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Estimating the Output Gap for Emerging Countries: Evidence from Five Southeast Asia Countries

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Abstract

This paper presents an application of a bi-variate unobserved components model of output and inflation to estimate the output gap for five emerging economies in Southeast Asia, including the Philippines, Malaysia, Vietnam, Indonesia, and Thailand. In this paper, time-varying stochastic volatility terms are added in the model to exhibit the change in the size of shocks to the trend and cyclical components of output and inflation of these economies. The results show that estimated output gaps are able to identify the recessions of these economies. Although the shape and magnitude of estimated gaps differ from country to country, these gaps imply that these economies tend to converge to a more stable business cycle over time, except for that of Malaysia. Secondly, inflation is very sensitive to the output gap in Vietnam and Indonesia, but not to those in the Philippines, Malaysia, and Thailand. Thirdly, results suggest that time-varying stochastic volatility is clearly seen in the innovations to the output gaps of the five emerging economies, and Indonesia's potential output. Meanwhile, results confirm that there is no need to add stochastic volatility terms in trend components of output and inflation, except for Indonesia's potential output.

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1. Introduction

Measuring potential output and the output gap plays a crucial role in the formulation and implementation of macroeconomic policies. For example, a positive output gap indicates an excess demand, which may require an increase in the interest rate to prevent the economy from overheating. Conversely, a negative output gap indicates a lack of demand, which may lead to a decrease in the economy's growth rate and a potential recession due to the falling of economic demand (Kara, Ogunc, Ozlale, & Sarikaya, 2007). Therefore, policymakers need to assess the degree to which fluctuations in observed output reflect the economy's optimal response to shocks, as opposed to undesirable deviations from the time-varying optimal path of output.

In the literature, various approaches have been proposed to estimate the output gap, and these approaches can be divided into two main groups: statistical methods and structural methods. The statistical methods, such as the Hodrick-Prescott (HP) filter, univariate Beveridge-Nelson (BN) decomposition, and univariate unobserved components (UC) methods, may be easy to calculate under certain assumptions, but they lack essential economic content as the link between macroeconomic variables. Consequently, estimating the output gap could be inaccurate due to the pure assumption about trend and cycle components of output. Alternatively, the structural methods, such as structural VAR and the production function, exploit economic theory to isolate the effects of structural and cyclical influences on output. These approaches may provide valuable information for policymakers, but they also have drawbacks. For instance, one disadvantage of the structural approach is that the data required are often unavailable in developing economies. Another disadvantage is its limited potential to identify many types of shocks when applying the structural VAR approach for emerging economies, which often have been characterized by high-frequency volatility of macroeconomics during the last decades. Moreover, the calculation of the structural approaches is often more tractable than those of the statistical approaches. Many researchers have recently used a mixed-approach, such as a bi-variate model, a tri-variate model, or a multivariate model, to combine the advantages of both statistical and structural methods. In particular, these models allow for adding economic structure to estimate the output gap by conditioning them on some basic theoretical relationships, such as a Phillips curve relating the inflation process to the output gap, or Okun's law relating the unemployment rate to the output gap. Additionally, the statistical properties of these techniques also clearly outperform structural methods, as these techniques are relatively easy to implement and can be augmented where available data permits see (Alichi, 2015). The UC model is a typical mix-approach to measuring the output gap and potential output, as well as other equilibrium rates for the economy. In the UC model, observed variables, such as real output, are decomposed into trend and cycle components to provide a better understanding of the dynamic characteristics of the variables and how these characteristics change over time. The UC models have natural state-space representation and can be based on the Kalman filter as its statistical treatment. For example, Kuttner (1994) provides a bi-variate UC model of output and inflation through a Phillips curve relationship and applies the Kalman filter to measure the output gap and potential output of the U.S. economy. The same model is replicated by Kichian (1999) for G7 countries, and popularized by Gerlach and Smets (1999) for the EMU-area. Alternately, Sinclair (2009) uses a bi-variate UC model of output and unemployment through Okun's law to estimate the output gap and potential output for the U.S. economy. Recently, Berger and Kempa (2014) propose a tri-variate UC model of output, the exchange rate, and interest rate to estimate the output gap for Canada's economy. More recently, Grant and Chan (2017) estimate the sensitivity of the output gap by considering both the uni-variate model of only output and a bi-variate model of output and inflation or unemployment for the U.S. economy. Nevertheless, most of the studies focus on industrialized countries, and little empirical research has been conducted to estimate the output gap in emerging economies. Among the limited literature on emerging markets in Asia, different approaches are used to estimate potential output and the output gap for these economies and diversity findings are concluded. For example, Bautista. (2003) applied a generalized Hamilton model to measure the output gap of four economies in Southeast Asia, namely Indonesia, Malaysia, Philippines, and Thailand, from 1993Q1 to 2002Q2. He argued that Markov regime-switching techniques could account for shocks to potential output and to trend growth due to the substantial adverse effect of the Asian financial crisis. Furthermore, he finds that the output gap is not measuring the business cycles of these economies. The output gap can be positive, zero, or negative during a recession, depending upon whether these shocks are real or normal shocks. Alternatively, Gerlach and Yiu (2004) applied statistical methods, including the HP filter, a band-pass (B.P.) filter, the BN filter, and the UC model, to estimate output gaps for eight countries in Asia, namely Hong Kong, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, and Taiwan from the 1970s and 1980s to 2001Q1. The authors find that the different methods generate broadly similar results, and these estimated gaps much well with common perceptions of the business cycle in these economies. In this article, the authors support using the UC approach to estimate the output gap in practice because doing so could allow confidence bands for the estimated gap, and the UC approach could also provide estimates of the potential output growth for these economies. However, the limitation of this paper is that it lacks economic content since it uses only output data. Recently, Maliszewski (2010) applies Bayesian methods to a two-equation AS-AD model to estimate the potential output gap for Vietnam from 1999Q1 to 2008Q4. She finds that the output gap has a substantial impact on inflation in the short-term. Furthermore, she suggests that the effect of the interest rate and real exchange rate on the output gap is small due to the underdeveloped monetary transmission mechanism in this economy.

This paper tries to fill the gap in the literature by applying a bi-variate UC model to estimate the output gap for emerging economies in Southeast Asia, including the Philippines, Malaysia, Vietnam, Indonesia, and Thailand from the 1990s to 2019. In this model, stochastic volatility terms are included to describe the change in the size of shocks to transitory and contemporary components of output and inflation. For example, the adverse shocks from the Asian financial crisis and the Global financial crisis may lead to an increase in the volatility of the macroeconomics of these emerging economies. The model is also modified to fit the specific features of the Southeast Asia economies, such as a downward trend of inflation during the period under study. The main conclusions are as follows. Firstly, the estimated output gaps of these emerging economies can identify these economies' recessions as defined by the National Bureau of Economic Research (NBER). Although the shape and magnitude of estimated gaps differ from country to country, the results suggest that these economies tend to converge to a more stable business cycle over time, except for that of Malaysia. Secondly, while a slowdown in the potential output growth is found in four emerging countries, the Philippines economy clearly shows an upward trend of potential growth of output. Thirdly, inflation is very sensitive to the output gap in Vietnam and Indonesia, but not to those in the Philippines, Malaysia, and Thailand. However, the posterior mean of the slope of the Phillips curve of Indonesia has the wrong 'sign'. This can be explained by the special features of the Indonesian economy during the Asian financial crisis. Fourthly, this paper provides that there is no need to add stochastic volatility terms into the equation of trend components of output and inflation of these economies, except for Indonesia's potential output. However, time-varying stochastic volatility is clearly seen in the innovations to the output gap of these emerging economies, and it is also significant for the potential output of Indonesia. Lastly, the large variance of the Philips curve is found in all five economies. This implies that temporary shocks to inflation are essential drivers of inflation fluctuations in these economies. The remainder of the paper is structured as follows. Section 2 explains the empirical approach, including a bi-variate UC model and the procedure as well. Section 3 presents the estimations of the output gaps for five emerging countries in Southeast Asia. The final section is the conclusion.

2. Empirical Approach

The first part of this section concisely describes the evolution of output growth and the actual inflation of five emerging economies in Southeast Asia. The second part sets out a bi-variate UC model of output and inflation, which was designed to fit the macroeconomic data of five emerging countries in Southeast Asia. Then, the next part explains the Markov Chain Monte Carlo (MCMC) algorithm, which is applied to estimate the model.

2.1. An Overview of the Growth Rate and Inflation Developments of Five Emerging Economies in Southeast Asia

The research uses quarterly data from 1990Q1 to 2019Q2 from Malaysia and the Philippines, quarterly data from 1994Q1 to 2019Q2 from Indonesia and Thailand, and quarterly data from 1995Q1 to 2019Q2 from Vietnam. More specifically, real gross domestic product (real GDP) of Vietnam is taken from the General Statistics Office of Vietnam, and the real GDP of other countries is taken from the International Financial Statistics (IFS). Consumption price index (CPI) of five countries is taken from IFS. All data were seasonally adjusted using the Census X-12 method.

Table 1 concisely provides basic descriptive statistics of output growth and the inflation rate of five Southeast Asia economies. Based on major shocks to these economies, I divided the sample period into three sub-periods (Pre-AFC, Pre-GFC, Post-GFC) to calculate the mean and standard variance of output growth and the inflation rate of four economies, except for that of Vietnam. For the Vietnamese economy, I divided the sample period into two sub-periods: pre-GFC and post GFC. The first two columns in Table 1 show that both the mean and variance of the growth rates vary over time in all five economies. While the mean growth rates of Malaysia, Vietnam, and Indonesia decrease over time, the growth rates of the Philippines and Thailand tend to increase. On the other hand, the deviation of mean growth during the first sub-period tends to be larger than that of the remaining sample periods, indicating the considerable adverse impact of shocks from the Asian financial crisis. In other words, it suggests that the Asian financial crisis has the most considerable effects on these emerging economies. Thus, it makes sense to assume that the potential output growth of these economies varies across the whole sample period, and there could have been changes in the size of the shocks to trend and cycle components of the output of these economies.

Table-1. Descriptive statistic.

Countries	Period	The GDP growth		Inflation	
		Mean	Std	Mean	Std
Philippines	Pre AFC	2.67	2.66	8.95	5.23
	Pre GFC	4.53	1.68	4.56	2.85
	Post GFC	5.92	1.80	2.96	2.00
Malaysia	Pre AFC	7.41	5.76	3.76	1.80
	Pre GFC	5.24	3.34	2.23	3.01
	Post GFC	4.96	2.07	2.04	2.42
Vietnam	Pre GFC	7.09	1.95	6.02	6.99
	Post GFC	6.21	1.47	5.91	5.81
Indonesia	Pre AFC	8.10	1.90	8.73	3.93
	Pre GFC	3.23	6.24	12.30	17.16
	Post GFC	5.60	0.81	5.87	5.14
Thailand	Pre AFC	1.86	6.83	4.52	2.14
	Pre GFC	4.43	2.89	3.26	3.22
	Post GFC	3.64	3.69	2.04	3.31

Regarding the inflation rate, the last two columns of Table 1 imply that the actual inflation rate of these emerging economies tends to decrease over time, and the deviation of the mean inflation rate of these economies varies over time. For example, in the Philippines, actual inflation is at a high level in the first sample period and decreases thereafter. In Indonesia, inflation dramatically soars in 1998Q3 to peak at 67% and decreases to around 6% throughout the remainder of the sample period. In Vietnam, inflation is higher in the first sub-period to capture the boom-cycle of this economy. In Malaysia and Thailand, inflation tends to be less volatile than other countries examined. In this paper, the trend inflation of these economies is modelled as a random walk with a time-varying drift to capture these economies' specific features during the sample period. The next subsection will discuss a bivariate UC model, which is modified to fit the characteristic of emerging economies, in particular, five emerging economies in Southeast Asia.

2.2. A Bi-Variate Unobserved Components Model

2.2.1. Output Components

Following the main idea of Watson (1986) I decompose real GDP (y_t) into a stationary cycle (y_c^t) and nonstationary trend (y_t^τ) and the model can be written as follows,

$$y_t = y_t^\tau + y_c^t + \varepsilon_{1t}\varepsilon_{1t} \sim N\left(0, \sigma_{\varepsilon_1}^2\right) \tag{1}$$

where ε_{1t} is added to capture measurement error and temporary shocks. Since the trend and cycle components of output are not directly observed, the model requires additional assumptions to be identified. In particular, the potential output, y_t^τ, is assumed to follow a random walk with a stochastic drift μ_t. As mentioned above, μ_t is allowed to vary overtime to capture the enhanced productivity due to an improvement of human capital, technology developments. The cycle component, y_c^t, is assumed as a stationary autoregressive process. It can be written as

$$y_t^\tau = \mu_{t-1} + y_{t-1}^\tau + \eta_{y_t^\tau}\eta_{yt} \sim N\left(0, \sigma_{\eta_{y_t^\tau}}^2\right) \tag{2}$$

$$y_c^t = \phi_1 y_{t-1}^c + \phi_2 y_{t-2}^c + \eta_{y_c^t}\eta_{yc} \sim N\left(0, \sigma_{\eta_{y_c^t}}^2\right) \tag{3}$$

$$\mu_t = \mu_{t-1} + \eta_{\mu_t}$$

This model is a general representation of the trend and cycle decomposition of output. By casting into state-space form, the latent state variables (potential output, y_t^τ, output gap, y_c^t, and the growth rate, μ_t), the coefficient parameters (ϕ_1 and ϕ_2), and variance parameters, ($\eta_{y_t^\tau}$, $\eta_{y_t^c}$ and η_{μ_t}) can be estimated by using the Kalman-filter and maximum likelihood techniques. However, the identification of y_t^τ and y_t^c is solely based on statistical filters and thus lacks economic content. Therefore, this univariate trend/cycle decomposition is linked to inflation via the Phillips curve relationship to identify potential output accurately.

2.2.2. Inflation: The Phillips Curve

Following the states in the new Keynesian Phillips curve (NKPC), a fairly standard reduced-form Phillips curve can be written as

$$\pi_t = E(\pi_{t+1}) + \beta y_{t-1}^c + \varepsilon_{2t}\varepsilon_{2t} \sim N\left(0, \sigma_{\varepsilon_2}^2\right) \tag{4}$$

where $E(\pi_{t+1})$ denotes the expectation of future inflation at time t, transitory deviation of actual inflation from its expected value are driven by the lagged output gap y_{t-1}^c. The slope of the Phillips curve, β, measures the sensitivity of inflation to the output gap. Note that the expected value of future inflation is an unobserved variable, and UC methodology is a proxy for expected inflation. Following the earlier studies, which used the trend in inflation as a measure for the expected term in the NKPC, modelling trend inflation as a simple random walk could be sufficient to capture the structural change of the economy (Doménech & Gomez, 2006), (Basistha & Nelson, 2007). However, this way could give these emerging economies an implausible result since the inflation of these economies tends to decrease over time. Therefore, trend inflation of these emerging economies in this paper is modelled as a random walk with drift. The model implies that trend inflation is an I(2) process. Note that trend inflation here would need to have a series of negative shocks that could not be reversed within the sample. However, these shocks can hardly be described as a standard Gaussian white noise process with mean zero. Thus, modelling trend inflation as a random walk with drift could work well with the downward trend of these economies' inflation during the period under analysis. Now, the Phillips curve can be rewritten as

$$\pi_t = \pi_t^* + \beta y_{t-1}^c + \varepsilon_{2t}\varepsilon_{2t} \sim N\left(0, \sigma_{\varepsilon_2}^2\right) \tag{5}$$

$$\pi_t^* = \theta_t + \pi_{t-1}^* + \eta_{\pi_t^*}\eta_{\pi_t^*} \sim N\left(0, \sigma_{\eta_{\pi_t^*}}^2\right) \tag{6}$$

$$\theta_t = \theta_{t-1} + \eta_{\theta_t}$$

Where θ_t evolves according to an AR(1) process, and the variances ε_{2t}, $\eta_{\pi_t^*}$ and η_{θ_t} are white noise error terms. The advantage of the AR(1) specification applied here is that the smoothness of trend inflation is not imposed but instead estimated. Note that the trend inflation in this paper should be seen as a special feature of inflation of five emerging economies for the period under analysis rather than as characteristic of the trend inflation of these emerging economies. Moreover, emerging markets often experience a massive change in the structural economy and high uncertainty in macroeconomic variables due to both domestic shocks and external shocks. Therefore, incorporating stochastic volatility terms into the model could help estimate the output gap of these emerging economies more accurately. In particular, the time-varying stochastic volatility terms, $\exp(h_t^k)$ $with\ k = 1, \ldots 5$, are added to the trend and cycle components to exhibit the changes in the size of shocks to the potential output, trend inflation, potential output growth, AR(1) trend inflation component, and the output gap. For example, the volatility of the shocks to the output gap of these emerging economies could be increased due to the shocks from the Asian financial crisis, which led to a large contraction output in these economies during this period. The Eq 2 –Eq 4 and the Eq 6 can be now extended as

$$y_t^t = \mu_{t-1} + y_{t-1}^t + \exp(h_t^1)\psi_t^1\psi_t^1 \sim N(0,1) \quad (7)$$
$$\pi_t^* = \theta_t + \pi_{t-1}^* + \exp(h_t^2)\psi_t^2\psi_t^2 \sim N(0,1) \quad (8)$$
$$\mu_t = \mu_{t-1} + \exp(h_t^3)\psi_t^3\psi_t^3 \sim N(0,1) \quad (9)$$
$$\theta_t = \theta_{t-1} + \exp(h_t^4)\psi_t^4\psi_t^4 \sim N(0,1) \quad (10)$$
$$y_c^t = \phi_1 * y_{t-1}^c + \phi_2 * y_{t-2}^c + \exp(h_t^5)\psi_t^5,\psi_t^5 \sim N(0,1) \quad (11)$$

where the observation error ψ_t^k with k = 1,2,3,4,5 are included to capture the measurement and sampling errors. All stochastic volatility terms are modelled as random walks

$$h_t^k = h_{t-1}^k + \text{?}_t^k \qquad \text{?}_t^k \sim N\left(0, \sigma^2_{\text{?}_t^k}\right) \quad (12)$$

for k = 1,2,3,4,5 and the process error ?_t^k measures the variation in the underlying volatility dynamics. Note that the stochastic volatility components $\exp(h_t^k)\,\psi_t^k$ are nonlinear but they can be transformed into linear components by taking the logarithm of their squares

$$\ln(\exp(h_t^k)\,\psi_t^k)^2 = 2\,h_t^k + \ln(\psi_t^k)^2 \quad (13)$$

where $\ln(\psi_t^k)^2$ is log-chi-square distributed with expected value -1.2704 and variance 4.93. The linear model in Eq 13 is approximated by an offset mixture time series model as

$$g_t^k = g_{t-1}^k + \xi_t^k \quad (14)$$

where $g_t^k = \ln((\exp(h_t^k)\,\psi_t^k)^2 + c)$ with c = 0.001 is an offset constant, and the distribution of ξ_t^k is the mixture of normals, as

$$f(\xi_t^k) = \sum_i^M q_i\, f_N(\xi_t^k \mid m_i - 1.2704, v_i^2), \quad (15)$$

with component probabilities q_i, means m_i = -1.2704 and variances v_i^2. Similarly, this mixture density can be written in terms of the component indicator variable ι_t^k as

$$\xi_{\text{i}}^k(\iota_t^k = i)$$

$$N(m_i - 1.2704, v_i^2),\ with\ \Pr(\iota_t^k = i) = q_i, \quad (16)$$

Following Shephard and Omori (2004) I use a mixture of M = 10 normal distributions to make the approximation to the log-chi-square distribution. The values for $\{q_i, m_i, v_i^2\}$ are provided by Shephard and Omori (2004) in their Table 1.

2.2.3. MCMC Algorithm

This paper will apply the Gibbs sampler to simulate draws of the posterior distributions of the unknown parameters and the unobserved states using only tractable conditional distributions.

For notational convenience, I define a state vector $\alpha_t = (y_t^\tau, \pi_t^*, \mu_t, \theta_t, y_t^c)$, a stochastic volatility vector $h_t = (h_{1t}, h_{2t}, h_{3t}, h_{4t}, h_{5t})$, and an indicator vector $\iota_t = (\iota_t^{y^\tau}, \iota_t^{\pi^*}, \iota_t^{\mu}, \iota_t^{\theta}, \iota_t^{y^c})$. The unknown coefficient parameters are collected in the vector $\lambda = (\phi_1, \phi_2, \beta)$, and the variance parameters are collected in the vector $\sigma = (\varepsilon_1, \varepsilon_2)$. The data vector is denoted by $x_t = (y_t, \pi_t)$. Stacking observations over time, I denote x = $\{x_t\}_{t=1}^T$ and similarly for α, h and ι. The posterior density of interest is given by $f(\alpha, h, \iota, \lambda \mid x)$. After giving the initial values of variables and parameters, the sampling scheme is as follows:

- Sample the trend and cycle components in state vector α from $f(\alpha \mid h, \lambda, x)$.
- Sample the hyperparameters in λ from $f(\lambda \mid \alpha, h, \iota, y)$ and σ from $f(\sigma \mid \alpha, h, \iota, y)$.

- Sample the mixture indicators ι from $f(\iota \mid \alpha, h, \lambda, x)$ and the stochastic volatility terms h from $f(h \mid \alpha, \iota, \lambda, x)$.

These steps are repeated J = 1000 times. After leaving the draws of the burn-in period of B = 200, the sequence of 800 remaining draws (B + 1, ..., J) is used to approximates a sample from the desired posterior distribution $f(\alpha, h, \iota, \lambda \mid x)$.

3. Empirical Results

3.1. Prior Choice

This paper uses the same prior distributions of the unknown parameters. In particular, I assume a normal distribution for coefficient parameters (β and $\emptyset$) and inverse Gamma distribution for the variance parameters of the output and inflation equation (ε_1 and ε_2). Following Frühwirth-Schnatter and Wagner (2010) the prior distribution of the time-invariant part of the trend and cyclical volatilities is given by h_0^k ~ $N(a_0, A_0)$ for k = 1, 2, 3, 4,5. The prior distribution on the time-varying part of the volatility of trend/cyclical components is uninformative and centered at zero: $\sigma_{\lambda,k} \sim N\,(0,1)$ for k = 1, 2, 3, 4, 5. More detailed, I use an informative prior on the $(\phi_1 + \phi_2) \sim N(0.7, 0.01^2)$ for the sum of the coefficient parameters of the output gap. Note that the prior belief of 0.7 for $(\phi_1 + \phi_2)$ is an average of values typically found in the literature. [1] [2]

I use the prior belief of 1.2 for ϕ_1 implies a prior belief of -0.5 for ϕ_2, which is in line with the typical hump-shaped pattern in response to cyclical shocks. In terms of the slope of the Phillips curve, I set a prior distribution of $\beta \sim N\,(0.5, 0.25^2)$, which implies that the 95% interval of our prior belief ranges from -0.38 to +0.62. This value is in line with a wide range of results in the literature. [3]

In terms of variance parameters, ε_1 and ε_2, I set the prior beliefs to ε_1 = 0.1, ε_2= 1.0. The strength of the two priors is the same and equal to 0.15 (Maliszewski, 2010), (Aiyar & Tchakarov, 2008) and among others). Regarding the stochastic volatility terms, there is no prior information about these components for emerging countries. In this paper, I set the prior beliefs a_0 for the constant volatility part h_0 of the level shocks to unobserved variables (y^τ, y^c, π^*, μ and θ) to the log of the standard deviation of the respective HP components. And the prior standard deviation $\sqrt{A_0}$ was set to 0.05 for the respective volatility terms.

3.2. The Posterior Distribution of Parameters

Table 2 shows the mean with the 10% and 90% percentiles of the posterior distribution of all parameters of the five emerging economies. Firstly, it is clearly seen that the output gaps of these emerging economies are relatively persistent. While the posterior mean of ϕ_1 and ϕ_2 are close to the prior in the Philippines, Malaysia, and Indonesia, the posterior mean of ϕ_1 is less than 1, and ϕ_2 is close to zero in the Vietnamese and Thailand economies. This result is in the range reported in the literature.[4]Secondly, inflation is very sensitive to the output gap in Vietnam and Indonesia, but not to those in the Philippines, Malaysia, and Thailand. In Vietnam, the posterior mean of beta is 2.63, indicating that a positive output gap of 1% is associated with a positive deviation of the inflation rate from its trend of 2.63%. This result is in line with Maliszewski (2010), who confirms that the output gap is an important driver of the inflation fluctuations in this economy. However, the negative of the posterior mean of beta in Indonesia indicates that a negative output gap of -1% is associated with a positive deviation of the inflation rate from its trend of 2.77%. The reason could be that the estimation is mainly influenced by the specific feature of Indonesia's economy during the Asia financial crisis. The historical economy suggests that the adverse shocks from the regional crisis and instability of macroeconomic policies led this economy to drop to a deep crisis due to its weakness in banking systems and financial markets. During the second half of 1998, there was the spread of the banking system's collapse, a significant drop in foreign direct investment inflow, a large output contraction, and a sharp fall of the domestic currency, which put more pressure on inflation. In particular,

[1] Maliszewski (2010), and (Aiyar and Tchakarov, no date) found that the estimated coefficient parameters of output gap equation are around 0.7 for the Vietnamese and the Thailand economies.
[2] Bautista. (2003) found that the coefficient parameters of the output gap are around 0.9 for the Philippines and the Thailand economies, 0.7 for the Indonesian economy, and 0.3 for the Malaysian economy
[3] Maliszewski (2010) found that the estimated slope of the Phillips curve is 0.4041 for the Vietnamese economy and (Aiyar and Tchakarov, 2008) find that it is 0.268 for the Thailand economy.
[4] Maliszewski (2010) found that the lagged output gap coefficient of Vietnam is slightly lower than the prior. And (Aiyar and Tchakarov, 2008) also reported a much lower value of the lagged output gap coefficient for Thailand.

Table-2. Parameter estimates.

	Philippines			Malaysia			Vietnam			Indonesia			Thailand		
Para	**Mean**	**5%**	**95%**	**Mean**	**5%**	**95%**	**Mean**	**5%**	**95%**	**Mean**	**5%**	**95%**	**Mean**	**5%**	**95%**
$\emptyset_1$	1.09	0.83	1.32	1.10	0.94	1.29	0.65	0.33	0.97	1.34	1.13	1.52	0.98	0.77	1.23
$\emptyset_2$	-0.25	-0.43	-0.10	-0.20	-0.36	-0.07	0.08	-0.21	0.29	-0.60	-0.75	-0.41	-0.08	-0.31	0.10
β	0.34	0.01	0.76	0.16	-0.01	0.34	2.63	1.28	5.53	-2.59	-3.88	-0.93	0.29	0.13	0.45
$\sigma^2_{\varepsilon_1}$	0.12	0.07	0.22	0.28	0.13	0.49	0.32	0.11	0.69	0.12	0.06	0.24	0.63	0.22	1.24
$\sigma^2_{\varepsilon_2}$	17.38	16.49	18.26	17.13	16.32	18.04	15.20	14.20	16.18	17.17	15.56	21.26	14.77	13.95	15.63
$\sigma^2_{\varphi_1}$	0.35	0.04	0.67	0.33	0.04	0.66	0.20	0.02	0.39	0.19	0.02	0.47	0.31	0.03	0.60
$\sigma^2_{\varphi_2}$	0.03	0.00	0.07	0.01	0.00	0.02	0.06	0.00	0.18	0.01	0.00	0.02	0.01	0.00	0.05
$\sigma^2_{\varphi_3}$	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02
$\sigma^2_{\varphi_4}$	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.03
$\sigma^2_{\varphi_5}$	0.78	0.08	1.66	2.26	1.02	3.71	1.00	0.13	1.99	9.60	5.49	13.76	1.33	0.27	2.31

Note: The ordering of state variables is as follows: (1) potential output, (2) trend inflation, (3) output growth, (4) the AR(1) inflation compoment, (5) the output gap.

Indonesia's inflation dramatically soared to around 75% in 1998Q3 while the output was below its potential level, about 20%.

Regarding the variance parameters, the posterior mean of ε_1, ψ_1, ψ_2, ψ_3, ψ_4, and ψ_5 are very small and close to the prior in these economies, with the exception of ψ_5 of Indonesia. It means that in the Indonesian economy, the measurement and sampling errors of the innovations to the output gap partly account for the volatility of the innovation to Indonesia's output gap.

In terms of the variance parameter of the Phillips curve, ε_2 is large in all five emerging economies with the median of the posterior distribution of ε_2 is between 14 to 16 for these economies. It implies that temporary shocks to inflation are also important drivers of inflation fluctuations in these economies. These results raise questions about the main drivers of inflation fluctuations in emerging economies. In future research, more macroeconomic variables and more economic relationship should be added to the model to investigate the dynamics of movements of macroeconomic variables in these economies.

3.3. Potential Output and Potential Growth Estimates

Potential output, depicted in panel (a) of each figure, is estimated as a smooth upward trend that tracks the low-frequency movement in real GDP of the Philippines, Malaysia, Vietnam, and Thailand. In these economies, the standard deviation of innovations to potential output is also constant over time, with a posterior median between 0.1 and 0.3 (see panel (f) of each figure). In Indonesia, potential output significantly dropped during the period of 1998Q2-1999Q3 due to the substantial adverse effect of the Asian financial crisis. Furthermore, the considerable increase in stochastic volatility of potential output occurred during the period of 1998Q1-1999Q3, showing up the high level of macroeconomic uncertainty in Indonesia due to the negative effect of the Asian financial crisis on this economy (see panel (f) of fig 4).

Panel (d) of each figure depicts the time variation of the potential growth of these economies. It is clearly seen that the Philippines' potential growth rate increases from an annual rate of about 0.7% in 1990 to about 1.5% at the end of the sample (see panel (d) of fig 1). This result is in line with that of an earlier study on this economy[5]. In other economies, the potential output growth tends toward a slowdown in the post-global financial crisis period. In particular, Malaysia's potential growth steadily decreases from an annual rate of about 1.75% in 1990 to 1.3% at the end of the sample period, while Vietnam's potential output growth steadily decreased from 1.75% in 1995 to 1.58% in 2019. Alternately, Indonesia's potential growth rate and Thailand's potential growth rate move within the range of 1.2% - 1.4%, and 0.8% - 0.9%, respectively. From panel (i) of each figure, note that the standard deviation of innovations to potential output growth is constant over time with a posterior median of about 0.03 in all five emerging economies.

3.4. Trend Inflation and its AR (1) Component

Panel (c) of each figure plots actual inflation and the posterior result of trend inflation of each economy. The smooth in trend inflation of the five emerging economies implies that inflation's fluctuations are mainly caused by the output gap and its idiosyncratic shocks. While trend inflation of Philippines, Malaysia, Indonesia, and Thailand tends to decrease over time, Vietnam's trend inflation is likely more volatile during the whole sample period. In particular, an upward trend of Vietnam's inflation rate reflects the excess demand and a bubble period of this economy during the prior-crisis, while the inflation's fluctuations during the post-crisis period are likely the effects of the global financial crisis and instabilities of macroeconomic policies in Vietnam. The standard deviation of innovations to trend inflation is found to be constant over time with a posterior median of about 0.1 in these economies (see panel (h) of each figure).

Panel (e) of each figure plots the posterior results of the AR(1) component of trend inflation. While this series is smooth and constant below zero in Malaysia, Indonesia, and Thailand, it is more volatile in the Philippines and Vietnam. Obviously, these results confirm that the AR(1) component has contributed to the curve of trend inflation in these economies. Moreover, these results imply that these economies are likely to be close to a low average inflation rate over time. The standard deviation of innovations to the AR(1) component of trend inflation is found to be constant over time with a posterior median of about 0.1 in these economies (see panel (j) of each figure).

3.5. The Output Gap Estimates

The estimated output gap is depicted in panel (b) of each figure. In general, the estimated output gaps can pinpoint the turning points in these economies' business cycle. Although the shape and magnitude of estimated gaps significantly differ from country to country, these gaps imply that these economies have converged to a more stable economy overtime. Additionally, the stochastic volatility of innovations to the output gap of all five emerging economies is clearly time-varying over the whole sample period (see panel (g) of each figure). The individual output gap and its innovation will be detailed below.

[5] Felipe and Estrada (2018) find that the potential output growth of the Philippines tends to increase in recent years

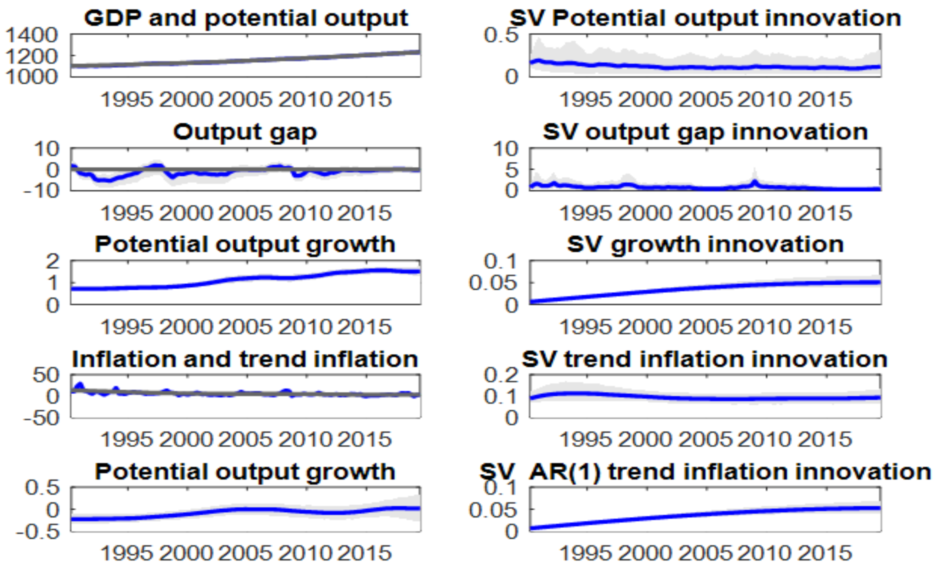

Figure-1. The Philippines.

The Philippines

Panel (b) of Figure 1 displays the posterior results of the estimated output gap of the Philippines. This result confirms that the estimated output gap can point out the Philippines' business cycle, turning points quite accurately. The first sizable drop in the output gap occurred during 1990 - 1995, showing the strong impact of the power crisis in the 1990s on the Philippines' productivity. The second sizable drop occurred during 1998 – 2006, exhibiting the decrease in demand due to the shock of the Asian financial crisis and the falling of food prices due to the subsequent El Nino episode. This result contradicts (Bautista., 2003) who confirms that the effects of the Asian financial crisis on the Philippines economy was only a slowdown and not as a recession. The third sizable drop occurred in 2009, showing the negative shocks from the Global financial crisis on this economy. In particular, in 1993Q3, the Philippines' actual activity was below its potential activity about 5.6%, while it was 4% and 2.9% in 1998Q4 and 2009Q2, respectively. This result implies that the impact of the shocks from the domestic political crisis in the 1990s was more severe than that of other shocks.

The time-varying stochastic volatility of innovations to the Philippines' output gap is depicted in panel (g) of fig 1. The considerable increase in volatility, 1.5, 1.4, and 2.2, respectively, are clearly seen in 1992Q2, 1998Q1, and 2009Q1 showing the high volatility of macroeconomic in the Philippines due to the adverse shocks from the domestic political crisis in the 1990s, the Asian financial crisis in 1997, and the Global financial crisis in 2008.

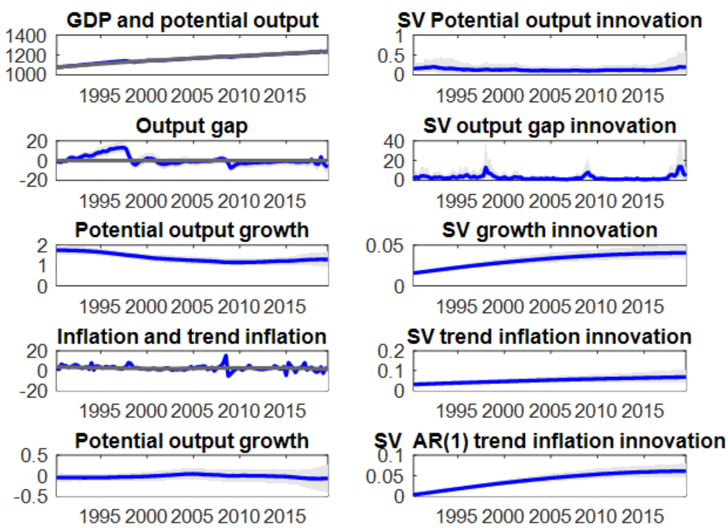

Figure-2. Malaysia.

Malaysia

Panel (b) of Figure 2 displays the posterior results of the estimated gap of Malaysia. The result shows that Malaysia experienced a cyclical boom with actual output exceeding potential by as much as 12.5% in 1997. The first sizable drop in the output gap occurred in 1998Q4, showing the negative effect of shocks from the Asia financial crisis on this economy. The second sizable drop in the output gap occurred in 2001Q4, showing the poor in the export performance and the effect of the bursting of the technology bubble in the United States during the 2000s. The third sizable drop in the output gap occurred in 2009Q1, showing the impact of adverse shocks from the Global financial crisis. During the remainder of the sample period, the gap is negative due to the substantial impact of shocks from instability macroeconomic policies and the shocks from the trade war on this economy. In particular, actual Malaysian activity of about 4.6% in 1998Q4 was below its potential activity, while it was 4.0% and 6.6% in 2001Q4 and 2009Q2, respectively. It implies that the impact of the shock from the Asian financial crisis is smaller than that of the Global financial crisis.

As can see in panel (g) of fig 2, the innovation to the output gap of Malaysia is at a high average in the first sample period. The first considerable increase in volatility of the output gap, about 12.94, occurred in 1998Q1 showing the shocks from the Asian financial crisis. The second significant increase in the innovation to the output gap of about 8.0 occurred in 2009Q1 capturing the shocks from the Global financial crisis. At the end of the sample period, the innovation to the output gap of Malaysia dramatically increased to 13.7 in 2018Q4, indicating a high level of volatility of the Malaysian economy due to its instability in macroeconomic policies and the adverse impact from the trade war.

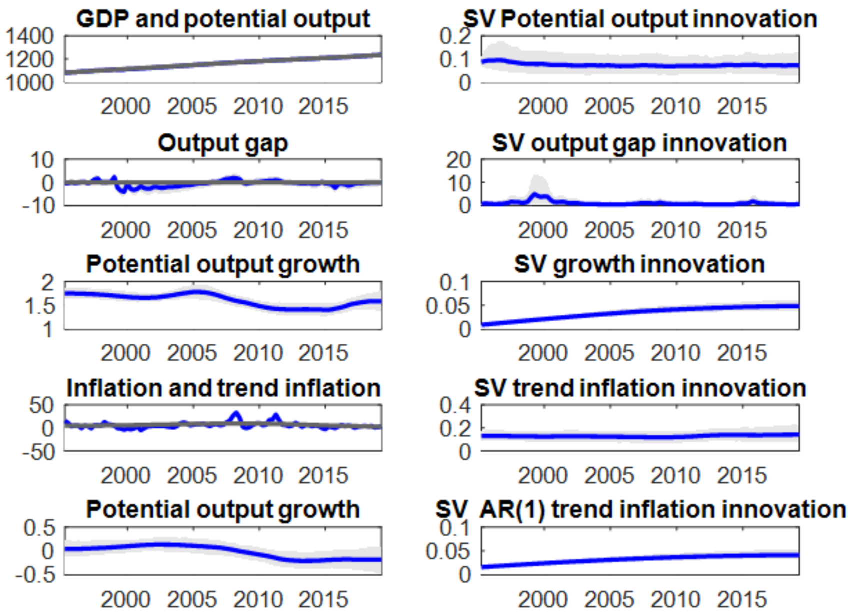

Figure-3. Vietnam

Vietnam

Panel (b) of Figure 3 depicts the posterior results of the output gap of Vietnam. The first considerable drop in the output gap of about 8.0 occurred in 1999Q4, then it remained consistently negative until 2006Q2 reflecting the weaknesses of the reformed economy and the negative effects of the Asian financial crisis. Before suffering the Global financial crisis, this economy experienced a cyclical boom period in which the actual productivity exceeded its potential, reaching around 2% in 2008Q1. However, the output gap dropped to negative in 2009Q1 due to adverse shocks from the Global financial crisis. In response to these shocks, various stimulus packages were implemented to boost up this economy. Although the policymakers tried to control prices and inflation, to stabilize the value of the local currency and to encourage the development of financial institutions in Vietnam, these policies have been inconsistent over time and partly contributed to recent macroeconomic instabilities of Vietnam.

Panel (g) of this figure shows the time-varying stochastic volatility of innovations to the output gap in Vietnam. The considerable increase in the innovation to the output gap of about 4.1 occurred in 1999Q2, exhibiting the change in volatility due to the Asian financial crisis and the reform of this economy. Then, the stochastic volatility drops to a low level throughout the remainder of the sample period.

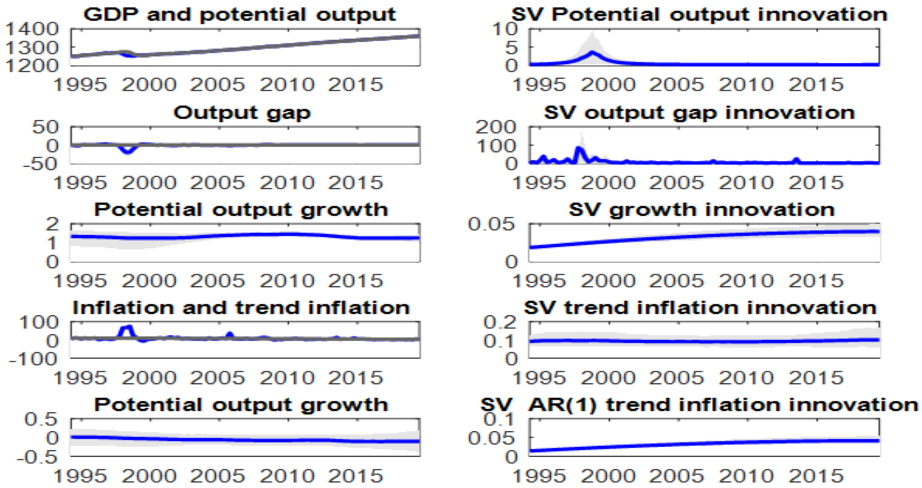

Figure-4. Indonesia.

Indonesia

Panel (b) of Figure 4 depicts the posterior results of the output gap of Indonesia. The actual productivity exceeded its potential, reaching around 3.1% in 1996Q4, indicating a cyclical boom period of this economy. The first sizable drop in the output gap occurred in 1998 to reflect the substantial impact of the Asian financial crisis, which led actual output to drop below its potential, falling to about 20.4% in 1998Q2. Since then, the gap has been moving above zero, indicating that the impact of the Global financial crisis on the Indonesian economy is limited, and this economy tends to converge to a more stable business cycle as do those of other economies in this region.

The time-varying stochastic volatility of innovations to Indonesia's output gap is depicted in panel (g) of fig 4. The most considerable increase in volatility is clearly seen during the first sample period and reached a peak at 74.4 in 1998Q1, reflecting the mass uncertainty of this economy in the pre-AFC period and post-AFC period. Since then, the innovation to the Indonesian economy's output gap has dropped considerably to around 3.5 on average throughout the remainder of the sample period.

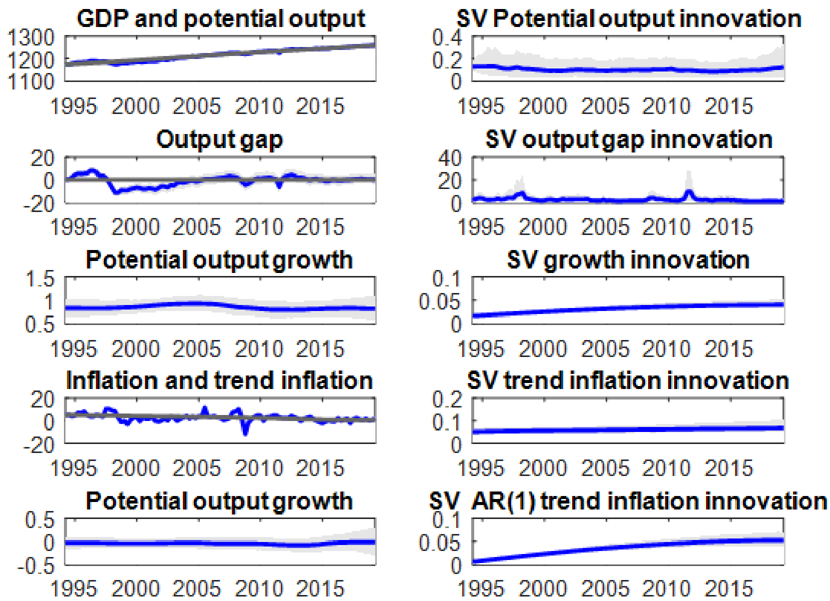

Figure-5. Thailand.

Thailand

Panel (b) of Figure 5 depicts the posterior results of the output gap of Thailand. The result shows that Thailand experienced a cyclical boom with actual output exceeding potential by as much as 8% in 1996. The first sizable drop in the output gap occurred between late 1997 to 2005Q2, showing the prominent impact of shocks from the Asian financial crisis, the shocks from the Tech Bust, and the increase of oil price in the 2000s. The second sizable drop in the output gap occurred between late 2008 to early 2012, reflecting the negative effect of the Global financial crisis and the shocks from the Great Flood in Thailand in 2011. While the actual output, about 11.5% in 1998Q3, was below its potential, Thailand's actual activity, about 4.6% and 6.3% in 2008Q4 and 2011Q2, respectively, was below its potential activity. This result implies that the Asian financial crisis shocks are much more severe and more prolonged than others. At the end of the sample period, the gap is likely to be close to zero, indicating that this economy tends to converge to a more stable business cycle.

Panel (g) of fig5 depicts the time-varying stochastic volatility of innovations to the output gap in Thailand. The impact of shocks from the Asian financial crisis shows up as a considerable increase in innovation on the output gap of about 8.5 in 1998Q2. Then, the low volatility of innovation to the gap was exhibited until 2008Q1. During the Global financial crisis, the innovation to the output gap slightly increased and peaked at 9.5 in 2011Q4 to reflect the strong impact of shocks from the Great Flood, which affected the industrial area and its production. However, it quickly drops to below one at the end of the sample period.

4. Conclusion

Measuring potential output and the output gap plays a crucial role in the formulation and implementation of macroeconomic policies. In the literature, many researchers have done to estimate the output gap for industrialized countries, but little empirical research has been conducted to estimate the output gap for emerging economies in Southeast Asia. Moreover, the common methodology and assumption of estimating the output gap for industrialized economies maybe not suit emerging economies, which often experience large changes in structural and frequently macroeconomic uncertainty. Therefore, this paper tries to fill the gap in the literature by applying a bi-variate UC model of output and inflation to estimate the output gap for five emerging economies in Southeast Asia, including the Philippines, Malaysia, Vietnam, Indonesia, Thailand from the 1990s to 2019. In this paper, trend inflation is modelling as a random walk with a time-varying drift to fit the specific feature of these emerging economies. The advantage of the AR(1) here is the smooth trend of trend inflation is estimated but not imposed. Moreover, time-varying stochastic volatility terms are also added into unobserved components to exhibit the change in the size of shocks to transitory and contemporary components of output and inflation of emerging economies.

The main findings are as follows. Firstly, the estimated output gaps of these emerging economies are able to identify the recession periods as defined by the NBER, and these economies tend to converge to a more stable business cycle over time, except for that of Malaysia. This result is in line with previous empirical research, which provides some convergence of the business cycle in a group of emerging economies in Asia (Claessens, Kose, & Terrones, 2012). Similar to previous studies, this paper finds that the output gap of these emerging economies is relatively persistent. While the mean of the posterior distribution of cycle $\emptyset_1$ and $\emptyset_2$ are close to the prior in these economies in the case of the Philippines, Malaysia, and Thailand, the median of the posterior distribution of $\emptyset_1$ is less than one and $\emptyset_2$ are close to zero in the case of Vietnam and Thailand. This result is in the range reported in the literature. Secondly, a slowdown in the potential growth is found in four emerging countries, including Malaysia, Vietnam, Indonesia, and Thailand. In the Philippines, the potential output growth increases from about 0.7% on an annual base in 1990 to about 1.5% at the end of the sample. This result is in line with Felipe and Estrada (2018), who find that the Philippines' potential output growth tends to increase in recent years. Thirdly, while the Phillips curve slope is found very small in the Philippines, Malaysia, and Thailand, inflation is very sensitive to the output gap in Vietnam and Indonesia. However, the negative relationship between the lagged output and inflation in Indonesia is a specific feature of this economy within the period under analysis. Fourthly, time-varying stochastic volatility is clearly seen in the innovations to the output gap of these emerging economies, and it is also significant for the potential output of Indonesia. Meanwhile, it confirms that there is no need to add stochastic volatility terms in the equation of trend components of output and inflation of these economies, except for Indonesia's potential output. Lastly, the large variance of the Phillips curve of these economies implies that temporary shocks to inflation are important drivers of inflation fluctuations. In future research, more macroeconomic variables and more economic relationships should be added into the model to investigate the dynamics of movements of macroeconomic variables in these economies.

I also note that a decrease in sizable gaps here does not mean that these countries achieve the targets of low inflation and stable growth in the long-run. These economies should focus on reforming financial markets and banking systems to improve the effectiveness of domestic policies. Furthermore, policymakers also need to assess other macroeconomic variables and their relationships to offer good recommendations for monetary and fiscal policies. In other words, this paper still has some issues that should be resolved in future research. Firstly, the high volatility of innovation to the Indonesian gap during the Asian financial crisis and the negative relationship between the lagged output gap and inflation raises the suggestion that it would be desirable to offer another model to estimate the output gap for this economy. Secondly, the significant variance of the Philips curves in all five emerging economies confirms that temporary shocks to inflation are important drivers of inflation fluctuation. Therefore, it is necessary to understand the economic relationships between macroeconomic variables and other variables, such as financial variables, which may impact the output and inflation fluctuations of these emerging economies. This task could be undertaken in further research.

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