Macroeconomic Determinants of the Movement of the Yield Curve

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Abstract

Monetary policy has a significant effect on long-term interest rates and shocks due to inflation and monetary policy have the largest impact on the volatility of long-term interest rates. Long-term interest rates provide significant upward momentum on short-term interest rates and shocks to peso-dollar exchange rate and budget deficit have the strongest impact on the volatility of short-term interest rates. Inflation, peso-dollar exchange rate and non-performing loans significantly drive the medium-term interest rates and shocks due to these are the largest source of volatility for medium-term interest rates.

Keywords: yield curve, Nelson-Siegel model, VAR, volatility
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Introduction

In the Philippines, the 91-, 182- and 364-day treasury bills or T-bills provide default-free short-term investment instruments for fixed-income investors and these are actively traded in the secondary market. In the middle of the 1990s, the Philippine government has begun introducing treasury bonds or T-bonds, securities of at least two years maturity, to finance its declining cash position and growing budget deficit. The growth of the volume of T-bond issues resulted in active trading of these government securities in the secondary market. By 2001, the average percentage of total monthly transaction volume for a 10-year T-bond, which was the smallest percentage share among the T-bonds of at most ten years maturity, was 6.8% with no less than 4.2% a month while the 2-year T-bond accounted for the largest share with a monthly average of 23.8%. For the short-term maturities, the 91-day and 364-day T-bills average shares of the monthly total were 11% and 18.6%, respectively.

The study of the dynamics of macroeconomic variables and the *level*, *slope* and *curvature* which represent the long-term, short-term and medium-term interest rates, respectively, of the yield curve is fairly nascent and this study is a first using Philippine data. Also, usual studies on Philippine interest rates used primary market yields of government treasuries. This paper, on the other hand, used secondary market yields which are more sensitive to changes in market conditions.

Although the existence of the relationship between interest rates and macroeconomic variables is widely accepted, a systematic analysis of what moves yields across the term structure was only initiated recently by Ang and Piazzesi (2003). Their findings show that inflation largely accounts for the movement of the level and slope of the yield curve. Following the 1999 to 2002 versions of the work of Ang and Piazzesi (2003) several papers were written to determine what macroeconomic variables drive the movement of the yield curve. The frequently cited papers include those written by Evans and Marshall (2001), Hördahl, Tristani and Vestin (2002), Dewachter and Lyrio (2003) and Diebold, Rudebusch and Aruoba (2003) using data from the U.S. or Germany.

These papers dwelt on three types of macrofactors: inflation, monetary policy and real activity. We evaluated these but at the same time included fiscal policy, as

argued by Lindé (1998), and external factors to confirm the extent at which these macrofactors influence the behavior of the Philippine yield curve, in particular.

This study aims to determine what macroeconomic variables or macrofactors affect the movement and volatility of these yield curve factors using vector autoregressive process of order one or VAR(1).

The Nelson and Siegel Yield Curve Model

One of the widely used yield curve models is the Nelson and Siegel (1987). The *level-slope-curvature* representation of the yield curve was derived from the forward rate model by Nelson and Siegel (1987) an expression of which we used from the one specified of Diebold, Rudebusch and Aruoba (2003).

$$y_t(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) + C_t\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right)$$

The *level* L_t, *slope* S_t and *curvature* C_t are time-varying coefficients that capture the behavior of the long-term, short-term and medium-term interest rates. This model provides a parsimonious representation of the graph of the term structure of interest rates wherein several varying yields of government treasuries at increasing maturity can be accounted for by three factors only.

Vector Autoregressive Process (VAR)

In modeling the yield curve and macroeconomic factors there is a need to capture the dynamic relationship between them as these move simultaneously in time. The non-structural VAR process addresses this dynamic relationship among the yield curve's unobserved factors and the macroeconomic variables that the structural approach to simultaneous equations fails to consider. A VAR process of order 1, VAR(1), which is adequate according to Diebold, Rudebusch and Aruoba (2003), is shown in the equations below.

$$(\mathbf{f}_t - \mu) = \mathbf{A}(\mathbf{f}_{t-1} - \mu) + \eta_t$$

$$\mathbf{y}_t = \Lambda\mathbf{f}_t + \varepsilon_t$$

These equations show that every endogenous variable of the vector, $\mathbf{f}_t$, is modeled as a function of lagged values of all the endogenous variables of the vector, $\mathbf{f}_{t-1}$, in the system. This enables the process to account for the dynamic impact of changes in the interrelated time series variables. Moreover, it allows us to incorporate the *level*, *slope* and *curvature* of the yield curve that we want to estimate and examine in the process as state variables.

Empirically, a random movement in a particular macroeconomic variable has an effect on other variables in the economy. The innovations in the vector, $\boldsymbol{\eta}_t$, in VAR permit the examination of the dynamic impact of random disturbances in the macroeconomic variables on the *level*, *slope* and *curvature*.

In this study we only considered a unidirectional analysis of the VAR parameter estimates, that is, the impact of macrofactors on the yield curve factors. Impulse responses of the yield curve factors against the macroeconomic variables are evaluated and the contributions of the macrofactors on the variances of the yield curve factors are examined.

The Data

The following are the macroeconomic variables used in this study: Consumer Price Index INFLATION, BSP overnight lending rate, value of production index of key manufacturing enterprises MANUF, peso-dollar exchange rate FOREX, the government's budget DEFICIT, non-performing loans of the banking industry NPL and the federal funds rate of the U.S. Federal Reserve FFR. And for the term structure, we used the Philippine secondary market treasury yields with maturities 3, 6, 12, 24, 60, 84 and 120 months from the Money Market Association of the Philippines MART 1 rates. The MART 1 rates represent 90% of the market for treasuries. All the yields are expressed as gross yield-to-maturity. The period covered is from January 1999 to November 2004.

The Nelson-Siegel yield curve factors were computed using ordinary least squares at each time point. Lambda, λ, is the parameter at which the curvature factor is at its peak. The peak is at the 18^{th} month according to Dewachter and Lyrio (2003).

Table 1 shows the results of the Augmented Dickey-Fuller test for stationarity and the order of integration needed to achieve stationarity.

Table 1. Stationarity Conditions of Yield Curve Factors and Macroeconomic Variables

Variable	Order of Integration	ADF
LEVEL	1	-10.0531***
SLOPE	1	-7.7180***
CURVATURE	1	-10.4996***
INFLATION	1	-4.7810***
BSP	1	-7.3943***
MANUF	1	-14.9597***
FOREX	1	-6.9832***
DEFICIT	0	-10.1904***
NPL	1	-10.4631***
FFR	2	-10.5870***

*** significant at 1% level

All the macroeconomic variables used in the study are expressed in percentages: year-on-year change of the consumer price index, the value of production index and the peso-dollar exchange rate; ratio of total non-performing loans of the banking industry to the total amount of loans, ratio of budget deficit to the total revenue of the government.

The descriptive statistics of the stationary variables are given below in Table 2.

Table 2. Descriptive Statistics

STATISTICS	D(LEVEL)	D(SLOPE)	D(CURVATURE)	D(INFLATION)	D(BSP)
Mean	-0.061	-0.025	0.029	-0.039	-0.090
Median	-0.054	0.003	-0.032	0.000	0.000
Maximum	2.869	6.767	5.752	1.100	4.000
Minimum	-1.785	-3.454	-5.020	-1.700	-1.500
Std. Dev.	0.753	1.211	2.192	0.573	0.636
Skewness	0.641	2.245	0.205	-0.889	3.317
Kurtosis	6.066	15.953	3.375	3.975	26.165
STATISTICS	D(MANUF)	D(FOREX)	DEFICIT	D(NPL)	D(FFR,2)
Mean	0.337	-0.048	-30.502	0.045	0.005
Median	0.510	0.000	-30.334	0.060	0.010
Maximum	42.450	6.990	19.390	1.740	0.350
Minimum	-59.830	-15.100	-71.393	-2.270	-0.460
Std. Dev.	14.629	3.197	19.924	0.667	0.156
Skewness	-0.957	-1.265	0.233	-0.493	-0.528
Kurtosis	7.689	8.689	2.859	4.499	4.140

Results and Discussion

In Table 3 we find that the *level* is significantly influenced by the BSP policy rate. The positive coefficient means that monetary policy tightening would raise expectations of higher interest rates in the future. Being the only macrofactor that is significant, conditional on the other macroeconomic variables, confirms that long-term interest rates are indeed strongly influenced by monetary policy.

Table 3. Yield Curve Factors and Macroeconomic Variables onto Yield Curve Factors

Variable	D(LEVEL)	D(SLOPE)	D(CURVATURE)
D(LEVEL(-1))	-0.153068	0.380159*	-0.911204***
D(SLOPE(-1))	-0.065653	-0.067248	-0.123270
D(CURVATURE(-1))	0.051556	0.097099	-0.196444*
D(INFLATION(-1))	-0.139783	-0.096183	1.102340***
D(BSP(-1))	0.320558**	-0.226768	0.206357
D(MANUF(-1))	0.002353	0.008033	0.001949
D(FOREX(-1))	-0.011114	-0.035533	0.144500*
DEFICIT(-1)	0.000806	0.000620	-0.003694
D(NPL(-1))	-0.039628	0.084277	0.886870***
D(FFR(-1),2)	-0.043173	0.956831	0.299847
R-squared	0.113719	0.133687	0.327183
Adj. R-squared	-0.019223	0.003740	0.226261
Log likelihood	-75.19487	-107.7184	-140.2589
Akaike AIC	2.434139	3.363383	4.293112
Schwarz SC	2.755353	3.684596	4.614326
Mean dependent	-0.057680	-0.027222	0.044857
S.D. dependent	0.757925	1.219992	2.203608
Log likelihood		-1144.024	
Akaike information criterion		35.54354	
Schwarz criterion		38.75568	

*significant at 10% level
** significant at 5% level
*** significant at 1% level

The *slope* on the other hand is only significantly influenced by the *level*. A rise in long-term yields put upward pressure on short-term interest rates. While for the *curvature*, a rise in long-term yields pushes downwards the medium-term interest rates. It is possible that when long-term treasuries are sold by investors in the previous period, causing their prices to drop and their yields to rise, the funds may shift to the medium-term treasuries. This results in an increase in the demand for medium-term treasuries,

raising their prices and their yields down, pushing down medium-term interest rates. A negative coefficient in the coefficient of the *curvature* in previous onto the *curvature* in the current period may simply imply the technical correction that we regularly observed in financial markets.

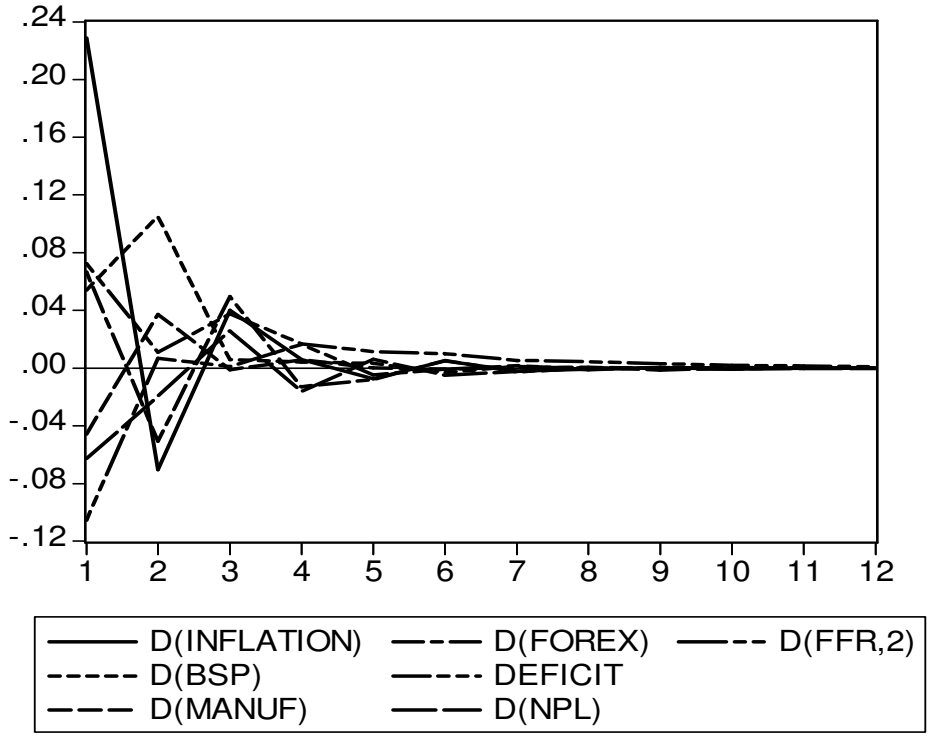
Inflation, peso-dollar exchange rate and non-performing loans are also significant variables for the *curvature*. The significance of inflation is consistent with theory. For the exchange rate, when the peso depreciates against the dollar this depreciation puts significant upward pressure on medium-term interest rates. On the other hand, a rise in non-performing loans would prompt banks to raise interest rates on medium-term loans putting upward pressure on medium-term interest rates.

Impulse Responses

Level

We now evaluate the impact of shocks due to macrofactors on the *level*, *slope* and *curvature*. Figure 1 shows the responses of the long-term interest rates due to

Figure 1. Response of D(LEVEL) to One Standard Deviation Innovation of the Macrofactors



innovations in the macrofactors. Shocks due to inflation have the strongest upward impact on long-term interest rates and this corrects immediately but the effects dissipate only after four months. Referring to Table 2, if monthly inflation-change, i.e. the ($INFLATION_t - INFLATION_{t-1}$), deviates upward from the average monthly inflation-change by 0.573% then this will push upward by about 0.24% or 24 basis points the monthly change in long-term interest rates, i.e. the ($LEVEL_t - LEVEL_{t-1}$). The monthly change in long-term interest rates fluctuates in a wide range of 30 basis points for three months. While a monetary policy tightening shock of 0.636% above the average monthly overnight lending rate-change, i.e. the mean of ($BSP_t - BSP_{t-1}$), will push upward by about 0.06% or 6 basis points the monthly change in long-term interest rates.

Shock due to non-performing loans on the other hand has a downward impact on long-term interest rates. This may be explained by the growth of bad loans in the early period of 1999 to 2004 after the 1997-1998 Asian Financial Crisis. Banks that were saddled with bad loans and which are major players in the market for treasuries demanded more of the long-term bonds causing their prices to rise and their yields to fall pushing down long-term interest rates. This confirms the assertion of Reside (2000) that banks switch to riskless government securities when they are hampered with non-performing loans.

A downward shock of 19.924% in the budget deficit ratio with respect to the total monthly government revenue would push upward the monthly change in long-term interest rates by around 0.09 or 9 basis points. The budget deficit ratio of ±19.924% seems large but if we examine Table 2 we find that it fluctuates within the range of -71.393% to 19.39% of monthly revenue with an average of -30.502%. Of all the macroeconomic variables, it is budget deficit that has a longer sustained upward impact on long-term interest rates as seen in Figure 1. Shocks due to budget deficit only dissipate after 9 months.

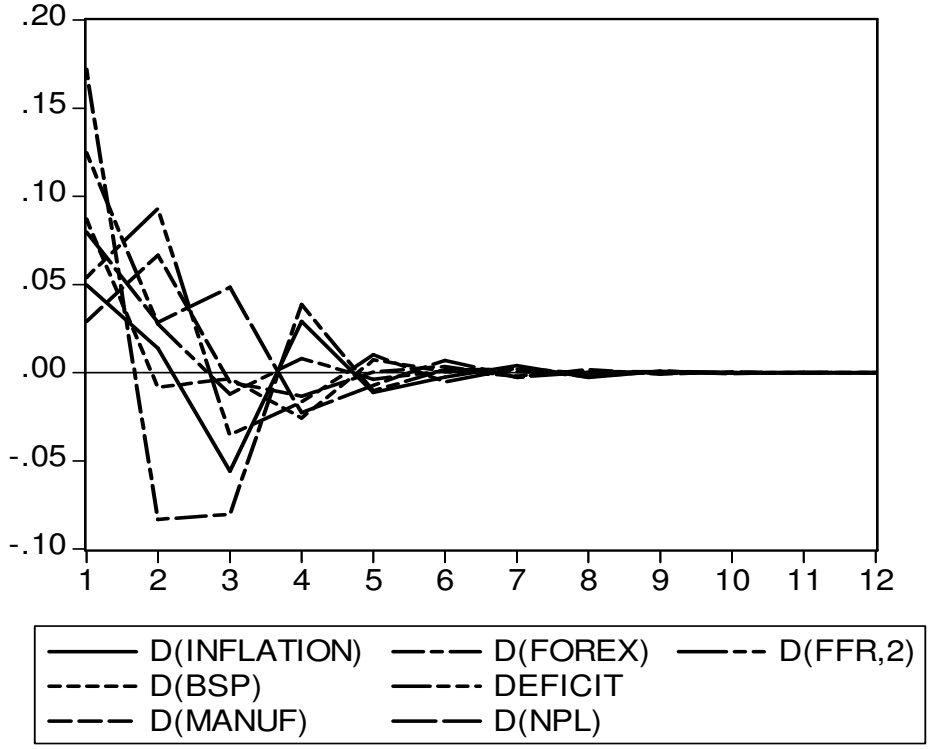
It is worth noting that a change in the direction of U.S. monetary policy of 0.156% as reflected in the Federal Funds rate, i.e. ($FFR_t - 2FFR_{t-1} + FFR_{t-2}$), will have a downward impact on long-term interest rates of around 0.10% or 10 basis points. This may be taken as the immediate impact of a monetary surprise policy change by the U.S.

Federal Reserve on Philippine long-term interest rates. Though the effect of this shock immediately dissipates.

Slope

The shocks due to macrofactors all have upward impact on the *slope*. Shocks on the peso-dollar exchange rate and the budget deficit dominate the other macroeconomic variables. An upward shock of 3.197% from the average monthly year-on-year peso-dollar exchange rate-change, i.e. ($FOREX_t$ – $FOREX_{t-1}$), would push upward the monthly change in short-term interest rates by about 0.17% or 17 basis points. The monthly change in short-term interest rates fluctuates at a wide range of 25 basis points with a 3 month period as can be seen in Figure 2. While a similar shock due to the budget deficit as in the *level* would push upward the monthly change in short-term interest rates by about 0.13% or 13 basis points.

Figure 2. Response of D(SLOPE) to One Standard Deviation Innovation of the Macrofactors



The monetary policy shock comes next then the shock due to non-performing loans and a one-period lag impact due to shock in U.S. monetary policy. These are then followed by inflation and real activity as measured by the value of production index.

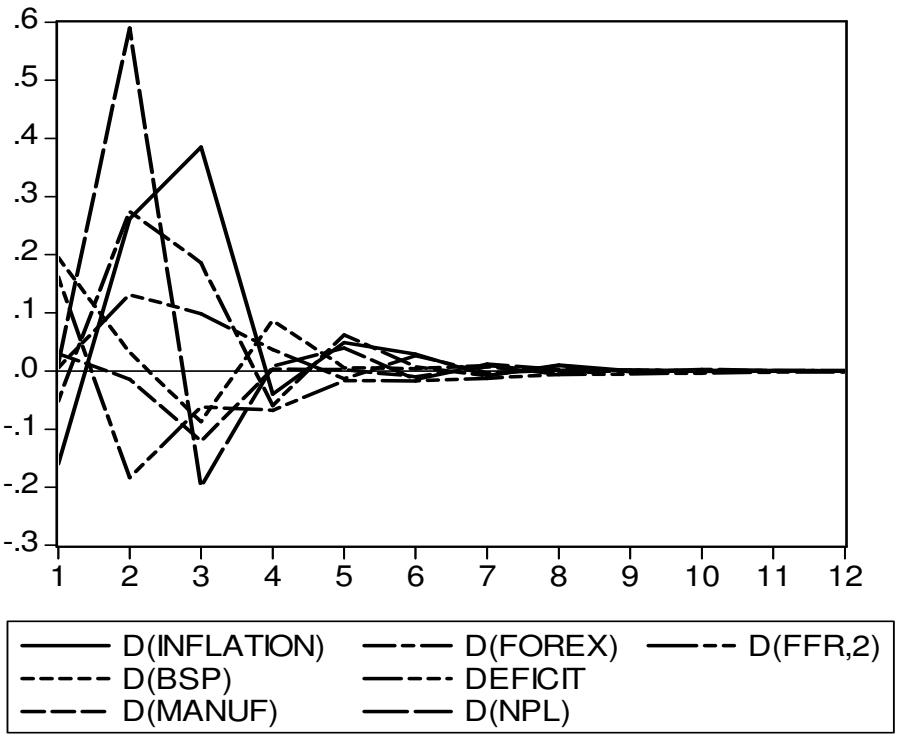
These results show that short-term interest rates are subject mainly to shocks due to the peso-dollar exchange rate and the budget deficit. The stronger monetary policy shock relative to inflation implies that monetary policy tightening is effective in keeping inflation in check through the policy rates impact on short-term interest rates.

Unlike in the studies in the U.S. and Germany, where monetary policy and inflation shocks are dominant, we find here that peso-dollar exchange rate and budget deficit shocks have greater impact on short-term interest rates.

Curvature

Shocks due to the macrofactors have greater volatile effects on the *curvature*. In Figure 3, the non-performing loans, inflation and peso-dollar exchange rate are the largest

Figure 3. Response of D(CURVATURE) to One Standard Deviation Innovation of the Macrofactors



sources of shocks. Although the shocks' impact are delayed by a month the range of fluctuations are 80, 55 and 30 basis points for these three macroeconomic variables,

respectively, are wide. An upward shock of 0.667% from the average monthly non-performing loans ratio-change, i.e. (NPL_t – NPL_{t-1}), would push upward the monthly change in medium-term interest rates by about 0.60% or 60 basis points. An upward shock of 0.573% from the average monthly inflation-change, i.e. ($INFLATION_t$ – $INFLATION_{t-1}$), would push upward the monthly change in medium-term interest rates by about 0.55% or 55 basis points. While upward shock of 3.197% from the average monthly peso-dollar exchange rate-change, i.e. ($FOREX_t$ – $FOREX_{t-1}$), would push upward the monthly change in medium-term interest rates by about 0.30% or 30 basis points.

These three are followed by monetary policy and budget deficit shocks with impacts of 20 and 16 basis points, respectively, and a month lagged impact of the U.S. monetary policy shock of more than 10 basis points. Real activity on the other hand has minimal impact relative to the rest but is still a source of fluctuations in the medium-term interest rates for 4 months.

Variance Decomposition

Table 4 shows the macroeconomic sources of the variance of the yield curve factors. It is not a surprise that the variations of the yield curve factors are due to their

Table 4. Variance Decomposition of the Yield Curve Factors

Variables	Yield Curve Factors		
	D(LEVEL)	D(SLOPE)	D(CURVATURE)
D(LEVEL)	78.20	6.88	11.35
D(SLOPE)	3.40	84.73	3.91
D(CURVATURE)	1.75	2.20	68.11
D(INFLATION)	8.90	0.40	4.45
D(BSP)	2.12	0.49	0.98
D(MANUF)	0.53	0.32	0.29
D(FOREX)	1.47	2.62	2.16
DEFICIT	1.11	0.97	1.24
D(NPL)	0.80	0.60	7.00
D(FFR,2)	1.73	0.78	0.52

own stochastic behavior. But inflation comprises 8.9% of the variation in the long-term interest rates and 4.45% of the variation in the medium-term interest rates. While non-performing loans account for 7% of the variation in medium-term interest rates. Although relatively smaller, the peso-dollar exchange rate accounts for 1.47%, 2.62%

and 2.16% of the long-term, short-term and medium-term interest rates, respectively. And, monetary policy accounts for 2.12% of the variation of the long-term interest rates.

We can see here that the importance of the shocks of macrofactors on the variation of the yield curve factors is relative small, except perhaps for inflation. The variance decomposition results also show that the effects of the shocks in the impulse response analysis are relatively transitory. Although if we take the perspective of a fixed-income trader a 25 basis point change in the yields of treasuries is already significant in making profits or not out of a trade. A 50 basis point change in the interest rate charged on a firm for borrowing money from a bank is already large when, say, we are looking at monthly adjustment on a loan of 10 million pesos.

Conclusion

We have shown that monetary policy has a significant effect on long-term interest rates. At the same time, shocks to inflation and monetary policy have the largest impact on the volatility of long-term interest rates. Now, long-term interest rates provide significant upward momentum on short-term interest rates. And shocks to peso-dollar exchange rate and budget deficit have the strongest effect on the volatility of short-term interest rates. Inflation, peso-dollar exchange rate and non-performing loans significantly drive the medium-term interest rates and shocks due to these three are the largest source of volatility for medium-term interest rates.

The results imply that Philippine monetary policy has significant effect on long-term interest rates but at the same time it is overwhelmed by shocks due to the peso-dollar exchange rate and budget deficit when it comes to short-term interest rate volatilities. It seems then that the intervention being done by monetary policymakers to keep the volatility of the peso-dollar exchange rate at a manageable level is beneficial. But interventions can only be done to a certain extent given that we have a limited level of foreign exchange reserve. On the fiscal policy side, it is necessary for the government to move towards balancing its budget by improving its revenue collection so that it will not hamper the growth of investments due to high interest rates. Reducing expenditures may have a dampening effect on real activity.

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