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AN ANALYSIS OF THE PHILLIPS CURVE IN BRUNEI: EMPIRICAL EVIDENCE

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Abstract

The Phillips curve is still a valued and fundamental macroeconomic theory, although groups of economists called "monetarists" and "new classical economists" criticized harshly basic tenets of the tradeoff between inflation rates and output gap. This paper chose Brunei as the case study to examine empirically the validity of the Phillips curve by employing the Hodrick-Prescott (HP) filter methods. In other words, this paper used as the HP filter method to estimate the output gap by decomposing the actual output into the "trend" output and "cycle" output. The former can be used as the potential output while the latter can be used the output gap. In a nutshell, empirical findings of the present study show that there is a long-run relationship – and also long-run causality -- between Brunei's output gap and inflation rate. These findings provide an additional empirical support to the validity of the Phillips curve in the context of an Asian country, which is the main finding of the empirical analysis done in this study.

Keywords: Phillips curve, Brunei

Introduction

N. Gregory Mankiw chose the Phillips curve as a topic for his Harry Johnson Lecture, which was subsequently published in *The Economic Journal* in 2001. Mankiw mentioned that one of ten fundamental principle of economic science is that a society faces a short-run trade-off between inflation and unemployment or the theory of the Phillips curve. However, there are some economists who believe that the Phillips curve was still a speculative idea (Mankiw, 2001).

On the other hand, Mankiw (2001) commented that the existence of the Phillips curve is inexorable because it is impossible to make sense of the business cycle, and in particular the short-run effects of monetary policy, unless we admit the existence of a tradeoff between inflation and unemployment. Thus, the Phillips curve remained mysterious because the economists have not produced satisfactory theory to explain the phenomena.

The basic theoretical foundation of the Phillips curve can be derived from the relationship between output gap and inflation rate. In his seminal paper, David Romer (1993) pointed out that unanticipated monetary shocks affect both prices and real output. In his theoretical model, the difference between actual output and the "natural" rate of output is positively related with difference between actual inflation and expected inflation.

$$y = y^* + \beta(\pi - \pi^e) \qquad (1)$$

where β is slope coefficient, y is actual output, y^* is the natural rate of output or the potential output, π is inflation rate and π^e is expected inflation rate.[1] These relations can be rearranged into:

$$y - y^* = \beta\ (\pi - \pi^e) \qquad (2)$$

The equation (2) can be rearranged into:

$$\pi - \pi^e = 1/\beta\ (y - y^*) \qquad (3)$$

Furthermore, $1/\beta$ can be replaced by $-\gamma$.

$$\pi - \pi^e = -\gamma\ (y - y^*) \qquad (4)$$

where γ is slope coefficient which can be considered as the slope of the Phillips curve. Second step is to estimate natural rate of unemployment. The equation (4) can be re-arranged to:

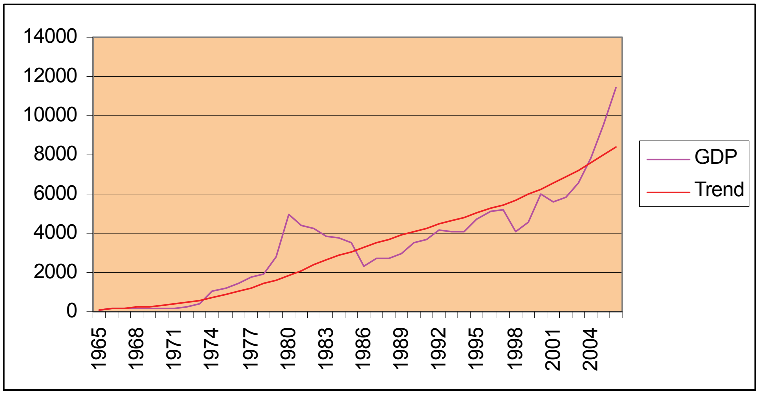
$$\pi = \pi^e - \gamma\ (y - y^*) \qquad (5)$$

Under the adaptive expectation hypothesis, expected inflation (π^e) equals to the last period's inflation (Ball and Mankiw, 2002).

The Phillips curve is still a valued and fundamental macroeconomic theory, although groups of economists called "monetarists" and "new classical economists" criticized harshly basic tenets of the tradeoff between inflation and output. As Hart observed, "The Phillips curve still plays a prominent role in macroeconomic theory and associated empirical work" (Hart, 2003:108). Thus, this paper chose Brunei as case study to examine empirically the validity of the Phillips curve by employing the Hodrick-Prescott (HP) filter method. In other words, this paper used the HP filter method to estimate output gap by decomposing the actual output into the "trend" output and "cycle" output. The former can be used as the potential output while the latter can be used the output gap.

As Figure 1 showed, the economic development in Brunei from 1965 to 2006 can be divided into four periods:1) period one (1965-1973), 2) period two (1974-1985), 3) period three (1986-2003), 4) period four (2004-2006). In period one (1965-1973), the Bruneian economy under-performed and suffered from the negative output gap, except in year 1965. In the period two (1974-1985), Bruneian economy recovered and output gap turned to positive. However, in period three (1986-2003), the Bruneian economy suffered the negative output gap. Finally, in period four (2004-2006), the Bruneian economy recovered and output gap turned to positive.

Figure 1: Output gap in Brunei from 1965 to 2006 (thousand US dollars)



This paper consists of five sections. Following this Introduction, Section 2 briefly review the previous literatures on the Phillips curve. Section 3 discusses about data and research methods. Section 4 reports and discusses research findings. Concluding remarks are offered in Section 5.

Literature review

Since William Phillips established an empirical evidence for the so-called Phillips curve in 1958 (Phillips, 1958), the idea are tested and empirically confirmed by economists (Samuelson and Solow, 1960; Gordon, 1970). This confirmation is known as the "Solow-Gordon confirmation". However, the economist who belonged to the different school of thought mercilessly attracted the hypothesis (Phelps, 1967; Friedman, 1967; Lucas, 1976). The existence and usefulness of the Phillips curve was largely ignored by economists and policy-makers in the 1980s.

However, in the 1990s, there had been a revival of interest in the Phillips curve research and the topic has again become "the subject of intensive debate" (Debelle and Vickery, 1998). Thus, King and Watson tested the Phillips curve hypothesis using the U.S. post-war macroeconomic data. Their findings provided empirical support to the existence of a trade-off relation between unemployment rate and inflation rate in the United States (King and Watson, 1994). A study by Hogan examined the Phillips curve using the U.S. macroeconomic data over the period 1960-1993. The results supported the existence of a significant and negative relationship between unemployment and inflation although the traditional Phillips curve seemed to over-predict the rate of inflation (Hogan, 1998).

Recent methodological innovations allow a more thorough examining of the Phillips curve hypothesis. For example, some researchers employ panel data analysis to analyse the "common" Phillips curve in different countries over the same period of time. DiNardo and Moore examined 9 OECD (Organisation for Economic Co-operation and Development) member countries and confirmed the existence of the "common" Phillips curve in these countries (DiNardo and Moore, 1999). Turner and Seghezza employed the panel data method to examine the Phillips curve in 21 OECD countries over the period from the early 1970s to 1997. Turner and Seghezza concluded that the overall result provided a "strong support" for the existence of the "common" Phillips curve among 21 member countries of the OECD (Turner and Seghezza, 1999).

Furthermore, Shadman-Mehta (2001) re-evaluated the trade-off relationship between inflation and unemployment using the UK data for the period of 1860-1999. The researcher concluded that the wage equation cannot be inversed to determine unemployment rate. Islam *et al.* (2003) examined the Phillips curve hypothesis in the United States for the period of 1950-1999. They found that they were weakly cointegrated and long-run causality is unidirectional from the unemployment rate to the inflation rate. Thus, the researcher concluded that "This study, thus, affirms that the long-run Phillips curve relation still holds, although in weak form".

More importantly, several researchers have made attempts to examine empirically output-inflation tradeoff or the Phillips curve in the open economy settings. For example, Temple (2003) tested Romer's hypothesis that a lower sacrifice rate (the steeper slope of the Phillips curve) in more open economies. However, he found out weak empirical evidence for the negative correlation between openness and sacrifice rate. Temple concluded that he find little support for the theoretical prediction.

Loungani, Razin and Yuen (2001) tested the openness and output-inflation tradeoff by choosing the extent of capital control as a proxy of openness. According to their findings, in the countries with greater restriction on capital mobility, a given reduction in the inflation rate is associated with a smaller loss in output. In other word, there is negative relationship between degrees of openness and sacrifice ratio.

Wynne and Kersting (2007) reviewed the literature on the topics. According to him, the theory indicates that there should be negative relationship between openness and inflation rates and the Phillips curve should be steeper in more open economies. However, he pointed out that the empirical findings could not show consistent results.

Methods and Data

This paper examined empirically the validity of the Phillips curve in Brunei for the period 1981-2006. All data were obtained from the World Development Indicators 2010 which was produced by the World Bank (2010). Three separate econometric methods are used in this research, i.e., 1) unit root test, 2) Johansen cointegration test, and 3) Granger causality based on the VECM. The simple Phillips curve could be estimated by using following equation:

For the purpose of the estimation of the Phillips curve, equation (5) is re-arranged into:

$$\pi_t = \pi_{t-1} - \gamma\ (y_t - y_t^*) + \varepsilon_t \qquad (6)$$

where π_t is inflation rate in the year t, π_{t-1} is the inflation rate in the previous year to the year t, γ is slope coefficient of the "output gap", (y_t - y_t*) is output gaps which is estimated by Hodrick-Prescott (HP) filter, ε_t is error term. In other words, if the Phillips curve based on the HP estimate of the output gap, the output gap can be replaced by the cyclical output:

$$\pi_t = \pi_{t-1} - \gamma\, c_t + \varepsilon_t \qquad (7)$$

where c_t is the cyclical output. In this expectations-augmented Phillips curve, γ can be considered as the slope of the Phillips curve. Support for the Phillips curve would require negative and significant coefficients for the output. The empirical analysis will be based on the equation (7).

In the first stage of the study, in order to assess the Phillips curve in Brunei, unit root test is used to examine the stationarity of data sets. The current paper uses the augmented Dickey-Fuller (ADF) unit root test to investigate the stationarity (Dickey and Fuller, 1979, 1981). The ADF test is based on the following regression,

$$\Delta x_t = \mu + \beta_{t-1} t + \sum_{i=1}^{n} \gamma_i \Delta x_{t-i} + \varepsilon_t \qquad (8)$$

where x_t is a variable of interest, t is a linear time trend, Δ is the difference operator. β and γ are slope coefficients. ε_t is the error term. The ADF tests tend to be sensitive to the choice of lag length n which is determined by minimising the Akaike Information Criterion (AIC) (Akaike, 1974).
The AIC criterion is defined as:

$$AIC(q) = T \ln\left(\frac{RRS}{n-q}\right) + 2q \qquad (9)$$

where T is the sample size, RRS is the residual sum of squares, n is lag length, q is the total number of parameters estimated.

In the second stage, this study would employ the Ordinary Least Squares (OLS) regression model if the variables are integrated of order zero. On the other hand, if the variables are integrated of order one, the Johansen cointegration test would be used to check the long-run movement of the variables (Johansen, 1988, 1991). The Johansen cointegration test is based on maximum likelihood estimation of the K-dimensional Vector Autoregressive (VAR) model of order p,

$$Z_t = \mu + A_1\, \Delta Z_{t-1} + A_2\, \Delta Z_{t-2} + \ldots A_{k+1}\, \Delta Z_{t-p+1} + \varepsilon_t \qquad (10)$$

where Z_t is a $k \times 1$ vector of stochastic variables, μ is a $k \times 1$ vector of constants, A_t is $k \times k$ matrices of parameters, and ε_t is a $k \times 1$ vector of error terms. The model could be transformed into an error correction form:

$$\Delta Z_t = \mu + \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + \ldots \Gamma_{k+1} \Delta Z_{t-p+1} + \pi Z_{t-1} + \varepsilon_t \qquad (11)$$

where π and $\Gamma_1, \ldots, \Gamma_{k+1}$ are $k \times k$ matrices of parameters. On the other hand, if the coefficient matrix π has reduced rank, $r < k$, then the matrix can be decomposed into $\pi = \alpha\beta'$. The Johansen cointegration test involves testing for rank of π matrix by examining whether the eigen values of π are significantly different from zero. There could be three conditions: 1) $r = k$, which means that the Z_t is stationary at levels, 2) $r=0$, which means that the Z_t is the first differenced Vector Autoregressive, and 3) $0<r<k$, which means there exists r linear combinations of Z_t that are stationary or cointegrated.

For example, if r is equal to 1, then the relationship between the variables could be written as:

$$\begin{bmatrix} \Delta\pi_t \\ \Delta c_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \sum_{i=1}^{k-1} \begin{bmatrix} \Gamma_{i,11} \, \Gamma_{i,12} \\ \Gamma_{i,21} \, \Gamma_{i,22} \end{bmatrix} \begin{bmatrix} \Delta\pi_{t-i} \\ \Delta c_{t-i} \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \left[\beta_1 \, \beta_2\right] \begin{bmatrix} \Delta\pi_{t-1} \\ \Delta c_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} \qquad (12)$$

The vector β represent the r linear cointegrating relationship between the variables. The current study uses the Trace (Tr) eigenvalue statistics and Maximum (L-max) eigenvalue statistics (Johansen, 1988, 1991).

The likelihood ratio statistic for the trace test is:

$$Tr = -T \sum_{i=r+1}^{p-2} \ln(1 - \hat{\lambda}_i) \qquad (13)$$

where $\hat{\lambda}_{r+1}, \ldots\ldots\ldots, \hat{\lambda}_p$ are the smallest eigenvalues of estimated $p - r$. The null hypothesis for the trace eigenvalue test is that there are at most r cointegrating vectors. On the other hand, the L-max could be calculated as:

$$L - \max = -T \ln(1 - \hat{\lambda}_{r+1}) \qquad (14)$$

The null hypothesis for the maximum eigenvalue test is that r cointegrating vectors are tested against the alternative hypothesis of $r+1$ cointegrating vectors. If trace eigenvalue test and maximum eignevalue test yield different results, the results of the maximum eigenvalue test should be used because power of maximum eigenvalue test is considered greater than the power of the trace eigenvalue test (Johansen and Juselius, 1990).

Table 1: Johansen Test Model Specification

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept in CE	No	Yes	Yes	Yes	Yes
Intercept in VAR	No	No	Yes	Yes	Yes
Linear Trend in CE	No	No	No	Yes	Yes
Linear Trend in VAR	No	No	No	No	Yes

CE denotes cointegrating equation, VAR denotes Vector Autoregression

Among major problems of the Johansen cointegration test is that the test statistics are very sensitive to the choice of model specification and the lag length. As shown in Table 1, five (5) different model specifications are used for the Johansen cointegration test.

The optimal model specification and the lag length are determined by minimising the Akaike Information Criterion (AIC) (Akaike, 1974). In the third stage, this study runs the Granger-causality test based on the following the VECM (Granger, 1969):

$$\Delta\pi_t = \beta_1 + \sum_{i=1}^{n}\beta_{2i}\pi_{t-i} + \sum_{i=1}^{n}\beta_{3i}c_{t-i} + \beta_4 EC_{t-1} + \varepsilon_t \tag{15}$$

where EC_{t-1} is the lagged error correction term.

This paper uses the Granger-causality test based on the VECM. There are two advantages to using this method rather than the standard Granger causality test. First of all, the Wald test of the independent variables indicates the short-run causal effect. Secondly, significant and negative error correction term (EC_{t-1}) indicates the long-run causal effects.

Empirical Results

The ADF unit root test was conducted in order to examine the stationarity of the variables. The results from the ADF test are shown in Table 2. Despite minor differences in the findings as reported in the table, the obtained results indicate that the two variables – *inflation rate* (π) and *output gap* (c) -- are integrated of order one, I(1).

Table 2: ADF Unit Root Test

	Levels		First Difference	
	Constant without trend	Constant with trend	Constant without trend	Constant with trend
π	-1.878(2)	-4.339(0)*	-6.425 (0)**	-6.446(0)**
c	-2.790(0)	-1.854(0)	-3.900 (0)**	-4.933(0)**

Notes: Figures in parentheses indicate number of lag structures
** indicates significance at 1% level
* indicates significance at 5% level

In the second stage, the Johansen cointegration test was used to test the long-run movement of the variables. As Engle and Granger (1987) pointed out, only variables with the same order of integration could be tested for cointegration. As such, in the present study, both variables could be examined for cointegration.

Table 3: Optimal Lag Length Selection for the Johansen Test (Maximum Lag Length=2)

Lag Length	AIC
0	3.492
1	2.872*
2	3.106

AIC denotes the Akaike Information Criterion
*indicates optimal lag length selected by the AIC

First of all, the Akaike Information Criterion (AIC) was used to determine optimal lag length selection while maximum lag length is set for two (2). Table 3 shows that optimal lag length for the Johansen cointegration test is one (1), which minimises the AIC.[2]

Secondly, the AIC was used again to determine the most appropriate model specification for the Johansen cointegration test. As Table 4 shows, the best model specification is Model 1 and number of cointegrating equation is one (1).

Table 4: Optimal Model Specification Selected by the Akaike Information Criterion

	Model 1	Model 2	Model 3	Model 4	Model 5
Number of CEs = 0	3.344	3.344	3.484	3.484	3.402
Number of CEs = 1	3.053*	3.098	3.175	3.211	3.066
Number of CEs = 2	3.335	3.440	3.440	3.254	3.254

CE denotes cointegrating equation
*indicates optimal model selection selected by the AIC

Results of the cointegration tests are reported in Table 5 and Table 6. Both the Trace Eigenvalue test and the Maximum Eigenvalue test indicate one cointegrating equation. The findings indicate that there exists the long-run relationship between the two variables, such as *inflation rate* (π) and *output gap* (c), which means that these variables are co-integrated.

Table 5: The Johansen Cointegration Test (Trace Eigenvalue Statistic)

Eigenvalue	Trace statistic	5 percent critical value	Probability	Number of co-integrating equations
0.462	16.217	12.320	0.011	None*
0.050	1.238	4.129	0.310	At most 1

The result corresponds to VAR's with one lag
* indicates significance at 5% level

Table 6: The Johansen Cointegration Test (Maximum Eigenvalue Statistic)

Eigenvalue	Max statistic	5 percent critical value	Probability	Number of co-integrating equations
0.462	14.979	11.224	0.011	None*
0.050	1.238	4.129	0.310	At most 1

The result corresponds to VAR's with one lag
* indicates significance at 5% level

In other words, although the variables are not stationary at levels, in the long run, they closely move with each other. Long-run cointegration when the variables are normalised by cointegrating coefficients could be expressed as:

$$\pi = -9.942\,c \tag{16}$$

This cointegrating vector equation indicates that there exists a negative long-run relationship between inflation rates and output rates. These results support the existence of a trade-off relationship between inflation rate and output gap. In other words, the findings reveal that Brunei represents a textbook example to proof the validity of the Phillips curve in which output gap and inflation rate have the inverse relationship.

Finally, the Granger-causality method based on the VECM was employed to examine the long-run and short-run causal relationships between the two variables. Firstly, the Akaike Information Criterion was used to determine the optimal length for the causality test while maximum lag length is set for three (3). As Table 7 shows, optimal lag length for causality test is one (1) which minimises the AIC.

Table 7: Optimal Lag Length Selection for Causality Test (Maximum Lag Length=3)

Lag Length	AIC
1	3.053*
2	3.113
3	3.282

AIC denotes the Akaike Information Criterion
*indicates optimal lag length selected by the AIC

Next, results of the Wald Test and t-tests are reported in Table 8. The findings show that the error correction term (EC_{t-1}) is statistically significant and negative. This means that there is a long-run Granger causality between the inflation rate and output gap. In other words, the long-run Granger causality *does* confirm the existence of the long-run equilibrium relationship between output gap and inflation rate in Brunei as indicated in the Johansen cointegration test. On the other hand, as the results of the Wald test indicate, the Granger causality between the variables could not be detected in the short-run. This means that there was no causal relationship between unemployment rate and inflation rate over short periods of time in Brunei.

Table 8: Granger-Causality Test based on VECM

Dependent Variable: $\Delta\pi$		
Variable	**Degree of Freedom**	**Wald Test Statistics**
Δc	1	1.472
	Coefficient	**t-statistic**
EC_{t-1}	-0.317	-3.554*

The result corresponds to VAR's with one lags
* indicates significance at 5% level

In a nutshell, empirical findings of the present study show that there is a long-run relationship – and also long-run causality -- between Brunei's output gap and inflation rate. These findings provide an additional empirical support to the validity of the Phillips curve in the context of an Asian country, which is the main finding of the empirical analysis done in this study.

Conclusion

The Phillips curve has become an important tool for the macroeconomic policy. Taking into consideration an intense debate about the validity of the Phillips curve hypothesis has engendered and a fact that the majority of the previous research studies on the Phillips curve have been conducted in the context of the Western economies, the current study's aim was to conduct an empirical analysis to assess the relationship between output gap and inflation rate in a Asian economy, the Bruneian economic context. Three different methods were employed in this paper to examine the relationship between the two variables.

Since the unit root tests indicated that inflation rate could be considered as integrated of order one and unemployment rate could be considered as integrated of order one, the study proceeded using the Johansen cointegration methods to examine the long-run relationship between unemployment and inflation.

The findings of the current research showed that there existed the cointegrating relationship – as well as long-run causal relationship -- between inflation rate and output gap in Brunei. In other words, the current study offered an additional empirical support for the validity of the Phillips curve.

These findings encourage a closer look at the existence of the Phillips curve in other Asian countries, such as Malaysia, Thailand, Indonesia, etc. Assessing the existence of the Phillips curve in other Asian economies could be insightful because different socio-economic backgrounds of the Asian countries could influence the relationship between output gap and inflation rate in each particular country.

Endnotes

[1] More comprehensive model specification should include persistence effects (i.e. $y_{t-1} - y^*_{t-1}$).
[2] Sewa (1978) argues that Akaike Information Criterion could choose the models of higher order than the true model. However, Sewa points out that this bias could be negligible when the selected lag length is less than (N/10), where N equals numbers of observation.

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