export from previous year in unit of millions of metric tons per hectares

Price is an annual price of Thai 5% broken white rice based on milled rice basis in unit of USD per metric ton which is also an F.O.B. basis

POC is an annual price of Thai 5% broken white rice deflated by consumer price index from World Bank

Con is an annual domestic consumption in unit of millions of metric tons per hectares

As mentioned, running regression in this study is based on stepwise regression, or backward elimination. A parameter with p-value over 0.05 is eliminated one-at-a-time and a whole set of raw data except an eliminated one are used to rerun regression again. This method may not yield the highest R-square or adjusted R-square value because some factors that have been eliminated may contribute to its R-square. However, it is worthwhile to do this method to trade R-square off with major contributors to a variable that is used to run regression. For example, seven factors may have R-square of 99% while four factors have R-square of 97% for the same model. If these four factors have p-value less than 0.05, it means it should be kept with the model. This supports null hypothesis where it is not rejected that coefficient in front of a variable is not zero. Also, less variable incurred, easier analysis to variable sensitivity obtained. Data used to run for all cases are from year 1998 to September 2017 as these data are available in all variables used in regression. After multiple runs of stepwise linear regression with backward elimination have been done, equations representing potential demand and supply curve are known. These curves have substitution effect incorporated from raw data when run by regression. Effect of substitutes are included in curves. The equation shows the relationship between import and other variables which is a demand curve.

$$Im = -6326.63 - 85.16x + 1.08WP - 0.11ES + 1.25Ex - 4.95POC \quad (27)$$

It is seen from equation (27) that time series, world population, ending stocks, export quantity, and deflated price affect quantity demanded.

The same method is done with export curve. Equation below shows the relationship between export and other variables. This is a supply curve due to prior reasons stated in chapter 2.

$$Ex = -23.12 + 0.08Pro + 0.78Im + 0.81POC \quad (28)$$

It is seen that world rice production, import quantity, and deflated price affect quantity supplied.

3.3 Effect of quantity shift to price shift

Supply and demand curve are obtained and can be used to find annual agricultural equilibrium price when setting import equal to export.

$$Im = Ex \tag{29}$$

Economics theory demonstrates that amount of import should be equal to amount of export in long run equilibrium. As the study would like to determine a stable value of elasticity, the equation of import is then placed to equal the equation of export. A relationship among deflated price, a price over CPI, and other terms can be found by rearranging terms. This is called an unshifted equation and will be used to subtract a shifted equation that will be stated next.

$$I = X\ Unshifted;$$

$$-6326.63 - 85.16x + 1.08WP - 0.11ES + 1.25Ex - 4.95POC = -23.12 + 0.08Pro + 0.78Im + 0.81POC \tag{30}$$

Rearranging equation (30) can yield a new equation in terms of deflated price;

$$POC = -1094.94 - 14.78x + 0.19WP - 0.02ES + 0.22Ex - 0.01Pro - 0.14Im \tag{31}$$

This equation in terms of POC is an estimated value of deflated price gained from regression model when re-inputting all raw data in each year back into the equation.

To determine elasticity, sensitivity of quantity changed with respect to price changed is essential. As formula of elasticity is a delta, means a change, of quantity over a delta of price, times with its price over quantity of that year, derived export and import equations can be used to visualize sensitivity or slope of elasticity.

$$Im = Ex' = Ex - q \quad (32)$$

Hence, a factor named q is included in the shifted equation which demonstrates a simulation of reduction in quantity of rice supplied globally. This is to see sensitivity of price movement when some quantity is pulled out of the system. Because for each change in quantity, price does not change equally to quantity changed.

$$I = X\ Shifted;$$

$$-6326.63 - 85.16x + 1.08WP - 0.11ES + 1.25Ex - 4.95POC = -23.12 + 0.08Pro + 0.78Im + 0.81POC' - q \quad (33)$$

Rearranging equation (33) can yield a new equation in terms of deflated price;

$$POC' = -1094.94 - 14.78x + 0.19WP - 0.02ES + 0.22Ex - 0.01Pro - 0.14Im + 0.17q \quad (34)$$

This equation in terms of POC is an estimated value of deflated price gained from regression model when re-inputting all raw data in each year back into the equation after a quantity of q is removed as a simulation of reducing supply.

3.4 Slope of elasticity

An unshifted equation is subtracted by a shifted equation to see amount of changes incurred on deflated price when q is an amount that is removed from the system.

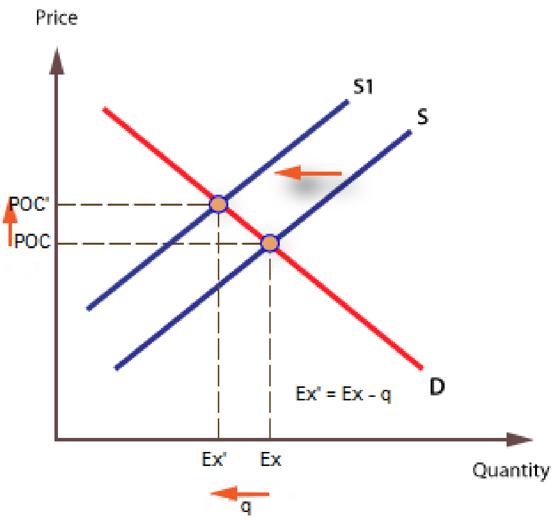


Figure 10: Effect of quantity removed to supply curve given fixed demand

By subtracting equation (33) with equation (34), an obtained relationship is:

$$\Delta POC = -0.1737q \tag{35}$$

Rearranging equation (35) into a form of $\frac{\Delta Q}{\Delta P}$, equation becomes

$$\frac{\Delta Q}{\Delta P} = -5.7569 \tag{36}$$

From equation (15), elasticity definition can be changed into a form of

$$\varepsilon = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta P}{P}} = \frac{\Delta Q}{\Delta P} \times \frac{P}{Q} = b \times \frac{P}{Q}$$

It is seen from equating equation (15) and equation (36) that

$$b = -5.7569 \quad (37)$$

With delta of q over delta of deflated price, slope of elasticity, b, can be calculated. The value obtained is -5.7569. This value of -5.7569 is considered as a universal slope, not elasticity, which can be used to predict price movement given some export quantity is removed. By putting this value into an equation 6, annual elasticity can be obtained by multiplying deflated price and dividing quantity exported on each year.

3.5 Net export analysis

This method is used to find capable countries that are suitable to be included in oligopoly rice common market. A country with more scalability has more potential in producing and exporting rice without harming its own domestic consumption. In this study, domestic consumption is stable while produce decreases when reduce export. One criterion is to use amount of export minus by import. Another is to see production capacity of each country as it has scalability to countries that export. However, as discussed in chapter 2, only net export is used for determining scalable countries.

3.6 Member selection for rice export reduction agreement

A method to determine ranking of net exporters is to rank them by percentage compared to total amount of global net export.

Total quantities of export from these countries are summed up and are separated from non-member countries to be used in export reduction calculation in the model.

Data from USDA is used to rank countries that have a lot of net trade, export minus import, or their production. As export minus import data is processed, it is found that USDA has limited data on each country. For example, countries that have export value may not have import value. Therefore, a country without an import or export value is assumed to have zero amounts for simplification of calculation. Rankings are then summed up to a value of the global export, import, or production. It is found that at least 5 countries are recommended to form an agreement, starting from the most net export to the least: India, Thailand, Vietnam, Pakistan, and USA with total net export of 82.78% of total rice in the world. This can be changed in scenario analysis.

3.7 Application of autoregressive time-series model

An application of an autoregressive time-series model can be shown as the amount of years that price will be affected by shock and the intensity of that shock. (Mills, 1990) From the equation (17):

$$P_{actual} - P_{theoretical} = u\Delta P_y + v\Delta P_{y-1} + w\Delta P_{y-2} + \in$$

Results have been done and shown as:

Table 6: Results for application of autoregressive time-series model

u	v	w
0.83	0.13	0.06
Sum square error		122631.04

The objective is to find value of u, v, w that minimize sum of square of $\in$. It is found that value of u, v, w are 0.83, 0.13, and 0.06 respectively. Interpretation of these value means that the more years that price have passed the current year, the less impact it shocks price. These values will be used in model to find price shocks.

3.8 Revenue calculation

Revenue gained by all countries including non-members are calculated from shocked, or lagged, price and shocked quantity. Referred from equation (3):

$$Revenue_i = P_{riceadj\ i} \times Q_{shocked\ i}$$

Revenue of each year is gained. Revenues will be discounted to sum their value at present time.

3.9 Cost calculation

This study uses the second paper from cost literature. The unit from paper is rai. Recommended volume of production is 550 kg per rai. This relationship can be used to relate rai, tons, and THB together. A table below shows calculation of total fixed cost which will be unchanged throughout years, while variable costs will change.

Table 7: Estimation of fixed cost in producing rice

Fixed cost in 2017 and so on			
	THB		Tons
Fixed Cost per rai	984.88	Recommend per rai	0.55
Variable Cost per rai	4098.39	Fixed Cost per ton	1790.69
Total Cost per rai	5083.27	2017 export	44,400,000.00
Fixed Cost		฿79,506,676,363.64	
1 USD equals		30.16	
Fixed Cost		$2,636,420,221.72	
Fixed Cost in millions		**$2,636.42**	

This is an example of calculation for global fixed cost in producing rice for export. USD to THB conversion came from exchange rate used in equating price of white rice in USD and THB units. Additional calculation in variable cost is described next. Using this production per quantity as cost per unit, future variable costs can be calculated with changed shock quantity times with this value.

$$Variable\ Cost_i = Q_{shocked\ i} \times Cost\ per\ unit_i \qquad (38)$$

Table 8: Estimation of variable cost in producing rice

Example of Variable cost 2017			
	THB		Tons
Variable Cost per rai	4098.39	Recommend per rai	0.55
		Variable Cost per ton	7451.62
		2017 export	44,400,000.00
Variable Cost		฿330,851,847,272.73	
1 USD equals		30.15705755	
Variable Cost		$10,970,959,175.21	
Variable Cost in millions		**$10,970.96**	

Variable cost will vary from 2017 and depends on quantity of rice export. In this case, variable cost tends to decrease over time given interest of this study is to reduce rice export over years.

Fixed cost is assumed to be fixed over years based on starting year 2017 because this study would like to simulate the max possible fixed cost starting from 2017 so when export production is reduced, fixed cost is assumed to be already invested and cannot be changed. Annual total cost is referred from equation (8):

$$Cost_i = Variable\ Cost_i + Fixed\ Cost_i$$

Costs of each year are now gained. Costs will be discounted to sum their value at present time. A high composition of fixed cost to total cost may imply that export should be increased instead of reduced because fixed cost is high. Because it is clear from literature that past paper stated fixed cost was 19.4% of total cost, it is possible to reduce export.

3.10 Discounting revenue and cost to present value

Recalled from equation (25):

$$DCF = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \cdots + \frac{CF_n}{(1+r)^n}$$

Revenues and costs are discounted at risk-free interest rate of 1.67% from average rate of three-month U.S. Treasury bill. Sum of these values are then present values of revenues and costs. These together yields profit among members and non-members by export reduction.

An application of this discounted cash flow turns equation (25) to (2):

$$PV(Revenue_i - Cost_i) = \frac{Revenue_i - Cost_i}{(1+r)^i} + \frac{Revenue_{i+1} - Cost_{i+1}}{(1+r)^{i+1}} + \cdots + \frac{Revenue_n - Cost_n}{(1+r)^n}$$

3.11 Substitution price limit as a pricing limit

$$P_{wheat} = P_{rice\ y-1} \times \frac{CPI_y}{CPI_{y-1}} \times PC$$

This equation (6) recalled is used to find price limit of wheat in each year and put in to the model.

3.12 Optimization model

With all information gathered, the optimization model is the formed. The objective is to maximize profit among members. Decision variable is the amount of export left after reduction range from zero to one hundred percent from total export quantity among members on each year. Decision variable among years are independent. Major constraints are: decision variables on each year cannot outrange zero to one hundred and shocked rice price must never exceed wheat price, which is difference of these values must be less than or equal to zero.

3.12.1 Objective function

Profit maximization model is equation (1):

$$\text{Max Profit } \pi = \sum_{i=1}^{n} PV(Revenue_i - Cost_i)$$

Where i is index of each year and, n is number of years, and PV means present value of both revenue and cost.

An example of n equal to 12 will be done in this study. This means the model is simulated from year 2018 to 2029.

3.12.2 Decision variable

x_i is the amount of export left after reduction in unit of percentage range from zero to one hundred percent from total export quantity among members on each year. Decision variable among years $\boldsymbol{i}$ are independent.

3.12.3 Constraints

Subject to:

$\mathrm{I} = index\ set\ of\ years = \{1, 2, 3, \dots, n\};$

$x_i \geq 0, \forall i \in I;$

$x_i \leq 1, \forall i \in I;$

$Revenue_i \geq 0, \forall i \in I;$

$Cost_i \geq 0, \forall i \in I;$

$P_{riceadj\ i} - P_{wheat\ i} \leq 0, \forall i \in I;$

3.12.4 Mechanism of the model

Expected export quantity growth is found from previous pattern of export quantity movement along years. It is found that average export forecast growth is 3.36%. This value is used to project export growth among non-members because non-members will not act on quantity reduction and still produce at an assume growth rate cumulative annually. Members will not have this growth rate when cooperate and hence members are assumed to produce at same rate to 2017 times with decision variable of quantity remaining from reduction along future years. It is required that global export quantity including non-members must be included because global rice of price depends on global export, not export from members.

Mechanism of the model starts with a decision variable in each year is multiplied with member summed export quantity from 2017. This value is then added with quantity produce from non-members. Altogether, these will result in remaining global export quantity in that year recalled from equation (9).

$$(x_i \times Q_{member2017}) + Q_{nonmember2017} = Q_i$$

Next, quantity gained can be used to determine global rice price shifted by means of elasticity relationship formula. A mean of deflated price from 1998 to 2017 is used instead of future deflated prices because export has a predictable growth rate for non-members at 3.36% while deflated price moves between 1.57 and 4.45. Without food crisis event in 2008, the max deflated price would have been 3.50. This study would like to include all events in consideration to be usable in all circumstances regarding price and quantity changes. The universal slope of -5.7569 is then used and multiplied with mean of deflated price from 1998 to 2017 and divided with global quantity with growth on export for non-members without export reduction in each year.

Price obtained will be in a form of deflated price because slope of b is found from regression with deflated price one of variables. Deflated price will be multiplied with projected CPI from PwC to obtain price before shock.

After price in each year is obtained from global quantity, next method is to find a shocked price from lagged effect of reducing quantity of export. Formula of a change in shocked price effect is recalled from equation (17):

$$P_{actual} - P_{theoretical} = u\Delta P_y + v\Delta P_{y-1} + w\Delta P_{y-2} + \in$$

Assuming residual in future will be zero, when rearrange equation; it is found that actual price is the sum of theoretical price with its following shocked values. Shocked prices in the future are therefore obtained by using this equation where substitute variable as annual price for rice and the equation results in (4):

$$P_{rice'i} = P_{rice\ i} + \Delta P_{shocked\ i}$$

A shocked price is then adjusted with expected inflation in form of CPI to reflect the most possible price as in equation (5):

$$P_{riceadj\ i} = P_{rice'i} \times \frac{CPI_i}{CPI_{i-1}}$$

Shocked price with CPI is limited not to exceed wheat final product price. From chapter 2, wheat price is denoted in any year i as shown in equation (6):

$$P_{wheat\ i} = P_{rice\ i-1} \times \frac{CPI_i}{CPI_{i-1}} \times PC$$

Shocked price with CPI included yields shocked quantity in future years by putting values back into elasticity relationship again results in a new equation (39).

$$\varepsilon_i = \frac{\frac{Q_{shocked\ i} - Q_{member\ 2017}}{Q_{member\ 2017}}}{\frac{P_{riceadj\ i} - P_0}{P_0}} \tag{39}$$

Equation of elasticity application hence becomes equation (40):

$$Q_{shocked\ i} = \left(\varepsilon_i \times \frac{P_{riceadj\ i} - P_0}{P_0} \times Q_{member\ 2017}\right) + Q_{member\ 2017} \tag{40}$$

This shocked quantity is a quantity used to find revenue together with shocked price in each year from equation (3).

$$Revenue_i = P_{riceadj\ i} \times Q_{shocked\ i}$$

Cost on each year is calculated from variable and fixed cost in equation (8).

$$Cost_i = Variable\ Cost_i + Fixed\ Cost_i$$

These revenues and costs are then discounted at risk-free interest rate of 1.67% from average rate of three-month U.S. Treasury bill and then summed together to result total profit from recalling equation (2).

$$PV(Revenue_i - Cost_i) = \frac{Revenue_i - Cost_i}{(1+r)^i} + \frac{Revenue_{i+1} - Cost_{i+1}}{(1+r)^{i+1}} + \cdots + \frac{Revenue_n - Cost_n}{(1+r)^n}$$

Where r = 1.67%

Ultimately, profit gained from export agreement in countries is compared to profit before agreement occurs to analyze additional gain for members. Calculation of profit before agreement has almost identical steps to after agreement. Difference is that price and quantity of rice will grow based on consumer price index and forecast export growth. Additional gain for each member can be calculated using ratio compare with contribution in export quantity before and after agreement.

3.12.5 Model outlook

Model is formed with all components mentioned and written in excel. Time of model is chosen to be 13 years to stabilize variation of values and average them with fair estimation. The draft outlook of the model is shown in Table 9.

Table 9: Model design draft

Percent left from reduction	Adjusted Shocked Price with Global CPI	Quantity of member export by lagging	Global Total Discounted Revenue	Global Total Discounted Revenue
100%				
100%			Global Total Discounted Cost	Global Total Discounted Cost
100%				
100%			Global Total Discounted Profit	Global Total Discounted Profit
100%				
100%				**Additional Gain**
100%				
100%				
100%				
100%				
100%				
100%			With Export Reduction	Without Export Reduction
100%				

Solver is set to maximize profit of members to support the objective. Decision variable in each year changes within limit of constraints. Additional gain is amount of money gained more with export reduction among members agreement compared to without reduction.

3.13 Scenario analysis

Members in this study at the beginning are: India, Thailand, Vietnam, Pakistan, and USA with total net export of 82.78% of total rice in the world. This can be changed in scenario analysis. In the first scenario, India is removed. Second scenario, USA is removed. Third scenario, country that has net export less than USA, Burma, is included in membership. It is found that in the first scenario, membership percentage of world rice net export becomes 54.55%. The second scenario becomes 76.32%. The third scenario becomes 87.56%. This affects amount of Q_i in equation (9) recalled:

$$(x_i \times Q_{member2017}) + Q_{nonmember2017} = Q_i$$

Because $Q_{member2017}$ and $Q_{nonmember2017}$ depend on membership and non-membership export.

3.14 Sensitivity analysis

Worst case elasticity is -0.51 and best case elasticity is -0.13 from data in chapter 2. Base case slope in each year is -5.7569 which will have to multiply with deflated price and divide with quantity exported in each year to result in annual base case elasticity.

Chapter 4

Results and Analysis

4.1 Results of export remaining in each year

Results of export remaining in each year are from maximization of profit from solver. According to constraints and objective function, export reduction and remaining on each year is shown in a table by percentage remaining and quantity remaining. Each country result can be determined by same percentage that is used with global export agreement. An export reduction resulted from profit maximization model is seen to be applicable in view of exporters control, but not realistic in terms of moral and rice shortage around the world. With result shown to reduce export up to 33% in later years, there will be a major rice shortage occurred among global consumers.

Table 10: Results of movements given no export constraints binded

Percent left from reduction	Year	Adjusted Shocked Price with Global CPI	Quantity of global export fixed starting 2017 in million tons
100%	2017	398.58	44.40
81%	2018	914.86	36.59
75%	2019	929.38	34.37
73%	2020	948.44	33.42
71%	2021	969.40	32.83
70%	2022	991.86	32.49
69%	2023	1015.37	32.29
69%	2024	1039.66	32.16
68%	2025	1064.46	32.97
67%	2026	1089.30	32.00
67%	2027	1113.35	31.95
67%	2028	1136.10	31.96
66%	2029	1152.53	31.99

One of interesting input is to set a constraint for additional gain to be zero to visualize how much quantity reduction will allow equal profit compared to that of no reduction at all.

Table 11: Quantity reduction given equal gain if no reduction occurs

Percent left from reduction	Year	Adjusted Shocked Price with Global CPI	Quantity of global export fixed starting 2017 in million tons
100%	2017	398.58	44.40
95%	2018	505.96	42.62
93%	2019	516.85	41.87
92%	2020	525.30	41.47
91%	2021	533.05	41.20
91%	2022	539.91	41.03
90%	2023	545.41	40.93
90%	2024	549.23	40.89
89%	2025	549.94	40.91
89%	2026	545.20	41.04
90%	2027	531.18	41.43
90%	2028	503.28	41.75
92%	2029	443.28	42.55

Solver shows that quantity reduction ranges between about 5 to 11%. By plotting graph of additional gain or loss for Thailand, it shows that reduction that makes additional gain zero in all year is at about 9%, meaning export remaining is about 91%.

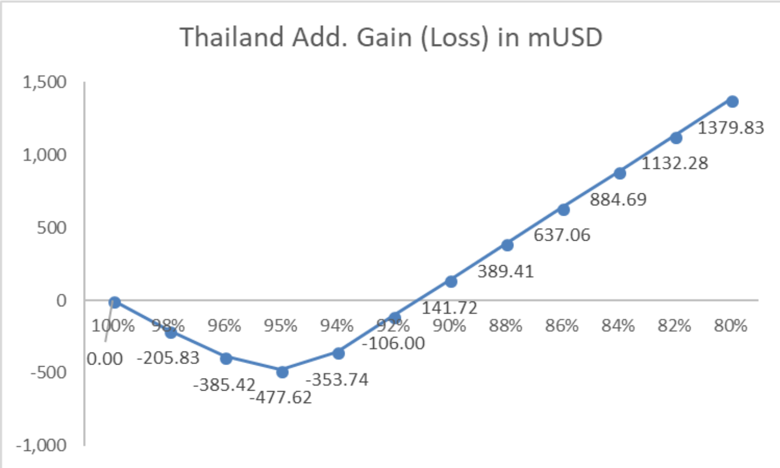


Figure 11: Additional gain (loss) for Thailand given percent of export reduction

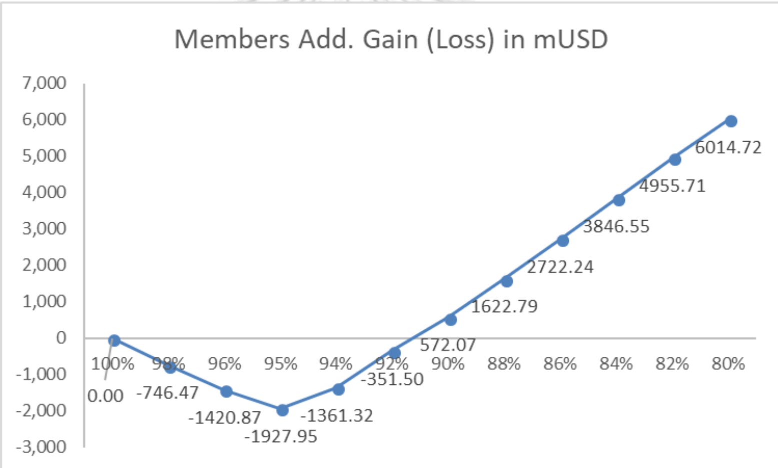


Figure 12: Additional gain (loss) for members given percent of export reduction

Figures imply that an additional loss to starts from zero when no reduction is applied. This is because value will equal to normal price mechanism when there is no reduction. Values under additional loss for Thailand does not tend to move linearly. Values under additional loss move more parabolic. After loss turns into gain, value moves more linearly. Except for non-members, they get a positive slope of gain.

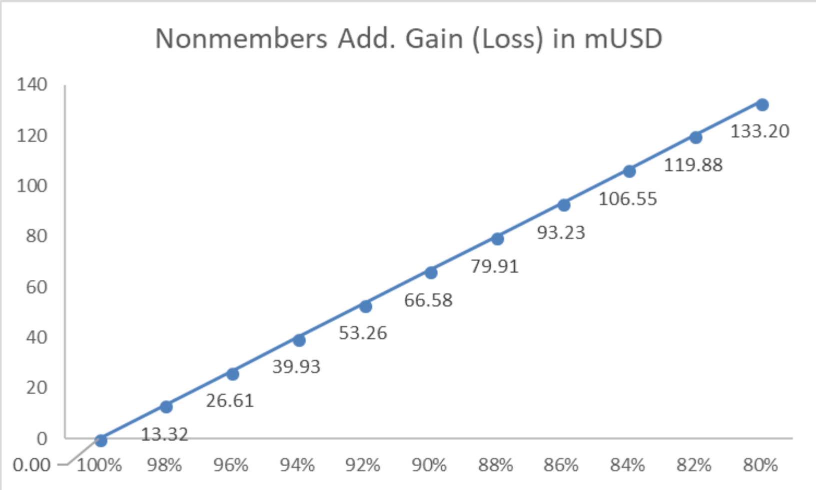


Figure 13: Additional gain for non-members given percent of export reduction

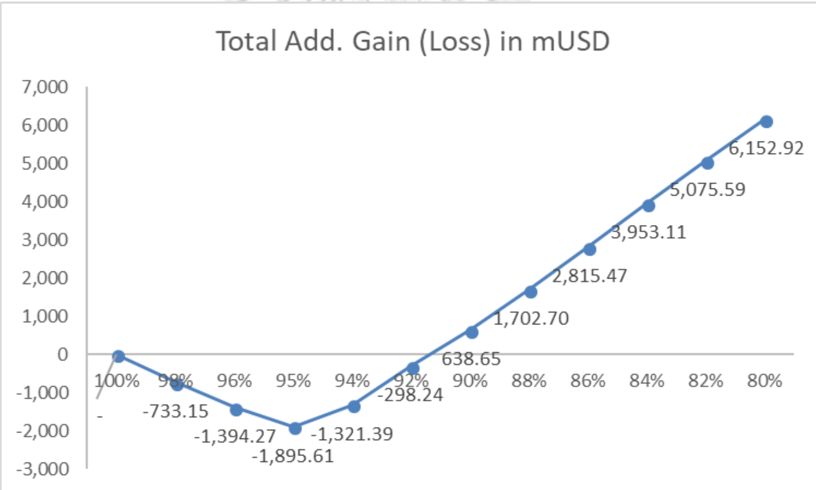


Figure 14: Total additional gain (loss) given percent of export reduction

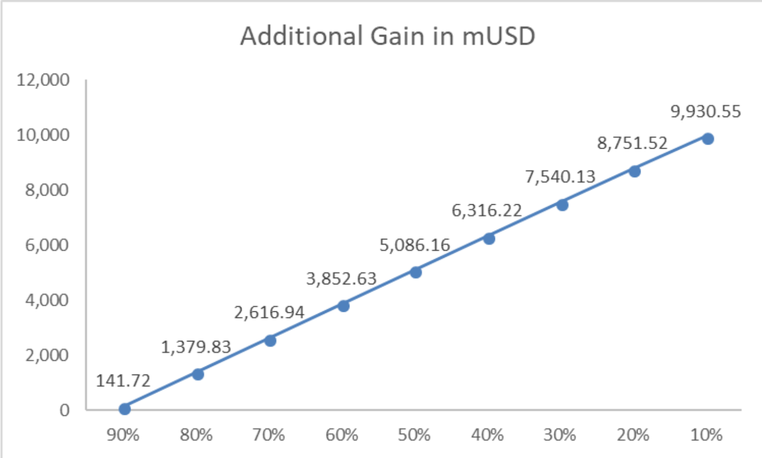


Figure 15: Additional gain for Thailand given percent of export reduction

This figure continues the previous figure where it shows that relationship of additional gain to percentage of export reduction tend to increase linearly. This is only a demonstration of results based on model. In reality, a reduction that leaves rice only 10% of total member export to gain more money is very difficult to be applied. These graphs are based on base cases on both sensitivity and scenario.

Table 12: Results of profit given 5% export reduction limit binded

Percent left from reduction	Year	Adjusted Shocked Price with Global CPI	Quantity of global export fixed starting 2017 in million tons
100%	2017	398.58	44.40
95%	2018	522.44	42.43
95%	2019	521.36	42.54
95%	2020	520.27	42.65
95%	2021	519.19	42.76
95%	2022	518.11	42.87
95%	2023	517.02	42.99
95%	2024	515.94	43.12
95%	2025	514.86	43.25
95%	2026	513.78	43.38
95%	2027	512.69	43.52
95%	2028	511.61	43.66
95%	2029	510.53	43.80

Result shows that Thailand obtains loss of 477.62 million USD compared to that without export. An export reduction of 5% may not affect overall rice consumers. However, when rice is reduced by 5% each year, profit drops dramatically. This reduction is proven later at 4.2 that it results in loss rather than additional gain. This means that a rice export reduction of 5% is not sufficient to create gain.

What can be seen by limiting reduction to 10% is that less global profit is obtained compared to maximum reduction at 33%. This is because elasticity has a great role to increase price when quantity is reduced. However, 10% is still considered huge amount of global rice export quantity loss in world rice trade. 10% is set to see a positive additional gain after passing breakeven at about 9%. Because 10% reduction of export is only applicable to members who will comply to agreement, it is seen from the table below that total quantity will increase by a bit in each year despite a fixed limit at 10% due to non-member constant export growth stated earlier.

Table 13: Results of profit given 10% export reduction limit binded

Percent left from reduction	Year	Adjusted Shocked Price with Global CPI	Quantity of global export fixed starting 2017 in million tons
100%	2017	398.58	44.40
90%	2018	644.48	40.36
90%	2019	553.99	40.47
90%	2020	545.94	40.58
90%	2021	537.51	40.69
90%	2022	537.03	40.81
90%	2023	536.24	40.93
90%	2024	535.10	41.05
90%	2025	533.59	41.18
90%	2026	531.66	41.31
90%	2027	529.29	41.45
90%	2028	526.44	41.59
90%	2029	523.07	41.74

Thailand gains profit of 1.9 billion USD from this strategy which is an increase of 141.72 million USD in additional gain.

If quantity of export is reduced at same 10% size over years, value of annual export for members would be 37.238 million tons. With gathered data of non-members export calculated by subtracting global export with member export in 2017, the value of export is 3.025 million tons. From statistical analysis, it is seen that export growth is likely to continue at 3.36% rate for non-members. When combine these values together annually, table below shows that total global export with effect from member export reduction would have the same value as table above. Note that unit in the table is in thousand metric tons.

Table 14: Members and non members export contribution to annual global export

	10% Exp Reduction	3.36% Exp Growth	
Year	Members Export	Non Members Export	Total global export
2017	37,238	3,025	40,263
2018	37,238	3,127	40,364
2019	37,238	3,232	40,469
2020	37,238	3,340	40,578
2021	37,238	3,453	40,690
2022	37,238	3,569	40,806
2023	37,238	3,689	40,926
2024	37,238	3,813	41,050
2025	37,238	3,941	41,178
2026	37,238	4,073	41,311
2027	37,238	4,210	41,448
2028	37,238	4,352	41,589
2029	37,238	4,498	41,735

4.2 Results of additional gain among members

Additional gain is defined as an increase in profit when export reduction agreement is executed compared to when assume that market will stay normal with assumed growth on price with CPI and quantity with export growth of 3.36% occur to both members and non-members. In the first case where export limit is not set to 10%, it is seen that differences between gain of with and without export reduction is enormous. Thailand gain is around 2 billion dollars. An increase in profit resulted from profit maximization model is seen to be a maximum benefit for exporters, but not realistic in terms of sustainability. With result shown to reduce export up to 33% in later years, there will be rice shortage occurred among global consumers and profit will plunge fast years after years given equilibrium is severely damaged.

Table 15: Additional gain for Thailand given no export constraint

Additional Gain for Thailand	million USD
No export constraint	2,693.07

When a constraint of 5% is applied, Thailand encounters a loss compared to when no reduction agreement is applied. With an export reduction limit set to 10%, it is seen that profit gained is reduced, but has more chance to be sustainable. Starting with analysis on changes in monetary gain in Thailand, it is seen that profit has increased by 141.72 million USD compared to that of without export reduction.

Table 16: Additional gain for Thailand given 5% and 10% export constraint

Additional Gain for Thailand	million USD
5% export constraint	- 477.62
10% export constriant	141.72

A sensitivity analysis is then performed with case of export reduction fixed at 10% and members export percentage share fixed at base case of 82.78%. First, worst case scenario which elasticity is at -0.51 is performed. Thailand would face a loss if reduce export at 10% when compared to no reduction agreement. This occurs from the elasticity that tends to be more elastic. It would require more reduction to breakeven profit from that of no reduction occurs. When elasticity becomes most inelastic, Thailand obtains a larger gain than base case if reduce export at 10% when compared to no reduction agreement. This occurs from the elasticity that tends to be less elastic. It would require less reduction to breakeven profit from that of no reduction occurs.

Table 17: Additional gain for Thailand in three cases of sensitivity analysis

Additional Gain for Thailand	million USD
Best Case	1,247.05
Base Case	141.72
Worst Case	- 390.02

Total rice quantity, which members altogether have, affects rice price. For example, members that contain 80% of total rice export quantity in the world can control rice price better than members that contain 50% of total export quantity. Tables below show differences between rice price and quantity movement when members percentage of global export rice possession changes.

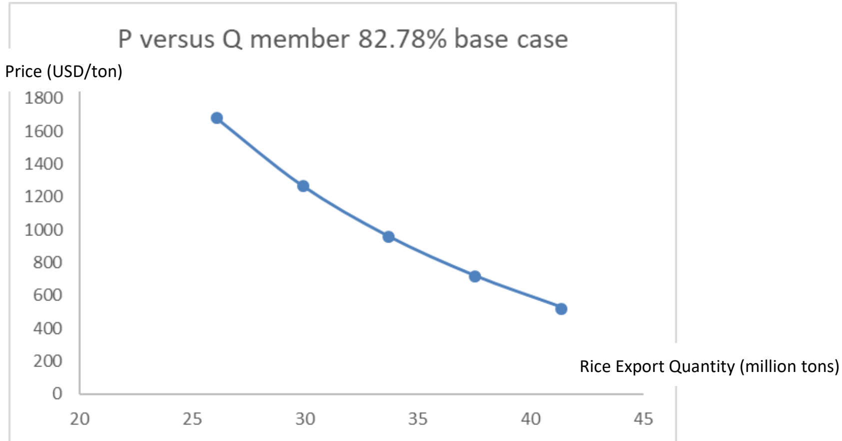


Figure 16: Rice price and quantity movement at base case scenario

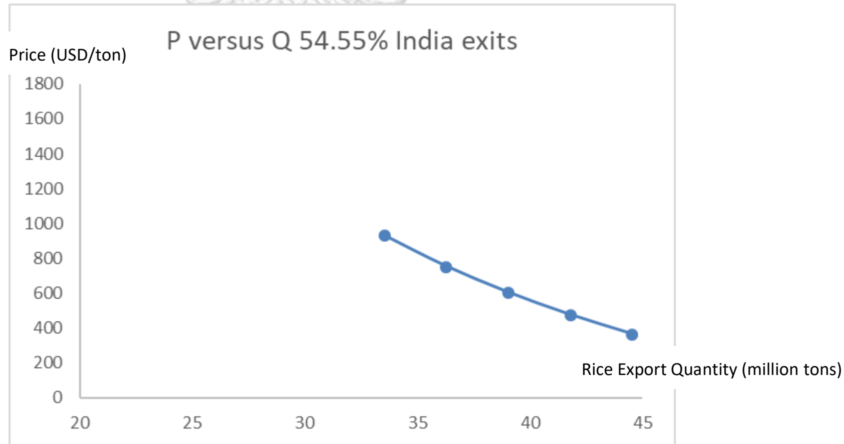


Figure 17: Rice price and quantity movement when India exits membership

From first figure, most of rice export is with members. When members agree to reduce export quantity, price can be raised significantly because members control 82.78% of overall rice quantity. A significant control in price is lost when total percentage of rice export that members control is reduced as seen in second figure. An x-axis shows global quantity which includes both member and non-member total rice possession summed together. It is also seen that quantity of global rice decreases much less in the second figure compared to the first figure as total rice quantity is affected less when member has less control in total rice quantity.

With effect of members rice control shown, a scenario analysis is performed with export reduction fixed at 10% and elasticity fixed at base case from slope of elasticity calculation on topic 3.4. From topic 3.13 there will be three additional scenarios simulated to see changes in additional gain for total exporters and Thailand.

Table 18: Additional gain for Thailand in three scenarios

Additional Gain for Thailand	million USD
First Scenario	- 1,149.37
Second Scenario	- 239.64
Third Scenario	253.73

With first scenario members dominance in rice export quantity of 54.55%, It is seen that Thailand as an example would face a big loss than base case if reduce export at 10% when compared to no reduction agreement. This is because the price and quantity that union can control is too little to affect global price significantly.

With second scenario members dominance in rice export quantity of 76.32%, it is seen that Thailand as an example would face a loss if reduce export at 10% when compared to no reduction agreement. This is because the price and quantity that union can control is too little to affect global price significantly.

With third scenario members dominance in rice export quantity of 87.56%, it is seen that Thailand as an example would face a larger gain than base case if reduce export at 10% when compared to no reduction agreement. This case which has export in control more than base case of 82.78% shows more profit because overall quantity of rice is more in control and therefore shifts price of rice more. From these observations, the more export quantity that members can control, the more global price of rice that can be controlled. The quantity shifted among three cases are different; especially in the first case where reducing export quantity could not control overall equilibrium export quantity or price.

It is noticeable that with only 10% of export reduction among member countries, global export is efficiently reduced from up to 66 million tons to 41 million tons by year 2029 while gain on that country even increases compared to when agreement is not done. This analysis continues with other countries that are members and includes non-members benefit from this action. The table below shows individual gain among countries that are members of the union along with total amount of non-members given base cases of scenario and sensitivity.

Table 19: Summary of additional gain or loss at 10% export reduction

	Profit in million of USD		
	With Export Reduction	Without Export Reduction	Additional Gain
India	$2,187.55	$1,985.92	$201.63
Thailand	$1,911.78	$1,770.06	$141.72
Vietnam	$1,139.09	$1,036.13	$102.96
Pakistan	$766.13	$690.76	$75.37
USA	$654.80	$604.41	$50.39
Members	$6,659.35	$6,087.28	$572.07
NonMembers	$588.21	$521.63	$66.58
		Percentage gain for members	**8.01%**
		Percentage gain for nonmembers	**12.60%**

The calculation is done by using export quantity contribution on each country as a percentage to total global export and use that percentage to multiply with average profit per year. Overall, it is seen that both members and non-members gain positive additional gain from the agreement with member rice export reduction of 10% where nonmembers get more additional gain percentage because they do not reduce quantity of export while they receive the same raised price from agreement among members. Non-members get more additional gain even when members obtain loss. This is shown in table below when export is reduced at 5%.

Table 20: Summary of additional gain or loss at 5% export reduction

	Profit in million of USD		
	With Export Reduction	Without Export Reduction	Additional Gain
India	$1,350.66	$1,985.92	-$635.26
Thailand	$1,292.44	$1,770.06	-$477.62
Vietnam	$696.55	$1,036.13	-$339.58
Pakistan	$430.60	$690.76	-$260.16
USA	$389.08	$604.41	-$215.33
Members	$4,159.33	$6,087.28	-$1,927.95
NonMembers	$553.97	$521.63	$32.34
		Percentage gain for members	**-26.98%**
		Percentage gain for nonmembers	**5.73%**

Stakeholders in this agreement include only producers-related side. Consumers in each country will experience the higher price of rice and will have to pay higher for each kilogram of rice they buy. However, unused land from rice can be used to produce other commodities which eventually creates a lower price for that commodity due to a higher supply.

4.3 Implementation of export reduction to Thailand

Discussion from 2.16 and results from 4.1 and 4.2 show an appropriate quantity from export reduction and additional gain that will be implemented to farmer households. Data from 2.16 shows that 2.67 tons per household is the value that farmers will gain from selling at original export. This implementation of export reduction in Thailand would base on both base cases fixed from scenario and sensitivity analysis. With 10% reduction, revenue gained by farmers will be from selling rice at 2.403 tons per household. This is as expected from 2.16 which stated that a reduction in export means farmers may obtain revenue more than by selling 2.67 tons per household to a miller because a price raise.

Statistics from a literature shows that lack of farmers in this country tends to increase. The study mentioned reason that young age labors tend to move from farmers to other occupations. This increases average age of labor throughout previous years. This could be a benefit to farmers because it means that households are also decreasing while export quota is reduced. Therefore, value of 2.403 tons per household is only an estimation from statistics given household is fixed. If applied with literature statistics trend, number of farmers are less and hence denominators decrease. The value may be more than 2.403. However, to reduce complications, this study ceases the result at 2.403 tons per household as effect from rice export reduction agreement at 10% annually.

Monetary value that farmers may gain when sell 2.403 tons of rice or 2.67 tons of rice at original quantity can be estimated with average price per tons of rice that is sold globally. An average price of 533.30 per ton of rice means farmers will receive 1,201.76 USD which in Thai is 36,241.67 THB at conversion rate used in this study of 30.16 THB per 1 USD. A revenue reduction from original export quantity selling at 2.67

tons is 2,405.36 THB per household. Note that this monetary value discussed is considered from rice that is affected by export reduction. Other parts that farmers produce for such as domestic consumption is assumed to be at the same value.

Table 21: Difference of export revenue gained per household for farmers

Average Undiscounted Price	Average Undiscounted Price no reduction
533.30	450.10
Farmers export per household no reduction	Difference of undiscounted revenue (THB/year)
2.67	2,405.36
Farmers export per household with reduction	Percentage of export revenue increased
2.40	6.64%
Undiscounted revenue no reduction (USD/year)	Undiscounted revenue no reduction (THB/year)
1,201.76	36,241.67
Undiscounted revenue with reduction (USD/year)	Undiscounted revenue with reduction (THB/year)
1,281.53	38,647.04

From table, revenue gained is 6.64% equal to export quantity reduced because consideration is only based on export by farmers. If consider revenue reduction with total production per household, this percentage would be different.

Table 22: Difference of total revenue gained per household for farmers

Average Undiscounted Price	Average Undiscounted Price no reduction
533.30	450.10
Farmers production per household no reduction	Difference of undiscounted revenue (THB/year)
4.27	6,420.71
Farmers production per household with reduction	Percentage of total revenue increased
4.00	11.08%
Undiscounted revenue no reduction (USD/year)	Undiscounted revenue no reduction (THB/year)
1,922.04	57,963.20
Undiscounted revenue with reduction (USD/year)	Undiscounted revenue with reduction (THB/year)
2,134.95	64,383.91

Total production used to calculate export per household is 15.8 million tons from topic 2.16. Farmer household is 3.7 million. Therefore, farmers total production per household is 4.27 tons. Revenue increase of 6,420.71 THB contributes in total revenue increase from 57,963.2 to 64,383.9 for 11.08%. This means revenue actually increases by 11.08% for scope of total rice for farmer households.

However, the stated farmer household of 3.7 million households contains households that incur high costs in rice production. (Saiseenews, 2016) Therefore, another interesting calculation is to calculate with the number of low cost farmer households. From data calculation, there are about 31.41% of total households that can produce rice in a limited area which results in a higher cost than those who can produce rice in large area. If this group of farmers are taken out from household revenue calculation, there will be 2.54 million households left. And dividing 2.54 with numbers from topic 2.16 with same methodology results in values of export and production per household. Tables below show alternative monetary value gained by this calculation.

Table 23: Difference of export revenue gained per efficient household for farmers

Average Undiscounted Price	Average Undiscounted Price no reduction
533.30	450.10
Efficient Farmers export per household no reduction	Difference of undiscounted revenue (THB/year)
3.89	3,503.68
Efficient Farmers export per household w reduction	Percentage of export revenue increased
3.50	6.64%
Undiscounted revenue no reduction (USD/year)	Undiscounted revenue no reduction (THB/year)
1,750.50	52,789.99
Undiscounted revenue with reduction (USD/year)	Undiscounted revenue with reduction (THB/year)
1,866.68	56,293.67

Table 24: Difference of total revenue gained per efficient household for farmers

Average Undiscounted Price	Average Undiscounted Price no reduction
533.30	450.10
E. Farmers production per household no reduction	Difference of undiscounted revenue (THB/year)
6.23	9,366.70
E. Farmers production per household with reduction	Percentage of total revenue increased
5.84	11.08%
Undiscounted revenue no reduction (USD/year)	Undiscounted revenue no reduction (THB/year)
2,802.22	84,506.78
Undiscounted revenue with reduction (USD/year)	Undiscounted revenue with reduction (THB/year)
3,112.82	93,873.48

It is seen from two different cases by different number of households that monetary value gained per each household depends on perspective of calculation on number of households. Revenue per household is larger when consider with assumption of efficient farmers applied.

This calculation that removes aged farmers may reflect future reduced farmer households that obtain more revenue to serve domestic consumption and export because there are less total revenue sharers. This is based on assumption that farmers have sufficient land to produce rice at designated capacity.

4.4 Export quota implementation and limitation

It is seen from 4.1 that if quantity of export reduction agreement is limited to 10%, Thailand will have export quantity of 9.225 million metric tons. An implementation that will regulate quota up to this export quantity is a construction of contract system in secondary market such as AFET or currently TFEX. Pricing in secondary market is fair because it has bid-ask system that can match buyers with sellers. Education on secondary market usage is needed to let farmers compete fairly. Because export limit is 9.225 million metric tons, an export contract of 1 kg per contract in total of 9.225 billion units (1 ton = 1,000 kgs) are then placed in TFEX and let farmers bid and ask with their satisfied price. Nevertheless, there will be difficulties in implementing quota ticket to export rice at the beginning such as construction of the system and introduction of tickets to be known widespread. Also, costs of system construction and introduction to farmers to learn the system may be high.

4.5 Potential rice reduction effect to consumers among countries

An example of additional gain from reduction and revenue effect to farmers are shown. However, there is still another significant effect to be considered which is consequences to consumers. Consumers in countries with poverty would have less financial strength to purchase rice and hence has possibility to eventually cannot consume sufficient rice. A 10% reduction from members means about 2 million tons of rice is out from the rice system. There are two possible implementations. First one is to status quo which is not to reduce rice export. Countries get normal profit while there is no risk in famine increased. This choice is considered based on moral where additional gain may result in effect on rice consumers. Second one is to reduce export more than about 9% at least to get an additional gain. Indonesia once encountered rice shortage and decided to encourage consumers to refrain from consuming rice every Tuesday. Another suggestion from government is to eat substitute such as products from tapioca. (ประชาชาติธุรกิจ, 2012) If countries that are affected from export reduction can manage consumer strategy to handle the circumstance like this, export reduction is possible to be done without harming consumers significantly.

4.6 Limitations of the model

From discussions among rice reduction, additional gain, effect on farmers, and implementations, there are some limitations that have to be discussed. Overall, these limitations would make this model completely feasible only in theory. In practice, model results may diverge to some degree. First, it is difficult for members to group together like in the model. Although this study assumes that members will not cheat, as result is shown in table that nonmembers would always get additional gain more than members, it is tempting that members would eventually leave. A strong bond and trust between members are significantly required. Members may implement a monetary penalty if members leave without a proper reason. For example, a monetary fine for leaving is pre-calculated based on export ratio that each country has in control and notified to all members. Next, recalled from a risk-free rate in chapter 2 that this rate at 1.67% makes additional gain tend to bias towards the higher value. When this value changes, gain will decrease. Next, rice supplies in each country depends on climate and environment. However, these uncertainties have been incorporated in through historical data which contains uncertainty data such as food crisis in 2008. These uncertainties are shown as a result of error between export or import prediction versus actual value in the future. Next, in reality there would be someone who tries to grow rice and make money themselves when export reduction occurs. There are also some other factors than stated factors which affects import or export.

Chapter 5

Conclusions and Recommendations

5.1 Feasibility of export reduction and revenue effect among members

Discussions from chapter 4 shows that export reduction agreement may not affect rice consumers when export quantity among members is reduced at appropriate amount and subjected to limitations of model. Note that results would alter if situations are different from given scenario or sensitivity as seen in the discussion of results. However, a small reduction would instead result in decrease of gain. A reduction should be more than 9% to obtain an additional gain which may affect consumption in countries with poverty. This study shows gain from export reduction which will result in huge reduction. Therefore, a weighting between benefit in country gain and consumers must be carefully decided. No reduction and let rice go by normal system is also possible. In other words, results depend on scenario and this gives benefit to both producers and consumers. Producers gain additional revenue from raised price of rice and utilize free land from rice production to produce other commodities. Consumers may encounter a little more expensive rice price but may benefit from opportunity to consume other commodities offered by producers on unused land. This gives benefit to both producers and consumers as stated in discussion 4.2. An optimal point of production is not to produce as many as possible, but to produce on a quantity that benefits everyone. In other words, reduction of export that results in an increase in price makes both members and nonmembers gain additional profit, but amount of reduction should make the agreement sustainable which means it should not affect consumer behavior significantly.

5.2 Recommendations for further studies

This model is applicable to other commodities and other scopes. For example, wheat at regional scope. Each commodity has unique characteristic such as elasticity. In further time, CPI and export projections will turn to historical number over years rather than projections. It is recommended to update CPI, export projections, and any forecast numbers chronologically to reflect the most accurate value gained during that time.

APPENDIX

Exhibit 1: Result of demand curve using backward elimination

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Welcome to Minitab, press F1 for help.

Stepwise Regression: Import versus WP / 1M, World Rice Production, ...

Backward elimination. Alpha-to-Remove: 0.05

Response is Import on 9 predictors, with N = 20

Step	1	2	3	4	5
Constant-	-7648.9	-7358.9	-7022.5	-6732.4	-6543.2
WP / 1M	3.2441	2.9821	2.7646	2.3455	1.5763
P-Value	0.361	0.254	0.182	0.096	0.035
Ending Stocks	-0.137	-0.102	-0.111	-0.104	-0.112
P-Value	0.561	0.244	0.152	0.073	0.025
Export	0.41	0.52	0.70	0.94	1.12
P-Value	0.006	0.001	0.000	0.000	0.000
POC	-2.53	-3.07	-3.78	-4.29	-4.68
P-Value	0.410	0.332	0.241	0.151	0.048
x	-48.85	-56.73	-69.34	-75.62	-81.20
P-Value	0.231	0.210	0.098	0.072	0.041
R-Sq(adj)	76.15	76.50	76.77	76.88	76.88

Exhibit 2: Result of supply curve using backward elimination

Stepwise Regression: Export versus WP / 1M, World Rice Production, ...

```
Backward elimination.  Alpha-to-Remove: 0.05


Response is Export on 9 predictors, with N = 20


Step                        1       2       3       4       5       6
Constant               374.09  300.91  215.52  145.09   64.72   13.12

World Rice Production   0.014   0.018   0.032   0.054   0.065   0.078
P-Value                 0.285   0.247   0.188   0.133   0.077   0.039

Import                   0.71    0.69    0.74    0.75    0.69    0.78
P-Value                 0.006   0.002   0.002   0.000   0.000   0.000

POC                      0.76    0.85    0.77    0.83    0.79    0.81
P-Value                 0.151   0.072   0.068   0.046   0.026   0.022

R-Sq(adj)               77.49   77.71   77.85   77.78   77.71   77.77


Step                        7
Constant               -35.08

World Rice Production   0.089
P-Value                 0.023

Import                   0.72
P-Value                 0.000

POC                      0.80
P-Value                 0.019
```


Exhibit 3: Linear trendline of the predictor export

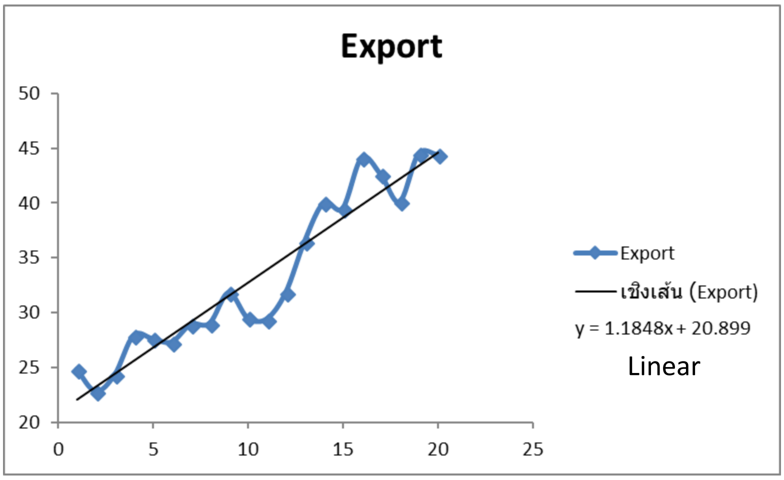
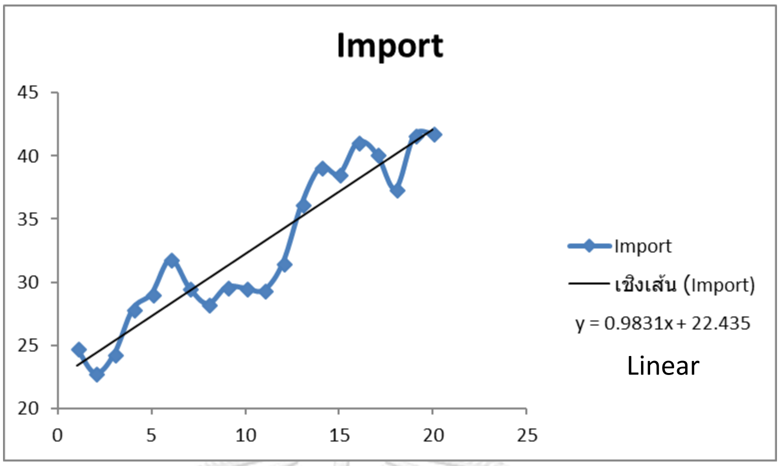


Exhibit 4: Linear trendline of the predictor import



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