Journal of Innovation in Business and Economics
Vol. 07 No. 02 December 2023 Page 139-158
P-ISSN: 2580-9431 E-ISSN: 2581-2025 http://ejournal.umm.ac.id/index.php/jibe

Received: 25-07-2023 | Revised in Revision: 26-09-2023 | Accepted: 13-11-2023

Real Business Cycle: Stochastic driving force decomposition of output dynamics in East Java

Mochamad Rofik[1], Ayu Dwidyah Rini[2], David Kaluge[3], Rafael Alfarado[4]
PhD Student in Economics, Universitas Brawijaya, Indonesia[1,2]
Department of Economics, Universitas Brawijaya, Indonesia[3]
Department of Economics, Universidad Nacional de Loja, Ecuador[4]

DOI: https://doi.org/10.22219/jibe.v7i02.28160

Abstract
This study aims to examine output dynamics in East Java using the Real Business Cycle (RBC) model. We constructed an RBC model with two stochastic shocks originating from the demand and supply sides. The RBC model in this study indicates that output dynamics, driving the business cycle in East Java, are predominantly influenced by exogenous shocks from the demand side. Moreover, the model reveals that certain variables, such as wage levels, consumption, and capital accumulation, display inertia patterns in response to shocks. Therefore, by releasing the assumptions underlying the RBC model and incorporating fiscal and monetary policies, we contend that the response time lag exhibited by some of these variables can provide authorities with an advantageous opportunity to mitigate the impact of shocks and formulate effective policies. Additionally, understanding the sources of shocks and the timing of policy implementation are identified as the two primary factors determining policy effectiveness.

Keywords: Real Business Cycle; stochastic shock; dynamic output; East Java

Introduction

The business cycle, a fundamental phenomenon in the economy, has been extensively addressed in the literature. Analysis of the business cycle offers valuable insights into the economic structure of a region, revealing factors such as the level of technological progress, resilience, and future growth projections. By scrutinizing the patterns and dynamics of the economy over time, we can discern the strengths and weaknesses of an economy, enabling the formulation of policies to enhance its growth potential and mitigate excessive aggregate output dynamics. Classical economists typically employ the Real Business Cycle (RBC) model to analyze the output dynamics that propel business cycles (Rebelo, 2010; Romer, 2015).

Research in this area has underscored the significance of various factors, including shocks to technology and aggregate demand, in propelling economic fluctuation (Fernández-Villaverde & Guerrón-Quintana, 2020; Jawadi et al., 2022; Li et al., 2022). Furthermore, the insights derived from business cycle analysis contribute to well-informed decision-making on economic policies. Jaroensathapornkul (2020); and Jawadi et al. (2022) emphasize that analyzing the business cycle allows us to assess a region's economic health and resilience in the face of external shocks. In this context, the RBC model assumes a crucial role by providing a framework to comprehend the underlying mechanisms driving these economic fluctuations (Romer, 2015)

The RBC model assumes that aggregate output is a variable generated by the decisions of each economic agent, and these decisions are made with the assumption that each agent is oriented towards optimizing utility with all the resource constraints it faces. This indicates that the RBC model is based on

[1]E-mail: mochamadrofik@student.ub.ac.id

microeconomic theory that seeks to understand how individuals respond to optimize utility (Prescott & Kydland, 1990; Romer, 2015). Specifically, Plosser (1989) revealed that the RBC model is an attempt to investigate individual responses to utility optimization and measure how it influences the overall economic equilibrium. The RBC model also explains how fluctuations in aggregate output occur and how these fluctuations are influenced by exogenous factors such as technology shock and resource availability (Fernández-Villaverde & Guerrón-Quintana, 2020; Plosser, 1989; Romer, 2015).

Although the RBC model in this study does not involve the variables of money quantity and fiscal policy, it does not mean that this research overlooks the roles of monetary and government institutions. The study assumes that monetary and fiscal policies, in general, can smooth the changes in output dynamics that drive business cycles (Mountford & Harald, 2009; Ocampo & Ojeda-Joya, 2022). Therefore, in the latest section of our results and discussion, we release the assumptions underlying the model and discuss the output dynamics from the perspectives of fiscal and monetary policies. We argue that this is important because the roles of monetary and fiscal authorities cannot be overlooked in the economy, including in East Java, which can be categorized as a small open regional economy in Indonesia.

Numerous empirical studies have investigated the dynamics of economic growth (Amalia et al., 2018; Susilo et al., 2020), consumption (Zulkarnain, 2022), investment (Qurrata & Ramadhani, 2021), as well as unemployment and wages (Christianto et al., 2022) in East Java. However, these studies often rely on regression analysis or autoregressive models without robust theoretical foundations. Drawing on the existing literature, we assert that our paper represents the first attempt to construct a RBC model in East Java. Additionally, previous literature generally fails to discern whether fluctuations in aggregate output stem from the demand or supply side. Identifying the driving factors of shocks is pivotal for the effectiveness of fiscal and monetary policies.

Thus, instead of solely constructing an RBC model for East Java Province with shocks from the demand side, we extend our model to incorporate potential shocks from the supply side. This enhancement allows a comprehensive understanding of the sources of economic fluctuations. Our study provides valuable insights for policymakers to formulate appropriate policies that ensure effective and efficient policy transmission. For instance, assuming economic shocks in East Java result from both the demand and supply sides, policies directed solely towards the demand side—such as monetary interventions or direct cash assistance—might not yield optimal results and could even be counterproductive. By utilizing the RBC model, policymakers gain insights into how economic agents respond to various shocks, enabling policies that are not only data-driven but also consider the sources of shocks.

The rest of this paper consists of three main parts: 1) the construction of the model that explains in detail how the RBC model is built with its underlying assumptions; 2) the results and discussion that explain how economic variables respond to shocks from the demand and supply sides, including nowcasting and forecasting, as well as policy implications when the assumptions are relaxed; and 3) the conclusion that contains a summary and policy recommendations.

Research Method

Following the classical RBC model, our study incorporates several key assumptions. Firstly, we assume perfect competition, creating an environment where firms and households operate without dominant market power, barriers, and with perfect information flow. This assumption allows economic agents the flexibility to allocate resources freely and efficiently in response to changes in economic conditions, while also presupposing that agents hold rational expectations. Secondly, we assume flexible prices and wages. This implies that prices and wages respond instantly to changes in supply and demand conditions. The assumption further suggests that markets quickly clear, with no nominal rigidities hindering market adjustments. Thirdly, our RBC model employs an agent-based framework, assuming that all households and firms share identical preferences, technologies, and behaviors. While a simplification, this assumption facilitates aggregation.

In addition to these fundamental assumptions, we underscore the role of exogenous shocks in driving aggregate output dynamics. Specifically, our study posits that shocks originate from two sources: demand-side shocks and supply-side shocks. These shocks are assumed to follow a stochastic or random process, with demand-side shocks impacting the technology efficiency of firms, and supply-side shocks influencing the operational costs of firms. Ultimately, these shocks lead to dynamic changes in aggregate output, driving business cycles. Furthermore, our model assumes no government intervention or monetary authority, operating within a closed economic system. Consequently, our RBC model focuses on market forces, representing macroeconomic variables' behaviors in response to exogenous stochastic shocks from both the demand and supply sides.

Household

Suppose that households maximize their utility based on only two choices, consumption (C), or leisure (L), as represented by equation (1). Using a logarithmic transformation, the utility function follows equation (2). Meanwhile, all income is used for consumption and savings (ς), with all saving being used for investment (I), as represented by equation (3). However, households face budget constraints when maximizing their utility; choosing current consumption or deferring consumption in the future through savings. Households are constrained by total income, which is the product of working hours (H) and wage rates (W) plus investment returns (r), i.e., the rate of return multiplied by the amount of capital. Mathematically, this is represented by equation (4).

$$\max_{C_t, L_t} E_t \sum_{t=0}^{\infty} \beta^t \; u\,(C_t, L_t), \beta > 0 \tag{1}$$
$$\max_{C_t, L_t} E_t \sum_{t=0}^{\infty} \beta^t \; [\log(C_t) + \delta\, Log\,(L_t)], \beta > 0 \tag{2}$$
$$\varsigma_t = I_t \tag{3}$$
$$C_t + \varsigma_t = W_t H_t + r_t K_t \tag{4}$$

Furthermore, this study defines the accumulation of capital over time, also known as the capital accumulation law, following equation (5). This equation states that the level of capital in the current period (K_t) is equal to the investment in the current period (I_t) plus the level of capital in the previous period (K_{t-1}), adjusted for the depreciation rate (δ). This assumption also reflects the reality that assets deteriorate and become less productive over time. The capital accumulation law in equation (5) also shows that higher levels of investment lead to greater accumulation of capital and ultimately can result in higher levels of output. Meanwhile, the level of investment is certainly dependent on intertemporal consumption (equation 4), if households tend to prefer to defer consumption, then savings tend to increase, and as a result, the level of investment will also be higher and vice versa. Also, the level of intertemporal consumption depends on the rate of investment return, with higher rates of return tend to encourage households to defer consumption.

$$K_t = I_t + (1 + \delta)\, K_{t-1} \tag{5}$$
$$C_t + K_{t+1} = W_t H_t + (1 + R_t - \delta) K_t \tag{6}$$

By substituting equation (5) into equation (4), the final budget constraint equation is obtained as shown in equation (6). Then, this study normalizes total time, so that the total time available to labor is equal to 1, and we define leisure (L) as total time minus working hours, following equation (7). By substituting equation (7) into equation (2), the household optimization problem follows equation (8); with the constraint in equation (6), the final utility optimization constraint equation follows equation (9).

$$L_t = 1 - H_t \tag{7}$$
$$\max_{C_t, H_t} E_t \sum_{t=0}^{\infty} \beta^t \,[Log\,(C_t) + \delta Log(1 - H_t)] \tag{8}$$
$$\max_{C_t, H_t, K_{t+i}} \mathcal{L} = \sum_{t=0}^{\infty} \beta^t \{[Log(C_t) + \delta Log(1 + H_t)] - \lambda_t [C_t + K_{t+1} - W_t H_t - (1 + R_t - \delta) K_t]\} \tag{9}$$

The solution to equation (9) is obtained from the first derivative of consumption (C), working hours (H) and capital in the future period (K_{t+1}) as shown in equations (10)-(12).

$$\frac{\delta \mathcal{L}}{\delta C_t} = \beta^t \frac{1}{C_t} - \lambda_t = 0 \rightarrow \lambda_t = \frac{1}{C_t} \tag{10}$$
$$\frac{\delta \mathcal{L}}{\delta H_t} = \beta^t - \gamma \frac{1}{1 - H_t} + \lambda_t W_t = 0 \rightarrow \lambda_t W_t = \frac{\gamma}{1 - H_t} \tag{11}$$
$$\frac{\delta \mathcal{L}}{\delta K_{t+1}} = \beta^t - \lambda_t + \beta^{t+1} \lambda_{t+1} (1 + R_{t+1} - \delta) \rightarrow \beta^t \lambda^t = \beta^{t-1} \lambda_{t+1} (1 + R_{t+1} - \delta) \tag{12}$$

Substituting equation (10) into equation (11) yields equation (13). Equation (13) depicts the trade-off between working hours and leisure time, where workers must decide how many hours (H) to allocate to work, considering the wage rate (W) and the opportunity cost of leisure time $(C\gamma)$. Labor utility will be maximized when the marginal benefit of an additional hour of leisure time is equal to the marginal benefit of an additional hour of work. The parameterγ represents how important leisure time is to the labor, where a higher value of γ indicates a greater preference for leisure. $W_t - C_t\gamma$ represents the net wage, which is the amount of wage received by the labor after considering the opportunity cost of leisure time. Therefore, this equation can be interpreted as the fraction of time allocation chosen by the labor from the total available time.

$$\frac{1}{C_t}W_t = \frac{\gamma}{1-H_t} \rightarrow 1 - H_t = \frac{C_t\gamma}{W_t}$$

$$H_t = 1 - \frac{C_t\gamma}{W_t}$$

$$H_t = \frac{W_t - C_t\gamma}{W_t} \quad (13)$$

Equation (14) is obtained by substituting equation (10) into equation (12). Equation (14) is an intertemporal budget constraint that describes how households allocate income. $\frac{C_{t+1}}{C_t}$ represents the expected consumption ratio in the next period to current consumption. This ratio is also known as the marginal rate of substitution between consumption in different time periods, and this equation explains how households face trade-offs between consuming now or in the future. β represents the household discount factor multiplied by the expected rate of return in period $t+1$, and δ is the depreciation rate.

$$\beta^t \frac{1}{C_t} = \beta^{t+1}\frac{1}{C_{t+1}}(1 + R_{t+1} - \delta)$$

$$\beta^t \frac{C_{t+1}}{C_t} = \beta^{t+1}(1 + R_{t+1} - \delta)$$

$$\frac{C_{t+1}}{C_t} = \frac{\beta^{t+1}}{\beta^t}(1 + R_{t+1} - \delta) = \beta(1 + R_{t+1} - \delta)$$

$$\frac{C_{t+1}}{C_t} = \beta(1 + R_{t+1} - \delta) \quad (14)$$

The intertemporal budget constraint implies that households will save more when the expected investment return is higher. The equation also explains the concept of time preference, which reflects how much households value their current wealth relative to the utility they will gain by delaying consumption. A higher β indicates that households place a higher value on future consumption relative to current consumption, and therefore, households will be more willing to allocate a larger portion of their income for investment. Equations (13) and (14) are the final solutions to the household utility optimization problem.

Firm

The productivity level of firms in this study is based on the Cobb-Douglas production function. In order to model the total factor production of East Java, we extended the traditional Cobb-Douglas production function. Specifically, K represents the input of capital, H represents the input of labor measured in hours, and S represents raw materials or intermediate goods, which will be referred to as input goods. In this model, output is a function of the level of capital, labor, and input goods used in production, implementing a constant elasticity of substitution. This elasticity of substitution is represented by α, which is the elasticity of output with respect to capital, H is the elasticity of output with respect to working hours or labor, and the parameter $1-\alpha-\theta$ is the elasticity of output with respect to input goods. Meanwhile, A represents the level of technology. Mathematically, these assumptions are represented by equation (15).

$$Y_t = A_t K^{\alpha} H^{\theta} S^{1-\alpha-\theta} \quad (15)$$

The production function is a key element in the RBC model, as economic fluctuations will depend heavily on the level of technology and the availability of input goods. Referring to equation (15), in principle, firms seek to maximize their production, but they face constraints on the cost of capital, labor, and the availability and price of input goods, which mathematically follows equation (16). The firm's production optimization problem with its constraints is formally expressed in equation (17).

$$K_t r_t + H_t W_t + P_t S_t \tag{16}$$

$$\max_{K_t, H_t, Q_t} \pi = \sum_{t=0}^{\infty} A_t K_t^{\alpha} H_t^{\theta} S_t^{1-\alpha-\theta} - \lambda(K_t r_t + H_t W_t + P_t S_t) \tag{17}$$

The optimization function in equation (17) is solved by taking the first derivative for each input variable, namely capital, working hours, and input goods supply, resulting in equations (18)-(20). Through algebraic manipulation, we obtain the equations for the return on investment, wages, and price of input goods, respectively shown in equations (21)-(23).

$$\frac{\delta\pi}{\delta K_t} = \alpha\, A_t K_t^{\alpha-1} H_t^{\theta} S_t^{(1-\alpha-\theta)} - r_t \tag{18}$$

$$\frac{\delta\pi}{\delta H_t} = \theta A_t K_t^{\alpha} H_t^{\theta-1} S_t^{(1-\alpha-\theta)} - W_t \tag{19}$$

$$\frac{\delta\pi}{\delta Q_t} = (1-\alpha-\theta) A_t K_t^{\alpha} H_t^{\theta} S_t^{-\alpha-\theta} - P_t \tag{20}$$

Equation (21) describes the dynamics of the investment return (r), Y represents output, and K represents the stock of capital, and $\frac{Y}{K}$ indicates the output-to-capital ratio, or a measure of productivity and efficiency, which reveals how much output is produced per unit of capital. The parameter α represents the sensitivity of interest rates to changes in the output-to-capital ratio. A higher value of α indicates a stronger relationship between the investment return and the output-to-capital ratio, implying that changes in productivity have a larger impact on the rate of return. In this model, changes in the investment return can have a significant effect on investment decisions, as the investment return affects the cost of capital that must be paid by firms and the expected returns on investment by households.

$$r_t = \alpha\, A_t K_t^{\alpha-1} H_t^{\theta} S_t^{1-\alpha-\theta}$$

$$r_t = \alpha\, A_t \frac{K_t^{\alpha}}{K_t} H_t S_t^{1-\alpha-\theta}$$

$$r_t = \alpha \frac{Y_t}{K_t} \tag{21}$$

W in equation (22) represents wages, θ represents a constant parameter, Y represents output, and H represents the number of working hours. $\frac{Y}{H}$ represents output per hour, which is a measure of labor productivity or efficiency and indicates how much output is produced per unit of work input in hours. The parameter θ describes the sensitivity of wages to changes in the output per hour ratio; a higher θ value implies a stronger relationship between wages and output per hour and is an indicator of the sensitivity of productivity or efficiency changes to wage levels. Equation (22) generally represents how the dynamics of output and working hours can affect wage levels.

$$W_t = \theta A_t K_t^{\alpha} H_t^{\theta-1} S_t^{(1-\alpha-\theta)}$$

$$W_t = \theta A_t K_t^{\alpha} \frac{H_t^{\theta}}{H_t} S_t^{(1-\alpha-\theta)}$$

$$W_t = \theta \frac{Y_t}{H_t} \tag{22}$$

Equation (23) explains the relationship between output (Y), the use of input goods (S), and the elasticity of substitution between inputs represented by α and θ. This equation shows that output is a function of the level of input goods used in production, and these inputs are combined using a production function with a constant elasticity of substitution. The parameter $1-\alpha-\theta$ represents the elasticity of substitution between these inputs. This elasticity of substitution equation also captures the firm's response to changes in input prices (P). For example, if the relative price of input goods increases, this equation can show the policy that the company will take, which is to reduce the use of input goods and switch to other inputs that are relatively cheaper, such as increasing labor or capital. Equation (23) also provides a clear understanding that scarcity of input goods will lead to higher price of input goods, and according to equation (17), this will reduce output.

$$P_t = (1-\alpha-\theta)A_t K_t^{\alpha} H_t^{\theta} S_t^{-\alpha-\theta}$$
$$P_t = (1-\alpha-\theta)A_t K_t^{\alpha} H_t^{\theta} S_t^{(1-\alpha-\theta)-1}$$
$$P_t = (1-\alpha-\theta)A_t K_t^{\alpha} H_t^{\theta} \frac{S_t^{(1-\alpha-\theta)}}{S_t}$$
$$P_t = (1-\alpha-\theta)\frac{Y_t}{Q_t} \quad (23)$$

Decomposition of stochastic shock

In this study, we divide shocks into two parts, namely shocks originating from the demand side represented by the disruption of technology efficiency, and shocks originating from the supply side represented by the disruption in the supply of input goods. To simplify both shocks, we assume that they are auto-regressive with the addition of stochastic shocks.

Demand shock

Equation (24) explains how technology is affected by persistent stochastic shocks over time. Specifically, parameter ρ_1 determines the magnitude level of technology shocks, where a higher value of $\rho_1$indicates that the current period's technology is influenced by the level of technology in the previous period. Meanwhile, e is assumed to be an independently and identically distributed (IID) random variable with a mean of zero and a limited variance. Linearization is employed for ease of estimation while remaining consistent with the assumption that technology shocks are relatively small in relation to the current period's level of technology, but unpredictable and varying over time.

$$A_t = A_{t-1}^{\rho_1} e^{u_t}$$
$$\ln A_t = \rho_1 \ln A_{t-1} + e_t$$
$$a_t = \rho_1 a_t + e_t \quad (24)$$

We assume that e is not only caused by changes in technological developments but can also be caused by consumer preferences and behavior that may change over time due to various factors such as cultural shifts, demographic changes, and changing social norms. Changes in consumer behavior may not be immediately adaptable by companies, leading to a time lag between changes in consumer preferences and a company's ability to effectively adjust production processes to accommodate changing tastes. Companies may need to invest in new technology, add production facilities, or retrain workers to meet constantly changing consumer demand. Consequently, when companies cannot quickly adjust their production processes, it can result in decreased efficiency and productivity. Lower levels of production due to slow adaptation to technology can lead to a decline in economic output, lower working hours, and a decrease in consumption and investment, leading to an economic slowdown.

Supply shock

In this study, we define the supply of input goods (S) as the multiplication of natural supply (m) with the level of input goods supply (Z), which follows equation (25). Equation (26) is the logarithmic linearization of the stochastic process for the input goods supply shock. In this equation, z represents the input goods supply shock, and u is the stochastic error. The parameter ρ_2 represents the persistence of the shock, providing information about how much the current shock is related to the previous shocks. Furthermore, like demand-side shocks, supply-side shocks are also stochastic, persistent, and unpredictable.

$$S = Z.m \quad (25)$$
$$Z_t = Z_{t-1}^{\rho_2} e^{u_t}$$
$$\ln Z_t = \ln(Z_{t-1}^{\rho_2} e^{u_t})$$
$$\ln Z_t = \rho_2 \ln Z_{t-1} + u_t$$
$$z_t = \rho_2 z_{t-1} + u_t \quad (26)$$

Competitive equilibrium

In the RBC model, competitive equilibrium is a state in which all agents in the economy simultaneously optimize their decisions according to the constraints they face. Based on the model construction in subsection 2.3 and the addition of one equation representing the goods market clearing, competitive equilibrium is represented by 11 conditions as shown in Table 1.

Table 1. Dynamic equilibrium

No	Equation	Notes
1	$Y = C + I$	Goods market clearing
2	$K_t = I_t + (1+\delta)\, K_{t-1}$	Capital accumulation
3	$\frac{C_{t+1}}{C_t} = \beta(1 + R_{t+1} - \delta)$	Intertemporal consumption
4	$Y_t = A_t K^{\alpha} H^{\theta} S^{1-\alpha-\theta}$	Production function
5	$P_t = (1-\alpha-\theta)\frac{Y_t}{S_t}$	Price of input goods
6	$S = Z.m$	Supply on input goods
7	$H_t = \frac{W_t - C_t\gamma}{W_t}$	Labor market clearing
8	$r_t = \alpha\frac{Y_t}{K_t}$	Investment return
9	$W_t = \theta\frac{Y_t}{H_t}$	Wages
10	$\ln A_t = \rho_1 \ln A_{t-1} + e_t$	Demand shock
11	$\ln Z_t = \rho_2 \ln Z_{t-1} + u_t$	Supply shock

Table 2. Calibration parameter

Parameter	Value	Parameter	Initial value
α	0.26	Y	1
β	0.99	C	0.7
γ	0.4	I	0.3
θ	0.65	K	3.5
δ	0.08	H	0.33
m	0.07	R	0.05
ρ_1	0.95	w	0.57
ρ_2	0.95	a	1
		z	1
		e	0
		u	0
		S	$s = Z.m$
		P	$P_t = (1-\alpha-\theta)\frac{Y_t}{S_t}$

Calibration and Model Solution

Calibration refers to the process of assigning values to the theoretical model parameters based on empirical evidence and existing literature. Calibration is an important step in this study because it relates to the model's ability to replicate real-world phenomena and make predictions about how economic agents behave, particularly the endogenous variables' behavior in response to shocks caused by exogenous variables. For parameters α and θ, we refer to Silangen (1994), while for the initial value of δ is 8%. For the parameter β and γ, we refer to Jegajeevan (2016). We suppose that parameter m has a value of 0.07, assume that the manufacture added value is around 14.23 times refer to Zamora et al. (2014). Meanwhile, for ρ_1 and ρ_2, we assume the values of 0.95 for each parameter.

Normalizing the Y value as 1, we apply an MPC of 0.7 as the initial consumption value and an initial value of investment is 0.3. We assume that the capital accumulation is 3.5 times that of Y, working hours are 1/3 of the total household time, the investment return rate is 0.05, and the wage rate is obtained from the percentage of minimum provincial wages to per capita income, which ranges around 0.57; for detail see Table 2. Furthermore, this study uses the Hodrick–Prescott (HP) Filter to calibrate business cycles in East Java. We use the HP filter because this method allows for a clear separation between the trend and the nominal GRDP cycle components. Additionally, the HP filter can provide smoother estimates of the GDP trend component compared to linear or exponential smoothing (Harvey & Trimbur, 2008; Sakarya &

de Jong, 2022). To measure the business cycle in East Java, we use quarterly data for the period 2000:Q1-2022:Q4.

The stochastic shock applies a gamma distribution; this distribution is chosen because it is a continuous probability distribution that can take a wide range of positive values and is suitable for productivity shocks. Additionally, the gamma distribution has a long right tail, which means it can accommodate the possibility of significant shocks (Chib & Ramamurthy, 2014). Furthermore, this study uses Bayesian methods to estimate parameter values based on prior distribution and uses the Random Walk Metropolis-Hastings (RWMH) algorithm to obtain posterior parameter distribution by involving East Java business cycle data (Garthwaite et al., 2016; Herbst & Schorfheide, 2014). Specifically, this study uses. Dynare 5.3 on Matlab R2020b software to find Dynamic Stochastic General Equilibrium (DSGE) solution based on RBC model that have been constructed as seen in Table 1.

Result and Discussion

A prior distribution serves as our initial assumption or hypothesis about the values of a model's parameters. This distribution relies on existing information and encapsulates our uncertainty regarding the parameters before the introduction of new data. In contrast, the posterior distribution is an updated probability that incorporates our prior beliefs (expressed through the prior distribution) along with the new data observed. It encapsulates our current understanding of the parameters, taking into account the evidence derived from the data. The calculation of the posterior distribution is facilitated by Bayes' theorem, which merges the prior distribution with the likelihood of the observed data given the model's parameters. The graph in Figure 1 shows that the posterior distribution has a sharply peaked curve for both demand and supply shocks, indicating that the data sufficiently supports the specified parameter values.

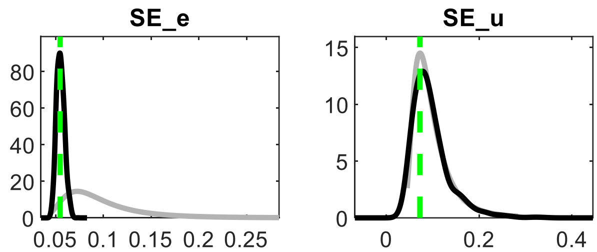


Figure 1. Prior and posterior distribution

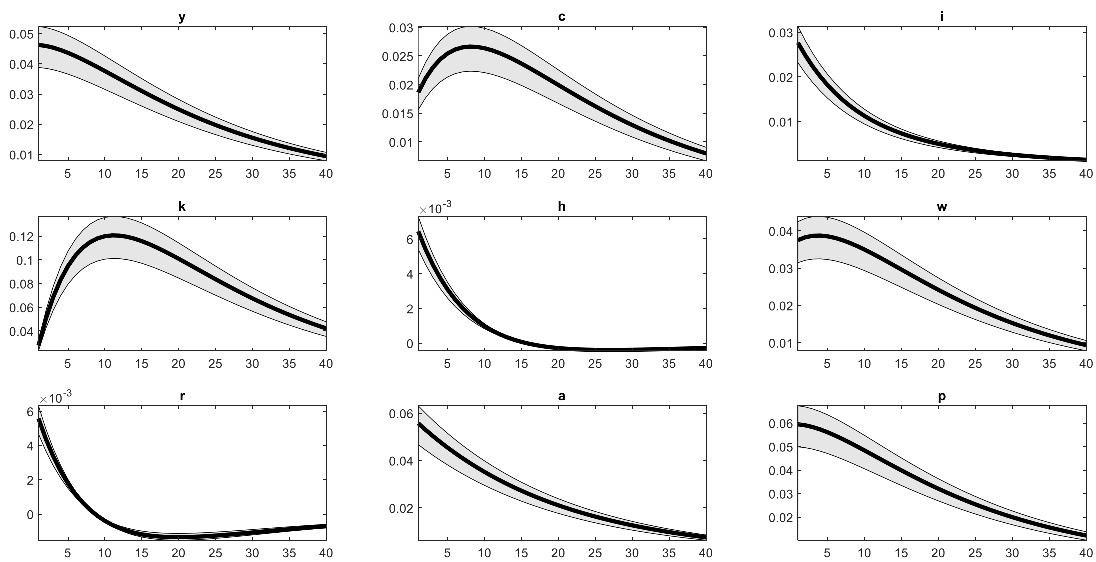


Figure 2. IRFs of demand shocks

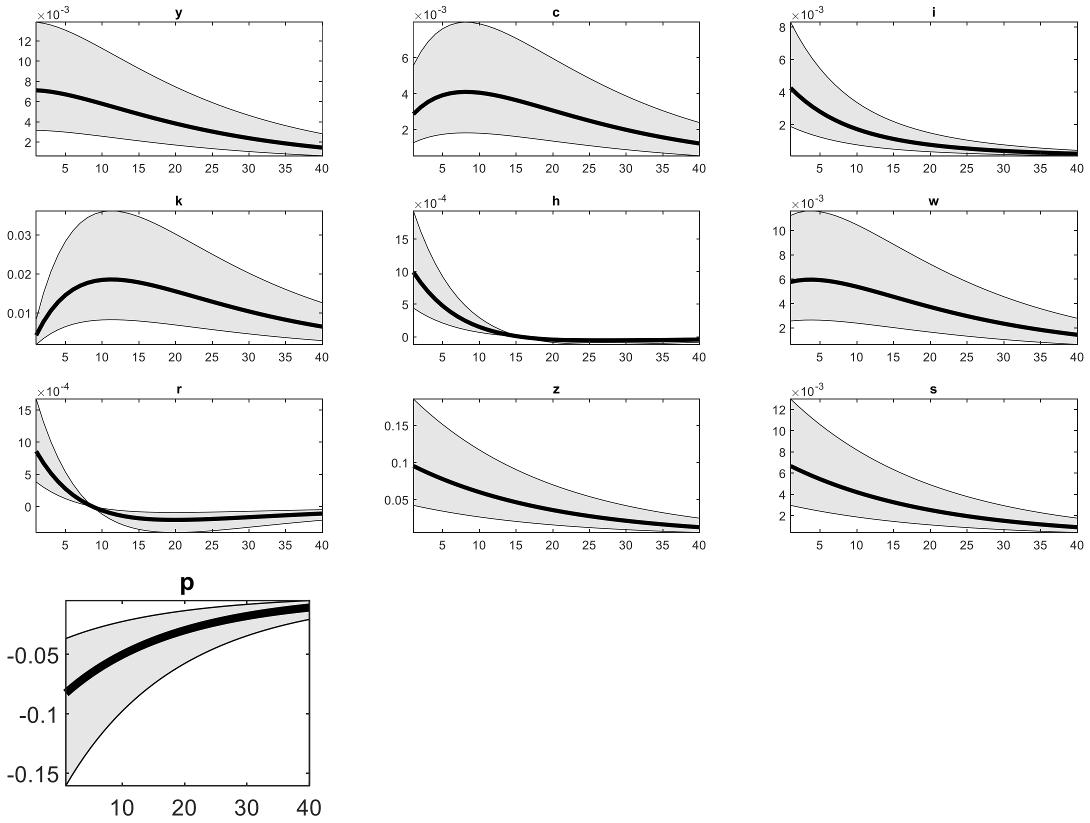


Figure 3. IRFs of supply shocks

Impulse Responds Functions (IRFs) of orthogonalized shock

Generally, IRFs of orthogonalized shocks show a tendency of a similar pattern on how economic variables behave towards stochastic shocks on both the demand and supply sides. However, for the same proportion of shocks, the impact of demand side shocks tends to be greater than supply side shocks as seen in Figure 2 and Figure 3. A clear difference only occurs in the price level of input goods, where input prices respond to demand and supply shocks in opposite directions.

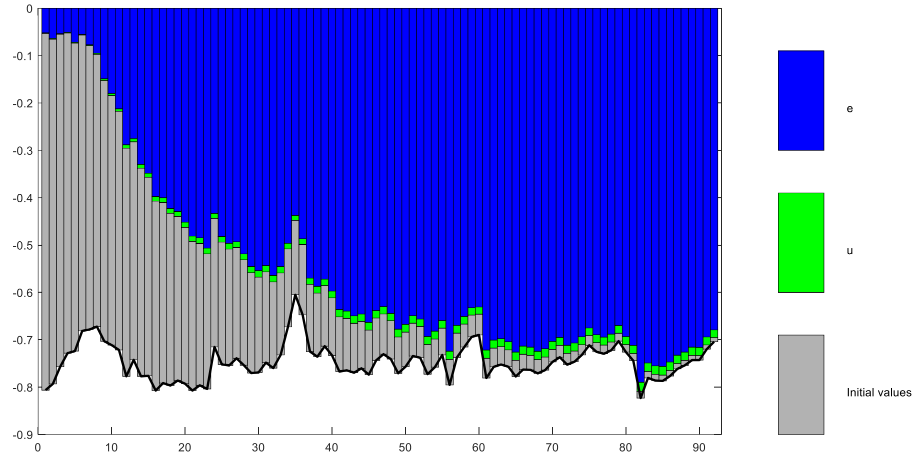
Employment dan wages

Based on the IRFs in Figure 2 and Figure 3, it is observed that shocks from both the demand and supply side are directly responded to negatively by the variable of working hours; the steep slope of the graph at the beginning of the shock phase indicates that the response of working hours to shocks is significant. The sensitivity shown also indicates that working hours play an essential role in the labor market adjustment process to changes in economic conditions. For example, during periods of declining demand, such as economic recessions or sudden increases in price of input goods, working hours tend to be quickly reduced. This negative response is the behavior of companies reducing labor inputs to adjust to changing economic conditions.

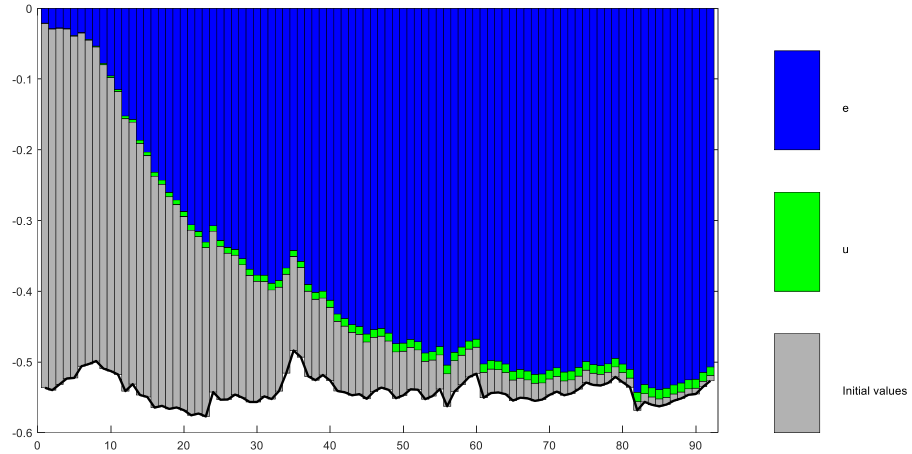
Meanwhile, slightly different from the variable of working hours that directly responds negatively in the initial phase of the shock, the wage level variable tends to still provide a positive response in the initial phase of the shock, as seen from the IRFs pattern that has a positive slope in the early phase before the slope value reverses direction after touching its inflection point. The findings from this model also illuminate that in the short run, wage levels tend to be sticky, while working hours are highly flexible to exogenous shocks. Referring to the existence of wage level inertia in responding to shocks, there is a probability that the wage level will not come under pressure when shocks from both the demand and supply sides can be promptly resolved by market mechanisms.

Consumption and Investment

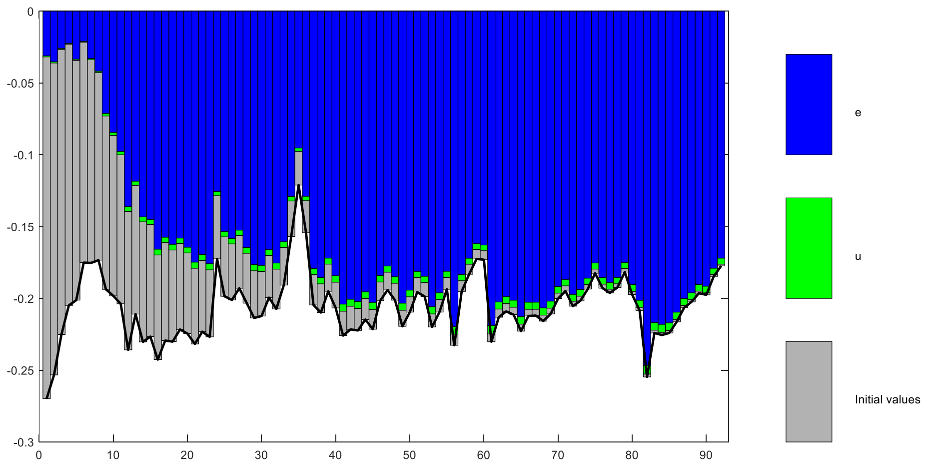
The IRFs indicate that there is an inertia effect on consumption in response to shocks from both the demand and supply sides. This means that households gradually adjust their consumption behavior over several periods. Meanwhile, shocks on the demand and supply sides lead to a direct reduction in the return on investment and working hours. In the short term, these results lead to higher consumption and a reduction in savings. As the model assumes that all savings are used for investment, the decrease in consumer willingness to postpone consumption will also lead to a proportional decrease in the level of investment. At this stage, we argue that the desire for immediate consumption still outweighs the concern for a decrease in working hours. However, the increase in consumption is not sustained, as shocks on the demand and supply sides eventually cause wage levels to decline. Therefore, in the sixth quarter following the shock, both consumption and investment will come under pressure.



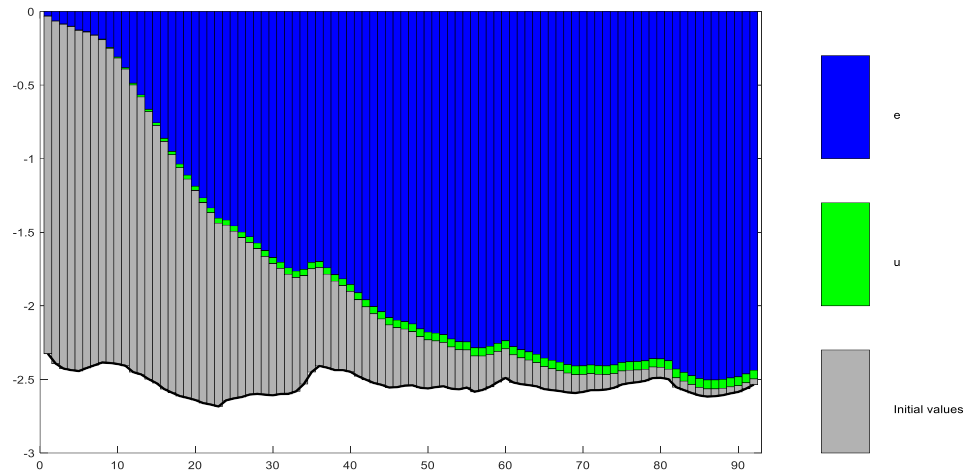
a. Output



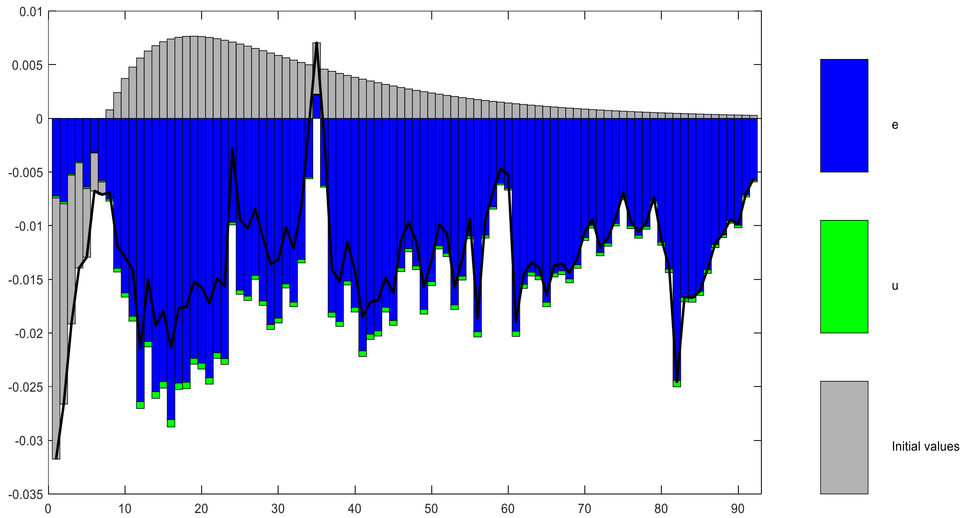
b. Consumption



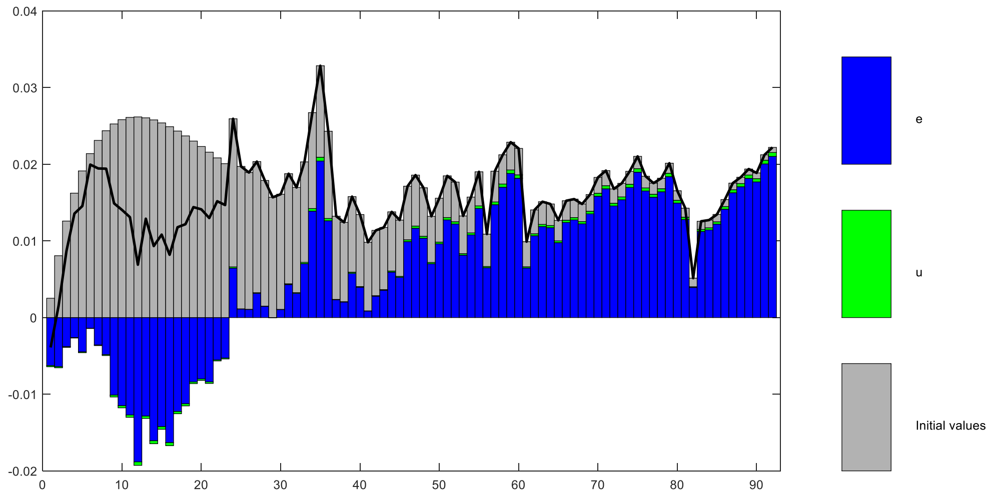
c. Investment



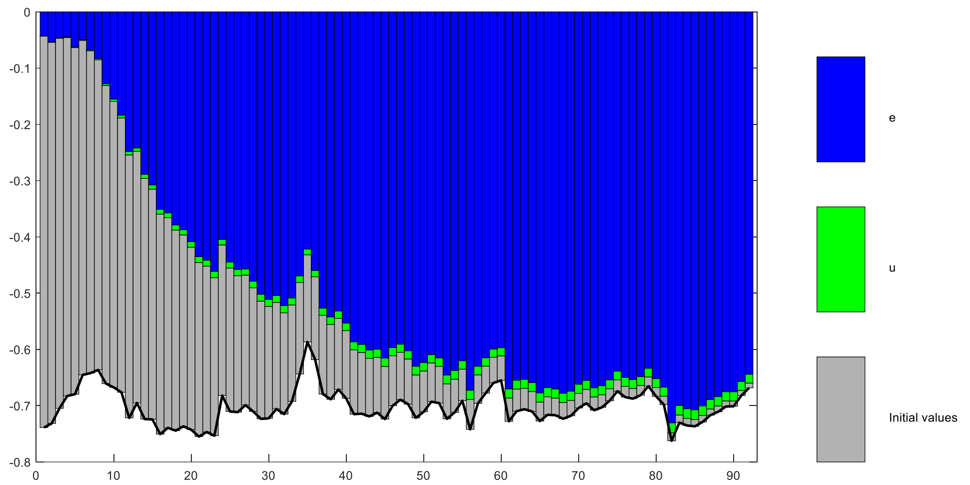
d. Capital



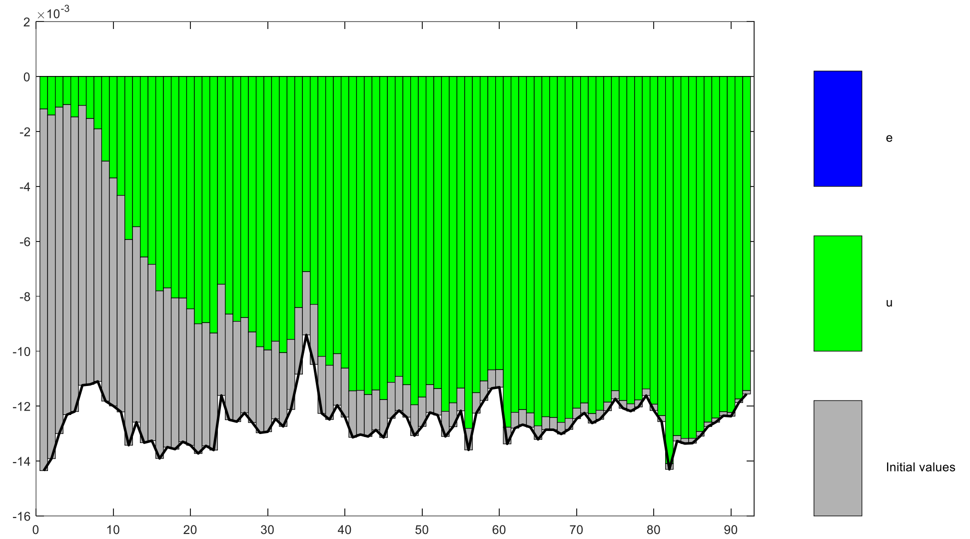
e. Working hours



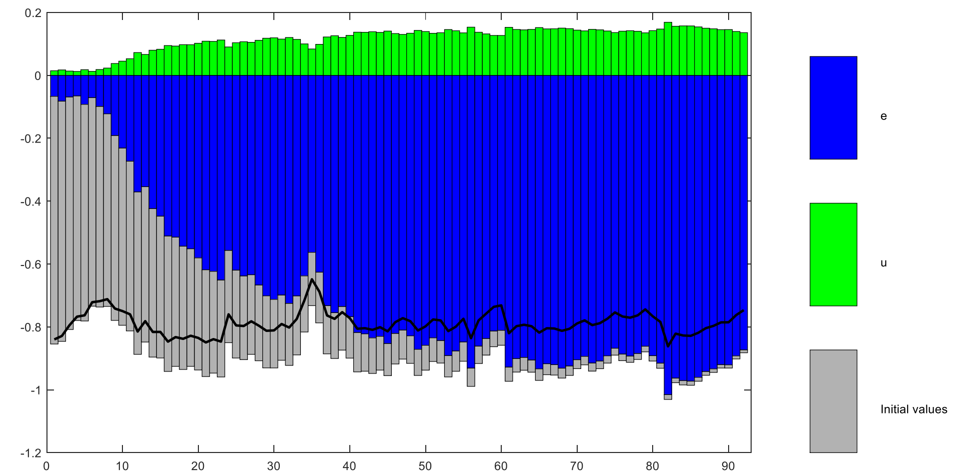
f. Investment rate of return



g. Wages



h. Supply of input goods



i. Price of input goods

Figure 4. Variances Decomposition

Capital accumulation

Inertia patterns are also found in the accumulation of capital variable in responding to demand and supply-side shocks. Referring to equations (5) and (6), capital accumulation is a function of investment in the current period plus the accumulation of capital in the previous period multiplied by the rate of return on investment minus the depreciation rate. Based on these equations and IRFs results, in the initial period of the shock, the capital accumulation variable does not experience pressure, and even capital accumulation still grows positively before eventually reaching its inflection point in the range of the 10^{th} quarter. This provides an explanation that before reaching the inflection point, the proportion of investment reduction that occurs is still lower than the growth of capital accumulation. Explicitly, the pattern of capital accumulation in responding to shocks in this model also confirms that capital accumulation in East Java is quite strong in facing exogenous stochastic shocks.

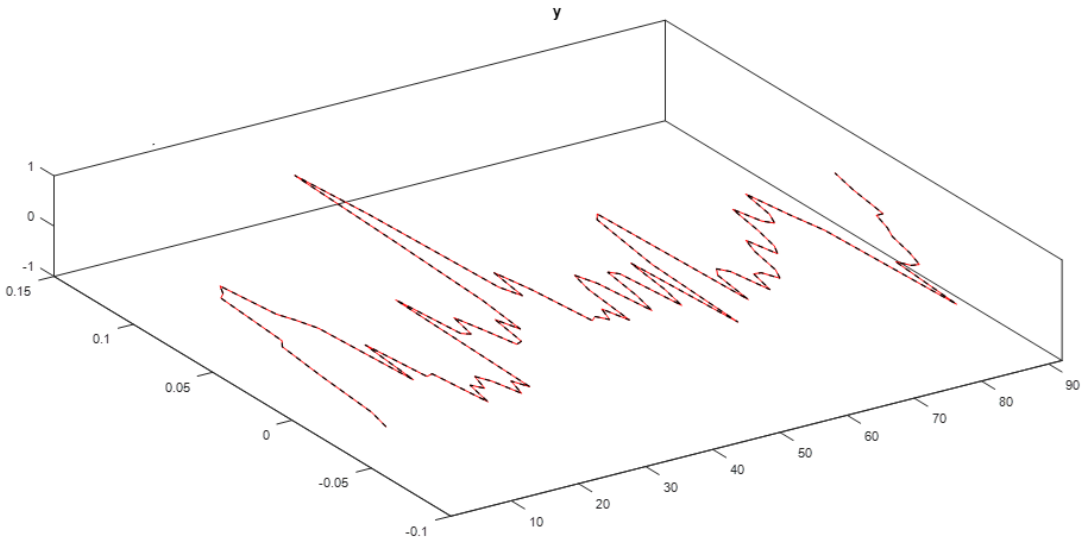


Figure 5. One step ahead forecast of business cycle

Price level of input goods

Demand-side shocks typically reduce input goods prices, while supply-side shocks tend to elevate them. However, both types of shocks negatively impact aggregate output. This highlights that fluctuations in input goods prices alone cannot serve as the sole indicator of business cycle movements. The direction of these price changes is heavily contingent on the source of the exogenous shock. Therefore, it is more insightful to focus on the underlying factors influencing price fluctuations, such as disruptions in supply chains, weather constraints, political and security issues, and the substitution rate of related input goods. Rather than fixating solely on input goods prices, it is more advantageous to observe the broader context of these fluctuations. On the demand side, understanding how input goods prices act as shock transmissions to aggregate output is best achieved by examining changes in consumer behavior and preferences, technological disruptions, and the industry's responsiveness to changes over time.

Aggregate output

Demand and supply shocks do not directly affect consumption levels, as the first derivative of the consumption function remains positive in the short term. Although employment levels may decrease in the short term, the wage rate tends to remain stable, thus maintaining consumer confidence. However, investment tends to respond directly to shocks with a sharp decline, as the rate of return on investment is very sensitive to uncertainty shocks. While the exogenous shock directly affects the output level in East Java, the slope of the aggregate output graph is relatively flat in the initial phase. This is not only due to the maintenance of short-term consumption levels, but also due to the robustness of capital accumulation growth. In general, this pattern indicates that regions or countries with high levels of capital accumulation tend to be more resilient in facing uncertainty shocks.

From a classical standpoint, we posit that when economic agents—comprising households and firms—possess a clear comprehension of recurrent shocks, the impact of such shocks on the economy tends to be diminished. This attenuation may arise from a thorough understanding of the shock's duration, enabling households and firms to establish more accurate return expectations. Consequently, this understanding acts as a preventative measure against a substantial decline in investment levels. Sustaining the level of investment is pivotal, as it fortifies capital accumulation, preserves productivity, wage levels, and employment. This, in turn, contributes to the stabilization of consumption patterns and aggregate output.

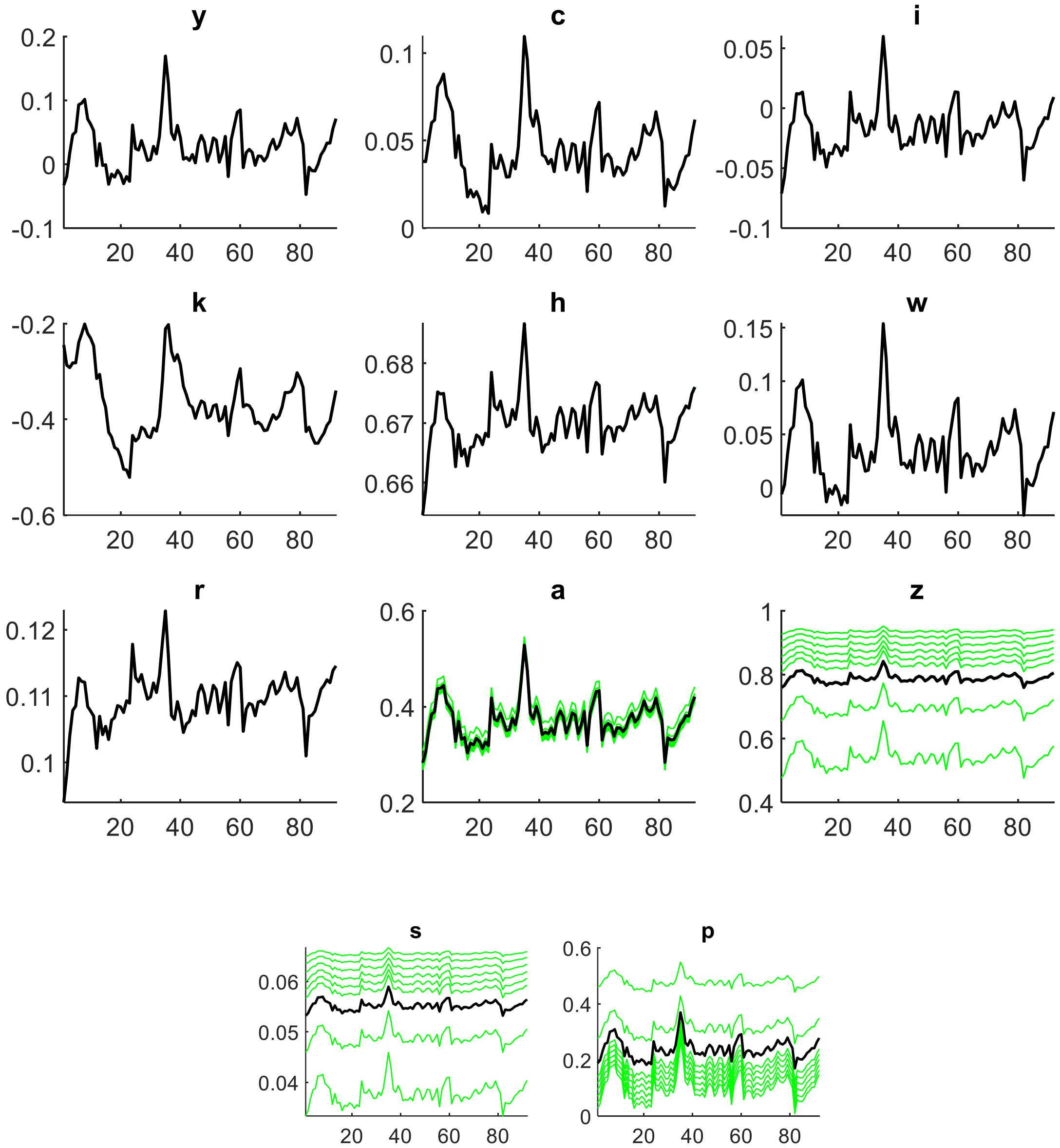


Figure 6. One step ahead forecast for all endogenous variable

Variance decomposition

As depicted in Figure 4, output dynamics are predominantly influenced by demand shocks rather than supply shocks. Returning to the foundational assumption of our model, demand shocks often stem from changes in consumer behavior and preferences, which firms may not directly address. This condition gives rise to fluctuations, supporting the manifestation of business cycles. While not as prevalent as demand shocks, supply shocks affecting input goods—such as weather constraints and supply chain disruptions—can disrupt the supply chain. In this model, total fluctuations in the supply of input goods are attributed to supply-side shocks, as illustrated in Figure 4. Supply shocks in input goods can result in heightened prices and increased operating costs. As evidenced in the Impulse Response Functions (IRFs), the prices of input goods serve as a transmission mechanism for supply shocks throughout the entire economy, influencing aggregate output.

Nowcasting, forecasting and steady state

One-step-ahead forecasts or nowcasts (refer to Figure 5) demonstrate promising results, showcasing the model's ability to accurately capture output dynamics with minimal error. This underscores the reliability of the developed RBC model in representing business cycles in East Java. Furthermore, this study elucidates the cyclical patterns of all endogenous variables, as depicted in Figure 6. Nowcasting in Figure 6 reveals that, during the in-sample period, endogenous variables exhibit similar cyclical movements.

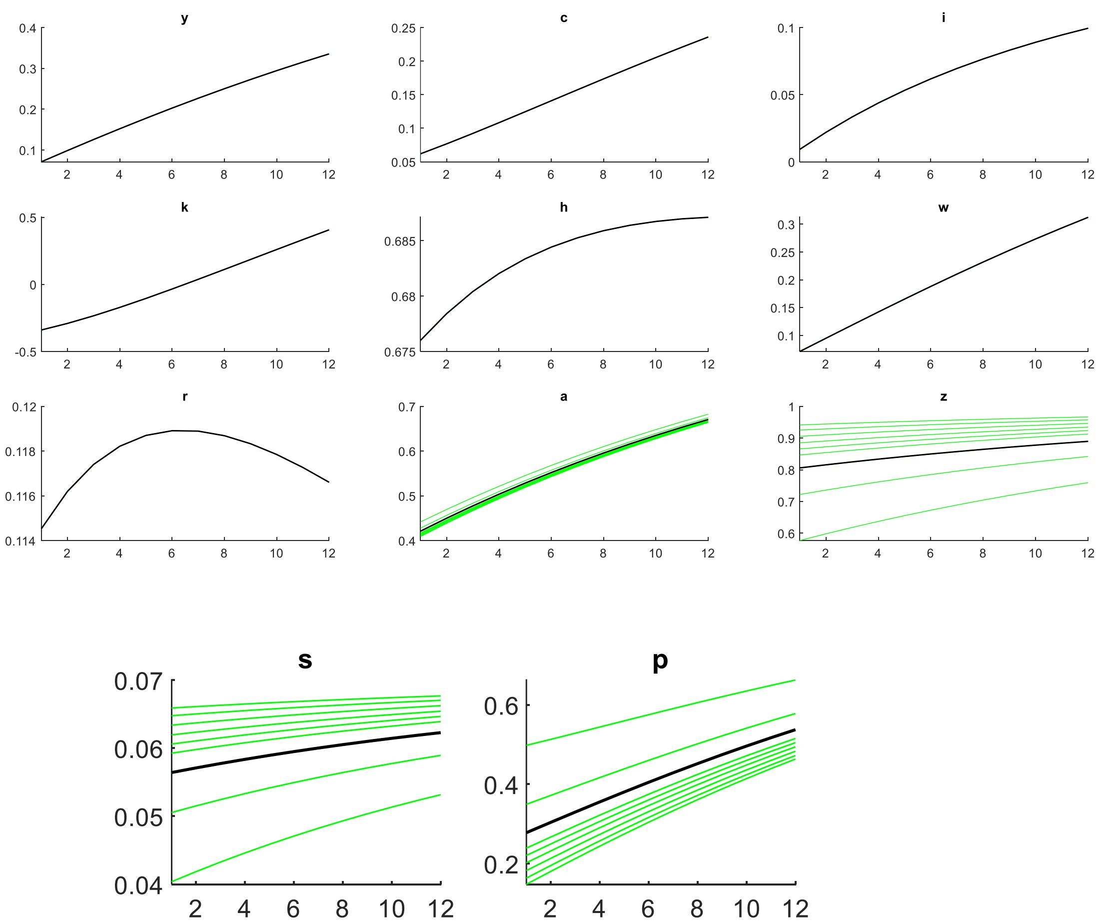


Figure 7. Short-run forecasting

Short-run forecast

Short-run forecasts in Figure 7, spanning the next 12 quarters (assuming Q1 2023 as the first quarter), project an upward trajectory for aggregate output, consumption, investment, capital accumulation, and wages. Working hours exhibit a similar trend, albeit with a diminishing pattern. Meanwhile, the investment rate of return follows an inverted U-shape, indicating a short-term decrease. Additionally, forecasts for the next 12 quarters signal a consistent trend of higher input goods prices compared to the supply trend. This anticipates increased expenses for input goods, potentially contributing to the diminishing trend in working hours and the inverted U-shape pattern in the investment rate of return, even amidst rising wages. Nevertheless, aggregate output is expected to sustain growth, propelled by technological efficiency and positive supply trends for input goods.

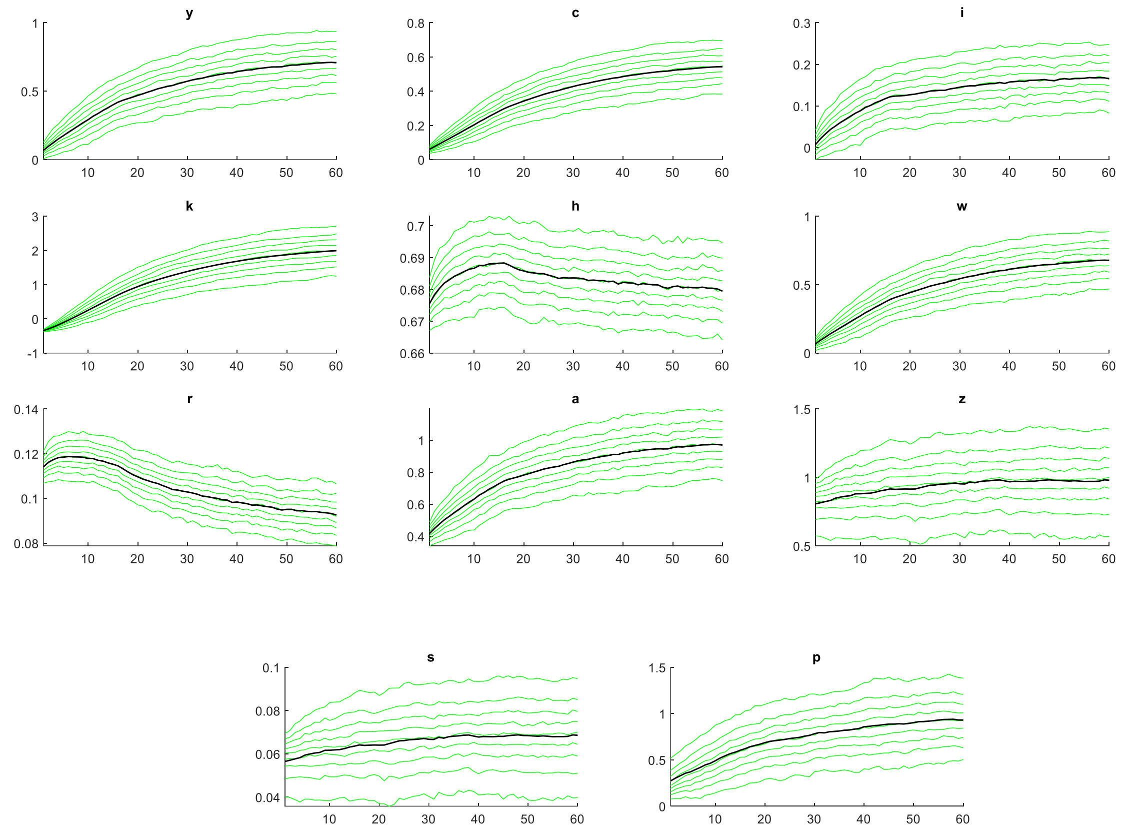


Figure 8. Long-run forecasting

Long-run forecast and convergency

Utilizing the constructed model and employing a long-term forecast spanning 60 quarters or 15 years, with 2023 as the first year (refer to Figure 8 and Table 3), it is evident that all variables converge toward their steady-state levels in the long run. Over this period, lasting approximately 15 years, most variables exhibit an increasing-diminishing trend, excluding the investment rate of return and working hours. Similar to the short-term forecast, the analysis reveals that input goods prices tend to increase more than their supply, exerting pressure on operating costs, alongside the trend of rising wages. Consequently, firms respond by reducing labor as technological efficiency increases. Amidst the continuous operational burden, the demand for capital by companies follows an increasing-diminishing pattern, contributing to a decline in the investment rate of return. These dynamics in the variables culminate in a deceleration of consumption and investment, leading to a contraction in the growth rate of aggregate output.

Beyond the model: Relaxing assumptions and embracing fiscal and monetary policy

In this subsection, we evaluate the model within the broader context of the East Java economy, acknowledging its susceptibility to the influence of the monetary policies of the Indonesian central bank and the fiscal policies of both central and regional governments. Our study contends that strategic implementation of monetary and fiscal policies can guide the economy toward a soft landing during contractions and facilitate acceleration during recovery phases. To address output dynamics arising from stochastic shocks on both the demand and supply sides, we adopt Monetarist and Keynesian approaches. Furthermore, in response to economic slowdowns stemming from technological delays in adapting to changing consumer preferences, fiscal authorities can leverage a range of policy instruments (Galí, 2020; Resosudarmo et al., 2021; Tervala & Watson, 2022). For example, they may provide technological support and investment incentives for companies to engage in research and development (R&D). This policy can take the form of tax breaks, grants, or funding for innovation and technology adoption programs.

Additionally, investing in education and training programs to enhance workforce skills becomes crucial, enabling a more rapid adaptation of workers to new technologies.

Furthermore, regulatory and policy interventions can be implemented to promote technology adoption that aligns with changing consumer preferences (Brückmann et al., 2021; Yusuf Dauda & Lee, 2015). For instance, sustainable technology can be encouraged, and consumer protection regulations can be put in place to promote innovation in products and services. Moreover, demand-side interventions, including consumer education and awareness campaigns, can create demand and promote preference changes. Supporting sustainable consumption, local or domestic products, and international cooperation can also foster knowledge sharing and technology transfer to aid industries in adapting to changing consumer preferences.

Assuming that the economic slowdown is caused by declining consumer purchasing power, incentive policies should not only be directed towards firms but also households. Direct cash assistance, subsidies, and temporary suspension of national health insurance premiums are potential options to increase consumer confidence among the unemployed and the poor (Brown et al., 2021; Hoffmann & Jones, 2021). Sustaining household purchasing power has the potential to fortify firms' investment expectations, fostering higher capital accumulation. This, in turn, can contribute to the maintenance of aggregate output, stimulating working hours and wages. We contend that a comprehensive and coordinated approach—integrating technology support, skills development, regulatory interventions, industry promotion, and purchasing power interventions—holds the key to effectively addressing the challenges posed by an economic slowdown rooted in declining technology efficiency and consumer purchasing power.

Table 3. Steady state

Variable(s)	Value	Variable(s)	Value
Y	0.747166	r	0.090101
C	0.574681	a	1
I	0.172485	z	1
K	2.15606	S	0.07
H	0.678738	P	0.960642
W	0.715531		

From a monetary perspective, monetary policy can play a crucial role in addressing demand-side shocks. The central bank has several potential tools that can be used. One of these tools is adjusting interest rates, where lowering interest rates can encourage borrowing and spending by firms and households (Fu & Ho, 2022). Additionally, the central bank can provide liquidity to banks and financial institutions, ensuring the smooth functioning of financial markets and promoting loans to firms for technology-related investments (Mehrotra & Moessner, 2023). Furthermore, exchange rate policies can also be used to influence the competitiveness of domestic industries, with currency depreciation making exports more competitive, thus increasing demand for products in the international market (Dees et al., 2021; Galadima & Aminu, 2019; Pham & Sala, 2020). As we know, since consumption is a contributor to GDP, this also has an impact on increasing aggregate output. Returning to the model, the increased aggregate output ultimately also drives other macroeconomic variables such as employment levels, wages, and capital accumulation. In addition, we also emphasize the importance of forward-looking policies that involve communication about future monetary policy intentions. This policy can provide certainty and guidance for businesses and consumers, helping them make informed decisions about technology investment, innovation, and consumption.

In contrast to demand-side shocks amenable to intervention through monetary and fiscal policies, addressing supply-side shocks, particularly those related to the availability and price of input goods, necessitates distinct interventions. Unlike the swift resolutions possible with fiscal and monetary tools, supply-side shocks stemming from factors like weather conditions and fragile supply chains pose challenges in quick resolution. Therefore, we posit that both governments and firms should invest in diversifying input goods and leveraging technology to mitigate the impact of supply shocks induced by seasonal changes, climate shifts, natural disasters, or political and security issues. Infrastructure development for inter-regional connections, especially to address supply chain constraints, also merits attention. On the regulatory front, continuous policies supporting innovation in the input goods sector can incentivize the use of regional and national raw-intermediate materials, reducing reliance on imports.

Conclusions, Suggestions and Limitations

Based on the constructed model, there are several variables such as wage level, consumption, and capital accumulation that have a time lag of several quarters before they are affected by stochastic shocks, both on the demand and supply sides. By relaxing the assumptions of the RBC model and involving the roles of fiscal and monetary policies, we argue that the appropriate policies can smooth the impact of exogenous shocks. The efficiency of such policies consists of at least two main things: a) mitigating the source of shocks. Regarding the source of shocks, at least the policy mix taken must be based on the source of shocks so that the proportion of policies can correspond to the problem to be addressed; b) Besides understanding the source of shocks, the timing of policies is also equally important. Based on the IRFs, a time lag of wage, consumption, and capital accumulation variables in responding to shocks can provide sufficient time for authorities to calculate the right timing of intervention at least before the variables reach their turning point. If this can be done, we believe that the impact of shocks will be softer and economic recovery will be faster.

Furthermore, we also pay special attention to capital accumulation. In some early periods of shocks, the capital accumulation variable is very strong, as indicated by a large positive gradient slope. The consequence is that regions or countries with large capitalization tend to be more resistant to shocks, so we encourage East Java to continue promoting sustainable investment.

Competing Interests

The author(s) declare that there are no competing interests relevant to the content of this article.

References

Ahmed, S., & Murthy, R. (1994). Money, Output, and Real Business Cycles in a Small Open Economy. *The Canadian Journal of Economics*, *27*(4). https://doi.org/10.2307/136195

Amalia, S. K., Santoso, D. B., & Sasongko, S. (2018). Convergence Analysis of Economic Growth in East Java. JEJAK, 11(1). https://doi.org/10.15294/jejak.v11i1.9643

Barro, R. J., & King, R. G. (1984). Time-Separable Preferences and Intertemporal-Substitution Models of Business Cycles. The Quarterly Journal of Economics, 99(4). https://doi.org/10.2307/1883127

Brown, A. J. G., Kohlbrecher, B., Merkl, C., & Snower, D. J. (2021). The effects of productivity and benefits on unemployment: Breaking the link. Economic Modelling, 94. https://doi.org/10.1016/j.econmod.2020.02.037

Brückmann, G., Willibald, F., & Blanco, V. (2021). Battery Electric Vehicle adoption in regions without strong policies. Transportation Research Part D: Transport and Environment, 90. https://doi.org/10.1016/j.trd.2020.102615

Chib, S., & Ramamurthy, S. (2014). DSGE Models with Student-t Errors. Econometric Reviews, 33(1–4). https://doi.org/10.1080/07474938.2013.807152

Christianto, S. Y., Prasetyani, D., & Rawidyo Putr, T. (2022). The Effect of Inflation Rate, Economic Growth Rate and Minimum Wages on Open Unemployment Rate in East Java Year 2013–2021. International Journal of Economics, Business and Management Research, 06(12). https://doi.org/10.51505/ijebmr.2022.61204

Dees, S., Pesaran, M. H., Smith, L. V., & Smith, R. P. (2021). Supply, Demand and Monetary Policy Shocks in a Multi-Country New Keynesian Model. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.1663882

Elly Magdalena Silangen. (1994). Pengaruh modal dan tenaga kerja terhadap pertumbuhan output sektor industri di jawa timur. Universitas Airlangga.

Fernández-Villaverde, J., & Guerrón-Quintana, P. A. (2020). Uncertainty shocks and business cycle research. Review of Economic Dynamics, 37. https://doi.org/10.1016/j.red.2020.06.005

Fu, L., & Ho, C. Y. (2022). Monetary policy surprises and interest rates under China’s evolving monetary policy framework. Emerging Markets Review, 52. https://doi.org/10.1016/j.ememar.2022.100895

Galadima, M. D., & Aminu, A. W. (2019). Shocks effects of macroeconomic variables on natural gas consumption in Nigeria: Structural VAR with sign restrictions. Energy Policy, 125. https://doi.org/10.1016/j.enpol.2018.10.021

Galí, J. (2020). The effects of a money-financed fiscal stimulus. Journal of Monetary Economics, 115. https://doi.org/10.1016/j.jmoneco.2019.08.002

Garthwaite, P. H., Fan, Y., & Sisson, S. A. (2016). Adaptive optimal scaling of Metropolis–Hastings algorithms using the Robbins–Monro process. Communications in Statistics - Theory and Methods, 45(17). https://doi.org/10.1080/03610926.2014.936562

Guo, J.-T., & Janko, Z. (2009). Reexamination of Real Business Cycles in a Small Open Economy. Southern Economic Journal, 76(1). https://doi.org/10.4284/sej.2009.76.1.165

Harvey, A., & Trimbur, T. (2008). Trend Estimation and the Hodrick-Prescott Filter. JOURNAL OF THE JAPAN STATISTICAL SOCIETY, 38(1). https://doi.org/10.14490/jjss.38.41

Herbst, E., & Schorfheide, F. (2014). Sequential monte carlo sampling for dsge models. Journal of Applied Econometrics, 29(7). https://doi.org/10.1002/jae.2397

Hoffmann, V., & Jones, K. (2021). Improving food safety on the farm: Experimental evidence from Kenya on incentives and subsidies for technology adoption. World Development, 143. https://doi.org/10.1016/j.worlddev.2021.105406

Jaroensathapornkul, J. (2020). Impacts of technological shock on the agricultural business cycle. Jurnal Ekonomi Malaysia, 54(1). https://doi.org/10.17576/JEM-2020-5401-1

Jawadi, F., Ameur, H. Ben, Bigou, S., & Flageollet, A. (2022). Does the Real Business Cycle Help Forecast the Financial Cycle? Computational Economics, 60(4). https://doi.org/10.1007/s10614-021-10193-8

Li, T., Li, X., & Liao, G. (2022). Business cycles and energy intensity. Evidence from emerging economies. Borsa Istanbul Review, 22(3). https://doi.org/10.1016/j.bir.2021.07.005

Mehrotra, A., & Moessner, R. (2023). Macroprudential policy and interest rate spillovers. Applied Economics Letters, 30(1). https://doi.org/10.1080/13504851.2021.1975025

Mountford, A., & Harald, U. (2009). What are the effects of fiscal policy shocks? Journal of Applied Econometrics, 24(6). https://doi.org/10.1002/jae.1079

Ocampo, J. A., & Ojeda-Joya, J. (2022). Supply shocks and monetary policy responses in emerging economies. Latin American Journal of Central Banking, 3(4). https://doi.org/10.1016/j.latcb.2022.100071

Pham, B. T., & Sala, H. (2020). The macroeconomic effects of oil price shocks on Vietnam: Evidence from an over-identifying SVAR analysis. Journal of International Trade and Economic Development, 29(8). https://doi.org/10.1080/09638199.2020.1762710

Plosser, C. I. (1989). Understanding Real Business Cycles. Journal of Economic Perspectives, 3(3). https://doi.org/10.1257/jep.3.3.51

Prescott, E. C., & Kydland, F. E. (1990). Business Cycles: Real Facts and a Monetary Myth. Quarterly Review, 14(2). https://doi.org/10.21034/qr.1421

Qurrata, V. A., & Ramadhani, N. (2021). The Impact of HDI, Minimum Wages, Investment and GRDP on Poverty in East Java in 2019. KnE Social Sciences. https://doi.org/10.18502/kss.v5i8.9393

Rebelo, S. (2010). Real business cycle models: Past, present, and future. Voprosy Ekonomiki, 2010(10). https://doi.org/10.32609/0042-8736-2010-10-56-67

Resosudarmo, B. P., Abdurohman, Yusuf, A. A., & Hartono, D. (2021). Spatial impacts of fiscal stimulus policies during the 2009 global financial crisis in Indonesia. Asia-Pacific Journal of Regional Science, 5(1). https://doi.org/10.1007/s41685-020-00176-2

Romer, D. (2015). ADVANCED MACROECONOMICS Fourth Edition. In Syria Studies (Vol. 7, Issue 1).

Sakarya, N., & de Jong, R. M. (2022). The spectral analysis of the Hodrick–Prescott filter. In Journal of Time Series Analysis (Vol. 43, Issue 3). https://doi.org/10.1111/jtsa.12622

Sujeetha Jegajeevan. (2016). Understanding Sri Lankan Business Cycles through an estimated DSGE Model. 9th International Research Conference (2016), Central Bank of Sri Lanka, Colombo.

Susilo, J. H., Tsani, L. I., Herianto, H., & Kholilurrohman, M. (2020). Econometrics Model of Economic Growth in East Java Province with Dynamic Panel Data through Generalized Method of Moment (GMM) Approach. Ekuilibrium : Jurnal Ilmiah Bidang Ilmu Ekonomi, 15(1). https://doi.org/10.24269/ekuilibrium.v15i1.2372

Tervala, J., & Watson, T. (2022). Hysteresis and fiscal stimulus in a recession. Journal of International Money and Finance, 124. https://doi.org/10.1016/j.jimonfin.2022.102614

Vinajera-Zamora, A., Marrero-Delgado, F., & Coello-Machado, N. (2014). The added value calculation in a manufacturing supply chain. an application in an electric power meter (127v) supply chain. Proceedings of 7th International Doctoral Students Workshop on Logistics, September.

Yusuf Dauda, S., & Lee, J. (2015). Technology adoption: A conjoint analysis of consumers' preference on future online banking services. Information Systems, 53, 1–15. https://doi.org/10.1016/j.is.2015.04.006

Zulkarnain, R. (2022). Flash Estimates of Household Final Consumption Expenditure in East Java. East Java Economic Journal, 6(1). https://doi.org/10.53572/ejavec.v6i1.84