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THE RELATIONSHIP BETWEEN FOOD PRODUCTION, AGRICULTURAL LAND, RICE PRODUCTION, AND RICE PRICE: AN EMPIRICAL STUDY ON THAILAND AND VIET NAM

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ABSTRACT

Food security has been considered as one of priorities in the development of socio-economics of Southeast Asian countries. The article aims to examine the causal relationship between food production, agricultural land, rice production and rice price in Thailand and Viet Nam between 1988 and 2017. We found that agricultural land positively affects food production index. We also found that paddy rice production has a positive relationship with food production index. Results showed that there are directional relationships running from food production index to agricultural land and paddy rice production; from agricultural land to paddy rice production; from paddy rice production to food production index; and from rice price to agricultural land. Further, there is a co-integration among variables in the long run. Lastly, policies are recommended to ensure food security and achieve a sustainable development in Thailand and Viet Nam.

Contribution/Originality: This study contributes to the existing literature by clarifying the causal relationship between food production, agricultural land, rice production and rice price in Thailand and Viet Nam between 1988 and 2017, using a vector autoregressive model.

1. INTRODUCTION

Rice plays an important role in agricultural production in Southeast Asia. For example, by 2008, this crop contributed about 35 percent to total value of agricultural production in Thailand and 44 percent in Viet Nam. In Viet Nam, number of households cultivating rice accounted for 9.3 million (Sombilla, Balisacan, Antiporta, & Dikitanan, 2011) and rice has created the main source of income for more than 60 million people living in the rural area (Hai, 2012).

Thailand is the second largest economy in Southeast Asia after Indonesia and by 2010, the annual growth of gross domestic product (GDP) of this country accounted for eight percent (FAO, 2012). Although Thailand is an exporting rice of the world, this country must face obstacles in food accessibility at the household level, especially in remote rural areas. Hardships in food availability and accessibility of this country caused by the global economic crisis, climate change and the growth in production of food fuel-crops in addition to the increase in global food price in recent years. In addition, profitability of rice farmers tended to decline because of increasing production costs and input prices (Isvilanonda & Bunyasiri, 2009).

Viet Nam presented a remarkable achievement in poverty reduction and food security in the last decades. The average growth of GDP of this country reached 7.5 percent between 1990 and 2004 (Ministry of Planning and Investment (MPI), 2015). The national poverty rate has dropped from 58.1 percent in 1993 to 24.1 percent in 2004 (Nhat, 2008). However, this country must tackle to threats in food security due to unstable prices, persisting poverty, climatic changes, and land use conversion (Hai, 2012).

What is the relationship between food production, agricultural land, rice production and rice price in Thailand and Viet Nam? How do these variables correlate in the short run and long run? Currently, there is no research assessing the relationship between these variables in Thailand and Viet Nam. Therefore, the research is carried out to contribute to existing literature. Specifically, this article aims to investigate the relationship between food production, agricultural land, rice production and rice price in Thailand and Viet Nam between 1988 and 2017 using a vector autoregressive (VAR) model. More importantly, policies are recommended to ensure food security and achieve a sustainable development in these countries.

The remainder of this paper is organized as follows. Section 2 presents the empirical review. Methodologies are discussed in section 3. Section 4 presents results and discussion. Conclusion and policy implications are summarized in section 5.

2. EMPIRICAL REVIEW

Some studies evaluate the relationship between food production, agricultural production and other variables. Sarkodie and Owusu (2017) investigated the relationship between carbon dioxide, crop and livestock production index in Ghana from 1960 to 2013. They found that a 1 percent increase in crop production index will increase carbon dioxide emissions by 0.52 percent, while a 1 percent increase in livestock production index will increase carbon dioxide emissions by 0.81 percent in the long run. There is a bidirectional causality between a crop production index and carbon dioxide emissions and a unidirectional causality exists from livestock production index to carbon dioxide emissions. Likewise, a study by Ngongi and Urassa (2014) assessed factors affecting food production and supply in Kahama district, Tanzania. Results showed that total annual income, the amount of maize and paddy produced, household size, the number of plots owned, and the number of cattle owned significantly affect the surveyed households' food production and supply. Moreover, food insecurity existed among farming households in the study area.

The relationship between food production, agricultural production and other variables is considered in Asia. Aryal and Kandel (2017) investigated food security and self-reliance in paddy in South Asia. They found that most of the poor and undernourished people of South Asia are living in rural areas and they are largely dependent on agriculture for their livelihood. The ratio of rice land to arable land is high in the subcontinent and employment generation and income creation can be implemented by increasing demand for rice. Similarly, Fan et al. (2011) estimated the effect of crop productivity and resource use on food security and environmental quality in China. Results indicated that trainings in soil management and agronomy should be increased to deal with food insecurity. In addition, genetic of crop varieties should be improved from combinations of improved crops and improved agronomical practices. Lastly, Siwar, Idris, Yasar, and Morshed (2014) examined issues of rice production and food security in Malaysia. The area has played an important role in the self-sufficiency level of rice in this country. Several approaches are carried out to improve the productivity and stability of food production.

3. METHODS

3.1. Data and Sources

A panel dataset for the relationship between food production, agricultural land, rice production and rice price of Thailand and Viet Nam for the last three decades (1988–2017) is gathered from the World Development Indicators released by the World Bank and the Food and Agriculture of the United Nations (FAO). The panel data is used for

this research because of the following advantages: (1) it benefits in terms of obtaining a large sample, giving more degree of freedom, more information, and less multi-collinearity among variables; and (2) it may overcome constraints related to control individual or time heterogeneity faced by the cross-sectional data (Hsiao, 2014).

3.2. The Vector Autoregressive (VAR) Model

The VAR model was chosen for this study because it explains the endogenous variables through their own history only, apart from deterministic regressors; therefore, this method incorporates non-statistical, a priori information (Pfaff, 2008). Further, this is a popular model in economics and other sciences, as it is simple and flexible to use with multivariate time-series data (Suharsono, Aziza, & Pramesti, 2017).

The VAR model can be defined in Equation 1 as follows (Pfaff, 2008):

$$Y_t = A_1 Y_{t-1} + \cdots + A_p Y_{t-p} + \mathcal{E}_t \qquad (1)$$

where: Y_t denotes a set of K, or endogenous, variables (i.e., food production index, agricultural land, rice production, and rice price); A_i represents (K x K) coefficient matrices for i = 1,..., p; and $\mathcal{E}_t$ is a K-dimensional process with $E(\mathcal{E}_t)$ = 0.

Stability is an important characteristic of the VAR model, which generates stationary time series with time-invariant means, variances, and covariance structure, given sufficient starting values. This characteristic can be checked with the following equation:

$$\det(I_k - A_1 z - \cdots - A_p z^p) \neq 0 \; for \; [z] = 1 \qquad (2)$$

where: I_k denotes the number of orders; A_i represents (K x K) coefficient matrices for i = 1,..., p; and z represents the number of roots.

If the solution for Equation 2 produces a root of z = 1, then either some or all variables in the VAR(p) process are integrated of order one, i.e., I(1).

The stability of an empirical VAR model can also be analyzed using the companion form and calculating the eigenvalues of the coefficient matrix. Thus, a VAR model may be specified as follows (Pfaff, 2008):

$$\mathcal{E}_t = A\mathcal{E}_{t-1} + V_t \qquad (3)$$

where: $\mathcal{E}_t$ denotes the dimension of the stacked vector; A represents the dimension of the matrix (K_p x K_p); and V_t represents (K_P x 1).

Indicators for Equation 3 can be calculated as follows:

$$\mathcal{E}_t = \begin{bmatrix} Y_t \\ \vdots \\ Y_{t-p+1} \end{bmatrix}; A = \begin{bmatrix} A_1 & A_2 & \ldots & A_{p-1} & A_p \\ I & 0 & \ldots & 0 & 0 \\ 0 & I & \ldots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \ldots & I & 0 \end{bmatrix}; V_t = \begin{bmatrix} U_t \\ 0 \\ \vdots \\ 0 \end{bmatrix} \qquad (4)$$

Equation 4 derives the computation of indicators in Equation 3.

Table-1. Description of Covariates in the VAR Model.

Variable definitions	Unit
Food production index	
Agricultural land	square km
Rice production	tonne
Rice price	US$

Note: US means United States Dollar.

Table 1 presents four covariates in the VAR model.

In this study, there are six steps to the VAR model procedure: (1) performing the unit root test; (2) determining lag length; (3) estimating the VAR model; (4) testing the Granger causality; (5) checking the stability of the eigenvalues; and (6) conducting the Johansen test for cointegration. The VAR model was estimated using the Stata/MP 14.2 software.

4. RESULTS AND DISCUSSION

4.1. Financial Development, Economic Growth, and Inflation in Southeast Asia: an Overview
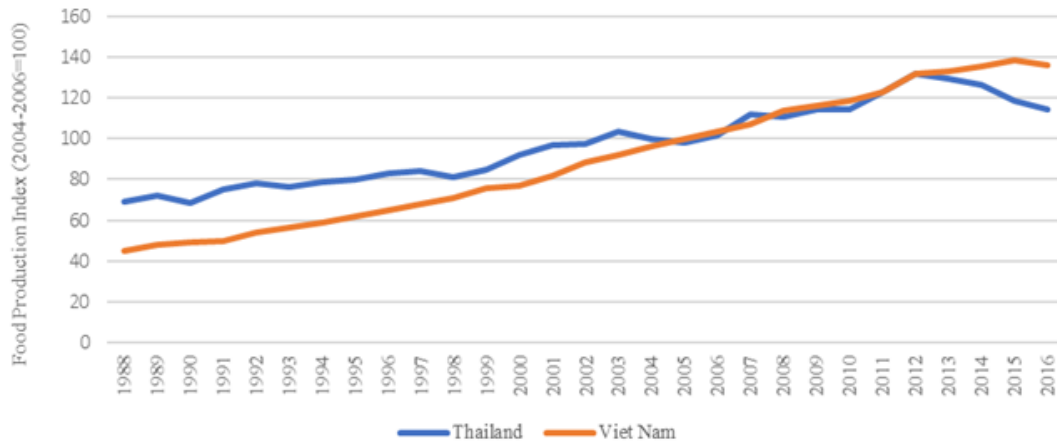

Figure-1. Food production indices of Thailand and Viet Nam.

Source: World Bank (2020).

Figure 1 shows food production indices of both countries significantly increased for 29 years (1988–2016). From 1988 to 2008, food production index of Thailand was higher than that of Viet Nam. However, food production index of Viet Nam tended to higher than that of Thailand from 2008 onward. For example, by 2016, food production index of Viet Nam accounted for about 136, while the index of Thailand accounted for about 114.
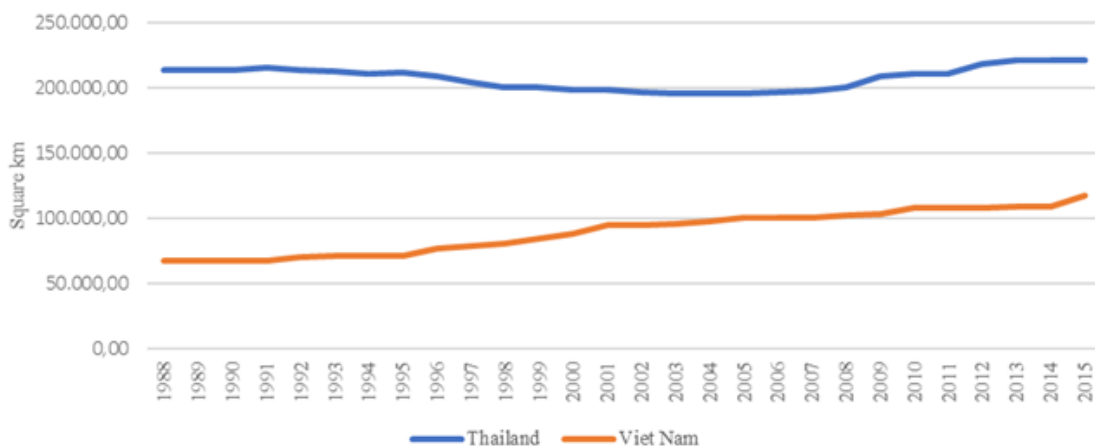

Figure-2. Agricultural Land of Thailand and Viet Nam.

Source: World Bank (2020).

Figure 2 shows that agricultural land of Thailand was about doubled higher than that of Viet Nam for 28 years (1988–2015). In 1988, agricultural land of Thailand was higher than that of Viet Nam more than tripled and by 2015, the gap accounted for about 1.8 times. These imply advantages of Thailand in agricultural and food production.
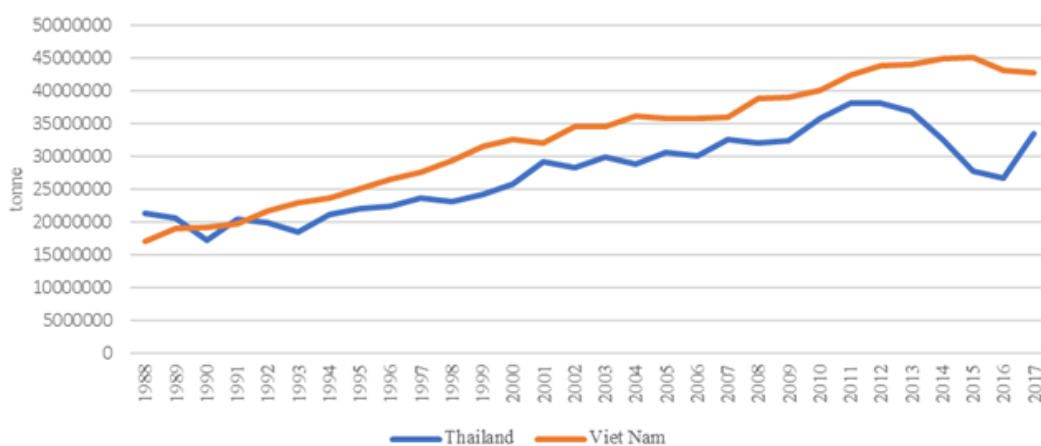
Figure-3. Production of Paddy Rice in Thailand and Viet Nam.
Source: FAO (2020).

Figure 3 shows the production of paddy rice of both countries rapidly increased between 1988 and 2017. However, for six years (2011–2016), production of paddy rice of Thailand tended to decrease by 12 million tonnes from 3.8 million tonnes in 2011 to 2.6 million tonnes in 2016. From 1990, Viet Nam has overcome Thailand in terms of producing paddy rice. By 2017, production of paddy rice of Viet Nam reached more than 4.2 million tonnes, while production of Thailand accounted for more than 3.3 million tonnes.
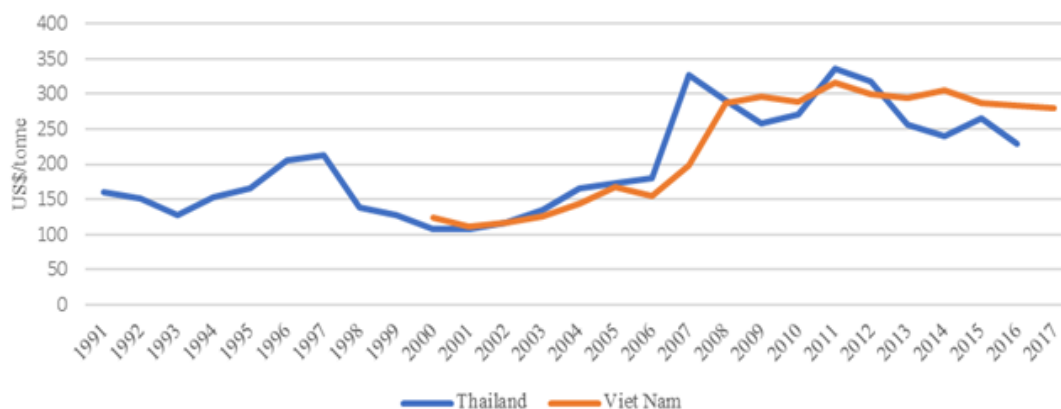

Figure-4. Producer Price of Paddy Rice in Thailand and Viet Nam.
Source: FAO (2020).

As seen in Figure 4, price of paddy rice of both countries tended to go up from 2001 to 2017. For seven years (2002–2008), price of paddy rice of Thailand was higher than that of Viet Nam. However, from 2013 onward, price of paddy rice of Viet Nam was higher than that of Thailand about US$22–55.

Table-2. Characteristics of food production, agricultural land, rice production, and rice price of selected countries in Southeast Asia.

Variables	Mean	SD	Min	Max
Food production index	90.15	30.61	0	138.7
Agricultural land	138576.9	69605.78	0	221100
Rice production	3.01e+07	7987504	1.70e+07	4.511e+07
Rice price	154.91	113.93	0	335.4

Note: SD denotes standard deviation.

It is evident from Table 2 that the average food production index and agricultural land of two countries account for 90.15 and 138,576.9 square km. Rice production and price of both countries account for 30.1 million tonnes and about US$154/tonne.

4.2. The Relationship between Food Production, Agricultural Land, Rice Production, and Rice Price in Thailand and Viet Nam

4.2.1. Performing the Unit Root Test

The unit root test is carried out to check the stationarity of the time series variables (Adeola & Ikpesu, 2016). In this study, the Augmented Dickey-Fuller (ADF) test and the Phillips-Peron (PP) test are used to examine the stationarity of tourism and economic growth in four Oceanian countries with the hypothesis as follows:

Null hypothesis (H_0): The variables contain a unit root.

Alternative hypothesis (H_a): The variables do not contain a unit root.

If a variable contains a unit root, then this implies that the time series of this variable is not stationarity.

Table-3. Results of the unit root test.

Variables		ADF Test		PP Test		Conclusion
		Level	**1st difference**	**Level**	**1st difference**	
LnFood production index	Constant	-3.45***	-6.13***	-4.87***	-9.33***	I(0)
	Constant & trend	-3.31*	-6.11***	-4.74***	-9.34***	I(1)
LnAgricultural land	Constant	-3.82***	-7.68***	-2.80*	-7.69***	I(1)
	Constant & trend	-4.22***	-7.70***	-3.16*	-7.74***	I(1)
LnRice production	Constant	-1.12	-6.29***	-1.36	-9.82***	I(1)
	Constant & trend	-1.67	-6.21***	-2.18	-9.74***	I(1)
LnRice price	Constant	-2.30	-5.33***	-2.30	-7.52***	I(1)
	Constant & trend	-2.27	-5.31***	-2.26	-7.48***	I(1)

Note: *** and * denote statistical significance at 1% and 10%, respectively

The results in Table 3 show that the time series of food production index (without trend) is stationary at the level [I(0)] because the absolute value of test statistic is greater than critical values at the 1% and 5%, respectively. However, the time series of agricultural land, rice production, and rice price are not stationary at the level. Thus, the first difference is carried out to examine the stationary of these variables. Results demonstrate that the absolute values of test statistics are greater than critical values at the 1% and 5%, respectively and therefore we can conclude that the time series of these variables do not contain unit roots and this suggests that the time series are stationary at the first difference [I(1)]. Results of the unit root test is consistent to employ the VAR model.

4.2.2. Determining Lag Length

The objective of this second step is to identify the optimal lag for the VAR model. If the lag is too small, then the residual of the regression will not show white noise and, as the result, the actual error will not be accurately estimated by the model (Suharsono et al., 2017).

Table-4. Selection of the Lag Length.

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-312.11				0.940	11.28	11.34	11.43
1	-47.75	528.72	16	0.000	0.000	2.41	2.70	3.14
2	8.91	113.34*	16	0.000	0.000	0.96*	1.47*	2.26*
3	16.21	14.60	16	0.553	0.000	1.27	2.00	3.15
4	27.65	22.86	16	0.117	0.000	1.44	2.39	3.90

Endogenous: LnFood production index; LnAgricultural land; LnRice production; LnRice price
Exogenous: Constant
Number of observations = 56

Notes: * denotes lag order selected by the criterion; LL—log-likelihood values; LR—sequential modified likelihood ratio test statistics; FPE—final prediction error; AIC—Akaike information criterion; HQIC—Hannan–Quinn information criterion; SBIC—Schwarz's Bayesian information criterion.

The results in Table 4 suggest that the optimal lag is 2 (the number of lags is equal to 2) as recommended by the AIC, HQIC, and SBIC indicators. Therefore, lag 2 was chosen to run the VAR model in the next step.

4.2.3. Estimating the VAR Model

The findings of the third step revealed that agricultural land positively affects food production index in lag 1, but it has a negative relationship with food production index in lag 2. We also found that paddy rice production has a positive relationship with food production index in lag 1, but it negatively affects food production index in lag 2. Food production index has a negative correlation to agricultural land and paddy rice production. Paddy rice production positively affects agricultural land, while it negatively influences rice price. Finally, agricultural land negatively affects paddy rice production, but it has a positive effect on rice price (see details in Table A1 of the Appendix).

4.2.4. Testing the Granger Causality

The purpose of this step is to assess the predictive capacity of a single variable on other variables (Musunuru, 2017). In this study, hypotheses need to be tested as follows:

Testing the relationship between food production index and other variables:

Null hypothesis (H_0): Food production index does not cause agricultural land, paddy rice production and rice price.

Alternative hypothesis (H_a): Food production index causes agricultural land, paddy rice production and rice price.

Testing the relationship between agricultural land and other variables:

Null hypothesis (H_0): Agricultural land does not cause food production index, paddy rice production and rice price.

Alternative hypothesis (H_a): Agricultural land causes food production index, paddy rice production and rice price.

Testing the relationship between paddy rice production and other variables:

Null hypothesis (H_0): Paddy rice production does not cause food production index, agricultural land and rice price.

Alternative hypothesis (H_a): Paddy rice production causes food production index, agricultural land and rice price.

Table-5. Results of the granger causality wald test.

Directional relationship	Probability	Conclusion
Food production index ⟶ Agricultural land	0.00 < 0.05	Reject H_0
Food production index ⟶ Rice production	0.00 < 0.05	Reject H_0
Food production index ⟶ Rice price	0.94 > 0.05	Accept H_0
Agricultural land ⟶ Food production index	0.10 > 0.05	Accept H_0
Agricultural land ⟶ Rice production	0.03 < 0.05	Reject H_0
Agricultural land ⟶ Rice price	0.12 > 0.05	Accept H_0
Rice production ⟶ Food production index	0.00 < 0.05	Reject H_0
Rice production ⟶ Agricultural land	0.06 > 0.05	Accept H_0
Rice production ⟶ Rice price	0.55 > 0.05	Accept H_0
Rice price ⟶ Food production index	0.04 < 0.05	Reject H_0
Rice price ⟶ Agricultural land	0.00 < 0.05	Reject H_0
Rice price ⟶ Rice production	0.20 > 0.05	Accept H_0

As can be seen from Table 5, there are directional relationships running from food production index to agricultural land and paddy rice production; from agricultural land to paddy rice production; from paddy rice production to food production index; and from rice price to food production index and agricultural land Table 5.

4.2.5. Checking the Stability of Eigenvalues

If all the eigenvalues lie inside the unit circle, then the VAR model satisfies the stability condition (see Figure 5).
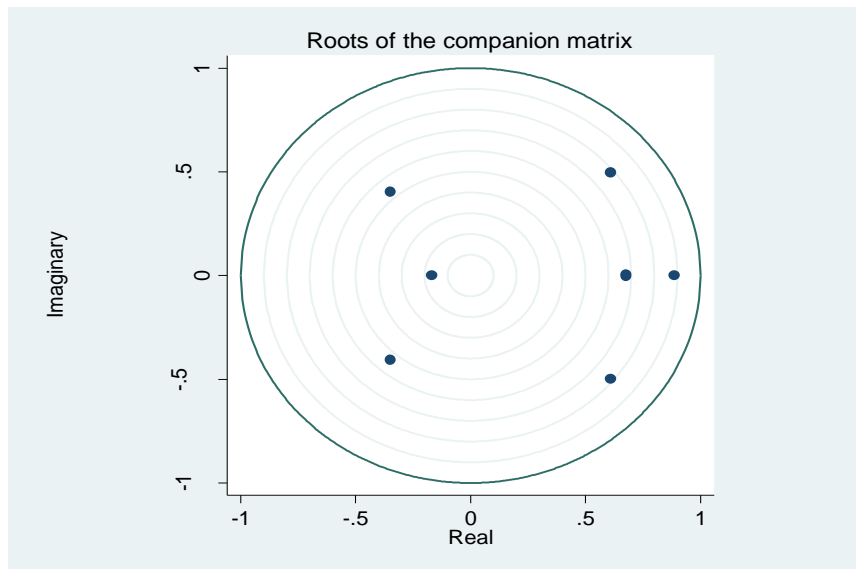
Figure-5. Checking the stability of eigenvalues in the VAR model.

4.2.6. Conducting the Johansen Test for Cointegration

This final step examined the long-term relationship among variables. If variables are cointegrated, then a long-term relationship among variables is possible (Musunuru, 2017).

The following hypotheses were tested:

Null hypothesis (H$_o$): There is no cointegration among variables.

Alternative hypothesis (H$_a$): There is cointegration among variables.

In this study, the Johansen cointegration test was performed using the trace statistic, which is a likelihood ratio-type test that operates under different assumptions in the deterministic part of the data generation process (Lüutkepohl, Saikkonen, & Trenkler, 2001).

Table-6. Results of trace statistic in the johansen cointegration test.

Maximum rank	LL	Eigenvalue	Trace statistic	5% critical value	1% critical value
0	-75.12		119.04	47.21	54.46
1	-25.77	0.81	20.33[*1*5]	29.68	35.65
2	-20.39	0.16	9.57	15.41	20.04
3	-16.94	0.11	2.67	3.76	6.65
4	-15.60	0.04			

Notes: [*1] and [*5] denote the number of cointegrations (ranks) chosen to accept the null hypothesis at 1% and 5% critical values.

Table 6 shows that the null hypothesis cannot be rejected in rank 1 (one cointegration) because the trace statistic is less than the 1% critical value (20.33 < 35.65) and the 5% critical value (20.33 < 29.68). These results thus imply one cointegration among variables at the 1% and 5% critical values.

4.3. Discussion

Results show that food production index has a negative correlation to agricultural land and paddy rice production and these reflect that if food production index increases, then agricultural land and paddy rice production decrease. Thus, food production index of two countries depends on other variables much more than agricultural land and paddy rice production. Paddy rice production positively affects agricultural land and this implies that agricultural land is still an important factor to enhancing paddy rice production. Paddy rice production has a negative influence on rice price and this suggests that an increase of production leads to a decline of rice price. Agricultural land negatively affects paddy rice production and this implies that paddy rice production of two countries depends on yield and technological advances much more than agricultural land.

We found that there are directional relationships from food production index to agricultural land and paddy rice production; from agricultural land to paddy rice production; from paddy rice production to food production index; and from rice price to food production index and agricultural land. Lastly, there is a co-integration among variables at 1% and 5% critical values and this reflects a long-term relationship among these variables.

5. CONCLUSION AND POLICY IMPLICATIONS

The research aims to investigate the causal relationship between food production, agricultural land, rice production and rice price in Thailand and Viet Nam between 1988 and 2017. We found that agricultural land positively affects food production index in lag 1, but it has a negative relationship with food production index in lag 2. We also found that paddy rice production has a positive relationship with food production index in lag 1, but it negatively affects food production index in lag 2. There is a co-integration among variables at 1% and 5% critical values.

Policies should be recommended to the governments of Thailand and Viet Nam to ensure food security and achieve a sustainable development. First, investment in agricultural research and development (R&D), infrastructure, and extension should be enhanced to improve agricultural productivity and reduce the dependence on agricultural land. In Thailand, productivity can be improved through enhancing micronutrient intake. Specifically, awareness of nutrition in diet and dietary guidelines should be provided and guided by the government. To enhance the accessibility to nutritious food, food quality and safety standards should be facilitated (Tiwasing, 2016). In Viet Nam, land protection for rice production (3.8 million hectares) is a cause leading to decreasing agricultural productivity since it challenged individuals in terms of performing efficient production and earning higher incomes (Petersen, 2017). Second, policy reforms need to be implemented to protect the food market and prices such as state trading, export bans, price subsidies, import tariffs, and price pledging are costly and inefficient. Thus, to encourage participation of the private sector is necessary since they contribute equally to the investment needs of strengthening product markets and involve small farmers as key players and partners (Sombilla et al., 2011). In Viet Nam, policy interventions in agricultural production, agricultural marketing and distribution, food safety and quality control, land policy, and international trade are necessary to achieve the target in food security (Hung, 2009). Lastly, cooperation in food security should be promoted. Thailand and Viet Nam should consider the cooperation in food security not only in the bilateral framework but also in the regional level. For example, in 2011, the Association of Southeast Asian Nations (ASEAN) plus three emergency rice reserve (APTERR) is established with participation of 10 ASEAN members plus People's Republic of China, Japan, and the Republic of Korea to provide food assistance and secure in emergencies caused by disasters.

REFERENCES

Adeola, O., & Ikpesu, F. (2016). An empirical investigation of the impact of bank lending on agricultural output in Nigeria: A vector autoregressive (VAR) approach. *The Journal of Developing Areas, 50*(6), 89-103.Available at: https://doi.org/10.1353/jda.2016.0140.

Aryal, M., & Kandel, M. (2017). Food security in South Asia and self-reliance in paddy. *Journal of Agriculture and Environment, 18*, 73-82.Available at: https://doi.org/10.3126/aej.v18i0.19892.

Fan, M., Shen, J., Yuan, L., Jiang, R., Chen, X., Davies, W. J., & Zhang, F. (2011). Improving crop productivity and resource use efficiency to ensure food security and environmental quality in China. *Journal of Experimental Botany, 63*(1), 13-24.

FAO. (2012). Experiences with domestic food prices and food policy responses during 2007-2011. Committee on Commodity Problems. Food and Agriculture Organization of the United Nations, March 2012.

FAO. (2020). FAOSTAT production of paddy rice in Thailand and Viet Nam. Retrieved from: http://www.fao.org/faostat/en/#data/QC [Accessed April 15, 2020].

FAO. (2020). FAOSTAT producer prices of rice in Thailand and Viet Nam. Retrieved from: http://www.fao.org/faostat/en/#data/PP [Accessed April 15, 2020].

Hai, L. T. (2012). Support for the association of Southeast Asian nations plus three integrated food security framework: The rice situation in Viet Nam. Technical Assistance Consultant's Report. Project Number: TA 7495-REG. Asian Development Bank, January 2012.

Hsiao, C. (2014). *Analysis of panel data* (3rd ed.). New York: Cambridge University Press.

Hung, T. M. (2009). Food security and sustainable agriculture in Viet Nam. Country Report: Viet Nam. Fourth Session of the Technical Committee of APCAEM. 10-12 February 2009, Chiang Rai, Thailand.

Isvilanonda, S., & Bunyasiri, I. (2009). Food security in Thailand: Status, rural poor vulnerability, and some policy options. *ARE Working Paper No. 2552/1. September 2009.*

Lüutkepohl, H., Saikkonen, P., & Trenkler, C. (2001). Maximum eigenvalue versus trace tests for the cointegrating rank of a VAR process. *The Econometrics Journal, 4*(2), 287-310.Available at: https://doi.org/10.1111/1368-423x.00068.

Ministry of Planning and Investment (MPI). (2015). 15 years achieving the Viet Nam Millennium development goals. Country Report, 11-14. Ministry of Planning and Investment, September 2015. Publishing license No. 41/GP-CXBIPH. Printing Joint Stock & Truong An Commercial Company, Viet Nam.

Musunuru, N. (2017). Causal relationships between grain, meat prices and exchange rates. *International Journal of Food and Agricultural Economics, 5*(4), 1-10.

Ngongi, A. M., & Urassa, K. (2014). Farm households food production and households' food security status: A case of Kahama district, Tanzania. *Tanzania Journal of Agricultural Sciences, 13*(2), 40-58.

Nhat, T. T. H. (2008). Tackling household food insecurity: The experience of Vietnam. *Asian Journal of Agriculture and Development, 5*(2), 41-55.

Petersen, E. (2017). Comparison of food security policies in Vietnam, Indonesia and Australia. Vietnam food security policy review. *ACIAR Monograph, 196,* 26-35. ACIAR 2017.

Pfaff, B. (2008). VAR, SVAR and SVEC models: Implementation within R package vars. *Journal of Statistical Software, 27*(4), 1-32.

Sarkodie, S. A., & Owusu, P. A. (2017). The relationship between carbon dioxide, crop and food production index in Ghana: By estimating the long-run elasticities and variance decomposition. *Environmental Engineering Research, 22*(2), 193-202.Available at: https://doi.org/10.4491/eer.2016.135.

Siwar, C., Idris, N. D. M., Yasar, M., & Morshed, G. (2014). Issues and challenges facing rice production and food security in the granary areas in the East Coast Economic Region (ECER), Malaysia. *Research Journal of Applied Sciences, Engineering and Technology, 7*(4), 711-722.Available at: https://doi.org/10.19026/rjaset.7.307.

Sombilla, M. A., Balisacan, A. M., Antiporta, D. B., & Dikitanan, R. C. (2011). Policy responses to the food price crisis and their implications: The case of four greater Mekong subregion countries. Occasional Papers: Knowledge for Development Effectiveness. *The International Fund for Agricultural Development (IFAD).*

Suharsono, A., Aziza, A., & Pramesti, W. (2017). *Comparison of vector autoregressive (VAR) and vector error correction models (VECM) for Index of ASEAN Stock Price.* Paper presented at the in AIP Conference Proceedings 1913, 1, pp. 020032-1-020032-9. AIP Publishing. International Conference and Workshop on Mathematical Analysis and its Applications (ICWOMAA 2017).

Tiwasing, P. (2016). *Nutrition, labour productivity and food security in Thailand.* A Thesis Submitted for the Degree of Doctor of Philosophy. School of Agriculture, Food and Rural Development, Newcastle University, June 2016.

World Bank. (2020). World development indicators. Agricultural land of Thailand and Viet Nam. Retrieved from: https://databank.worldbank.org/data/reports.aspx?source=2&series=AG.PRD.FOOD.XD&country=#. [Accessed April 15, 2020].

APPENDIX

Table-A1. Estimation of the VAR model.

Variables	Coefficient	Standard Error	t-statistic	p-value
LnFood production index				
LnFood production index				
L1	-0.097	0.09	-0.98	0.331
L2	0.741***	0.08	9.15	0.000
LnAgricultural land				
L1	0.401***	0.00	99.20	0.000
L2	-0.276***	0.03	-7.76	0.000
LnPaddy rice production				
L1	0.608***	0.12	4.81	0.000
L2	-0.307*	0.18	-1.70	0.095
LnRice price				
L1	-0.003	0.01	-0.33	0.746
L2	0.003	0.00	0.31	0.760
Constant	-5.006**	2.02	-2.47	0.017
LnAgricultural land				
LnFood production index				
L1	-7.335**	3.42	-2.14	0.037
L2	-5.899**	2.79	-2.11	0.040
LnAgricultural land				
L1	0.787***	0.13	5.63	0.000
L2	2.040	1.23	1.66	0.104
LnPaddy rice production				
L1	9.672**	4.37	2.21	0.032
L2	-1.644	6.23	-0.26	0.793
LnRice price				
L1	0.158	0.36	0.44	0.665

Table-A1. (Continued).

Variables	Coefficient	Standard Error	t-statistic	p-value
L2	0.374	0.33	1.10	0.275
Constant	-102.66	69.91	-1.47	0.148
LnPaddy rice production				
LnFood production index				
L1	0.041	0.11	0.37	0.710
L2	-0.177*	0.09	-1.97	0.055
LnAgricultural land				
L1	-0.010**	0.00	-2.35	0.023
L2	0.054	0.03	1.36	0.179
LnPaddy rice production				
L1	1.056***	0.14	7.49	0.000
L2	0.001	0.20	0.01	0.995
LnRice price				
L1	-0.010	0.01	-0.93	0.356
L2	0.011	0.01	1.07	0.292
Constant	-0.873	2.25	-0.39	0.700
LnRice price				
LnFood production index				
L1	-0.624	1.60	-0.39	0.698
L2	0.970	1.30	0.74	0.462
LnAgricultural land				
L1	0.267***	0.06	4.09	0.000
L2	-0.010	0.57	-0.02	0.986
LnPaddy rice production				
L1	-3.503*	2.04	-1.71	0.093
L2	4.457	2.91	1.53	0.133
LnRice price				
L1	0.843***	0.16	4.96	0.000
L2	-0.125	0.15	-0.79	0.433
Constant	-19.541	32.69	-0.60	0.553

Notes: L1 and L2 refer to lag 1 and lag 2; ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.