# The Influence of Price Transmission on Thai Hom Mali Rice Supply Chain

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*Abstract*—The study aims to define the relationship between prices of each player along the HM rice chain in Thailand. The study takes into consideration the time frame and other factors in the international environment that may influence or explain price volatility. Two statistical techniques, i.e., correlation coefficient and multiple regression analysis were applied in the study. Results showed that prices at each link in the Hom Mali Rice (HR) supply chain have strong positive linear relationship. The Brent oil price and the world reference price index were the only two external factors that presented significant impact over HR domestic price. The study outcomes explain the influence factors toward domestic HR price which set criteria for developing forecasting model in further study.

*Index Terms*— Thai Hom Mali rice, aromatic rice, price, influencing factors, supply chain

## I. INTRODUCTION

RICE is one of the significant socio-economic crops in Thailand that has generated income for small farmers for decades. In 2014, the area cultivated to rice in Thailand accounted for 62 percent of the total country's agricultural area [1]. Rice also brings more economical outcome for the country as it ranks first among the major food crop exported by Thailand [2]. Furthermore, that Thailand has ranked as one of the first top three major rice exporting countries in the world for many years [3] affirms that Thai rice plays a crucial role in the world food security and is a main influence in the price of rice in the world market [4]. Although Thailand rice export statistics from 2005-2014 showed a downward trend in export volume of both white rice 100 percent (WR) and Hom Mali rice (HR) for the past ten years, the export value of HR showed the opposing trend [11]. In the global rice market, data obtained from FAO [3] presented the upward trend of price of aromatic type such as Pak Basmati and Thai Fragrant as well as affirmed the market opportunity for these kinds of specialty rice in the premium market segment. In contrast, the price of other types of coarse rice such as Thai WR 100 percent, Viet, or Pak rice showed a gradual downward trend. For these reasons, HR was selected to be the major crop for this study.

However, as HR is a long duration rice variety (around 6 months), farmers have to plan and prepare for their production based on market conditions the year before. As common agricultural crop and due to the rice crop-ping season, most production is harvested at the same period which is around the end of every year. Harvesting at the same period causes a seasonal price drop situation. As farmers in general do not have good storage ware-house and good post-harvest technologies [5] and limited financial resources, most of them sell their crop at the earliest after harvesting [6]. Farmers fall into the classic newsvendor problem when there is an uncertain demand and supply at the time of sowing but limited time window for harvesting and selling [7].

Generally rice is perceived as a soft commodity although HR is categorized as specialty rice that has more gap margin. However, its price is also dictated by buyers as the world treats other commodities in the general commodity market. The ADB study [8] stated that the domestic rice prices in Thailand have been greatly influenced by world market trends. The ADB paper aroused curiosity to undertake a study on 1) the influence of the price set by other players' up in the link on members in both forward and backward especially in case of the HR sup-ply chain; and 2) the high fluctuation of price pattern at each stage in the supply chain such as paddy rice price (PR) (farm gate level price), domestic polished (DP) rice price (at rice millers/wholesalers level), and FOB price (at exporters level). Data obtained from the DIT [9] for PR and DP price showed the same pattern of high variation while FOB price (data obtained from the Thai Rice Exporters Association) [10] was more stable. As a result, this market situation instigates a challenge for stakeholders involved in the price scheme. This includes players in the supply chain who consider the price trend for production and market planning and the government who initiates rice subsidy policies at national level through monopoly price setting. An inappropriate price forecast can cause severe impact in the country's economy especially when it involves national level policy.

However, results from literature review indicated that there is a gap and the need to study the relationship among chain members' prices particularly in the HR supply chain. Therefore this study aims to observe HR price behavior from different perspectives: (1) as an influence of buyer' price toward the seller' price which is encouraged by a general commodity market scenario where price belongs to buyer; and (2) the traditional cost-plus scenario where the seller has the power to set the selling price. Finding relationships between each players' price along the Thai HR supply chain and an identification of those significant levels will be useful for further development of a forecasting

model based on price transmission effects among the chain members. Under the circumstance based on real market situation, the relationship model provided by this study could generate more accuracy in price forecasting model without or lessen the distortion of market mechanisms.

The remainder of this paper is structured as follows. Firstly, a review of literature related to factors influencing rice price at each supply chain level is summarized. Secondly, the scope of study and methodology to define and explain relationship among members' price is proposed. Thirdly, the numerical result is exhibited, followed by an analysis and discussions of findings. Finally, conclusion and suggestion for further study is presented.

## II. THAI HOM MALI RICE SUPPLY CHAIN STRUCTURE

The conventional Thai rice supply chain is comprised of many members engaged in different activities. Small farmers are the main producer in the chain who sells paddy rice to distributors such as paddy rice merchants, farmer institutions or agricultural cooperatives, and government institutions (as defined by the government pol-icy). The paddy rice is then entered into the processing line through rice millers. The output from the processing line is polished rice which is sold to end users through a variety of marketing channels such as exporters (inter-national market), wholesalers and retailers (domestic market) [12]. The KNIT [13] survey of HR marketing channels for crop year 2010/2011 in NE Thailand showed that most farmers (i.e., about 63.64 percent) sold their paddy rice to

agricultural cooperatives. Another 32.81 percent went to rice millers. However, at the milling process, most of paddy rice gathered by cooperatives and paddy rice distributors was sold to rice millers which made them the crucial player in this process. At the end, around 90.12 percent of paddy rice was held by rice millers. After the milling process, polished rice was sold to many marketing channels both in bulk (wholesaling) and branded packaging (wholesaling and retailing). Finally 84.10 percent of polished rice was consumed by the domestic market while the other 15.9 percent was exported to other countries. Sahavacharin [14] studied specif-ically in the HR supply chain of six major agricultural cooperatives in the NE Thailand. The study showed that major cooperatives not only gathered paddy rice from farmers but they also processed paddy rice to polished rice then sold their finished products (packed polished rice) in both owned-brand and OEM through a broad range of marketing channels such as other retail cooperatives, direct selling companies, retailers and the modern trade channel. Based on this literature review, the structure of the HR supply chain in the NE Thailand can be formulated as shown in Fig.1.

In conclusion, there are three major players in the chain including farmers, rice millers, wholesalers for domestic market, and exporters for international market who are included in this study that focuses on the price of products at these specific links in the chain denoted by $P_1$, $P_2$, and $P_3$, respectively (Fig.2).
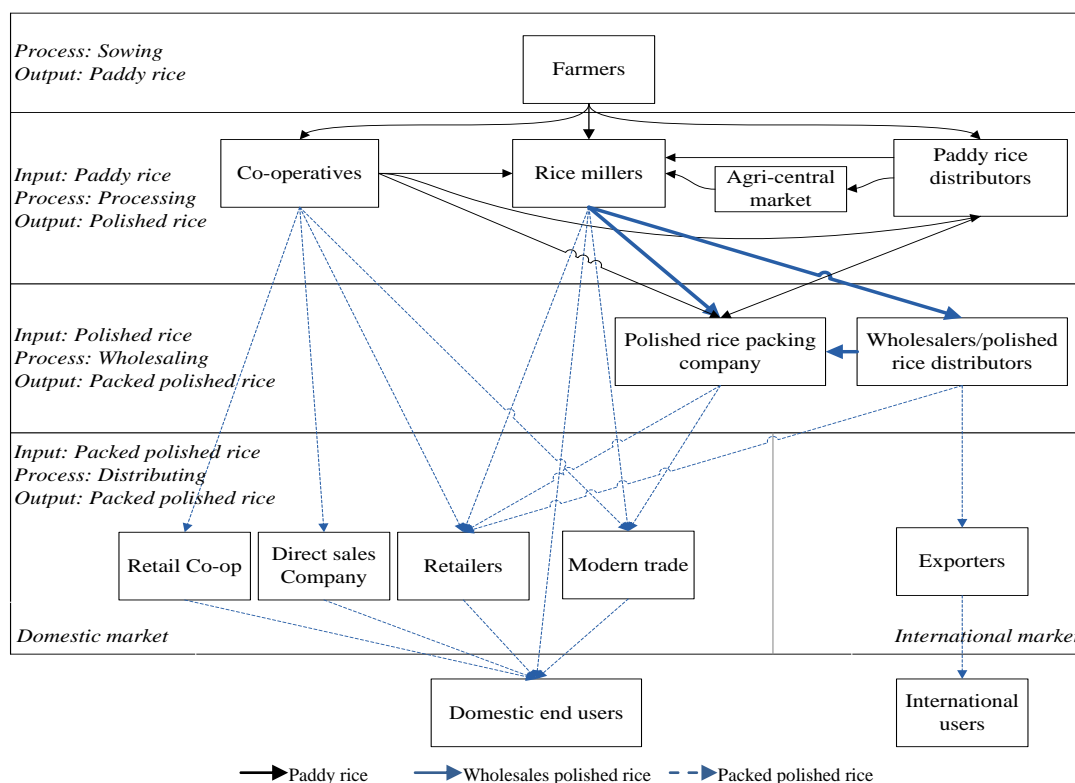


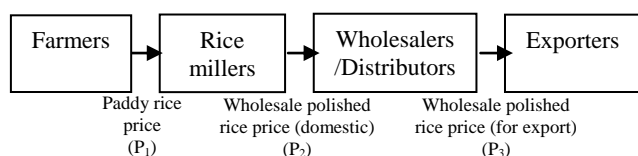Fig. 1. Supply chain of HR in the NE Thailand

Fig. 2. A Unit of analysis framework – major players in HR supply chain in the NE Thailand

### III. LITERATURE REVIEW ON FACTORS INFLUENCING RICE PRICE AT EACH STAGE OF THE CHAIN

The scope of a review in this study was categorized into two sections depending on the source of published papers; from Thailand academic research database such as the Thai National Research Repository (TNRR) and the Thai Library Information System (ThaiLIS), and from international research database such as SCOPUS, Sciencedirect, and Emerald published during 2005-2015. The keywords for searching the Thailand research database were "factors", "affecting" or "influencing" and "rice price". Whereas at international level, the scope was extended to cover "rice price" and "agricultural price" due to limited study in this thematic area of rice. In Thailand, previous studies on "factors influencing rice price" were still scarce although rice price has been a major issue in macroeconomic policy for a decade. All academic papers published during 2005-2015 were studied in order to fulfill a master degree requirement and most of them focused on five percent WR [15,16]. Only one paper studied in HR [17] showed the gap for further study. Findings of a previous study indicated that significant influencing factors toward price of rice can be categorized into two main viewpoints which are domestic and external factors. According to the domestic perspective, factors influencing price include quantitative factors such as $P_1$ [16], $P_2$ [15], $P_4$ [15], and volume of rice exported [15]; while qualitative factors include brand, new crop, return policy [17], and government policy [18]. According to the external perspective, quantitative factors include exchange rate [16, 18], production and stock of competitor countries [18]; while qualitative factors include natural disaster, and trading partner government policy [18].

None considered the effects of price transmission along the whole HR chain and effect of an international market price on each level of domestic rice price. Generally in an international commodity market, both exporter and importer countries cannot dictate the price but it is influenced by the reference price in the world market. Therefore, the exporter becomes a key person in the Thai rice supply chain, the first price transmitter and information linkage between the world price to domestic market. The price is then transmitted along the chain through the wholesaler, miller, and farmer levels, respectively [19].

When categorized in term of supply chain level, previous studied in general rice market indicated that $P_3$ (FOB) price setting behavior has been influenced by domestic policy [18,19], previous period of $P_3$ price [19], international market conditions [18,19] and price of export competitor countries [19]. For $P_2$ price, it has been influenced by $P_1$ [16], exchange rate [16], supply conditions such as expected supply volume [19], and $P_4$ price which wholesalers perceive reference international price through exporters. Lastly $P_1$

price where rice miller is a key person at this stage, therefore, it tends to be dictated by rice miller who have processing cost structure information on hand [19]. Influencing factors at this stage include $P_2$ [15,19] , $P_3$ [19], $P_4$ [15], and exported volume [15]. Moreover when considering conversely from farmers' selling decision, the time of selling and grain quality such as the actual moisture content are also other essential factors that affect farmers' profit margin [8] apart from the price range that set by forward chain members. Therefore in general rice market condition, buyer's price tends to influence over seller's price at stage by stage along the chain which confirms the scenario of buyer's market phenomenon of commodity products.

However, in case of specialty rice as HR that has unique aroma and texture, and limited supply production due to crop characteristics; there is another interesting research area considering effects of other chain member's price toward price of each stage along the chain in both backward and forward scenario. Fulfilling gaps of this research area will generate more understanding in price nature of specialty rice such as HR which benefit for policy makers to set more specific and effective supportive policy for this kind of specialty rice and also supply chain members to consider these studied factors as key consideration criteria in production and processing planning.

Though, price of rice is usually interfered by the government policy, this study did not specifically study in an effect of government policy toward the price and assumed that the real market price data used in this study was absorbed some effect from the policy already. This study was focus only uncontrollable factors whereas the government policy is a manmade mechanism that distort market price; which generates both direct and indirect effects; for a specific purpose. Therefore, understanding in nature of those uncontrollable factors may leads to more effective policy implementing. In addition, another contribution of this study is the extending considering scope to other external factors that may influence on domestic rice price reflected from an international academic study. The review showed that most papers studied commodity agricultural crop in developed countries such as Canada [26], USA [23, 24, 25, 26, 29, 30, 33], U.K [26], France [26], Taiwan [31]. Only two studied in developing countries in the ASEAN region as Thailand [26, 28] where one of the main agricultural crops is rice. In summary, exchange rate [22, 26, 34, 35], energy price [20, 21, 22, 23, 25, 26, 27, 29, 30, 32, 33, 35], global market reference price [28], and government policy [24, 31, 36], were suggested in literature as influencing factors toward agricultural prices. Only one has studied on annual crop rice such as indica rice [20]. Therefore, this paper tries to fill this gap by investigating the effect of these external factors toward price of domestic annual crop rice as HR.

### IV. DATA SOURCES

#### A. Domestic price

Domestic HR price data used in this study came from three main price levels representing price at each major player in the chain. The prices are given in Thai Baht (THB) per metric ton (MT). Paddy rice price at farm gate level

represented farmer's price ($P_1$). Domestic wholesale polished rice price represented rice miller's price ($P_2$). FOB HR 100 percent grade B rice price represented exporter's price ($P_3$). Time series price data was collected monthly from January 2007 to December 2014. These data were obtained from the Department of Internal Trade, the Ministry of Commerce ($P_1$); the Thai Rice Mill Association ($P_2$); and the Thai Rice Exporters Association ($P_3$), respectively.

### B. The world reference price

Rice price indices between 2007-2014 data provided by FAO [3] were applied as the world reference price. The FAO rice price index is calculated by using "A Laspeyres Index" or a "base-weighted" or "fixed-weighted" index where the price increase are weighted by the quantities in the baseline period (FAO base year 2002-2004 = 100). The FAO rice price index is calculated based on 16 rice export quotations, and the sub-index for aromatic rice follows movements in prices of Basmati and Fragrant rice [3]. The major Basmati exporter is India while the major Fragrant rice exporter is Thailand. However, both prices are highly correlated [37]. Therefore, the aromatic rice price index obtained from the FAOSTAT [3] was used in this study as the reference price for the world aromatic rice market (denoted by $P_4$).

### C. Fuel price

Fuel price, especially oil, is a significant factor affecting production costs in all industry sectors including agricultural and food production. When the production cost increases, the price of agricultural commodities is also expected to rise up. Particularly, in case of agricultural commodity used for biofuel production; the rising of oil price may push up prices of these crops resulted from an increase in market demand for substitute products [26]. The monthly energy price used in this study obtained from the data of monthly FOB Brent spot price in USD/barrel, provided by the US Department of Energy, was converted in THB/barrel by the monthly reference rate provided by the Bank of Thailand (BOT) (denoted by $P_5$). Brent oil price is used widely as a benchmark price in the world fuel market [30].

### D. The exchange rate

The exchange rate measured in this study is the value of THB per 1 USD obtained from the monthly reference rate provided by the Bank of Thailand (BOT) (denoted by $P_6$). The US currency is perceived as a major currency quoted in the world market including for agricultural commodity prices. The depreciation on the value of USD may result in an increasing purchasing power or foreign demand which may raise agricultural commodity prices [26]. Therefore, the weakness of the THB against the USD represented by an increase in the exchange rate may influence HR rice price especially at FOB price ($P_3$).

### V. METHODOLOGY

Aims of this study are, firstly, to define the relationship between prices of each player along the HR rice chain in the NE Thailand, in consideration of a particular time frame.

Secondly, the study aimed to examine if there is a non-linear relationship between those prices and if there are any other possible factors in an international environment that may influence or explain the volatility of those prices. Two primary statistics techniques were applied, namely, "correlation coefficient" and "multiple regression analysis".

### The correlation analysis

The correlation coefficient is one of the most popular techniques to analyze data in a variety of scientific disciplines [38] including economics [39], and agriculture [40]. Therefore, this study also applied both techniques to measure directions and the strength of a linear relationship between a pair of random variables $(x, y)$ [41] at different time frame i.e. 1 $(t-1)$, 2 $(t-2)$, and 3 $(t-3)$ months earlier, respectively, to test the hypothesis. Moreover, data were analyzed from different points of view which are 1) considering "cost plus" scenario where sellers have bargaining power over buyers to set the selling price (in case of normal products), and 2) considering "backward" scenario where buyers have more influence over sellers to set the price (buyers' market in general commodity products). In summary, data were analyzed using three different cases as below.

**Case 1**: Correlation between $(x, y)$ at the time $t$

| Time frame | Correlation test | |
|---|---|---|
| $(x^t, y^t)$ | $P_1^t, P_2^t$ | |
| | $P_1^t, P_3^t$ | $P_2^t, P_3^t$ |

**Case 2**: Correlation between $(x, y)$ at different periods in the "forward" supply chain perspective

| Time frame | Correlation test | |
|---|---|---|
| $(x^{t-1}, y^t)$ | $P_1^{t-1}, P_2^t$ | |
| | $P_1^{t-1}, P_3^t$ | $P_2^{t-1}, P_3^t$ |
| $(x^{t-2}, y^t)$ | $P_1^{t-2}, P_2^t$ | |
| | $P_1^{t-2}, P_3^t$ | $P_2^{t-2}, P_3^t$ |

**Case 3**: Correlation between $(x, y)$ at different periods in the "backward" supply chain perspective

| Time frame | Correlation test | |
|---|---|---|
| $(x^t, y^{t-1})$ | $P_2^{t-1}, P_1^t$ | |
| | $P_3^{t-1}, P_1^t$ | $P_3^{t-1}, P_2^t$ |
| $(x^t, y^{t-2})$ | $P_2^{t-2}, P_1^t$ | |
| | $P_3^{t-2}, P_1^t$ | $P_3^{t-2}, P_2^t$ |

However, since the correlation does not indicate cause-and-effect relationships [38], a further investigation technique such as multiple regression was applied in the last step to address the second objective of this study.

### Multiple regression analysis

Multiple regression is applied in this study to better explain the dependent variable $(y)$ using other additional independent variables $(x_{1,...,n})$ [41] under real international environment perspective (denoted by $P_4$, $P_5$, and $P_6$ respectively). Finally, the multiple regression equation is summarized.

In conclusion, input data used in this study were collected from two categories; 1) three domestic price levels ($P_1$, $P_2$, and $P_3$) represented prices data from each tier in domestic supply chain 2) other external factors represented three international reference indicators ($P_4$, $P_5$, and $P_6$) that potentially have influence over domestic prices. Then, all

input data were analyzed to clarify strength and relationship direction among those prices and other external factors using correlation and multiple regression analysis. Outputs generated from the analysis helped define key influence players, significant relationships under different time frames, and key external factors influencing domestic prices. Finally, findings from analysis of this study will contribute to further policy development and implementation, and design of forecasting techniques for the HR supply chain.

## VI. RESULTS AND ANALYSIS

### A. Relationship among prices along domestic HR supply chain

#### Case 1 – Relationship between (x, y) at time t

The results showed that in case 1, all pairs of variables were more than +0.90 which was near plus or minus 1.00. These indicated that all pairs of variables; $(P_1^t, P_2^t)$, $(P_1^t, P_3^t)$, and $(P_2^t, P_3^t)$; have strong positive linear relationship. When considered at each specific level, the variable with the most significant relationship with $P_1^t$ was $P_3^t$ at a significant level of 0.947. As same as $P_1^t$, the most significant relationship with $P_2^t$ was also $P_3^t$ at a significant level of 0.959. Therefore, $P_3^t$ seems to be the most influential price impacting both $P_2^t$ and $P_1^t$, respectively. From a pragmatic view point, the relationship between the price among the first tier buyer - seller is assumed to present a stronger relationship compared to other prices, consistent with the result from $(P_2^t, P_3^t)$ corresponding to this assumption. Markedly, both $P_2^t$ and $P_3^t$ price vary independently under market circumstances. However, in the case of $P_1^t$, results showed that the most significant relationship with $P_1^t$ was the second tier player as $P_3^t$. This may result from the intervening policies in the last decade that elevated farmers' income by manipulating paddy rice price.

#### Case 2 & 3 – Relationship between (x, y) at time t-n

When considering different time frames (case 3), results showed that the more length of time resulted in the weaker relationship between variables in both forward and backward scenario. While comparing forward and backward scenarios, results from case 2 and case 3 showed that the relationship level in both cases was more than 0.80 indicative of significant relationships among these variables. More specifically, results from case 2 showed more significant relationship than from case 3. These results confirmed the assumption that although HR is categorized as a commodity product, with its unique characteristics, forward chain members still have some bargaining power in the price setting game. Moreover, $P_2^t$ price from the previous period and $P_3^t$ price from the current period showed the most significant relationship at a significant level of 0.950.

### B. Influence of international factors over HM domestic prices

The correlation analysis can only define significant levels of relationship between two variables without an explanation on how those variables are influenced. Therefore, in the second step the multiple regression analysis was applied. Finally, the output from the analysis was provided in a multiple linear equation as the general descriptive form stated by Lind et al. [41] and as showed in the following equation (1). The set confidence level for this study is 95 percent.

$$\hat{Y} = a + b_1X_1 + b_2X_2 + b_3X_3 + \cdots + b_kX_k \qquad (1)$$

Where

$a$   is the intercept, the value of $\hat{Y}$ when all the $X$'s are zero.

$b$j  is the amount by which $\hat{Y}$ changes when that particular $X$j increases by one unit, with the values of all other independent variables held constant.

There are three assumptions in this study aiming to find influence factors over each price level along the chain under the same time frame $t$.

*Assumption*
$P_1^t = f(P_2^t, P_3^t, P_4^t, P_5^t, P_6^t)$
$P_2^t = f(P_1^t, P_3^t, P_4^t, P_5^t, P_6^t)$
$P_3^t = f(P_1^t, P_2^t, P_4^t, P_5^t, P_6^t)$

Where
$P_1$   is farmer's price (THB/MT)
$P_2$   is miller's price (THB/MT)
$P_3$   is exporter's price (THB/MT)
$P_4$   is world reference price index
$P_5$   is Brent oil price (THB/Barrel)
$P_6$   is an exchange rate (THB/USD)

*Influence factors over $P_1^t$*

In the first round test of function "$P_1^t = f(P_2^t, P_3^t, P_4^t, P_5^t, P_6^t)$" the result showed that there were three independent variables; $P_2^t$, $P_3^t$, and $P_5^t$; that statistically presented significant influence over $P_1^t$ at p-value of 0.0023, 0.0000, and 0.0494 respectively as shown in equation (2).

$$P_{1t} = 441.583 + 0.158P_{2t} + 0.249P_{3t} + 0.270P_{5t} \qquad (2)$$

*Influence factors over $P_2^t$*

In the test of function "$P_2^t = f(P_1^t, P_3^t, P_4^t, P_5^t, P_6^t)$" the results showed that there were two independent variables; $P_1^t$ and $P_3^t$; have statistically significant influence over $P_2^t$ at p-value of 0.0021 and 0.0000, respectively. The Multiple R was 0.9634 indicated that the correlation among the independent $P_1^t$ and $P_3^t$ and dependent variable $P_2^t$ is positive. The R square was 0.9281 indicated that around 92.8 percent of the variation in the dependent variable $P_2^t$ is explained by these set of independent variables. The multiple linear equation output generated from this stage is shown in the equation (3) below.

$$P_{2t} = 653.163 + 0.586P_{1t} + 0.628P_{3t} \qquad (3)$$

*Influence factors over $P_3^t$*

In the test of function "$P_3^t = f(P_1^t, P_2^t, P_4^t, P_5^t, P_6^t)$", the result showed that the independent variables; $P_1^t$, $P_2^t$ and

$P_4^t$; have statistically significant influence over $P_3^t$ at p-value of 0.0000, 0.0000, and 0.0063 respectively. The Multiple R was 0.9718 indicated that the correlation among the independent $P_1^t$, $P_2^t$, and $P_4^t$ and dependent variable $P_3^t$ is positive. The R square was 0.9444 indicating that around 94.44 percent of the variation in the dependent variable $P_3^t$ is explained by these set of independent variables. The multiple linear equation output generated from this stage is shown in the following equation (4).

$$P_{3t} = -71.991 + 0.771P_{1t} + 0.619P_{2t} + 15.444P_{4t} \quad (4)$$

Moreover, in order to validate the statistical results, the graph of residuals and standard residuals were plotted as shown in Fig. 3, 4, and 5 representing results from case $P_1^t$, $P_2^t$, and $P_3^t$, respectively. Each figures showed that there was a random distribution of both positive and negative values of residuals across the entire range of the horizontal axis. The plots were scattered and presented in unobvious pattern, indicated undoubtful on the linearity assumption. These plots supported the assumption of linearity and trusty of the assumption of linear relationship [41].
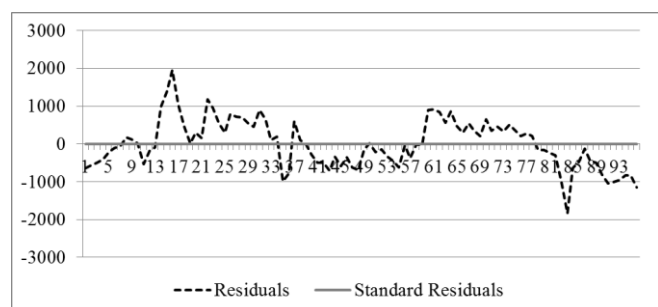


Fig. 3. The residual plot from an analysis result of $P_1^t$ test
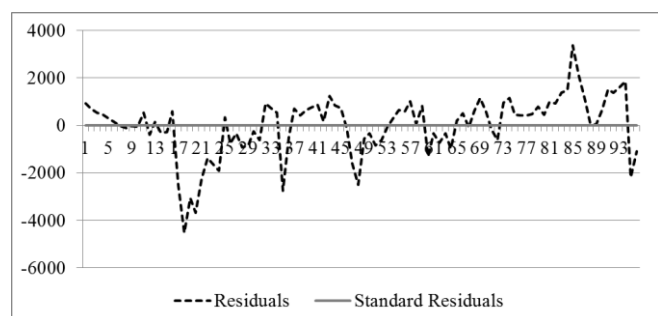


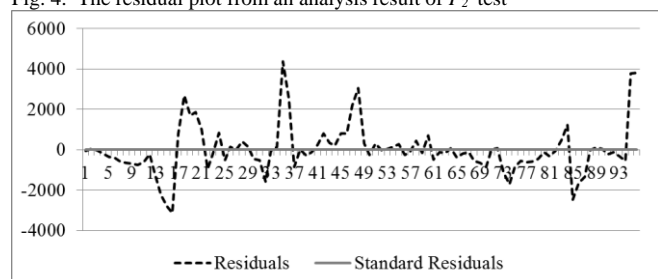Fig. 4. The residual plot from an analysis result of $P_2^t$ test



Fig. 5. The residual plot from an analysis result of $P_3^t$ test

## VII. Conclusions and recommendations for further study

Result from the correlation analysis showed that prices of each level in the HR supply chain include paddy rice price at farm gate level $P_1^t$, wholesale polished rice price at rice millers/wholesalers' level $P_2^t$, and export polished packed rice at exporters' level $P_3^t$ have strong positive linear relationship while $P_3^t$ seems to be the most influential price toward both $P_2^t$ and $P_1^t$ respectively. Especially in case of $P_1^t$, the second tier's price level $P_3^t$ showed a stronger relationship than the first tier's price level $P_2^t$. This can be confirmed by results from the multiple regression analysis where both $P_1^t$ and $P_2^t$ prices were significantly influenced by $P_3^t$. However, to some extent, $P_1^t$ absorbed effects of price intervention policy in reality. Therefore, a manipulated $P_1^t$ price may lessen an influence of $P_2^t$ toward $P_1^t$. Whereas the volatility of $P_3^t$, under general market mechanism has more powerful downward pressure over domestic HR price. These findings extend the scope of explanation on $P_1^t$ price from the previous study which indicated that rice millers/wholesalers are crucial influencing players over paddy rice buying price at this stage of the chain [6], [8], [19]. The result from this phase pointed out that the price intervention at an early stage of the supply chain or any global price shock events transferred through FOB price can possibly provide severe reaction effects along each tier in the supply chain. Hence, these factors should be carefully considered by concerned parties, especially the policy makers.

Furthermore under different time frame perspective, results showed that the most recent time frame showed a stronger relationship between variables in both forward and backward scenarios show that prices in the past do not have much influence over current prices. Specifically, results from both case 2 (considering forward scenario) and case 3 (considering backward scenario) showed strong linear relationships between tested variables but with case 2 showing more significant relationships than case 3. These results affirm an assumption that although HR is categorized as a commodity product with its unique characteristics, forward chain members also have some bargaining power over the price setting game. In order to find other possible factors in an international environment that may influence or explain the volatility of price patterns of each price level in the supply chain, the multiple regression analysis was applied. Results from this phase can be summarized in three stages which are;

$P_1^t$ **level**: There were three independent variables which showed statistically significant influence over $P_1^t$ which were $P_2^t$, $P_3^t$, and $P_5^t$. While $P_3^t$ showed the strongest impact over $P_1^t$. $P_5^t$ (the Brent oil price) is the only external factor that showed significant influence over $P_1^t$. This finding was in accordance with planting cost structure that machinery cost is the largest proportion in variable costs [6]. The findings reflect from an extensive use of machinery in production nowadays.

$P_2^t$ **level**: There were two independent variables which showed statistically significant influence over $P_2^t$ which were $P_1^t$ and $P_3^t$. $P_3^t$ showed the strongest impact over $P_2^t$. There were no external studied factors that showed significant influence over $P_2^t$ calling attention to the need to extend the scope for further study.

$P_3^t$ **level**: There were three independent variables which

showed statistically significant influence over $P_3^t$ which were $P_1^t$, $P_2^t$ and $P_4^t$. $P_1^t$ and $P_2^t$ both shared significant impact over $P_3^t$. $P_4^t$ (the world reference price index) is the only external factor that showed significant influence over $P_3^t$ while Basmati, the combined computing reference index, is sold to a different market from HR.

Results affirmed the significance of $P_3^t$ price over $P_1^t$ and $P_2^t$ as presented by results from the correlation test. The Brent oil price $P_5^t$ and the world reference price index $P_4^t$ were the only two external factors that have significant impact on HR domestic price. None of the domestic prices was influenced significantly by $P_6^t$ (the exchange rate of THB/USD) which was different from the findings of a previous study of 5 percent WR for future market [16]. This affirmed the different price nature between WR and HR stressing the need for special and different treatments in pricing policy.

Nevertheless, the study had some limitations, for instance; it did not consider the extent of effect from manmade factors (for example, government policy) on each price level; and it did not consider the effect of price at time *t-n* on the price at time *t* of the same price level. Therefore, recommendations for further study include 1) study on impacts of government policy on domestic HR price at each tier in the supply chain by extending the studied period, or comparing other cases of different products or different study area (by country); 2) aims of this study focused only to define significant relationships between independent and dependent variables, and define impact of those independent variables toward dependent variables. The forecast accuracy is out of scope of this study which should be further developed. Findings from this study extended the scope of previous studies regarding pricing relationship among domestic prices at each tier along the HR supply chain. Contributions from this study do not only clarify understanding of HR pricing behavior, but also identify other factors that explain the volatility of each price level, and preliminary expected effects from distorted pricing mechanism on prices of other members' along the chain. These provide initial consideration for a framework for supply chain stakeholders, especially policy makers, to avoid distorted pricing policy at each specific supply chain level. Multiple equations acquired from this study can be applied by researchers to further develop a price forecasting model. The development of more accurate price forecasting tool will be useful for supply chain members in improving effectiveness of production planning. Furthermore, foreseen prices generated from the developed forecasting model can be implemented using various mechanisms to improve coordination among supply chain members, particularly, of newsvendor products.

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