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Abstract

Rice is a key agricultural product of Thailand and plays a vital role in the Thai economy. Rice production, however, is dependent upon environmental factors. Environmental uncertainty therefore, can impact rice crop areas in term of influencing the rice yield, rice production and generating ripple effects along the overall rice supply chain. The aim of this research is to investigate the effects of uncertain rice supply caused by drought years on the rice supply chain performance in Thailand. Three stochastic simulation models in different assumptions of rough rice production situations were developed which were based on historical data of normal and drought years in northeast Thailand. The results from using iThink software indicate that periodic enormous rice production loss because of a drought year create significant problems such as fluctuating inventory levels, stock-outs and unfilled customer demand compared to rice production loss under monsoon drought probability and mean rice production.

Keywords

Impact, Uncertain, Environment, Rice, Supply, Chain, Performance, Northeast, Thailand

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The Impact of Uncertain Environment on Rice Supply Chain Performance in Northeast Thailand

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Abstract – Rice is a key agricultural product of Thailand and plays a vital role in the Thai economy. Rice production, however, is dependent upon environmental factors. Environmental uncertainty therefore, can impact rice crop areas in term of influencing the rice yield, rice production and generating ripple effects along the overall rice supply chain. The aim of this research is to investigate the effects of uncertain rice supply caused by drought years on the rice supply chain performance in Thailand. Three stochastic simulation models in different assumptions of rough rice production situations were developed which were based on historical data of normal and drought years in northeast Thailand. The results from using iThink software indicate that periodic enormous rice production loss because of a drought year create significant problems such as fluctuating inventory levels, stock-outs and unfilled customer demand compared to rice production loss under monsoon drought probability and mean rice production.

Keywords – Rice supply chain, Uncertain Environment, Supply Chain Performance

I. INTRODUCTION

In managing their supply chains, many organisations face supply/demand difficulties and are tested in their ability due to environmental fluctuations such as rapid change in economies, markets, resource availability, products and technology [1]. In many categories agricultural crop, Rice is the most important agricultural crop in Thailand for the reason that rice farms make up over 50 percent of farm land use in Thailand [2]. Farmers who grow rice are suppliers to rice supply chain. Some rough rice is purchased from farmers by dealers immediately after harvesting paddy, and some rough rice is stored in farmers' storage facilities and transported to rice millers later. Rough rice is milled to finished bulk rice a component of which is packed after milling. Finished bulk rice is delivered from local rice mills to brokers in provincial area who undertake packaging also. Finished bulk rice is also delivered to inventories in Bangkok. Some of which is packaged before sale. In domestic trade, rice in small packages is purchased to customers through retailers. In international trade, rice is consigned to international traders at harbours [3].

Rice production relies on four main variables i.e. agro meteorology, maximum and minimum air temperature, total solar radiation or CO₂, and total rainfall [4]. Approximately 80% of crop productivity relies on weather conditions [5]. In rice production, therefore, rainfall is the climate determinant for rice crop period and

stability of crop yield [6] because, for instance, approximately 77% of total rice production was cropped in wet season (from May to September) which was applied on 86% of the annual rice area [7]. There are evidences that in Thailand drought or/and flood could damage cultivated rice area considerably. For example, for over last 30 years, Bangkok, Hat Yai and Chiangmai which the large cities of Thailand have experienced several floods related disasters that have affected a large number of people, farmers and productivity of agriculture residing in flood areas caused by too much rainfall and lack of water resource management. On the other hand, theoretically climate change might be beneficial such increased temperatures and carbon dioxide to growth of certain plants, and could has negative impact on agriculture such as rainfall characteristic change, warmer temperature affecting fishing industry [4] [6]. By the year 2100, several international climate models predict that there will be an increase in incidences of floods (3-6 times in a period of 100 years as opposed to 1 in 100 years previously seen) [8]. Since water resources, flooding and drought on Thailand and Laos are predicted that will face the effects of climate change, the rice yield might drop by 20 percent in 2040 in many provinces such as Thung Kula field, Chiang Rai, Sakon Na Khon, Sa Kaew and Khon Kaew in Thailand [9]. For that reason, rice supply chain performance can be impacted by uncertain rice supply and by interrupted rice flow among echelons in rice supply chain.

The objective of this study is to investigate the effect of uncertain rice supply because of drought year on rice supply chain performance in Thailand by comparing the results of a model that is assumed no drought year happening with other two models that are assumed that the amount of rough rice supply relates to probability of drought years and percentage of production loss in the drought years. According to available information, estimated rice production loss in northeast Thailand mainly caused by drought is the input data and a major factor that affect on uncertain rice supply to a rice exporter. Three stochastic simulation models were developed and used to analyse supply chain response measured by the number of unfilled customer orders and inventory fluctuations of a rice exporter company and a miller that is principally supplied rough rice from farmers in northeast Thailand.

II. METHODOLOGY

This research applies dynamics simulation modelling to study the effects of rice production's disruption. One simulation model was developed in continuous time for 3-echelon supply chain (farmers, millers, exporters) using iThink software. The three models are modified from a study of [10] to establish inventory parameters together with slightly increasing demand and production. The models were run for 50 rice production cycles with uncertain rice supply based on historical data from 1970 - 2002 in drought and normal years in northeast Thailand.

Model Structure

The rice supply chain model considered in this study consists of 3 sectors, which are farmers as suppliers, millers, exporters and shipping to customers. The primary focus is the transmission of uncertainty through this supply chain along with inventory fluctuation, average inventory level and unfilled customer orders. Fig 1 shows rice flow and information flow among each partner in the supply chain.

Fig. 1. Rice and information flow

Fig. 2 shows how customer demand, orders placed and rice shipped through supply chain partners using causal loop diagram. Customer demand which is order placed with exporters decreases exporter packed rice inventory level that its decrease will increase total packed rice inventory gap (target inventory level minus exporter packed rice inventory level). Subsequently, exporter order backlog will transport the packed rice from exporter inventory to customers according to their demands. Production processes are ordered by this packed rice inventory gap to clean, polish, quality checking e.g. colour and length, and packing that rice from these processes increases exporter packed rice inventory level, but reduces exporter rice inventory level. As this inventory level decreases, total exporter rice inventory gap (target inventory level minus exporter rice inventory level) increases that add demand to miller. The order placed with miller reduces miller rice inventory level that increase total miller rice inventory gap which then is orders placed with mill process. According to orders placed with mill process, miller order backlog ships rice to exporter after finishing mill process which pull rough rice from miller rough rice inventory. As this inventory level decreases, total miller rough rice inventory gap increases (target inventory level minus miller rough rice inventory level). However, there is no relationship between total miller rough rice inventory gap and rough rice from farmers since the largest quantity of rice is

purchased soon after harvest in December [7]. Rough rice inventory of miller, therefore, is assumed no storage capacity.

Model assumption

Many assumptions are set regarding constant variables and random variables affecting on the rice supply chain that are customer demand and the quantity of rice from farmers shown in Table 1.

+ : two variables move in the same direction
- : two variables move in opposite direction

Fig. 2. Causal loop diagram of rice supply chain

As Customer demand in global trade depends on many factors; world population or eating behaviours, its demand trend have slightly increased by approximately 3% (historic data from 1961 to 2003). On the other hand, rice consumption has been declined by 4% in 2010 because of diet in many areas such as Japan, Taiwan and China [11]. The Arkansas Global Rice Model (AGRM) used in the FAPRI baseline is the global rice quantitative model based on a multi-country econometric framework consisting of a supply sector, a demand sector, and a set of trade and price linkage equations. The model is dynamic that its structure reflects to supply, demand, export (or import), stocks, and price transmission equations of 31 countries around the world [12]. Under the AGRM, The percentage of annual rice production change related to Thai rice supply and utilisation, and rice consumption change related to world rice consumption from year 1997 to 2018 [13] are fitted to be probability distributions estimated as in these formulas.

The percentage of annual rice consumption change is normal distribution (1.04, 1.41) (1)

The percentage of annual rice production change is normal distribution (1.54, 2.14) (2)

The percentage of annual rice consumption change is estimated to gradually increase because of population growth even though average per capita consumption would decline. Meanwhile, the percentage of annual rice production change is predicted to steadily rise due to yield improvement and rice area expansion [13].

Uncertain rice supply from farmers is shown in probability of production loss in drought year in a research of [7] as shown in Table 1.

Table 1. Estimation of rice production losses, northeast Thailand 1970 – 2002 [7]

Province	Mean Output (000 t)	Production loss in Drought year		Monsoon drought probability
		Quantity (000 t)	Percent (%)	
Zone I				
Kalasin	330	41	12	0.04
Nakhon Phanom	270	22	8	0.12
Nong Khai	240	27	11	0.12
Sakon Nakhon	350	44	12	0.09
Sisaket	480	90	19	0.04
Ubon Ratchathani	720	205	29	0.06
Zone II				
Khon Kaen	450	129	29	0.15
Loei	130	26	20	0.09
Maha Sarakham	360	64	18	0.06
Udon Thani	630	107	17	0.15
Zone III				
Chaiyaphum	310	170	55	0.15
Total	4,270	925	21.66	-

The largest quantity of rice is purchased soon from farmer to miller after harvest in December of each year. Moreover, shipping lead-time is ignored as well as mill process and clean/packing processes produce expended 10% of order placed with these processes. Target inventory level depends on storage capacity. Order placed with mill process and clean/packing process is based on this formula

Order quantity placed with Process equal to MAXIMUM [Order Placed Process minus Inventory Level, Target Inventory Level minus Inventory Level] (3)

There are specific parameters used in this model as shown Table 2.

Table 2. Parameter setting for the model with drought or normal year

	Miller		Exporter	
	Rough rice	Rice	Rice	Packed rice
Initial Inventory	132.45	132.45	132.45	132.45 (000 t)
Target Inventory Level	-	-	5,000	5,000 (000 t)
Order placed with exporter in first year	4,270 (000 t)			
Order placed with exporter in each year	Order placed with exporter in previous year + The percentage of annual rice consumption change (Formula 1)			
Rough rice production from farmer in first year	Mean output of each province (Table 1)			
Rough rice production from farmer in each year	[Rough rice production from farmer in previous year + The percentage of annual rice production change (formula 2)] * Percent of production loss in drought year			

According to estimated average beginning stock from 1997 to 2018 in Thai rice supply and utilization in a report of [13] presenting approximately 12.4 percent of total rice production each year, Initial Inventory is set to be 12.4 percent of mean rice production in Northeast Thailand. Therefore, initial inventory equal to 529.81 calculated from 0.124 multiplied by 4,270. As four inventories in this rice supply chain, each initial inventory assumed that is equal at the beginning of simulation is 132.45 (000 t). In addition, transportation and manufacturing capacity are unconstrained in order that the results are not confounded by these capacities.

In accordance with above assumptions, three models are different in assumptions of rough rice production presented in this study. Model 1 presented that rough rice production from farmers relies on mean output in Table 1 and increase each year as shown in (2). Model 2 presented the amount of rough rice supply relates to probability of drought years and percentage of production loss in drought years referred to Table 1. Finally, model 3 presented that rice supply chain is reduced dramatically by assumptions that all provinces will face drought at the

same year in every 5 years (year 5, 10, 15, 20, 25, 30, 35 and 40) which lead to 21.66% production loss of total output in that year.

III. RESULTS

The simulations are run for 50 years. The focus is on the following measures of supply chain performance that are inventory level of each sector, and unfilled customer orders by comparing among Model 1, Model 2 and Model 3 as given in Fig. 3, 4, 5, 6 and 7.

Fig.3. Exporter Packed Rice Inventory

Fig. 3 shows that packed rice inventory will stock out from year 2 until year 8, 18 and 23 of Model 1, 2 and 3 respectively. Then, this number considerably grows up within about next 5-7 years. At the same time, rice inventory of miller will have stocked out from year 2 until year 13, 22 and 34 of Model 1, 2 and 3 respectively as shown in Fig. 4. Then, this number considerably grows up within about next 3-4 years.

Fig.4. Miller Rice Inventory

Fig.5 Miller Rough Rice Inventory

Fig. 5 presents that farmers in Model 1 can crop rice more than Model 2 and 3 leading to rough rice inventory of miller dramatically increase from year 15, 24 and 33 to the end of simulation time respectively. Consequently, in Fig. 6, the customer order will have been filled completely since year 12, 21 and 33 of Model 1, 2 and 3 respectively.

Fig.6 Unfilled customer order

Fig 7 presents that rough rice output from farmers is different in 3 models. In Model 1, there is slightly increase trend because it does not rely on uncertain production loss in drought compared with Model 2 and 3 that its output is dropped but still grow up in each year.

Fig. 7. The amount of rough rice output form farmers

IV. DISCUSSION

According to the above results, packed rice inventory levels of the 3 models as given in Fig. 1 remain stocked out over the some periods of time because customer demand is more than rough rice output. Nevertheless, after year 8, 18 and 23 of Model 1, 2 and 3 respectively, packed rice inventory levels dramatically increase for the reason that rough rice output is changed to be rather than rice consumption or customer demand. As Model 3 has fluctuating rice production, this is no packed rice, milled rice and rough rice in these inventories longer than Model 1 and 2 as shown in Fig 3, 4 and 5. The rice inventory level of miller in Model 3 is varied after year 32. It might be because customer demand decrease coupled with drought year happening. After year 12, 21 and 33 of Model 1, 2 and 3 respectively, rough rice inventory of

millers is dramatically increased, since rough rice outputs are rather than customer demand. Without rice production loss caused by drought years, rice production in Model 1 can be changed from that rough rice inventory of millers is less than customer demand to be more than customer demand within short time, whilst Model 2 and 3 are estimated to lose some rice production because of uncertain environment that needs longer time to have rice in each inventory.

By inspection, it can be seen from Fig. 4. that after nearly year 12, 21 and 33, the exporter can meet all customer order as shown that unfilled customer order is null in Model 1, 2 and 3 respectively. Meanwhile, in Model 2, the unfilled customer order is varied between 200 and 500 (000 t) during year 10 – 25. On the other hand, this number of Model 3 is higher than Model 1 and 2 that vaguely fluctuate between 500 – 1000 (000 t) from year 10 to 30.

V. CONCLUSION

These simulation models allow specification of many characteristic and constraints that rely on reliable input information. To maintain the scope of this study within bounds, many factors were not considered. The results of 3 Models show that in Model 3 enormous rice production loss because of drought year creates the most problems which are fluctuated inventory levels, stock out inventory and unfilled customer demand compared to Model 2 and 1. Meanwhile, Model 2 also creates problems of supply chain performance that the drought years lead to stock out inventory and unfilled customer order as well. These findings indicate that as rice production is estimated to be higher than rice consumptions in the future, it can reduce the impact of rough rice production loss in drought year on rice supply chain performance in Northeast Thailand. Therefore, these uncertain environments clearly less affect on supply chain performance when using information from [13]. However, if farmers can not increase rice yield and production according to the study of [13], the uncertain environments such as drought and flood can create supply shock resulted to raise rice price and drop agricultural GDP of Thailand [7].

The main limitations of this paper are the lack of information on wet years affecting on rice supply, and the probability of wet to dry climatic conditions in this study. Study of the latter is proposed for future research.

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