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NATURAL RATE OF INTEREST IN INDONESIA: KALMAN FILTER APPROACH

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ABSTRACT

In the long run, nominal interest rates will move closer to the equilibrium (natural) real interest rate plus inflation expectations. Natural real interest rate has become an important concept for policy makers since it is used as a benchmark whether the stance of monetary policy has been set in accordance with the economic conditions (neutral), too tight or too loose.

This paper estimates the natural rate of interest (NRI) in Indonesia during 2000q1 - 2011q2 using Kalman filter. The results show a sharp decline of NRI from 2000q1 to 2006q4, but an increasing trend after that. NRI calculations indicate that during period of 2010q3 to 2011q2, Bank Indonesia policy rate was considered to be neutral. By using headline inflation as part of inflation expectations, NRI in 2011q2 is estimated about 0.94%. Comparing with SVAR method, calculating NRI using Kalman filter method is better since it gives smoother movement of NRI and more robust in predicting inflation and growth.

Di masa mendatang, tingkat suku bunga nominal akan bergerak lebih dekat ke arah suku bunga riil (natural) ekuilibrium ditambah dengan prakiraan inflasi. Suku bunga riil natural telah menjadi konsep yang penting bagi para pembuat kebijakan karena digunakan sebagai tolak ukur apakah kebijakan moneter telah ditetapkan sesuai dengan kondisi ekonomi (netral), terlalu ketat atau terlalu longgar.

Makalah ini memperkirakan suku bunga natural (NRI) di Indonesia selama kuartal 1 tahun 2000 – kuartal 2 tahun 2011 menggunakan Kalman filter. Hasilnya menunjukkan penurunan NRI yang tajam sejak kuartal 1 tahun 2000 hingga kuartal 4 tahun 2006, tetapi trennya terus meningkat sejak saat itu. Perhitungan NRI menunjukkan bahwa selama kuartal 3 tahun 2010 hingga kuartal 2 tahun 2011, tingkat kebijakan Bank Indonesia dianggap netral. Dengan menggunakan inflasi headline sebagai bagian dari prakiraan inflasi, NRI pada kuartal 2 tahun 2011 diperkirakan sekitar 0,94%. Dibandingkan dengan metode SVAR, perhitungan metode filter Kalman lebih baik karena memberikan pergerakan NRI yang lebih mulus dan lebih kokoh dalam memprediksi inflasi dan pertumbuhan.

1. INTRODUCTION

In the long run, nominal interest rates will move closer to the equilibrium (natural) real interest rate plus long-term inflation expectations. Natural real interest rate has become an important concept in some of the literature because it is used as a benchmark for monetary policy. In theory, monetary policy can be evaluated whether the policy rate has been set in accordance with the economic conditions or not.

Like an output gap, a natural real interest rate cannot be observed directly, so it must be estimated. The estimation is ranging from the very simple method, i.e. the average of the actual interest rate in certain period, to the very complex one, i.e. using Dynamic Stochastic General Equilibrium (DSGE) model. Since it is unobservable, the estimates contain uncertainty.

Recent literature that contributes to the empirical approach to the NRI concept is Laubach and Williams (2003). The approach they use is to estimate the natural real interest rate along with potential output using Kalman filter technique in a small-scale macroeconomic model. In this approach, the natural real interest rate is associated with the growth of

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economic potential. Thus, the estimated natural real interest rate is time-varying and associated with long-term economic growth. This method became popular since it provides some sort of middle ground compromise between the DSGE approach and the statistical approach.

In Indonesia, NRI has been calculated by Nugroho and Mochtar (2006). Based on Structural Vector Auto Regressive (SVAR) model, they argue that Indonesia's NRI in 2006 was about 2%. Now, the question is that: what is the level of NRI in Indonesia in 2011? Does it remain the same, increase, or decrease? Considering the inflation rate in June 2011 was 5.54% and the policy rate was 6.75%, is a central bank's stance can be categorized a stight? What method is good for estimating the NRI? Does NRI have a predictive power to macroeconomic variables? This paper attempts to answer the questions above using Kalman filter techniques. This paper will compare the results with other estimations using HP filter and SVAR.

The paper is written with the following systematics. Part two discusses theories and methodologies in estimating the NRI. Part three describes the methodology and data. Part four presents the empirical results and analyses the findings. Part five concludes.

2. LITERATURE REVIEW AND HYPOTHESIS

2.1. The Concept of Natural Rate of Interest (NRI)

Various studies on the NRI have begun more than 100 years ago, starting from a seminal work of Wicksell (1896) to the study of current policy, for example Woodford (2003). The definition of NRI has evolved along with the development and advancement of literature in the field of monetary policy. Wicksell (1896) describes the characteristics of the NRI as follows: (i) the level of interest rates which balances saving and investment, (ii) reflects marginal productivity of capital, and (iii) consistent with the (aggregate) price stability.

These three characteristics of Wicksell's natural rate suggest that it is consistent with the equilibrium of the economy in the long run. Natural rate is not constant at a certain level, but it will fluctuate according to technological changes that affect the productivity of capital. The three definitions of the natural rate are then adopted by subsequent generations.

For example, economists in the inter-war period followed Wicksell's definition with emphasis on the characteristics of the neutral rate between saving and investment balance (equilibrium). Friedman (1968) and Phelps (1968) emphasize on the long-term characteristics of the natural rate of unemployment. In recent time, the definition of the New Keynesian can be referredas a synthesis from the definition put forth by Wicksell, because the NRI is defined as the interest rate in the general equilibrium conditions. Thus, implicitly, it is an interest rate that is consistent with the savings equals investment in a closed economic system.

There are some definitions of NRI: (i) NRI is the rate of interest that is consistent with a situation in which inflation and inflation expectations are stable at the inflation target and the output gap is zero and it is expected to remain zero over the medium run (Archibal and Hunter, 2000). (ii) NRI is the level of real interest rates that will make monetary policy neutral and stabilize inflation (Brzezina, 2003).(iii) NRI is the level of real interest rates that is consistent with closed output gap in the medium term (Bernhardsen, 2007).

Equilibrium real interest rate is influenced by many factors, including productivity, population growth, and long-term saving preferences. NRI is also influenced by variety of disturbances that affect the medium-term economy. This can be illustrated that the NRI moves around and towards the equilibrium (long run) real interest rates.

In circumstances where there is a wage stickiness and price formation, the central bank can affect real interest rates and economic growth using interest rate policy. Real interest rate can deviate from its neutral level, depending on the stance of monetary policy. This in turn depends on the central bank's policy on trade-offs between various objectives, such as stable inflation on one side, and stable output orunemployment on the other side.

2.2. Estimation Methods of NRI

a. Historical Interest Rates

Taking the assumption that monetary policy in the long run has to deal with deflationary pressures roughly as often as inflationary pressure, it follows that in the calculation of the average level of the real interest rate in the long period of time, the cyclical component of the interest rate will lead to zero. Therefore, the average of the real interest rate would give the estimate of NRI.

If the value of the NRI is constant over time, then the average of the historical real interest rate throughout the entire business cycle will give an indication of the level of NRI. The problem of this method is that the NRI cannot be assumed to be constant over time. Difficulties can also occur when determining the business cycle

b. Based on NRI of Other Countries

This method uses the approach by taking the NRI estimates from advanced countries and then adjusting it to take into account specific risk factors of the country. The differences of NRI between countries can be caused by different risk premia or differences in the fundamental factors that affect saving and investment.

Hawkesby et al (2000) estimate risk premium in New Zealand. They assume that there is no default or liquidity premium between short-term interest rates in New Zealand, Australia and the U.S. Therefore, the currency risk premium is derived from the actual

interest rate differential between New Zealand and Australia and the actual interest rate differential between New Zealand and the United States.

This approach is used by Archibald and Hunter (2000) to estimate the NRI of New Zealand. They use NRI estimates of the United States and Australia as a basis. The problem of this method is that NRI from advanced countries also have significant uncertainties.

c. Based on Market Participants' Expectations

This method measuresthe market expectations of future short term interest rates. This is done by calculating the real return bonds, market surveys (e.g. consensus forecast), and by estimating market expectations through market rates. The drawback of this method is that the results do not necessarily represent the actual interest rate expectation of the market. In addition, the market participant's expectation of future interest rate can also deviate from the NRI.

d. Based on Structural Vector Auto Regresive (SVAR) Model

The SVAR model is a popular approach based on Blanchard and Quah's work (1989) on imposing long-run restriction to estimate potential output. The same technique is then used to estimate the natural rate of interest.

Brzoza-Brzezina (2005) use this approach to estimate the NRI in the United States. The biggest innovation to the Blanchard–Quah method in the Brzoza-Brzezina (2005) paper is the replacement of the orthogonality assumption with respect to the shocks with a short-run restriction. They argue that models of such specifications would have lower restriction and better flexibility. They conduct estimations using the federal fund rate and the interest rate of the treasury bills. Indications from both estimates are relatively similar, i.e. the NRI shows a significant variation from its real rate. These results are not in line with the estimates of Laubach and Williams (2001) for the United States and Neiss and Nelson (2001) for the UK, where the variance of the natural rate to the real rate is much lower. However, other research papers (for example Rotemberg and Woodford, 1997) have the same conclusion that the variance of the NRI is relatively high.

e. Based on Small Macroeconomic Model with Kalman Filter (KF)

This method is proposed by Laubach and Williams (2001) where the estimation of unobserved components (i.e. NRI and potential output) are done in parallel using the Kalman filter technique. Identification of NRI is obtained by defining the IS curve equation in the simple reduced form, which links the output gap and the real interest rate gap (the difference between the real rate and NRI). While the Phillips curve equation links the inflation and the output gap. They also impose that the trend of growth rate as a determinant of the NRI.

The problem of this method is that the model used is generally a highly simplified model compared to reality. This estimate is usually very sensitive to technical choices used in the estimation process, thus uncertainty is also present in the output produced.

f. Based on DSGE Model

NRI can also be estimated by using DSGE model, which is generally based on New-Keynesian as found in Neiss and Nelson (2000). In this model, the economic agents are forward looking, while the central bank sets the interest rate to stabilize inflation and output over time. Wages and price are sticky in the short run, but flexible in the long run. If the assumptions of sticky nominal wages and prices are relaxed, it would acquire the flexible price version of the model. In this regard, NRI is defined as the real interest rate contained in the flexible price version of the model.

One of the contributions of the New Keynesian paradigm is the ability to obtain an explicit equation of the natural rate as a function of primitive factors underlying the economy. Calculation of the natural rate can be done by solving the equilibrium real interest rate obtained from the model when prices are assumed to be perfectly flexible and where there is no gap between real output and potential output. Various first order conditions that must be met in the equilibrium of the optimization of households and firms behaviors would lock the value of the natural rate to a particular level. The level of natural rate is determined by a variety of economic factors, such as time preference and willingness to change consumption between two periods, marginal productivity of capital, especially the level of capital stock, and shock that affects the household saving decision, such as innovation on total factor production and exogenous changes in the government spending.

3. METHODOLOGY

In this paper, we apply the methodology as suggested by Laubach and Williams (2003). This method uses Kalman filter on a small macroeconomic model where the natural real interest rate, potential output and the output gap are estimated simultaneously. The model is a *Neo-Keynesian*[1] model, which describes the behavior of inflation and the output gap through the modified IS curve and Phillips curve. The main equations of the model are as follow:

$$a_y(L)\bar{y}_t = b_r(L)\bar{r}_t + \varepsilon_{1t} \quad (1)$$

$$a_\pi(L)\pi_t = b_\pi(L)\bar{y}_t + \varepsilon_{2t}, \quad (2)$$

where $\bar{r}_t$ is the real interest rate gap, $\bar{y}_t$ is the output gap, π_t is the CPI inflation, ε_{it} and ε_{it} are the white

1 Neo-Keynesian models are not interested in forming level of variables, but rather pay attention to the deviation of these variables to its equilibrium level.

Table 1. Descriptive Statistics

	SBI or BI Rate	CPI Inflation	Core Inflation	Concencus Forecast	GDP Growth
Mean	10.20	8.22	7.10	7.45	5.28
Median	9.00	7.15	6.86	6.75	5.47
Std. Deviation	3.37	3.97	2.09	3.39	1.12
Number of Observation	135	135	135	46	42

noise errors. Output gap is defined as the difference between the (log) GDP and (log) potential output:

$$\bar{y}_t = 100(y_t - y_t^*) . \quad (3)$$

The laws of motion of unobservable potential output and its trend of growth are:

$$y_t^* = y_{t-1}^* + g_{t-1} + \varepsilon_{4t} \quad (4)$$

$$g_t = g_{t-1} + \varepsilon_{5t}, \quad (5)$$

where y_t^* is the potential output, g_t is the trend of potential output growth, ε_{4t} and ε_{5t} are the white noise errors.

The economic theory imposed by LW is presented by the relationship between the natural real interest rate and potential output growth:

$$r_t^* = cg_t + z_t, \quad (6)$$

where parameter *c* captures the relative risk aversion and other determinants of real natural interest rates, such as time preference of households, variations in government savings, and the uncertainty of interest rates. z_t is assumed to follow the stochastic process, i.e.:

$$z_t = \alpha z_{t-1} + \varepsilon_{3t} . \quad (7)$$

Equation (3), (4), (5) and (6) are state or transitory equations, while the IS curve equation (1) and the Phillips curve (2) are the observation equations. In this system, Kalman filter method is used twice. The first is to calculate the parameters by maximum likelihood, and the second is to estimate the unobserved components r_t^*, y_t^* g_t and z_t. The model can then be written in the form of state-space:

$$y_t = Z\alpha_t + Bx_t + G\varepsilon_t \quad (8)$$

$$\alpha_{t+1} = T\alpha_t + H\varepsilon_t . \quad (9)$$

This study uses two models, that is first, KF model with estimated output gap (KF1) and second, KF model without estimated output gap (KF2).

a. Model KF1

Signal equations

$$ygap_t = \alpha_1 ygap_{t-1} + \alpha_2 ygap_{t-2} + \alpha_3(r_{t-1} - r_{t-1}^*) + \alpha_4(r_{t-2} - r_{t-2}^*) + \varepsilon_{1t}$$

$$\pi_t = \beta_1\pi_{t-1} + \beta_2\pi_{t-2} + \beta_3\pi_{t-3} + \beta_4 ygap_{t-3} + \beta_5 x_t + \varepsilon_{2t},$$

state equation

$$r_t^* = r_{t-1}^*, \quad (10)$$

where x is import price and ygap is output gap estimated using adjusted HP filter.

b. Model KF2

Signal equations

$$y_t = \alpha_1(y_{t-1} - y_{t-1}^*) + \alpha_2(y_{t-2} - y_{t-2}^*) + \alpha_3(r_{t-1} - r_{t-1}^*) + \alpha_4(r_{t-2} - r_{t-2}^*) + y_t^* + \varepsilon_{1t}$$

$$\pi_t = \beta_1\pi_{t-1} + \beta_2\pi_{t-2} + \beta_3(y_{t-1} - y_{t-1}^*) + \beta_4 x_t + \varepsilon_{2t},$$

state equations

$$y_t^* = y_{t-1}^* + g_{t-1} + \varepsilon_{3t}$$

$$r_t^* = g_t + z_t$$

$$g_t = \gamma_1 g_{t-1} + \varepsilon_{4t}$$

$$z_t = \delta_1 z_{t-1} + \delta_1 z_{t-2} + \varepsilon_{5t} . \quad (11)$$

Real interest rate is defined as the difference between nominal interest rates and inflation expectations:

$$r_t = i_t - \pi_t^e . \quad (12)$$

In this paper, we use two types of inflation expectations, as follow:

a. A combination of the past of CPI inflation and BI inflation target

$$\pi_t^e = 0.65\pi_{t-1} + 0.35\pi_{t+1}^* . \quad (13)$$

b. BI inflation target

$$\pi_t^e = \pi_{t+1}^* . \quad (14)$$

To find out information or predictive content of NRI, we follow Stock and Watson (2003). Evaluation of in-sample measure is done using the following regression:

$$Y_{t+h}^h = \beta_0 + \beta_1(L)X_t + \beta_2(L)Y_t + u_{t+h}^t , \quad (15)$$

Where *X* is the variable of interest in which its ability to forecast *Y* is evaluated, $\beta_1(L)$ and $\beta_2(L)$ are polynomial lag operators and u_{t+h}^t is the error term, Y_{t+h}^h is a variable to predict *h* period ahead:

$$Y_{t+h}^h = \frac{400}{h}(\ln(Y_{t+h}) - \ln(Y_t)) . \quad (16)$$

To carry out pseudo out of sample we calculate the mean squared forecast error of the candidate forecast (forecast i) relative to the benchmark (forecast 0).

4. DATA

This study uses monthly data and quarterly data from 2000Q1 through 2011Q2. The data are short-term interest rate (BI rate), CPI inflation, core inflation, GDP growth, and the consensus forecast of inflation (Bloomberg and Asia Pacific Consensus Forecast)[2]. The descriptive statistics of the data can be seen in Table 1.

[2] Asia Pacific Consensus Forecast is a compilation of the results of a survey of 180 financial institutions and economic forecaster influential in the Asia Pacific region. The survey was conducted on the projection of GDP growth, inflation, trade balance and exchange rate.

Table 2. Estimation Results -CPI inflation

	KF1 – CPI			KF2 – CPI			KF2m – CPI		
	Coef	**SE**	**Signf**	**Coef**	**SE**	**Signf**	**Coef**	**SE**	**Signf**
α_1	0.982	0.309	***	1.271	0.283	***	1.381	0.039	***
α_2	-0.966	0.336	***	2.831	0.373	***	-0.386	0.038	***
α_3	-0.850			-0.750			-0.119		
α_4	-0.100			-0.150			-0.119		
β_1	0.941	0.050	***	-44.96	0.079	***	0.998	0.041	***
β_2	-0.034	0.057		46.05	0.072	***	-0.124	0.037	***
β_3	-0.246	0.039	***						
β_4	-0.119	0.049	**	7.521	0.893	***	0.921		
β_5	0.016	0.002	***	-1.228	0.295	***	0.124	0.038	***
γ_1				0.650			0.843		
δ_1				0.650			0.821		
δ_2				0.250			0.120		
	Final State	**Root MSE**	**Signf**	**Final State**	**Root MSE**	**Signf**	**Final State**	**Root MSE**	**Signf**
NRI	0.863	0.262	***	0.416	0.261		0.929	6.689	
YPOT				13.273	1.131	***	12.648	0.529	***
G				0.090	0.294		0.011	0.082	
Z				0.357	0.266		0.005	0.336	
Log likelihood	-220.28			-262.462			-308.765		

5. EMPIRICAL RESULTS

5.1. NRI Estimation

5.1.1. Using CPI as an Expected Inflation

Inflation expectation is calculated with 65% adaptive inflation (CPI) and 35% forward looking inflation (inflation target). We apply 2 models (KF1 and KF2) using both quarterly and monthly data.

Table 2 shows the estimation results of NRI using the Kalman Filter. For model KF1, we restricted the parameter α_3 and α_4 (difference between real interest rate and NRI) using value of -0.85 and -0.10 respectively. It is worth noting that the majority of the variable affecting inflation and output gap are statistically significant at the 1% and 5% level.

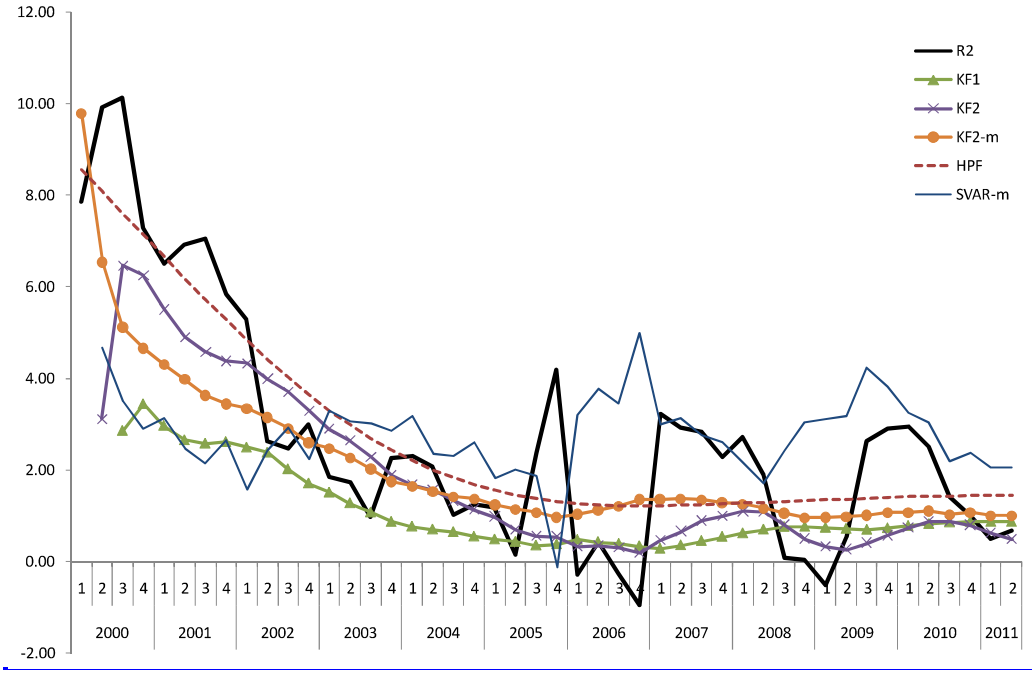

Figure 1. Real Interest Rate and NRI – CPI Inflation

Table 3. Real Interest Rate and NRI-CPI Annual

Tahun	R2	HPF	KF1	KF2	KF2-m	SVAR-m	Av-KF	Av-KF-HP
2000	8,80	7,84	3,14	5,28	6,52	3,69	4,98	5,70
2001	6,58	5,95	2,70	4,85	3,83	2,59	3,79	4,33
2002	3,34	4,22	2,14	3,83	2,99	2,28	2,99	3,30
2003	1,70	2,84	1,18	2,43	2,12	3,05	1,91	2,14
2004	1,66	1,92	0,66	1,42	1,48	2,60	1,19	1,37
2005	1,97	1,42	0,40	0,68	1,10	1,38	0,73	0,90
2006	-0,28	1,23	0,40	0,28	1,18	3,85	0,62	0,77
2007	2,81	1,24	0,40	0,74	1,33	2,87	0,83	0,93
2008	1,18	1,30	0,70	0,86	1,10	2,33	0,89	0,99
2009	1,39	1,37	0,71	0,38	1,00	3,58	0,70	1,87
2010	1,96	1,42	0,82	0,81	1,06	2,71	0,90	1,03
2011*	0,68	1,44	0,86	0,48	0,99	2,04	0,78	0,94

However, the estimated parameter for output gap in the inflation equation shows sign that is inconsistent with the hypothesis (negative). Meanwhile, estimation of NRI in the final state is 0.86 and significant at 1% level.

For model KF2, we restricted the parameter α_3 and α_4 (difference between real interest rate and NRI) using value of -0.75 and -0.15 respectively. Also, parameter γ_1, δ_1 and δ_2 in the state equations are restricted to the value of 0.65, 0.65 and 0.25 respectively. The estimation result shows that all parameters are statistically significant at the 1% level. However, β_5 (import price) parameter shows negative sign, which is inconsistent with the hypothesis. The unobserved variable potential output indicates significance at the 1% level, while NRI at the final state with the value of 0.42% is statistically insignificant.

For model KF2-m (monthly data), the parameters that we restrict are α_3, α_4 (difference between real

Table 4. Estimation Result:NRI -Inflation Target

	KF1 – Target			KF2 – Target			KF2m – Target		
	Coef	SE	Signf	Coef	SE	Signf	Coef	SE	Signf
α_1	1.095	0.178	***	1.167	0.561	**	1.432	0.077	***
α_2	-0.676	0.162	***	-0.036	0.590		-0.514	0.111	***
α_3	-0.850			-0.750			-0.120		
α_4	-0.100			-0.150			-0.120		
β_1	0.941	0.052	***	0.011	2.170		1.001	0.034	***
β_2	-0.034	0.057		0.112	2.276		-0.038	0.035	
β_3	-0.245	0.038	***						
β_4	-0.127	0.050	***	1.461	0.309	***	0.010		
β_5	0.015	0.002	***	-2.039	2.841		0.172	0.043	***
γ_1				0.650			0.910		
δ_1				0.650			0.820		
δ_2				0.250			0.120		
	Final State	Root MSE	Signf	Final State	Root MSE	Signf	Final State	Root MSE	Signf
NRI	2.947	0.079	***	0.514	1.343		2.207	7.228	
YPOT				7.985	2.021	***	13.391	0.513	***
G				0.075	1.245		0.024	0.082	
Z				0.439	1.585		0.006	0.336	
Log likelihood	-208.2			-208.8			-313.231		

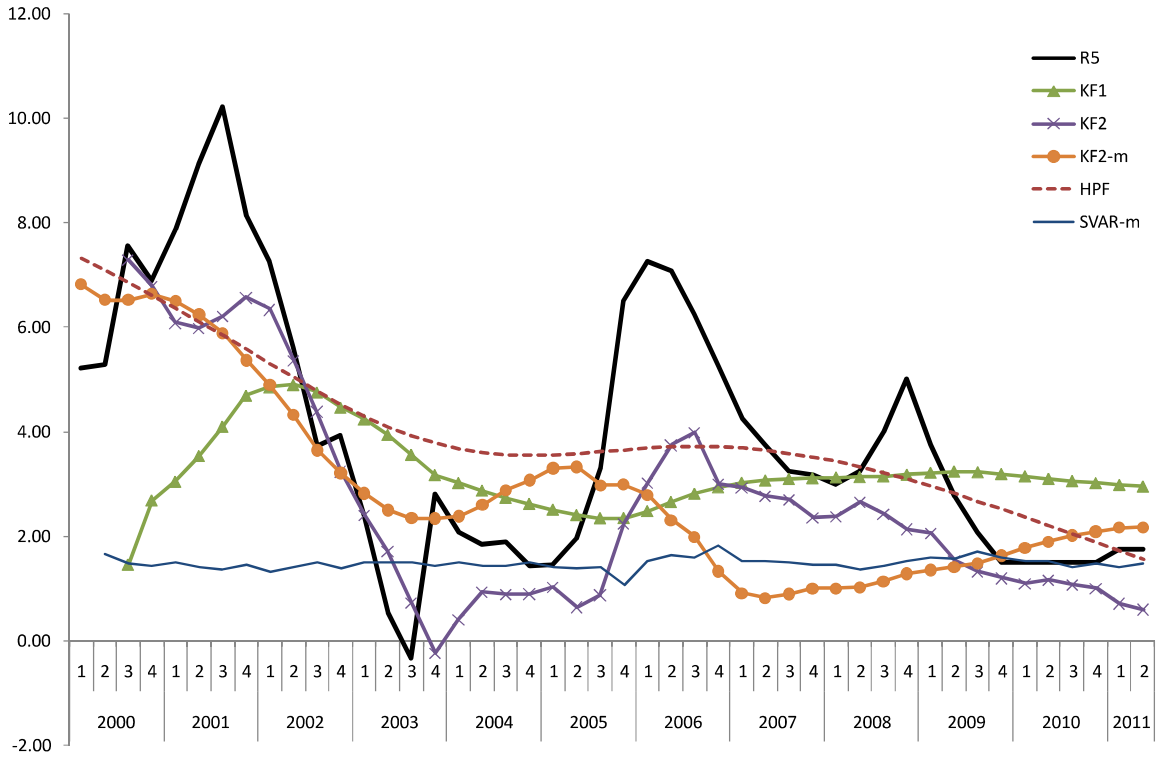

Figure 2. Real Interest Rate and NRI – Inflation Target

interest rate and NRI), and β_4 (*output* gap) using the value of -0.12, -0.12, and 0.92 respectively. Meanwhile, γ_1, δ_1 dan δ_2 in the state equations are also restricted using the value of 0.84, 0.82, and 0.12 respectively. The estimation result shows that all parameters are significant at the 1% level. The potential output (unobservable) variable also shows significance at 1% level. However, NRI variable at the final state with the value of 0.93% is statistically insignificant.

Figure 1 shows plots from the NRI variable calculated using different methods, namely KF1, KF2, KF2-m (monthly data), HP filter, and SVAR (monthly data) as well as the real interest rate series. Based on figure 4.1, it can be seen that the value of NRI at the end of the observation period (2011:2) using SVAR is higher than the value of NRI obtained either by the HP filter or Kalman Filter (all variations). In general, the movement of NRI from the KF is in line with the result obtained from the HPF. However, in level terms, NRI obtained from the KF is lower than the HPF. In comparison, NRI obtained using SVAR shows a more volatile movement and tend to be above the real interest rate from 2003 to 2011, which implies that that the monetary policy stance during these period was mostly loose (accommodative).

Table 3 shows the annual dynamics of real interest rate and NRI. The last two columns are the average result of KF (KF1, KF2, KF2m) and the average NRI from KF and HPF. If we look at the result from KF and HPF, there is a sharp decline in the NRI

Table 5. Real Interest Rate and NRI – Inflation Target Annual

Tahun	R5	HPF	KF1	KF2	KF2-m	SVAR-m	Av-KF	Av-KF-HP
2000	6,23	6,98	2,06	7,03	6,63	1,51	6,83	5,24
2001	8,83	5,99	3,84	6,21	6,00	1,42	6,10	5,35
2002	5,13	4,92	4,74	4,83	4,02	1,39	4,42	4,53
2003	1,35	4,03	3,72	1,14	2,50	1,47	1,82	2,46
2004	1,80	3,60	2,81	0,77	2,74	1,45	1,75	2,10
2005	3,30	3,61	2,39	1,19	3,15	1,31	2,17	2,24
2006	6,46	3,72	2,71	3,43	2,11	1,63	2,77	2,75
2007	3,60	3,62	3,07	2,68	0,91	1,49	1,80	2,22
2008	381	3,28	3,14	2,39	1,11	1,42	1,75	2,22
2009	2,52	2,75	3,21	1,52	1,47	1,60	1,50	2,07
2010	1,50	2,12	3,07	1,07	1,95	1,47	1,51	2,03
2011*	1,75	1,56	2,95	0,59	2,17	1,46	1,90	1,82

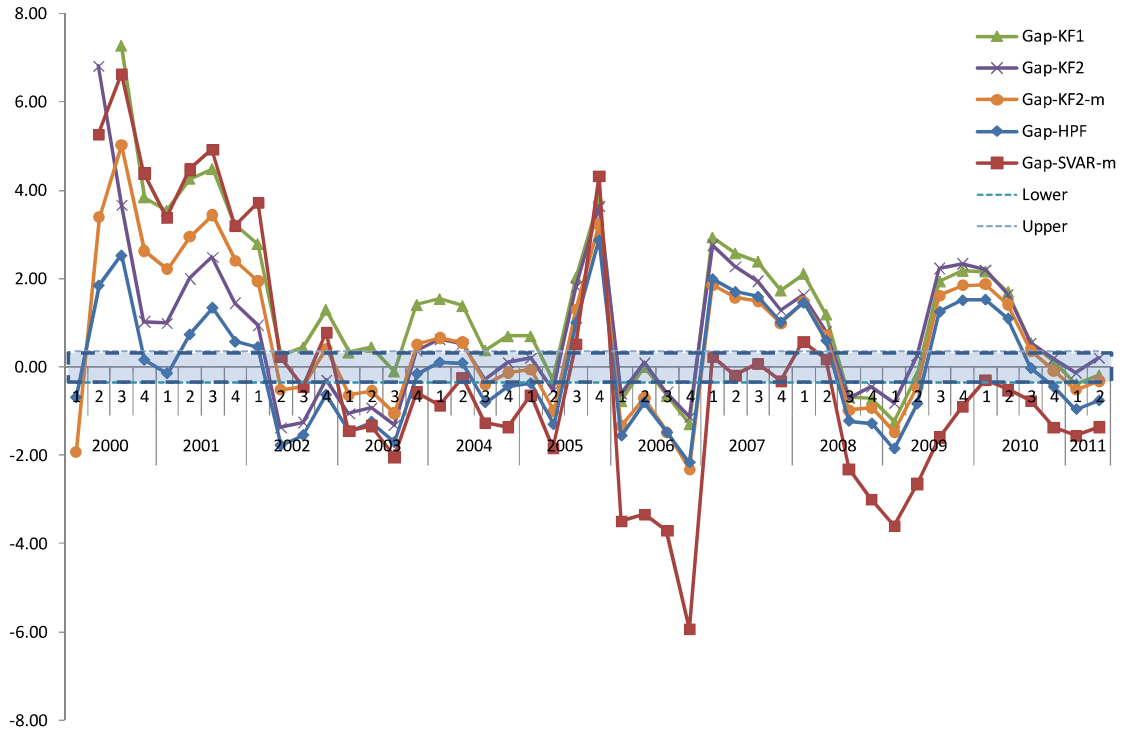

Figure 3. Real Interest Rate Gap and NRI – CPI

between period 2000 and 2006, whereas a slight increase in trend is observed during the period 2006–2011. Meanwhile, the NRI obtained using SVAR shows no visible decline.

For the second quarter of 2011, the NRI caculated using KF is 0.78%, lower than the NRI obtained from HPF (1.44%). If it is calculated using the mean value, the NRI obtained increased to 0.94% with the range of 0.48% to 1.44%. On the other hand, the NRI obtained from SVAR is 2.04%, which is far above the real interest rate.

4.1.2. Using BI's Inflation Target as an Expected Inflation

In previous subsection we used the CPI inflation as a part of inflation expectation. In the following section we use BI's inflation target as expected inflation. In this case, we assume perfect foresight, i.e. the public inflation expectation is fully anchored to the central bank's inflation target. A complete estimation results are presented in Table 4.

As in the previous estimation result, in the model KF1, although the majority of the parameters are statistically significant, the parameter β_4 (*output* gap) shows a negative sign, which is inconsistent with the theory (hypothesis). In the model KF2, while it is not significant statistically, the β_5 parameter (import price) shows a negative sign. At the final state, the unobserved variable NRI in the model KF1 shows significance at the 1% level. On the other hand, NRIs in the model KF2 and KF2m are not significant statistically.

By plotting the NRI values from different models (figure 2), it can be determined that the NRI obtained from KF1 recorded the highest value compared to other methods. NRI obtained from HPF shows a decreasing trend from 2000 to 2011. Looking at the movements of NRI obtained from the HPF and the KF2, we could see that they move in the same direction, i.e. undergo decreasing trends starting in 2007 to 2011. Although in level terms, the NRI obtained from KF2 is lower compared to the NRI obtained from HPF. In contrast, NRI obtained from KF2-m during the same period shows an increasing trend. As for the NRI from SVAR model, it shows a relatively stable movement at the low level of around 1.5%

Table 5 shows that in 2011, NRI obtained from the average of KF methods is 1.90% and NRI obtained from HPF is 1.56%. Thus the average NRI is 1.82% (with the range of 0.59% - 2.95%). Meanwhile, the NRI obtained from SVAR model is the lowest at 1.46% and relatively flat throughout the observation period (2000 – 2011), which, in our opinion, does not really make sense.

4.2. NRI Evaluation

4.2.1. Monetary Policy Stance

To measure the monetary policy stance, we need to calculate the gap between real interest rate and NRI. If the real interest rate gap shows a positive value (real interest rate is higher than NRI), then the monetary policy stance is categorized as tight. Conversely, if the real interest rate gap is negative, the monetary policy stance is categorized as loose (accommodative).

Figure 3 shows plots of the real interest rate gaps from each individual methods using hybrid CPI expected inflation (65% adaptive and 35% forward looking). Using this figure, the dynamics of the monetary policy stance on each individual method can be observed. In general, the movement of NRI gaps obtained from KF and HPF methods are in line with one another, especially starting from 2005 to 2011 where only slight difference is observed. Using the KF and HPF methods, the dynamics of monetary policy stance is more noticeable (i.e. more frequent and apparent switching periods of monetary policy stance) in comparison to the SVAR method.

Meanwhile, real interest rate gap obtained from SVAR shows that it moves below the zero line on the majority of the time during period 2003–2011. The gap is positive only in the second quarter of 2005. This would indicate that the central bank's monetary policy stance during this period was consistently loose (accommodative). On the contrary, records on the board meeting press conferences show that the monetary policy stance was not always accommodative. One clear example would be during the mid 2004 to early 2006.

Table 6 Current Implied Neutral Policy Rate (2011Q2)-CPI

	Average KF	Average KF & HPF
NRI	**0.78**	**0.94**
Expected Inflation	6.07	6.07
CPI (t-1)	6.65	6.65
Target (t+1)	5.00	5.00
Neutral Policy Rate	6.85	7.02
Current BI Rate	6.75	6.75
Delta	-0.10	-0.27
Stance (vs.±0.35)	***Neutral***	***Neutral***

Table 6 presents the implied neutral policy rate in the second quarter of 2011 using CPI inflation expectation[3]. As discussed previously (section 4.1.1), in 2011:2, NRI obtained from the average KF is 0.78% and NRI obtained from the average KF and HPF is 0.94% Meanwhile, BI Rate in this period is 6.75%. Thus, by calculating the CPI inflation expectation, we can determine the neutral policy rate[4]. Using the average KF and average KF and HPF methods, the neutral policy rates are 6.85% and 7.02% respectively. Using this result, it can be calculated that the delta[5] for each methods are -0.10% (average KF) and -0.27 (average KF and HPF). Given that these values are still within the band (±0.35%), the monetary policy stance in the second quarter of 2011 is categorized as neutral.

Next, Figure 4 presents the movement of real interest rate gap using BI's inflation target as the expected inflation (perfect foresight). As with the outcome using core expected inflation, the gap between real interest rate and NRI using SVAR method shows a positive value in the majority of the observation period. Although, at the end of the observation period, the value of the gap falls within the neutral band. This implies that, using SVAR method, the monetary policy stance is categorized as tight on the majority of the observation period. Meanwhile, using KF and HPF method, the dynamics of monetary policy stance is more noticeable, i.e. more frequent and apparent switching periods of monetary policy stance.

Based on the result of analysis of the implied neutral policy rate using BI's inflation target as the expected inflation, the monetary policy stance in the second quarter of 2011 is indicated as neutral. This condition is reflected based on the calculation of NRI obtained from the average KF (1.90%) and average KF and HPF (1.82%). Thus, the difference between BI rate and the neutral policy rate are -0.15% and -0.07% respectively. Both of these figures are still fall within the neutral band of ± 0.41%.

Table 7. Current Implied Neutral Interest Rate (2011q2)-Inflation Target

	Average KF	Average KF & HPF
NRI	**1.90**	**1.82**
Expected Inflation	5.00	5.00
Target (t+1)	5.00	5.00
Neutral Policy Rate	6.90	6.82
Current BI Rate	6.75	6.75
Delta	-0.15	-0.07
Stance (vs.±0.41)	***Neutral***	***Neutral***

4.2.2. Information Content

The second evaluation tool for NRI is to see the information content from each method, both in sample and out of sample.

a. In Sample

To view the information content from each method in predicting inflation and GDP 4 quarter ahead and 8 quarter ahead, first we observe the AIC value from each of its lag. The lag with the lowest AIC

[3] CPI expected inflation is approximated using 65% past CPI inflation (t-1) and 35% inflation target (t+1).

[4] Neutral policy rate is defined as a condition where the gap between real interest rate and NRI equals to zero. Since real interest rate is equal to the BI rate minus the expected inflation, then neutral policy rate could also be expressed as BI rate minus expected inflation minus NRI equal to zero. In the equilibrium, BI rate is equal to NRI plus expected inflation.

[5] Delta is the result of BI rate minus the implied neutral policy rate. If delta is negative, then the monetary policy stance is loose. If delta is zero, or is still within the band (± 0.35%) then the stance is neutral and if delta is positive, then the stance is tight. The band of 0.70% corresponds to the 68% confidence interval, i.e. the average of 0.385*SD from each methods.

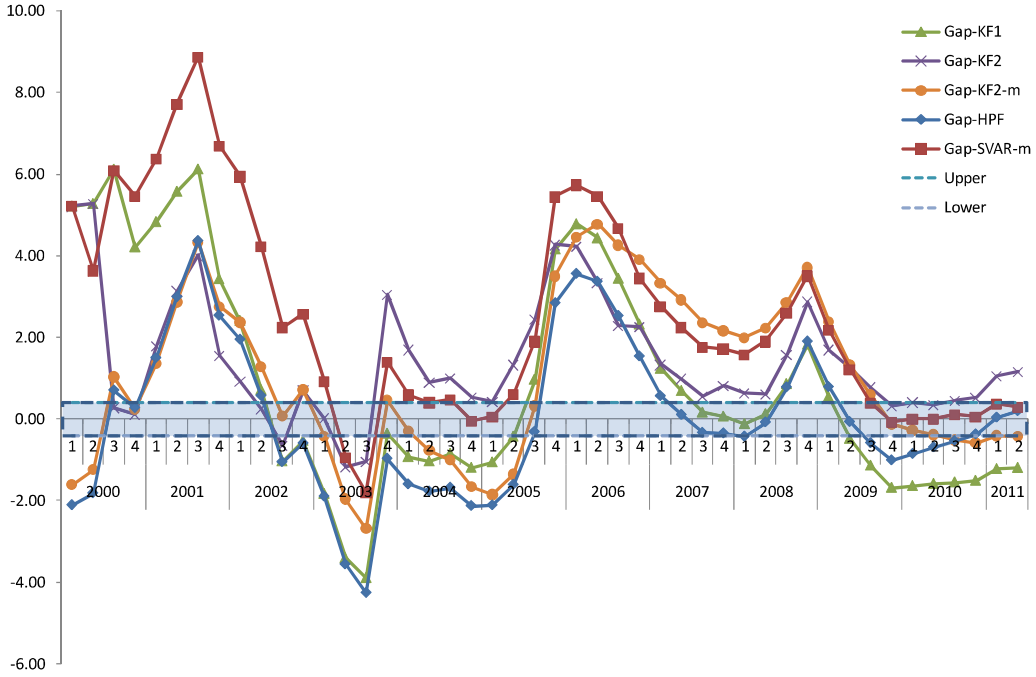

Figure 4. Real Interest Rate Gap and NRI – Inflation Target

value is then used in the model. Table 8 and table 9 present the result for 4 quarter ahead equation and 8 quarter ahead equation respectively.

Table 8. AIC value-4 quarter ahead

Lag	Inflation	GDP
0	4.414	2.587
1	4.460	2.392
2	4.524	2.236
3	4.582	2.235
4	4.651	2.097
5	4.610	2.151

It is found that (as shown in the table 8) the optimal lag for 4 quarters ahead inflation equation is 0, while for 4 quarter ahead GDP equation, the optimal lag is 4.

Table 9. AIC value-8 quarter ahead

Lag	Inflation	GDP
0	3.066	1.648
1	3.117	1.560
2	3.125	1.472
3	3.114	1.548
4	3.162	1.294
5	3.229	1.400

On the other hand, for 8 quarter ahead projection (as shown in Table 9), lag 0 is the optimal lag for inflation equation, while lag 4 is the optimal lag for GDP equation.

In-sample test, as shown in table 10, shows that the majority of variable coefficients on each models have negative signs. This is consistent with the hypothesis. However, KF methods have information content to predict inflation (for 8 quarter ahead) and GDP (for 4 quarter ahead). This is shown by the significance of the KF variables at 1%, 5% and 10% critical value.

Table 10. Information content-in sample

No	P/Y	4/8	Model	Coef	SE	Signf	Adj R2
1	P	4	HP	-0.064	0.275		0.620
2	P	4	KF1	0.123	0.168		0.625
3	P	4	KF2	0.070	0.218		0.621
4	P	4	SVAR	-0.063	0.150		0.621
5	P	8	HP	-0.343	0.138	**	0.789
6	P	8	KF1	-0.119	0.092		0.762
7	P	8	KF2	-0.229	0.118	*	0.775
8	P	8	SVAR	-0.153	0.068	**	0.783
9	Y	4	HP	-0.110	0.107		0.391
10	Y	4	KF1	-0.212	0.051	***	0.579
11	Y	4	KF2	-0.216	0.059	***	0.546
12	Y	4	SVAR	-0.087	0.054		0.483
13	Y	8	HP	-0.037	0.073		0.420
14	Y	8	KF1	-0.139	0.038	***	0.589
15	Y	8	KF2	-0.113	0.042	**	0.525
16	Y	8	SVAR	-0.052	0.042		0.444

b. Out of Sample

Meanwhile, using out of sample test (as shown in table 11) in general KF and HPF methods outperform SVAR method in predicting inflation and GDP. This is evident from the RMSE and U-theil value of KF and HPF which is smaller than the SVAR.

Table 11. Information content-out of sample

No	P/Y	4/8	Model	RMSE	UTHEIL
1	P	4	HP	0.7865	0.0704
2	P	4	KF1	1.1951	0.1144
3	P	4	KF2	1.5753	0.1567
4	P	4	SVAR	1.0545	0.0997
5	P	8	HP	2.1817	0.1985
6	P	8	KF1	2.9295	0.2497
7	P	8	KF2	2.1361	0.1947
8	P	8	SVAR	2.5935	0.2275
9	Y	4	HP	0.6997	0.0618
10	Y	4	KF1	0.5399	0.0468
11	Y	4	KF2	0.7506	0.0666
12	Y	4	SVAR	0.6060	0.0530
13	Y	8	HP	0.4391	0.0417
14	Y	8	KF1	0.4164	0.0397
15	Y	8	KF2	0.4293	0.0409
16	Y	8	SVAR	0.4398	0.0418

6. CONCLUSION

Comparing with SVAR method, calculating NRI using Kalman filter method is better since it gives smoother movement of NRI. The results show that there is a sharp decline of NRI in the period of 2000:1 to 2006:4. Meanwhile, in the period 2007:1 to 2011:2 NRI in Indonesia indicates an increasing trend, but relatively flat. This finding is confirmed by HP filter. On average, the two methods produce NRI Indonesia below 2%at the end of the period (2011:2). This indicates that the NRI Indonesia is now lower than 5 years ago (see Nugroho & Mochtar, 2006).

The level of NRI is highly dependent on how inflation expectations are defined (as a reduction of the nominal interest rate or BI rate). NRI measurements using CPI inflation and inflation target as inflation expectations indicate that monetary policy is neutral in the period of 2011:2.

Stance of monetary policy (tight, loose, or neutral) in this paper is based merely on the level of the policy rate. While other monetary policy instruments, such as reserve requirement, cannot be captured in the calculation of NRI. For example, the tight monetary policy should be considered when the level of reserve requirement increase, even though the real interest rate gap is unchanged.

Estimation of NRI in this study indicates that besides its usefulness to identify the stance of monetary policy, NRI also has good information content in predicting the movement of macroeconomic variables (inflation and growth) in the 8 quarters ahead. In addition, the testing on information content (both in sample and out of sample) showed that the NRI estimates from Kalman filter and the HP filter are relatively better than the NRI estimates fromSVAR.

Although it has been widely understood that each method or model contains uncertainties, the future research on NRI is still widely open, especially with the use of DSGE model. This model assumes sticky price in the short run, but flexible in the long term price.

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