Jurnal Ekonomi Malaysia 54(1) 2020 1 - 17
http://dx.doi.org/10.17576/JEM-2020-5401-1

Impacts of Technological Shock on the Agricultural Business Cycle

(Kesan Kejutan Teknologi ke atas Kitaran Perniagaan Pertanian)

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ABSTRACT

The real business cycles in ASEAN-5 countries namely Indonesia, Malaysia, the Philippines, Thailand, and Vietnam over 1971-2015 fluctuated more than their agricultural business cycles. This research utilized the two-sector real business cycle model developed by Da-Rocha and Restuccia (2002) to stimulate such a stylized fact. The model assumes that a social planner makes a decision in an initial period to choose the consumption, capital stock, and working hours in the agricultural and non-agricultural sectors. This will enable a representative agent to attain optimum utility for the entire life under certain economic restrictions and subject to technology shocks occurring in both sectors. The mathematical methods applied to solve this decision-making problem for the social planner includes linear quadratic approximations and stochastic dynamic programming methods. The simulation results suggest that the applied model could reasonably well replicate the fluctuations of the real business cycle, agricultural business cycle, and the non-agricultural business cycle. This reflects the situation where technology shocks in the agricultural and non-agricultural sectors are related to each other and influence the volatility of these two economies.This suggest that the governments should encourage research and development activities in both agricultural and non-agricultural sectors to develop new technology that can generate technology shock to promote greater economic strength.

Keywords: Agricultural business cycle; two-sector RBC model; ASEAN; technological shock; business cycle

ABSTRAK

Kitaran perniagaan benar negara-negara ASEAN-5 iaitu Indonesia, Malaysia, Filipina, Thailand, dan Vietnam bagi 1971-2015 adalah lebih turun naik berbanding kitaran perniagaan pertanian. Bagi mensimulasikan corak fakta yang sama, kajian ini menggunakan model kitaran perniagaan benar dua sektor yang dibangunkan oleh Da-Rocha dan Restuccia (2002). Model ini mengandaikan bahawa perancang sosial membuat keputusan dalam tempoh awal untuk memilih penggunaan, stok modal, dan waktu bekerja di sektor pertanian dan bukan pertanian. Ini akan membolehkan ejen perwakilan mencapai utiliti yang optimum untuk seumur hidup di bawah sekatan ekonomi tertentu dan tertakluk kepada kejutan teknologi yang berlaku di sektor pertanian dan bukan pertanian. Kaedah matematik digunakan untuk menyelesaikan masalah membuat keputusan bagi perancang sosial dalam kajian ini termasuklah penghampiran kuadratik linear dan kaedah pengaturcaraan dinamik stokastik. Hasil simulasi menunjukkan bahawa model yang diaplikasikan dapat menggambarkan corak turun naik kitaran perniagaan benar, kitaran perniagaan pertanian, dan kitaran perniagaan bukan pertanian. Ini mencerminkan keadaan di mana kejutan teknologi dalam sektor pertanian dan bukan pertanian adalah saling berkaitan antara satu sama lain dan mempunyai pengaruh terhadap turun naik kedua-dua sektor ekonomi ini. Ini mencadangkan bahawa kerajaan menggalakkan aktiviti penyelidikan dan pembangunan di kedua-dua sektor pertanian dan bukan pertanian untuk membangunkan teknologi baharu yang dapat menghasilkan kejutan teknologi bagi menghasilkan kekuatan ekonomi yang lebih besar.

Kata Kunci: Kitaran perniagaan pertanian; Model RBC dua sektor; ASEAN; kejutan teknologi; kitaran perniagaan

INTRODUCTION

In considering the key economic indicators for ASEAN countries as held by the Food and Agriculture Organization of the United Nations (FAO) and searchable on their database, it was found that the agriculture, forestry, and fishing value added as a percentage of gross domestic product (GDP) was in the range of 6.7%–22.5% in 2015 (Table 1.). Also, when comparing the percentages to those of Indonesia, Malaysia, the Philippines, and Thailand, the CLMV countries (Cambodia, Lao PDR, Myanmar, and Vietnam) clearly showed higher values. Here, although the agricultural sectors in Indonesia, Malaysia, the Philippines, and

Thailand seem to contribute less to driving their national economies, their agricultural sectors are still important in terms of showing promising growth rates and supporting economic development. Further, the growth rate of the agriculture, forestry, and fishing value added in all these countries was in the range -3.8%–4.0%, with Indonesia showing the highest growth rate followed by Myanmar, Vietnam, and Malaysia, respectively. Thailand, on the other hand, suffered from a serious drought in 2015, which caused a significant decrease in the growth rate of its agriculture, forestry, and fishing value added. At the same time, when considering the population density in ASEAN countries as an indicator, it could be found that the rural population as a percentage of the total population for Thailand was around 50% in 2015, while in Malaysia it was around 25.3%. Moreover, agricultural land as a percentage of total land area for Thailand and the Philippines was 46.3% and 55.6%, respectively. Apart from this, the OECD/FAO (2017) succinctly stated how economic development in the agricultural sector can contribute to the issue of raising food security. At the same time, the development of agricultural international trade is beneficial for both the farmers and consumers in ASEAN countries. Therefore, it is clear that to date, the agricultural sector has played a significant role in the economies of ASEAN countries.

Theoretically, analysis of the economic fluctuation of agricultural output in short-run periods has been an important issue for informing policy-makers aiming to drive economic development in the agricultural sector over the past three decades. According to the real business cycle (RBC) school of thought, the main cause of business cycle volatility in the short term tends to originate from technological shocks. This article, therefore, starts by analyzing the key issues behind the stylized fact accepted as the case for the agricultural sectors in the ASEAN-5 countries, namely Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. That is, this research article focuses only on ASEAN-5 countries. This is because the agriculture, forestry, and fishing value added indicators in ASEAN-5 countries generally show higher values than for the other ASEAN countries. At the same time, the ASEAN-5 countries' economic development opportunities in the agricultural sector have higher promise (Table 1.).

By applying values for the annual real GDP and real agriculture, forestry, and fishing value added gathered from the FAO databases to estimate the cycle components, starting from being adapted to the natural logarithm and then setting aside the trend growth component using the Hodrick–Prescott (HP) filter, Hodrick and Prescott (1997) proposed that, theoretically, time series data

TABLE 1. Contextual indicators for selected ASEAN countries, 2015

	Gross Domestic Product[a]	Gross Domestic Product	Agriculture, Forestry and Fishing Value Added[a]	Agriculture, Forestry and Fishing Value Added	Agriculture, Forestry and Fishing Value Added	Rural Population[b]	Agricultural Land[b]
	(USD, 2005 prices)	(Annual growth,%)	(USD, 2005 prices)	(Share of GDP, %)	(Annual growth,%)	(Share of total population, %)	(Share of total land area, %)
Cambodia	12,297.6	7.0	2,721.8	22.1	0.2	79.3	30.9
Indonesia	526,206.1	4.8	53,704.1	10.2	4.0	46.3	31.5
Lao PDR	5,807.5	7.6	1,308.1	22.5	0.6	61.4	10.2
Malaysia	231,175.1	5.0	15,375.4	6.7	1.1	25.3	23.9
Myanmar	28,884.0	7.3	8,558.6	29.6	3.4	65.9	19.4
The Philippines	174,660.3	5.9	15,745.0	9.0	0.1	55.6	41.7
Thailand	261,840.4	2.8	20,089.3	7.7	-3.8	49.6	43.3
Vietnam	104,331.0	6.7	14,565.7	14.0	2.4	66.4	35.1

Source: [a]FAOSTAT, http://www.fao.org/faostat/en/#data. [b]OECD/FAO (2017).

TABLE 2. Business cycle volatility in ASEAN-5 countries from 1971 to 2015 according to standard deviation values

	Indonesia	Malaysia	The Philippines	Thailand	Vietnam
Standard deviation of real business cycle	3.817%	3.571%	3.440%	4.274%	2.781%
Standard deviation of agricultural business cycle	1.410%	2.900%	2.598%	2.539%	2.515%

Source: Author's calculations.

would comprise a trend growth component and cyclical components. The former could be derived from solving the minimization problem of the loss function, while the latter could be calculated by removing the trend growth component of the data. Here, the movement of the real GDP cycle, the so-called real business cycle, as well as the real agriculture, forestry, and fishing value added cycle, the so-called agricultural business cycle, were plotted from the data and the results are displayed in Figure 1, which shows that the agricultural business cycle in the ASEAN-5 countries tends to move together with the real business cycle. Specifically, it can be seen that the movement of the agricultural business cycle with its peaks and turning points nearly aligns with the movement of the real business cycle. With respect to the RBC paradigm, its characteristic is known as a "procyclical movement." Interestingly, during recession periods, the real business cycle is severely reduced more than the agricultural business cycle, as occurred, for example, during the 1981 to 1986 Iran–Iraq war, which had significant negative economic impacts on Indonesia, Malaysia, the Philippines, and Thailand due to the great collapse in prices. Another crash occurred during 1997 to 1999 related to the Asian financial crisis, which originated with issues in the financial sector in Thailand but then spilled over to other countries in Asia, although the negative economic impacts on the agricultural sectors in Thailand and the Philippines were not as great as the overall economic impacts. Moreover, the stylized fact of the volatility of the agricultural business cycles of ASEAN-5 countries could be confirmed by looking at the standard deviation values (Table 2.). It could be seen that during 1971 to 2015, the real business cycle in the ASEAN-5 countries fluctuated in the range of 2.781%–4.274%; with the lowest figures being seen for Vietnam and the highest ones for Thailand compared to the other countries. On the other hand, by only focusing on the agricultural business cycle, it could be revealed that over the past 45 years, the agricultural business cycle has shown lower levels of fluctuation than those of the real business cycle. This leads to the research question from an RBC school economist's point of view: "How do technological shocks in the agricultural and non-agricultural sectors of each ASEAN country influence the volatility of the agricultural business cycle?"

LITERATURE REVIEW

According to the literature review performed, it appeared that the two most common approaches for analyzing short-term economic volatility are time series analysis in the econometric model and the microfoundation of macroeconomics model. Some interesting reported findings from using the first approach include, for instance, if the aggregate output is driven by integrating productivity shocks, then a sectoral output series should display few, if any, co-integrating relationships. Similarly, a serial correlation co-feature should be a rare occurrence. These conjectures were confirmed in an analysis using West German data by Lucke (1998). In addition, it was discovered that industry-level VAR models for United States' manufacturing supported both sticky-wage dynamic general equilibrium (DGE) and RBC models over sticky-price DGE models (Malley et al., 2005), while vector autoregression (VAR) analysis was applied to identify news shocks using data on four advanced small open economies (Kamber et al., 2017). More recently, the first approach was applied to several issues, such as environmental and labor economics. A structural vector autoregression (SVAR) model was used to analyze the impact of technology shocks on the correlation between carbon emissions and the United States business cycle. Also, anticipated investment technology shocks, and government spending and monetary policy shocks were added into such a model (Khan et al., 2019). Another study used SVAR and a dynamic stochastic general equilibrium (DSGE) model of a small open economy for analysis of the impact of migration shocks, and revealed that migration shocks can make a crucial contribution to the fluctuation of GDP per capita (Smith & Thoenissen 2019).

Delving extensively into the literature on ASEAN countries, further interesting findings were found such as from the use of an augmented VAR model, in which the Granger non-causality test indicated that the real business cycle of the United States did not correlate with that of ASEAN countries, while the real business cycles of ASEAN countries were more likely to correlate among themselves (Ong & Habibullah 2004). Estimations using a structural VAR model indicated that in the case of Vietnam, the major cause of macroeconomic fluctuations came from the supply side. However, in the long term, these were likely to have less significance (Ha 2015). Further, estimations using a VAR model reflected that although the Chinese market plays a very significant role in ASEAN countries at the present date, trading among other ASEAN member countries is also still important for movement of the real business cycle in each country (Lestari 2016). Apart from this, a qualitative discussion of the economic mechanisms and econometric model with panel data was applied for analysis of the impacts of a produced shock in the agricultural sector on the allocation of labor across sectors for rural India's economy. It was revealed that short-term gains in agricultural productivity stimulated the growth of manufacturing, construction, retail, and education sectors (Emerick 2018). Notice that although the majority of the empirical results for business cycle fluctuations have been drawn from time series analysis in econometric models, several previous literature studies have attempted to support their results using models derived from the notion of microeconomics, the so-called microfoundation of macroeconomics model.

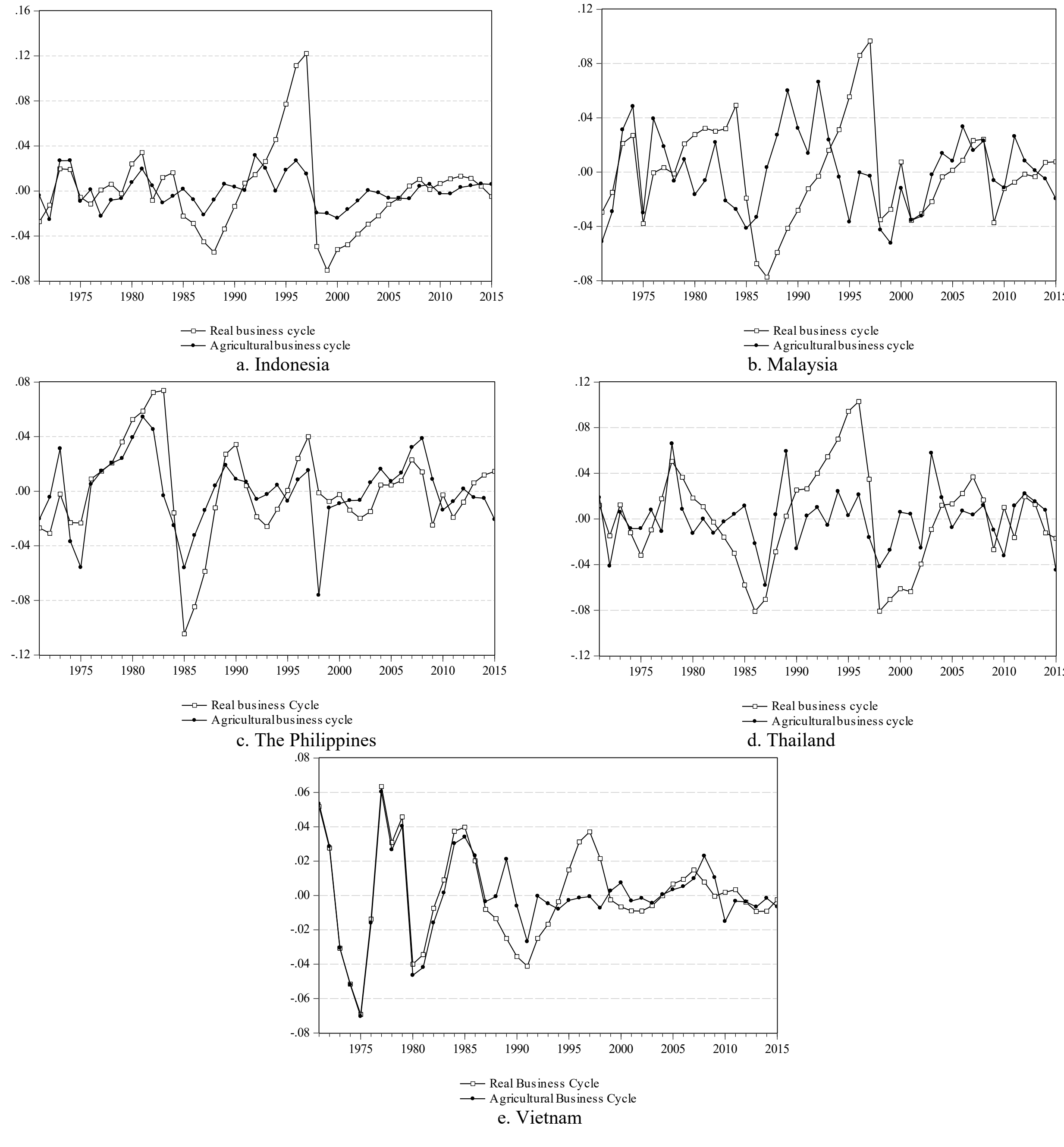


FIGURE 1. Volatility of the real business cycle and agricultural business cycle in the ASEAN-5 countries

It has been three decades since the real business cycle approach was first applied for macroeconomic analysis, as manifested in Kydland and Prescott's time to build and Long and Plosser's real business cycle models (Altug & Young 2015). In more deeply investigating the impacts of technology shocks or supply shocks, it was found that the research papers in the past have revealed some interesting findings; for instance, the introduction of the RBC models has been influential in refocusing attention on supply issues in macroeconomic analyses after the long postwar focus on aggregate demand management in Australia and most other Western economies (Crosby & Otto 1995). Meanwhile, research on the importance of technology shocks on the US business cycle has sharply decreased after a structural break in the late 1960s (Atella et al. 2008). At the same time, the RBC model has been further developed for looking at specific issues of shocks in a wide range of areas, e.g., the issue of how representative consumers have to do housework and how shocks in this area can affect the real business cycle (Benhabib et al. 1991), the application of the RBC model to the durable- and nondurable-goods-producing sectors (Hornstein & Praschnik 1997; Martín-Moreno et al. 2014), the inclusion of stochastic research and development (R&D) for new technologies in a continuous time RBC model with risk-averse agents (Wälde 2002), examination of the validity of the identification assumption in a DGE model with several possible sources of permanent shocks (Francis & Ramey 2005), the role of agricultural output in an RBC model (Da-Rocha & Restuccia 2002; 2006), the use of an RBC model with investment-specific technology shocks (Araújo 2012), the distinction between consumption and investment-goods-producing technologies (Ireland & Schuh 2008), and the use of a DSGE model with two types of financial shocks (Kaihatsu & Kurozumi 2014), etc. Furthermore, the model has also been developed based on the new Keynesian DGE model with sticky prices to analyze the business cycle in developing countries (Male 2009). It can thus be concluded that with respect to the standard RBC model, several literature reports have attempted to propose new shock issues, so as to describe business cycle fluctuations in short-run periods.

More recently, a standard RBC model was developed for the two-sector RBC model to handle specific issues, such as home production, the informal sector, capacity utilization, and international economics. Calibration of the RBC model with home production found that the number of OECD countries' tax-rate combinations that fall into the instability region rises when home goods account for a larger share of the aggregate consumption. It was also reported that persistent cycles could easily take place following a fundamental shock or even a "sunspot" shock (Xue & Yip 2018). With respect to the two-sector RBC model, volatility of the business cycle in both formal and informal sectors was analyzed for emerging countries (Horvath 2018). Also, an augmented RBC model with capacity utilization, investment adjustment cost, and indivisible labor was developed and utilized for analysis of the effects of temporary and permanent productivity shocks on the business cycle of hours worked and employment for a group of 15 emerging markets as well as for the United States (Coşkun 2019). Moreover, a two-country, two-sector international RBC model with investment and consumption goods sectors was developed with investment-specific technology shocks and used for an analysis of the volatility of the business cycle in emerging markets (Dogan 2019). At the same time, the two-countries RBC model was used to explain cross-country correlations between the loan rates, deposit rates, and loan premiums for both the United States relative to the Euro-area and the United States relative to China (Csabafi et al. 2019). Also, a medium-scale open-economy DSGE model was used for a comparative analysis of the volatility of Ethiopia's business cycle under interest rate and money growth rules, where it was found that the model with the money growth rule was essentially less powerful for the transmission of exogenous shocks originating from government spending programs, monetary policy, technological progress, and exchange rate movements (Melesse 2019).

According to the literature survey on research relating to short-term economic volatility in the case of Asia, many interesting findings were revealed from analyses of the stylized fact of the business cycles in Asian countries. For example, an analysis of a comprehensive set of stylized facts for business cycles in India from 1950 to 2010 implied that India looks similar to many advanced economies and less like other emerging market economies (Ghate et al. 2013). At the same time, an RBC model was used to mimic the Chinese business cycle from 1996 to 2005 (Li & Liu 2009). However, some disadvantages of the model have also been found, such as the RBC model is not supported and the new Keynesian model or the labor reallocation model was instead a good candidate to explain Japanese business cycles (Miyagawa et al. 2006). Also, it was found that the RBC model driven by both stationary and non-stationary productivity shocks was not successful at replicating some of the key features of the economic fluctuations in Turkey (Taştan 2013). Furthermore, an analytical issue called "synchronization" has also been widely researched. Such research includes a study on how it relates to business cycle correlations between countries in the Asia–Pacific region (Crosby 2003), another that allowed the degree of synchronization to fluctuate across the phases of the ASEAN-5's business cycles (Dufrénot & Keddad 2014), the synchronization of growth cycles between China, Japan, the United States, and other Asia-Pacific countries (Berdiev & Chang 2015), synchronization among 10 major East Asian countries (Huh et al. 2015), and the synchronization of key macroeconomic variables, such as gross domestic product, inflation, exports, and exchange rates within ASEAN countries (Sethapramote 2015). More recently, the DSGE model with asymmetric preferences, incomplete financial markets, and the terms of trade shocks was used to explain fluctuations of the stylized fact of the business cycle in China. It was also reported it could perform well for cases of a negative international co-movement of investment (Han 2019). Further delving into cases related to the agricultural sector, some simulation results derived from the use of a two-sector RBC model revealed that Thailand's agricultural business cycle has shown greater fluctuations than its non-agricultural business cycle has (Jaroensathapornkul 2010). On the other hand, a static general-equilibrium model with Stone–Geary preferences was used to describe how productivity shocks in the agricultural sector could generate large volatility in the industrial output of developing countries (Lee 2018).

From the above studies and up to the present time, both time series analysis in an econometric model and the microfoundation of macroeconomics model for analyzing short-term economic volatility in ASEAN countries have been continuously applied and developed. Nevertheless, literature reports concentrated on fluctuations of the agricultural business cycle can be rarely found. The key features of the business cycles in the Asian economies were proposed by Kim et al. (2003), who found that the movements of the real business cycles of various Asian countries shared similar characteristics. At the same time, Jaroensathapornkul (2010) used the two-sector RBC model of Da-Rocha and Restuccia (2006) to replicate the stylized fact of agricultural business cycle volatility in Thailand between 1997 and 2007. However, the stylized fact of this research article is based on the annual data sets between 1975 and 2015, while those of Jaroensathapornkul (2010) were based on quarterly data sets between 1997 and 2007. Also, the simulation results in this research article were derived from a new data set of parameters. This is important as the extent of the body of research for the rest of the ASEAN-5 countries is still quite limited. The research findings discussed in this article, therefore reflect an effort to explain the impact of technology shocks on the agricultural and non-agricultural sectors to add to the literature related to the use of the RBC model in ASEAN-5 countries. The findings from this research lead to some policy implications for ASEAN-5 countries in order to promote economic strength in the agricultural sector. In addition, the present work expands the knowledge frontier toward ASEAN countries, especially from the date of the formal establishment of the ASEAN Economic Community in December 2015.

METHODOLOGY

Based on the previous literature, the research methodology is separated into two parts. In the first part, a theoretical model is outlined. The economic environment of the model can be schematically represented as involving the scarcity of resources, production, and preferences. Further, a standard RBC model was developed as a two-sector RBC model for the agricultural and non-agricultural sectors. Ultimately, with respect to the theoretical model, the dynamic stochastic optimization problems of the social planner can be presented. In the second part, a method for solving the theoretical model and the simulation procedures are presented. The theoretical models, i.e., linear-quadratic methods, for approximating the dynamic programming problems with the two-sector RBC model are summarized. Then, the simulation procedures are separated into three steps: parametrization or calibration, dynamic response, and experiment. These are explained in more detail below.

THEORETICAL MODEL

The two-sector RBC model developed and utilized in the present study was based on Da-Rocha and Restuccia (2002) with the notion that a representative consumer consumes agricultural and non-agricultural products in order to obtain maximum utility of these resources for their entire indefinite life under a certain economic environment as follows:

SCARCITY OF RESOURCES

In the model described as follows, the agricultural sector is represented by a and the non-agricultural sector is represented by n. The model's variables are counted per capita, while the number of the population at the start is equal to 1 $(L_0 = 1)$. Therefore, the number of population at time t (L_t) is equal to $\eta^t L_0 = \eta^t$, which refers to population growth rate at time t. The scarcity of resources starts with a representative consumer consuming non-agricultural products $(c_{n,t})$ combined with a representative firm increasing its capital goods or investing (i_t) in an economic system not beyond non-agricultural products produced in a certain period of time $(y_{n,t})$. At the same time, the representative consumer consumes agricultural products $(c_{a,t})$ not beyond those produced in a certain period of time $(y_{a,t})$ as demonstrated in the equations below:

$$c_{n,t} + i_t \le y_{n,t} \tag{1}$$

$$c_{a,t} \le y_{a,t} \tag{2}$$

The investment in the present period (i_t) is the accumulation of capital stock for the following period of time (k_{t+1}) as demonstrated by the equation below:

$$k_{t+1} = i_t + (1-\delta)k_t \tag{3}$$

where δ refers to the depreciation rate with the assumption that it is a constant value in any period of time and where capital stock (k_t) is allocated for the agricultural and non-agricultural sectors as follows:

$$k_{a,t} + k_{n,t} \le k_t \tag{4}$$

PRODUCTION

The aforementioned representative firm in the agricultural and non-agricultural sectors employs a production function, which exhibits a constant return to scale, under a certain technological level or Solow residual $(z_{i,t}; i \in \{a,n\})$. Further, the technological level may be disturbed by external factors, i.e., so-called technological shocks $(\varepsilon_{i,t}; i \in \{a,n\})$, the movement of which can be defined by a first-order autoregressive model as follows:

$$\begin{bmatrix} z_{a,t+1} \\ z_{n,t+1} \end{bmatrix} = \begin{bmatrix} \rho_{a,a} & \rho_{a,n} \\ \rho_{n,a} & \rho_{n,n} \end{bmatrix} \begin{bmatrix} z_{a,t} \\ z_{n,t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{a,t+1} \\ \varepsilon_{n,t+1} \end{bmatrix} \tag{5}$$

where $\begin{bmatrix} \varepsilon_{a,t+1} \\ \varepsilon_{n,t+1} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2_{a,a} & \sigma^2_{a,n} \\ \sigma^2_{n,a} & \sigma^2_{n,n} \end{bmatrix}\right)$ and i.i.d..

The coefficient matrix in equation (5) reflects that the technological shocks propagate between the agricultural and non-agricultural sectors. In other words, the technological shocks in the agricultural (non-agricultural) sector have impacts on the technological level in the non-agricultural (agricultural) sector. This causes a volatility in the output of the agricultural $(y_{a,t})$ and non-agricultural $(y_{n,t})$ sectors. In addition, the conventional inputs in the agricultural sector include capital stock $(k_{a,t})$, labor $(\pi_{a,t}\bar{h}_a)$, and the cultivated area (t); while for the non-agricultural sector, they are capital stock $(k_{n,t})$ and labor $(\pi_{n,t}\bar{h}_n)$, as shown in the equations below:

$$y_{a,t} = \lambda_a e^{z_{a,t}} k_{a,t}^{\mu} \left(\pi_{a,t}\bar{h}_a\right)^{\phi} t^{1-\phi-\mu} \tag{6}$$

$$y_{n,t} = \lambda_n e^{z_{n,t}} k_{n,t}^{\theta} \left(\pi_{n,t}\bar{h}_n\right)^{1-\theta} \tag{7}$$

where μ and θ refer to the capital share parameter in the agricultural and non-agricultural sectors, respectively, and ϕ refers to the labor share parameter in the agricultural sector. The probability that the representative consumer shall work in each production sector is represented by the symbol $\pi_{i,t}; i \in \{a,n\}$ and the number of average working hours in the agricultural and non-agricultural sectors is represented by $\bar{h}_i; i \in \{a,n\}$. In addition, the time invariant technology parameter is represented by $\lambda_{i,t}; i \in \{a,n\}$

PREFERENCES

The representative consumer is allocated a consumption of agricultural products $(c_{a,t})$ and non-agricultural products $(c_{n,t})$ as well as a resting time $\left(l_t = \left(1-\bar{h}_a\right)^{\pi_{a,t}} \left(1-\bar{h}_n\right)^{\pi_{n,t}}\right)$ to obtain maximum utility for their entire indefinite life by applying a utility function of each period of time (U_t) as demonstrated in equation (8). The resting time combined with the average working time $(h_i; i \in \{a,n\})$ is equal to 1 for each economic sector and the possibility that the representative consumer will choose to work in the agricultural or non-agricultural sector (π_a, π_n) is collectively equal to 1 in each period of time, so the utility function is:

$$U_t = \left(\frac{b}{e}\right) \ln\left(\psi c_{a,t}^e + (1-\psi) c_{n,t}^e\right) + (1-b)\ln(l_t) \tag{8}$$

where e refers to the rate of substitution of the consumption of agricultural and non-agricultural products. The model refers to the second welfare theorem, whereby that allocation of such resources will create an optimal Pareto the same as resource allocation by a price mechanism. Further, the social planner will decide in the initial period their allocation of consumption $(c_{a,t}, c_{n,t})$, capital stock $(k_{t+1}, k_{n,t})$, and probability of working hours $(\pi_{a,t}, \pi_{n,t})$ in the agricultural and non-agricultural sectors that will be sufficient for the representative consumer to attain their maximum expected utility for their entire life $\left(E_0 \sum_{t=0}^{\infty} \hat{\beta}^t U\left(c_{a,t}, c_{n,t}, l_t\right)\right)$ under the equations and constraint inequalities (1)–(7). Therefore, the dynamic stochastic optimization problems can be expressed as follows:

$$\underset{\{c_{a,t}, c_{n,t}, k_{t+1}, k_{n,t}, \pi_{a,t}, \pi_{n,t}\}_{t=0}^{\infty}}{Max} E_0 \sum_{t=0}^{\infty} \hat{\beta}^t U\left(c_{a,t}, c_{n,t}, l_t\right)$$

, where $\hat{\beta}^t = \eta\beta$, and η and β represent the population growth rate and discount factor, respectively.

METHOD AND PROCUDURES

METHOD OF SOLVING

With respect to the linear-quadratic methods of approximating dynamic programming problems, first, it is necessary to find the variables at a steady state subject to $z_a = z_n = 0$ starting from the solution to maximize the above utility of the representative consumer. When solving the equation from the first-order condition, at steady state, the equation for the capital stock variables in the non-agricultural sector (k_n) and agricultural sector (k_a) will be as follows:

$$k_n = \pi_n \bar{h}_n \left(\frac{\xi + \delta}{\theta \lambda_n}\right)^{1-\theta} \tag{9}$$

where $\xi \equiv \frac{\eta}{\hat{\beta}} - 1$, and η and $\hat{\beta} = \eta\beta$ represent the discount factor and population growth rate, respectively. On the other hand, $\pi_n, \bar{h}_n, \delta, (1-\theta)$, and λ_n stands for the probability that the representative consumer will choose to work in the non-agricultural sector, the number of average working hours in the non-agricultural, the depreciation rate, the labor share parameter in the non-agricultural sector, and the time invariant technology parameter in the non-agricultural sector.

$$k_a = \frac{\mu k_n}{\theta}\left(\frac{s_a}{1-s_a}\right), \tag{10}$$

where $s_a \equiv \frac{p_a y_a}{p_a y_a + y_n}$, and can be identified as a percentage of GDP in the agricultural sector to total GDP. On the other hand, μ and θ represent the capital share parameters in the agricultural and non-agricultural sectors, respectively. Then, we use these to realize c_a, c_n, y_a, y_n, and i at the steady state subject to $z_a = z_n = 0$ (Da-Rocha & Restuccia 2002). Also, when wishing to get numeric figures, the parameter is substituted in the equation.

Then, to map the social planner's problem into a discounted stochastic optimal linear regulator problem, linear quadratic approximations are applied. First, we substitute the non-linear constraints into the objective function. Next, we perform a second-order Taylor series expansion around the steady state and define a transpose of a new state matrix, $\tilde{x}'$, as well as a transpose of a new control matrix, $\tilde{u}'$, as follows: $\tilde{x}_t' = \begin{bmatrix} 1 & \tilde{k}_{t+1} & \tilde{z}_{n,t} & \tilde{z}_{a,t} \end{bmatrix}$ and $\tilde{u}' = \begin{bmatrix} \tilde{k}_{n,t} & \tilde{\pi}_{a,t} & \tilde{\pi}_{n,t} & \tilde{i}_t \end{bmatrix}$. Then, to solve the new optimization problem, stochastic dynamic programming methods are used. We start by formulating Bellman's equation and guess that the value function is quadratic. Next, we solve for the value function by performing Ricatti equation iterations. The solution to the linear quadratic optimization problem is presented ultimately by a state-space representation (state equation and observation equation) (Hansen 1997).

SIMULATION PROCEDURES

Simulation procedures can be separated into three steps: parametrization or calibration, dynamic response, and experiment. In the first step, calibration is performed starting from defining the parameters, which can be categorized into 3 groups based on their origin: 1st group from the average of the figures in each country, 2nd group estimated by an econometric model, and the last group borrowed from previous literature (Table 3.). In the second step, simulation is performed starting from causing a technological shock to occur in the initial period. Basically, this is the so-called dynamic response. Then, we consider the convergence of the technology variable, After that, in the third step, we carry out the experiment by allowing this technological shock to occur in all periods of time and we analyze and compare the results with the stylized fact of each country before conducting a sensitivity analysis of the crucial parameter e.

RESULTS AND DISCUSSION

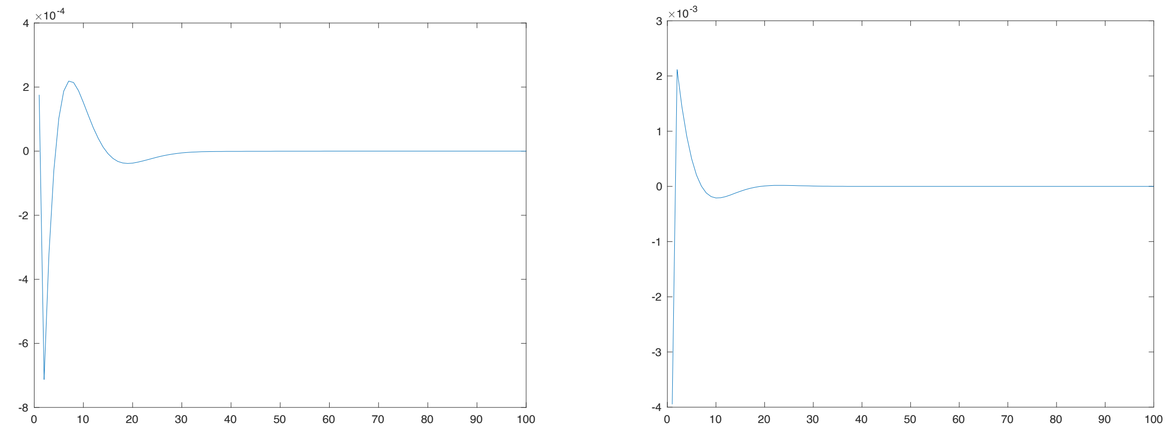
DYNAMIC RESPONSE

Upon experimentally creating a positive technology shock in the non-agricultural sector only in the initial period, it was discovered that the technology level response by the non-agricultural sector to such a shock followed a similar pattern in all the countries under investigation (Figure 2.). Further, the technology level was better in the early stage, but then converged to the level of a steady state, while the technology level response in the agricultural sector to such a shock showed a somewhat similar pattern in Indonesia, Malaysia, Thailand, and Vietnam. In particular, although the shock occurred in the non-agricultural sector, it could, however, still spill over to the agricultural sector. During the initial stage of such a shock, the technology level responded in a negative direction for a short period of time and then returned to a positive direction before converging to a steady state level. In the case of the Philippines, the technology level responded in the positive direction immediately and then converged to a steady state level. These discoveries in ASEAN-5 countries support the research findings for the cases reported for some Organization for Economic Cooperation and Development (OECD) countries and the United states, Thailand, India, and for the developing countries covered in Da-Rocha and Restuccia (2006), Jaroensathapornkul (2010), Emerick (2018), and Lee (2018), respectively, in studies assessing the impacts of shock on the agricultural sector. Apart from this, as the result of the dynamic responses, the cycles for the macroeconomic variables, namely capital stock, consumption, working hours, and output, in ASEAN-5 countries converged to the steady state in the long-run period. According to the experimental results above, this suggests that the theoretical model, i.e., the two-sector RBC model, for each country had enough credibility to take be taken on board for other experiments.

SIMULATION RESULTS

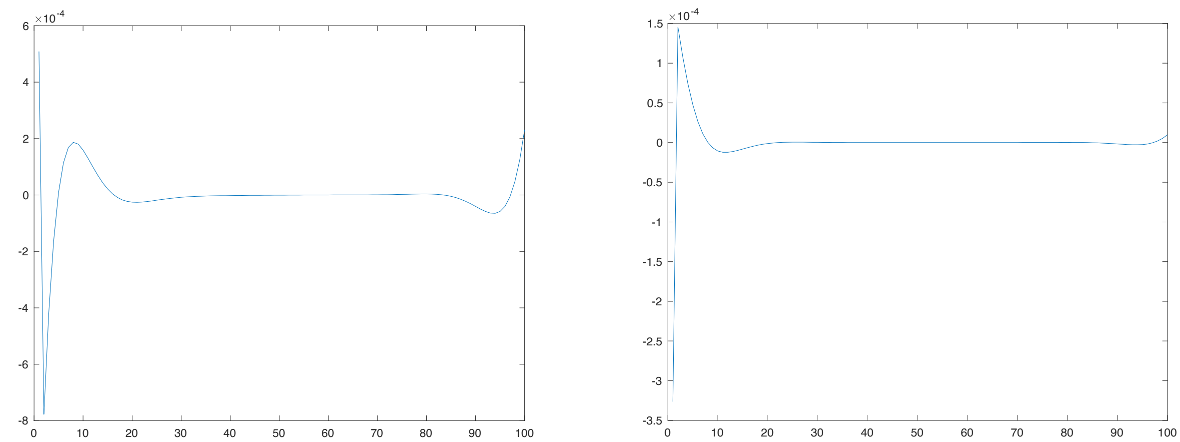
Upon allowing a technological shock to occur in all periods of time (100 simulated periods of time) and comparing the simulation results with the stylized fact of ASEAN-5 countries, it was revealed that the standard deviation reflected the volatility of the real business cycle, implying that the two-sector RBC model could reasonably well replicate the economic fluctuation in a real situation (Table 3). Further, in the cases of Indonesia, the Philippines, and Vietnam, it appeared that the agricultural business cycle showed lower volatility than the real business cycle and the non-agricultural business cycle. This supports the research findings of Han and Kim (1999), who found that a financial shock would cause more damage to the non-agricultural sector than to the agricultural sector in terms of GDP and investment in Korea. On the other hand, in the case of Malaysia, although the model could not well simulate the volatility of the agricultural business cycle, it could, nevertheless, fairly well simulate the volatility of the non-agricultural business cycle to the extent that the volatility was lower than that of the agricultural business cycle. In the case of Thailand, although the model could not simulate the volatility of the non-agricultural business cycle, it could, however, adequately simulate the volatility of the agricultural business cycle similarly to the stylized fact. These experimental results confirmed the notion of the economists in the RBC school that the actual cause of volatility in the real business cycle is a technological shock that can propagate among the various economic sectors of each country.

Considering the coefficients of autocorrelation reflecting the persistence of the business cycle, it was revealed that in the cases of Indonesia, Malaysia, the Philippines, and Vietnam, the two-sector RBC model could replicate the stylized fact to the extent that the real business cycle and agricultural business cycle correlated with their respective Lag in the 1st period in a positive director (Table 4). This implied that the technology shock was embedded and correlated between three periods of time. In addition, upon considering the parameter for correlation reflecting the characteristics of the cycle and if it was procyclical or countercyclical, it was suggested that in all countries, the model could obviously simulate the stylized fact; that is, in all countries, the agricultural business cycle and the non-agricultural business cycle manifested as procyclical. This experimental result reflected how the agricultural business cycle and non-agricultural business cycle moved in the same direction with the



Agricultural sector Non-agricultural sector

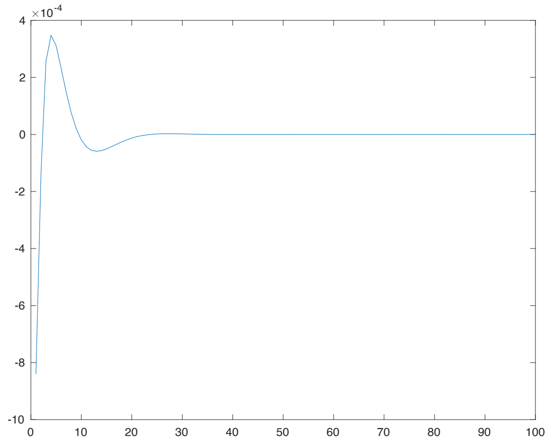
a. Indonesia

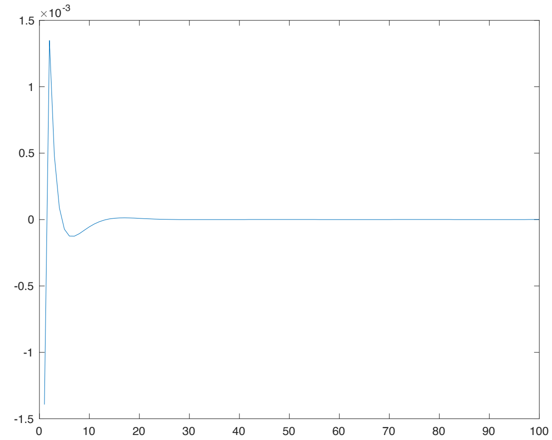


Agricultural sector Non-agricultural sector

b. Malaysia

FIGURE 2. Dynamic response of the technology level toward one-standard-deviation of innovation in the RBC model

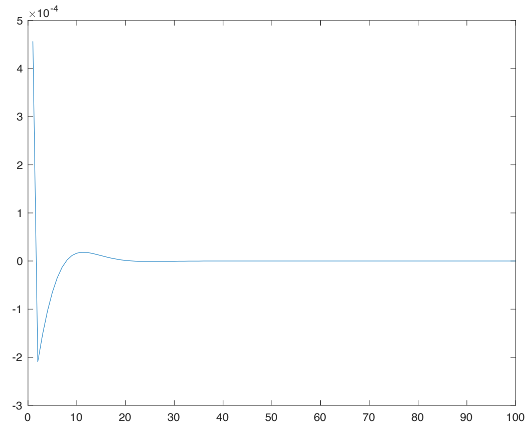


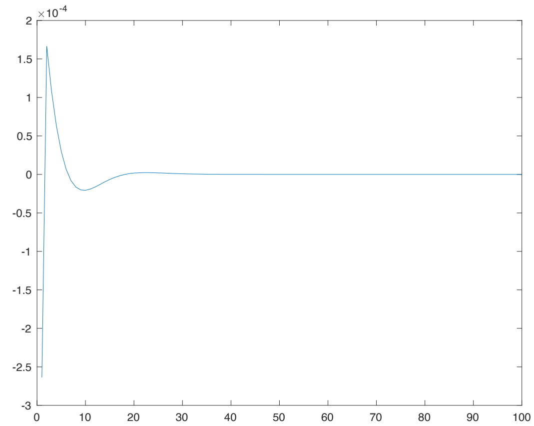


Agricultural sector

Non-agricultural sector

c. The Philippines

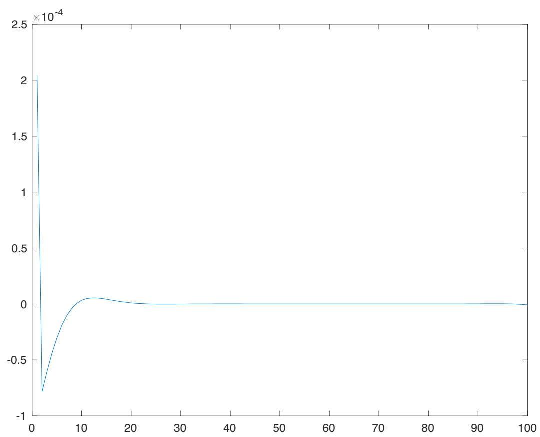


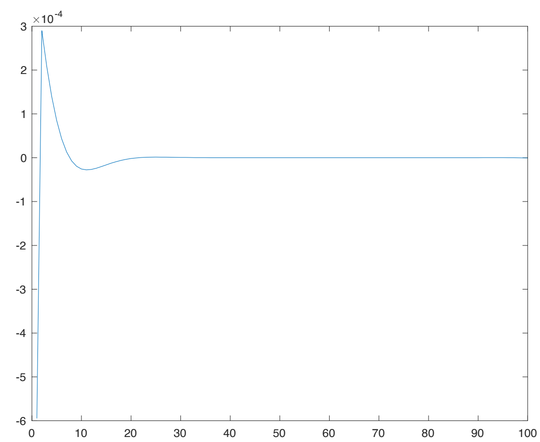


Agricultural sector

Non-agricultural sector

d. Thailand





Agricultural sector

Non-agricultural sector

e. Vietnam

Continues… FIGURE 2. Dynamic response of the technology level toward one-standard-deviation of innovation in the RBC model

TABLE 3. Parameterization

Parameter	Explanation	Indonesia	Malaysia	Philippines	Thailand	Vietnam
η	Population growth rate[a.]	0.0179	0.0229	0.0231	0.0134	0.0170
λ_a	Time invariant technology parameter in the agricultural sector[c.]	0.7209	0.3142	0.6527	0.8294	0.8691
π_a	Probability that the representative consumer will choose to work in the agricultural sector[a.]	0.4777	0.2082	0.4325	0.5496	0.5759
λ_n	Time invariant technology parameter in the non-agricultural sector[b.]	1	1	1	1	1
t	Cultivated area[b.]	1	1	1	1	1
$\overline{h}_a$	Number of average working hours in the agricultural sector[b.]	0.36	0.36	0.36	0.36	0.36
$\overline{h}_n$	Number of average working hours in the non-agricultural sector[b.]	0.5	0.5	0.5	0.5	0.5
ϕ	Labor share parameter in the agricultural sector[d.]	0.2543	0.0713	0.1702	0.1953	0.4617
$1-\theta$	Labor share parameter in the non-agricultural sector[d.]	0.5036	0.8892	0.4120	0.4959	0.4084
s_a	Percentage of GDP in the agricultural sector to total GDP[a.]	0.1606	0.1451	0.1400	0.1282	0.2481
$1-\phi-\mu$	Cultivated area parameter in the agricultural sector[b.]	0.1	0.1	0.1	0.1	0.1
$\rho_{a,n}$	Impact of a technological shock in the non-agricultural sector on the technology level in the agricultural sector[c]	0.1458	2.5909	0.2690	0.0165	-0.0248
$\rho_{n,a}$	Impact of a technological shock in the agricultural sector on the technology level in the non-agricultural sector[c.]	0.0332	-6.20e-05	0.1959	0.0597	0.0868
$\rho_{n,n}$	Impact of a technological shock in the non-agricultural sector on the technology level in the non-agricultural sector[c.]	0.9146	1.0211	0.6120	0.8976	0.9310
$\sigma^2_{a,a}$	Variance of a technology shocks in the agricultural sector originating from a technological shock in the agricultural sector[c.]	5.10e-06	9.90e-05	2.04e-05	1.79e-05	1.65e-07
$\sigma^2_{a,n}$	Variance of a technology shock in the agricultural sector originating from a technological shock in the non-agricultural sector[c.]	-2.20e-06	-1.39e-07	2.57e-06	-1.74e-06	-2.91e-07
$\sigma^2_{n,a}$	Variance of a technology shock in the non-agricultural sector originating from a technological shock in the agricultural sector[c.]	-2.20e-06	-1.39e-07	2.57e-06	-1.74e-06	-2.91e-07
$\sigma^2_{n,n}$	Variance of a technology shock in the non-agricultural sector originating from a technological shock in the non-agricultural sector[c.]	3.88e-05	2.75e-07	7.52e-06	1.55e-05	7.78e-07
δ	Depreciation rate[e.]	0.10	0.10	0.10	0.10	0.10
β	Discount factor[e.]	0.96	0.96	0.96	0.96	0.96
ψ	Weight parameter between the consumption of agricultural and non-agricultural products[b.]	0.50	0.50	0.50	0.50	0.50
b	Weight parameter between consumption and leisure[b.]	0.36	0.36	0.36	0.36	0.36
e	Rate of substitution of the consumption of agricultural and non-agricultural products[b.]	0.52	0.52	0.52	0.52	0.52

Source: [a.] Author's calculations (Source of data: http://www.fao.org) [b.] Da-Rocha and Restuccia (2002). [c.] Author's estimations (The estimated First-Order Autoregressive Model from equation (5)). [d.] Author's calculations (Source of data: Malaysia, Thailand, and Vietnam: Average monthly earnings of employees, International Labor Organization (http://www.ilo.org), the Philippines: Average Daily Basic Pay of Wage Workers by Major Industry Group, the Philippines Statistics Authority (http://www.psa.gov.ph), Indonesia: Average of Net Salary per Month of Employee by Main Industry, National Labor Force Survey (http://www.bi.go.id/sdds), Employment in agriculture and non-agriculture, Food and Agriculture Organization of the United Nations (http://www.fao.org)). [e.] Zimmermann (1997).

real business cycle. This was particularly true for Indonesia and the Philippines, where the model could obviously simulate the stylized fact.

SENSITIVITY ANALYSIS

As the consumption rates of agricultural and non-agricultural products (e) are key parameters in the model and as they are derived from existing research, this study, therefore conducted a sensitivity analysis starting from 0.1 up to 0.6. The simulation results suggested that changes to those parameters could influence the standard deviation reflecting the volatility in the real business cycle, agricultural business cycle, and non-agricultural business cycle in the ASEAN-5 countries (Table 5). Furthermore, by considering an approximation of the standard deviation of the real business cycle, agricultural real business cycle, and non-agricultural real business cycle in the simulated model and those of the stylized fact, in the case of Indonesia, it was implied that parameter e should be in the range of 0.1–0.2 and 0.1–0.3 for the Philippines. This is because, in the case of Indonesia, if parameter e is greater than 0.2, the standard deviations of the real business cycle and agricultural real business cycle in the simulated model will not be able to replicate those of the stylized fact. On the other hand, in the case of the Philippines, the standard deviation of the agricultural real business cycle was around 2.598. However, when parameter e was increased from 0.3 to 0.4, the standard deviation of the agricultural real business cycle in the simulated model decreased from 2.418 to 1.833. Apart from this, parameter e was rather sensitive to volatility of the real business cycle in the cases of Thailand, Malaysia, and Vietnam. In the case of Thailand, when the parameter was increased to 0.6, the standard deviation of the real business cycle in the simulated model decreased from 3.527 to 0.565. At the same time, when the parameter was decreased to 0.4, the standard deviation of the real business cycle in the simulated model decreased from 3.527 to 0.565. It could be said then that such derived parameters (e = 0.52) were rather appropriate. On the other hand, in the cases of Malaysia and Vietnam, these

TABLE 4. Simulation results

a. Indonesia

	Stylized fact				
	SD[b.] (%)	Autocorrelation			Cor.[c.]
		Lag1	Lag2	Lag3	
Real business cycle	3.817	0.887	-0.320	-0.0001	1.000
Agricultural business cycle	1.410	0.612	-0.281	0.101	0.659
Non-agricultural business cycle	4.289	0.875	-0.309	0.004	0.998
	Two-Sector RBC Model[a.]				
Real business cycle	4.671 (0.442)	0.551 (0.089)	0.131 (0.106)	-0.117 (0.115)	1.000
Agricultural business cycle	1.827 (0.187)	0.503 (0.080)	0.104 (0.101)	-0.117 (0.113)	0.646 (0.088)
Non-agricultural business cycle	3.743 (0.331)	0.268 (0.112)	0.021 (0.101)	-0.098 (0.100)	0.929 (0.011)

b. Malaysia

	Stylized fact				
	SD[b.] (%)	Autocorrelation			Cor.[c.]
		Lag1	Lag2	Lag3	
Real business cycle	3.571	0.727	-0.216	0.040	1.000
Agricultural business cycle	2.900	0.441	-0.063	0.120	0.107
Non-agricultural business cycle	0.389	0.832	-0.243	0.004	0.991
	Two-Sector RBC Model[a.]				
Real business cycle	2.898 (0.587)	0.058 (0.290)	0.077 (0.147)	-0.081 (0.144)	1.000
Agricultural business cycle	6.950 (0.965)	0.025 (0.145)	0.123 (0.115)	-0.119 (0.111)	0.270 (0.415)
Non-agricultural business cycle	6.671 (0.944)	-0.201 (0.129)	0.123 (0.137)	-0.100 (0.125)	0.071 (0.422)

Continues…

c. The Philippines

	Stylized fact				
	SD[b.] (%)	Autocorrelation			Cor.[c.]
		Lag1	Lag2	Lag3	
Real business cycle	3.440	1.041	-0.485	-0.064	1.000
Agricultural business cycle	2.598	0.531	-0.152	-0.002	0.651
Non-agricultural business cycle	3.758	1.064	-0.520	-0.052	0.996
	Two-Sector RBC Model[a.]				
Real business cycle	3.629 (0.567)	0.537 (0.102)	0.112 (0.106)	-0.164 (0.099)	1.000
Agricultural business cycle	1.275 (0.119)	0.399 (0.106)	0.053 (0.108)	-0.157 (0.091)	0.527 (0.130)
Non-agricultural business cycle	3.629 (0.567)	0.298 (0.129)	0.028 (0.106)	-0.161 (0.097)	0.938 (0.014)

d. Thailand

	Stylized fact				
	SD[b.] (%)	Autocorrelation			Cor.[c.]
		Lag1	Lag2	Lag3	
Real business cycle	4.274	1.054	-0.312	-0.120	1.000
Agricultural business cycle	2.539	-0.013	-0.269	-0.041	0.411
Non-agricultural business cycle	4.687	1.038	-0.258	-0.156	0.997
	Two-Sector RBC Model[a.]				
Real business cycle	3.527 (0.493)	0.291 (0.185)	0.002 (0.108)	-0.188 (0.113)	1.000
Agricultural business cycle	2.743 (0.318)	0.352 (0.171)	0.025 (0.109)	-0.191 (0.121)	0.995 (0.001)
Non-agricultural business cycle	0.843 (0.240)	0.068 (0.167)	-0.093 (0.088)	-0.179 (0.094)	0.940 (0.027)

e. Vietnam

	Stylized fact				
	SD[b.] (%)	Autocorrelation			Cor.[c.]
		Lag1	Lag2	Lag3	
Real business cycle	2.781	0.588	-0.007	-0.469	1.000
Agricultural business cycle	2.515	0.404	-0.88	-0.456	0.854
Non-agricultural business cycle	3.045	0.680	-0.014	-0.431	0.987
	Two-Sector RBC Model[a.]				
Real business cycle	1.462 (0.272)	0.417 (0.148)	0.063 (0.134)	-0.152 (0.119)	1.00
Agricultural business cycle	0.222 (0.026)	0.491 (0.111)	0.099 (0.116)	-0.130 (0.120)	0.375 (0.223)
Non-agricultural business cycle	1.391 (0.278)	0.306 (0.159)	0.014 (0.129)	-0.148 (0.110)	0.989 (0.003)

Note: [a.] Number in parentheses denotes the simulation's standard deviation. [b.]SD denotes the standard deviation. [c.]Cor. denotes the correlation coefficient.

TABLE 5. Sensitivity analysis of *e* in the volatility of the real business cycle

a. Indonesia[a.]

Standard Deviation (%)	$e = 0.1$	$e = 0.2$	$e = 0.3$	$e = 0.4$	$e = 0.52$	$e = 0.6$
Real business cycle	2.589 (0.597)	3.875 (0.614)	4.185 (0.702)	4.513 (0.541)	4.671 (0.442)	6.108 (0.759)
Agricultural business cycle	1.439 (0.505)	1.774 (0.519)	1.802 (0.290)	1.888 (0.260)	1.827 (0.187)	1.832 (0.207)
Non-agricultural business cycle	1.751 (0.570)	2.904 (0.624)	3.275 (0.804)	3.600 (0.738)	3.743 (0.331)	4.599 (0.608)

b. Malaysia[a.]

Standard Deviation (%)	$e = 0.1$	$e = 0.2$	$e = 0.3$	$e = 0.4$	$e = 0.52$	$e = 0.6$
Real business cycle	1.294 (0.616)	1.705 (0.636)	1.763 (0.519)	2.740 (0.784)	2.898 (0.587)	Na
Agricultural business cycle	1.301 (0.568)	2.000 (0.661)	2.508 (0.572)	4.473 (0.883)	6.950 (0.965)	Na
Non-agricultural business cycle	0.369 (0.033)	0.734 (0.100)	1.334 (0.144)	2.414 (0.363)	6.671 (0.944)	Na

c. The Philippines[a.]

Standard Deviation (%)	$e = 0.1$	$e = 0.2$	$e = 0.3$	$e = 0.4$	$e = 0.52$	$e = 0.6$
Real business cycle	3.760 (0.937)	3.961 (0.472)	3.980 (0.504)	3.881 (0.535)	3.629 (0.567)	4.812 (1.247)
Agricultural business cycle	2.308 (0.993)	2.499 (0.269)	2.418 (0.326)	1.833 (0.113)	1.275 (0.119)	1.222 (0.076)
Non-agricultural business cycle	2.467 (0.962)	2.581 (0.447)	2.903 (0.679)	3.271 (0.750)	3.629 (0.567)	3.941 (1.303)

d. Thailand[a.]

Standard Deviation (%)	$e = 0.1$	$e = 0.2$	$e = 0.3$	$e = 0.4$	$e = 0.52$	$e = 0.6$
Real business cycle	2.585 (0.352)	2.943 (0.489)	3.557 (1.495)	2.901 (0.752)	3.527 (0.493)	0.565 (0.083)
Agricultural business cycle	2.281 (0.326)	2.446 (0.445)	2.020 (1.064)	2.228 (0.529)	2.743 (0.318)	0.351 (0.038)
Non-agricultural business cycle	0.344 (0.070)	0.652 (0.140)	1.576 (0.477)	1.025 (0.278)	0.843 (0.240)	0.338 (0.039)

e. Vietnam[a.]

Standard Deviation (%)	$e = 0.1$	$e = 0.2$	$e = 0.3$	$e = 0.4$	$e = 0.52$	$e = 0.6$
Real business cycle	0.284 (0.069)	0.466 (0.115)	0.683 (0.190)	0.885 (0.246)	1.462 (0.272)	1.772 (0.860)
Agricultural business cycle	0.112 (0.015)	0.158 (0.023)	0.188 (0.023)	0.210 (0.028)	0.222 (0.026)	0.198 (0.022)
Non-agricultural business cycle	0.196 (0.082)	0.363 (0.128)	0.589 (0.215)	0.787 (0.271)	1.391 (0.278)	1.714 (0.887)

Note: [a.]Number in parentheses denotes the simulation's standard deviation.

sets of sensitivity analysis could not render clarity of such a parameter e, especially in the case of Malaysia, as when $e = 0.6$, the model could not simulate the real number in the standard deviation, autocorrelation, or correlation coefficient.

CONCLUSIONS

During the period between 1971 and 2015, the stylized fact of the business cycles of Indonesia, Malaysia, the Philippines, Thailand, and Vietnam suggested that in all of the said countries, their real business cycles showed more volatility than that of their agricultural business cycles. This research study, therefore, aimed to simulate such a stylized fact using the two-sector RBC model developed by DA-Rocha and Restuccia (2002). The theoretical modeling was initiated by assuming that a representative consumer would consume both agricultural and non-agricultural products. From that point, the model utilized the second welfare theorem assuming the case of a social planner making a choice in the initial stage about the consumption of capital stock and working hours in the agricultural and non-agricultural sectors in order to allow a representative agent to achieve maximum utility for their entire life under certain economic constraints and technology shocks occurring in the agricultural and non-agricultural sectors. The mathematical methods applied for solving such problems for the social planner included linear quadratic approximations and stochastic dynamic programming methods.

The result of the dynamic response analysis suggested that the model was credible, as when a technology shock occurred in the initial period, it had influence upon the variables during such an initial stage and the variables then gradually converged to a steady state. By furthering the experiment by allowing the technology shock to occur in all periods, it was revealed that the model could still well simulate the stylized fact, in terms of the volatility of the real business cycle, agricultural business cycle and non-agricultural business cycle. In other words, although this model may be far from the real economic situation, it could, however, pretty well explain short-term economic volatility in ASEAN countries. It could be implied that a technology shock in the agricultural and non-agricultural sectors was correlated to each other and could have an influence upon economic volatility in the two such sectors. However, efforts to minimize such volatility through fiscal and monetary policy may not be the basic approach of the RBC school as such volatility occurs under the maximum utility of the representative agent. The government should therefore use their best efforts to manage public goods efficiently. Moreover, the result of the dynamic response implied that the positive impact on agricultural GDP in ASEAN-5 countries was derived from not only the positive technological shock in the agricultural sector but also in the non-agricultural sector. Therefore, in order to improve the technological level in ASEAN countries, the government should play a significant role in promoting research and development (R&D) by budget allocation and the use of tax instruments. Apart from this, some limitations of this study should be noted and addressed in future research, including: (1) Instead of the HP filter, the Baxter–King (BK) filter is another method for smoothing time series data. Conceptually, Baxter and King (1999) proposed a modification of the HP filter that provides a wider chance to remove a cyclic component of a time series data. (2) The two-sector RBC model focused on agricultural and non-agricultural sectors in ASEAN-5 countries could be developed into an international two-sector RBC model among heterogeneous countries. Last but not least, (3) parameterization could be improved for each country since several parameters in this research article were derived from the previous literature.

ACKNOWLEDGEMENT

This research article was financially supported by the Faculty of Economics, Srinakharinwirot University.

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