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Measuring monetary policy by money supply and interest rate: evidence from emerging economies

Trung Thanh Bui, Kiss Dávid Gábor[1]

Abstract: Although measuring monetary policy is a contentious issue in the literature, much less evidence on this issue is available for emerging economies. This paper aims to investigate the role of interest rate and money supply in measuring monetary policy in twelve emerging economies that target inflation through the analysis of Granger causality, impulse response function, and forecast error variance decomposition. The empirical results show that both money supply and interest rate are useful predictors for changes in inflation. Moreover, both show a comparable power to explain the variation of inflation. However, a rise in interest rate increases rather than decreases inflation, whereas money supply has a positive and expected effect on inflation. These findings suggest that interest rate may not fully capture the overall stance of monetary policy or interest rate has a limited effect on inflation.

Keywords: monetary policy instruments, interest rate, money supply, emerging economies

JEL Classification: E51, E52, E53

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Introduction

Choosing a proper measure is of importance for the analysis of monetary policy (Bernanke and Mihov, 1998). According to Romer and Romer (2004), a sufficiently representative measure of monetary policy not only reduces the endogeneity between changes in monetary policy and changes in the state of the economy but also alleviates the underestimate of monetary policy effect on output and inflation. Therefore, the choice of a proper monetary policy indicator helps reveal the true relationship between monetary policy and economic objectives.

There is vast literature investigating the indicator problem of monetary policy for advanced economies (e.g., Bernanke, 1990; Laurent, 1988). The general consensus of these studies is that interest rate is the preferred indicator of monetary policy. On the

[1] Faculty of Economics and Business Administration, University of Szeged. Postal address: 6722, 1 Kálvária sgt, Szeged, Hungary. Email: trungbt@ueh.edu.vn (corresponding author), kiss.gabor.david@eco.u-szeged.hu

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contrary, the literature is limited for emerging economies. In addition to this, most studies using emerging economy data assume that monetary policy is properly measured by interest rate. However, institutional differences between emerging and advanced economies raise questions about the fact that interest rate is a "clean" indicator of monetary policy for emerging economies. Since the 1990s, many emerging economies have adopted inflation targeting. Conventionally, in this framework, the interest rate is the main instrument to achieve a preannounced target of inflation rate, whereas other instruments such as money supply or exchange rate are determined by the market forces. In practice, however, monetary authorities in emerging economies use the interest rate as well as other instruments to achieve several objectives of monetary policy. Monetary authorities can put great emphasis on output growth when recessions happen and political heat occurs or focus on maintaining the stability of the exchange rate because of factors such as competitive advantage. Consequently, it is likely that the interest rate cannot fully capture the stance of monetary policy.

Nevertheless, the effectiveness of interest rate and money supply in measuring the stance of monetary policy remains vague for emerging economies. Since the choice of a proper indicator of monetary policy is the first step to analyse further issues of monetary policy such as effectiveness, monetary policy rules, or transmission channels, it is of importance to have a rigorous study on the effectiveness of various monetary policy indicators in emerging economies. The objective of this paper is to investigate crucial questions about the indicator problem of monetary policy in emerging economies that follow inflation targeting. What is the role of money supply in the conduct of monetary policy? What is the importance of interest rate and money supply in measuring monetary policy in emerging economies? How do these indicators explain the movement and variation of inflation in emerging economies?

There are various factors motivating the analysis of the indicator problem for emerging economies targeting price stability. Firstly, we know little about the role of money supply and interest rate in measuring monetary policy for emerging economies, which is in contrast with the vast literature for advanced economies. Secondly, the use of multiple instruments suggests that interest rate may not be considered as a sufficiently representative measure of monetary policy in emerging economies. This paper provides comparative evidence about the indicator function of money supply and interest rate for emerging economies. Thirdly, the paper places emphasis on both causality and dynamic relationship between monetary policy indicators and inflation. This complements previous studies which favour only the effect of monetary policy indicators on inflation or output.

The rest of the paper is organized as follows. Section "Literature review" provides styled facts about inflation targeting in emerging economies and the literature about the use of money supply and interest rate as a measure of monetary policy. Section "Methodology and data" discusses the methodology used to investigate how money supply and interest rate can affect the movement of inflation and explain the variation of inflation. Section "Empirical results" discusses empirical results. Section "Conclusion" presents conclusions and policy implications.

Literature review

Monetary framework in emerging economies

Crises in the 1990s lowered economic growth, caused inflation, and led to difficulties in the implementation of monetary policy in many countries. To recover the economy, many countries conducted reforms in the financial system and the monetary policy framework. Among many reforms, the most remarkable one is the adoption of inflation targeting that is characterized by the commitment to achieve an explicit inflation target. Such a commitment helps improve the communication, accountability, transparency, and credibility of monetary policy (Wong, Clifton and Leon, 2001) as well as alleviate the problem of dynamic inconsistency (Lin and Ye, 2009). The economic gains of these improvements are a reduction in the expectation and volatility of inflation (Gonçalves and Salles, 2008; Lin, 2010; Lin and Ye, 2009) and a reduction in the trade-off between output and inflation (Wong, Clifton and Leon, 2001).

However, institutional differences lead to differences in the implementation of inflation targeting in emerging and advanced economies. In emerging economies, the government can affect the setting of the inflation target as well as the conduct of monetary policy (Jawadi, Mallick and Sousa, 2014), which is contrary to the high independence of the central bank in advanced economies. Since monetary authorities in emerging economies can follow objectives that do not appear for advanced economies, the departure of the inflation target from the inflation forecast is of great concern (Svensson, 1997). As a result, they often implement a tolerance band, whereby inflation can fluctuate in a specific range. More importantly, the existence of multiple objectives leads to the use of many instruments because these instruments are different and thus useful in different situations. Conventionally, to achieve preannounced inflation targets in the inflation targeting regime, monetary authorities usually use a reference interest rate and leave market forces to determine other instruments such as money supply and exchange rate (Acosta-Ormaechea and Coble, 2011). In practice, however, monetary authorities in emerging economies can alter instruments beyond interest rate to control inflation (Gerlach and Tillmann, 2012). According to Acosta-Ormaechea and Coble (2011), the exchange rate plays a more important role in the transmission mechanism in emerging economies like Peru and Uruguay.

Theoretical difficulties in measuring monetary policy

According to Handa (2009), the effectiveness of monetary policy depends on the appropriate selection of instruments, operating targets, intermediate targets, and goals. However, it should be noted that there is no clear-cut distinction between instruments and operational targets (Handa, 2009). In fact, they are often exchangeable. Generally, monetary authorities must select proper instruments, which are tools under their control, to manage the future path of inflation or output. Popular instruments are open market operations, discount window, policy rates, foreign exchange interventions, to name a few. The choice of a proper instrument requires a thorough consideration of the ability of monetary authorities to control (Friedman, 1968; Jawadi, Mallick and Sousa, 2014) and avoid large adjustments in the instrument (Friedman, 1968). Although instruments are under the control of monetary authorities, they cannot give numeric information about changes in monetary policy. In fact, operational targets are considered as the primary indicators of monetary policy. Empirical analysis often uses interest rate and money

supply as indicators of monetary policy. One reason is that they show a strong relationship with changes in instruments under the control of monetary authorities. In addition to this, they can show quantitative changes in the direction and size of monetary policy and have a relatively stable relationship with the objective of monetary policy.

The measure or indicator problem emerges because of the controversy about the effectiveness of interest rate and money supply in the implementation of monetary policy. According to Poole (1970), the choice of an optimal instrument depends on the source of uncertainty in the economy. Poole (1970) uses a simple IS/LM framework to compare the performance of interest rate and money supply in controlling output volatility. The analysis assumes that monetary authorities have no errors in controlling interest rate or monetary base and they must choose only one instrument to minimize output volatility. The analysis concludes that the interest rate is optimal (causes less volatile output) to deal with shocks from financial markets, whereas money supply is optimal to deal with shocks from commodity markets. Following studies (Bhattacharya and Singh, 2008) obtain a similar conclusion that interest rate is optimal to deal with nominal shocks whereas money supply is optimal to deal with real shocks. Atkeson, Chari and Kehoe (2007) rank monetary policy instruments based on the bond between instruments and objectives (tightness) or the observability of instrument adjustments (transparency). They conclude that the interest rate is superior to other instruments, the exchange rate stands at the second position, and money supply is at the bottom.

However, the consensus of Poole (1970) is open to question when applying it for emerging economies. Firstly, monetary authorities in emerging economies cannot control instruments as perfectly as counterparts in advanced economies. The large size of control error raises doubts about the application of the consensus of Poole (1970) for emerging economies. Secondly, it is cautious about concluding the superiority of interest rate or money supply when monetary authorities focus on price stability rather than output stability. Thirdly, monetary authorities in emerging economies can use both instruments rather than rely on only interest rate. One reason is that, compared to advanced economies, monetary authorities in emerging economies have limited knowledge about the source of uncertainty in the economy. According to the policy theory under uncertainty, risk-averse monetary authorities can diversify the risk by using both money supply and interest rate (Handa, 2009) as these instruments are different in nature and thus useful in different situations. Another reason is that two instruments can be complementary rather than competing. For instance, a reserve instrument can support interest rate instrument when financial friction is high (Sensarma and Bhattacharyya, 2016). Moreover, reserve requirements are of importance for central banks that want to maintain financial stability (Glocker and Towbin, 2012). Finally, monetary authorities can use interest rate even though it is not optimal according to Poole (1970). High output volatility when pegging interest rate allows individuals and firms more room to optimize the utility. Moreover, the use of interest rate can stem from political pressures (Cover and VanHoose, 2000).

Furthermore, small and open economies cope with more difficulties when deciding the superiority of interest rate and money supply. Gardner (1983) examines the performance of three instruments (interest rate, exchange rate, and money supply) and find that the choice of optimal instruments depends on the understanding of money demand and money supply and the relative importance of exchange rate. If monetary authorities

have perfect knowledge about money demand, the interest rate is superior to the reserve instrument. If they have perfect knowledge about money supply, reserve instrument is superior to the interest rate. However, when the exchange rate is of great concern, the interest rate is preferable, although monetary authorities have perfect knowledge about the process of the money supply. Under the New Keynesian framework, Singh and Subramanian (2008) examine the superiority of money supply and interest rate under different types of shocks. Based on the welfare yardstick, they find the superiority of money supply in response to demand (fiscal) shocks and the superiority of interest rate in response to supply (productivity) or money (velocity) shocks.

In summary, from the theoretical perspective, it is a difficult task to decide what is the best measure of monetary policy in emerging economies. The primary reason is the unique institutions in these countries. The problem of asymmetric information or a low level of financial development increases the uncertainty in the economy, which stimulates monetary authorities to use various instruments in the conduct of monetary policy. Hence, it is of importance to investigate how the interest rate and money supply work as a measure of monetary policy in emerging economies.

Empirical studies about measuring monetary policy in emerging economies

While the most appropriate measure of monetary policy is an ongoing issue, studies based on the prior that interest rate is the most proper indicator of monetary policy are popular for emerging economies. Since the seminal work of Sims (1972), many studies use the innovations of the short-term interest rate derived from the vector autoregression (VAR) model as exogenous changes in monetary policy (Acosta-Ormaechea and Coble, 2011; Peters, 2016; Phiromswad, 2015). Others, however, using interest rate as an overall measure of monetary policy in the analysis of the Taylor rule. See, for instance, Furlani, Portugal and Laurini (2010), De Mello and Moccero (2011), Sánchez-Fung (2011), Cermeño, Villagómez and Polo (2012), Jawadi, Mallick and Sousa (2014), and Yağcıbaşı and Yıldırım (2017), to name a few. However, the practical institutions raise doubts about the prior that interest rate is the best measure of monetary policy in emerging economies. As an illustration, Cermeño, Villagómez and Polo (2012) use the generalized method of moments (GMM) method to analyze the reaction function of monetary policy in Mexico from January 1998 to February 2008 and argue that short-term interest rate can reflect the behavior of the Bank of Mexico. However, it should be noted that the short-term interest rate may not be a good measure of monetary policy because it is not the primary instrument of monetary policy in Mexico during the period prior 2008 (Cermeño, Villagómez and Polo, 2012). Before 2008, monetary authorities in Mexico used an instrument, namely corto, to signal the market about their preference for the structure of the market interest rate.

Methodology and data

Methodology

This paper compares the performance of indicators of monetary policy in emerging economies through the analysis of Granger causality and the response of policy objective variables to shocks of monetary policy indicators (Bernanke and Mihov, 1998). Such an analysis indicates the strength of the linkage between indicators and objectives of monetary policy, which is in line with Atkeson, Chari and Kehoe (2007).

1) A scalar variable is a proper indicator of monetary policy if it causes changes in the objective of monetary policy. Granger causality test can be considered as a selection device to determine the causality between variables (Handa, 2009). In this paper, since the sample consists of countries that adopt inflation targeting, the analysis of the Granger causality between monetary policy indicators and inflation is of importance to capture the significance of these indicators as an overall measure of monetary policy.
2) An indicator of monetary policy is preferable if it causes inflation to change according to the monetary theory and explains a greater proportion of inflation variance.

Granger causality analysis

An indicator is useful to measure monetary policy when it is a significant predictor for changes in the objective of monetary policy. Following Sun and Ma (2004), a monetary policy indicator is effective to control prices/output if it Granger causes prices/output. On the contrary, an indicator is endogenous if there is a statistically significant Granger causality from prices/output to the indicator. In this paper, the analysis focuses on how a monetary policy indicator Granger causes inflation.

We examine the Granger causality from money supply and interest rate to inflation by using both the time-series and panel causality test. First, the augmented Granger test of Toda and Yamamoto (1995) is used because of the fact that variables under investigation are unlikely to be stationary at the same level. Another reason is to easily compare the results when considering many countries at the same time. Second, for panel data, we use Dumitrescu and Hurlin (2012) procedure to examine the causal effect of money supply and interest rate on inflation.

Granger (1969) causality test is a pioneering method for determining whether a variable is useful to forecast the movement of the other variable. Its VAR representation is:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_p Y_{t-p} + \varepsilon_t \tag{1}$$

where Y_t is a bivariate vector and ε_t is the white noise. Since the paper examines a sample of emerging economies that follow inflation targeting, Y_t includes inflation and a monetary policy indicator which can be either interest rate or money supply (M1 and M2).

Although the VAR model is popularly used in the literature, it copes with the stationarity condition. If variables are stationary at different levels, the Wald test in the VAR model may be subjected to size distortions. To overcome this issue, Toda and Yamamoto (1995) suggest adding the maximum integration order d into the lag of the standard VAR p as specified in Granger (1969). The next step is to estimate the VAR system using the augmented lag $p + d$ and then implement Granger test with the lag p. The VAR representation of the augmented Granger causality test is:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_{p+d} Y_{t-p-d} + \varepsilon_t \tag{2}$$

In the context of a panel or cross-country data, Dumitrescu and Hurlin (2012) make a significant contribution by constructing a process to test the Granger causality. A simple specification of the test is as follows:

$$Y_{i,t} = \beta_0 + \beta_1 Y_{i,t-1} + \beta_2 Y_{i,t-2} + ... + \beta_p Y_{i,t-p} + \varepsilon_t \quad (3)$$

The Granger causality test proposed by Dumitrescu and Hurlin (2012) is similar with Granger (1969) test. This means that x1 is a significant predictor of x2 when the past values of x1 have a significant effect on the present value of x2. However, the novelty of Dumitrescu and Hurlin (2012) test is that it constructs the average Wald statistic using Wald statistic for individual (country) in the panel. Therefore, the rejection of the null hypothesis of no Granger causality does not mean that the Granger causality does not exist for all individual countries.

Impulse response analysis

According to the existing literature, interest rate and money supply can represent overall changes in monetary policy. We use a VAR model to investigate the effect of monetary policy indicators on inflation. The lag lengths are selected by the Akaike Information Criterion criteria (AIC).

The vector of endogenous variables is:

$$Y = [DLCPI, DLY, DLEX, POLICY]' \quad (4)$$

where DLCPI, DLY, and DLEX are the first difference of the logarithm of the consumer price index, industrial production index, and exchange rate, respectively. POLICY is the set of monetary policy indicators, including R, DLM1, and DLM2 that are the short-term interest rate and the first difference of the logarithm of money supply M1 and M2, respectively. The inclusion of the exchange rate is important to capture the small and open nature of emerging economies as well as their fear of floating.

The effect of money supply and interest rate on inflation can be investigated through impulse response function (IRF) and forecast error variance decomposition (FEVD). While IRF indicates the direction and size of monetary policy effect on inflation, FEVD shows the importance of various indicators of monetary policy as a source of inflation variation.

It should be noted that the VAR model is recursive with the ordering in Equation (4). As shown in Equation (4), one variable shows a contemporaneous response to previous ones, whereas it shows a lagged response to the following variables. Accordingly, a policy variable (e.g., interest rate) shows an immediate response to changes in the economic conditions (inflation, output, and exchange rate). Other patterns of the response of the policy variable to inflation, output, and exchange rate are also examined to determine the robustness of the empirical estimates with respect to the specification choices. The analysis specified in section “Robustness test” indicates that the empirical results are robust to changes in the order of variables.

For more robustness, we examine the effectiveness of interest rate and money supply in controlling inflation using panel data. Since emerging economies under investigation is geographically and institutionally diverse, panel regression is proper to control the heterogeneity between emerging economies, thereby helping to obtain unbiased estimations. Furthermore, panel regression also contains more information and more degree of freedom. In sum, the Panel VAR compliments the traditional time-series VAR by con-

trolling unobserved heterogeneity of countries and improve the efficiency of the statistical inference.

Data

As mentioned above, we focus on emerging economies that follow inflation targeting. Because of data availability, the sample consists of twelve emerging economies: Brazil, Chile, Colombia, Mexico, Hungary, Poland, Romania, Turkey, Korea, Philippines, Thailand, and South Africa. The data are monthly, spanning from January 2000 to June 2018. In other words, there are 222 observations. They are mainly collected from the IMF. We use the money market rate, which is derived from the IMF, as a proxy for the short-term interest rate. For most countries, the exchange rate is derived from the IMF. For Turkey, Korea, and Thailand, the exchange rate is collected from the Bank for International Settlements. In this paper, the exchange rate measures the value of the domestic currency in terms of the euro (European countries) or the US dollar (other countries). Following the existing literature, we use changes in the consumer price index (industrial production index) as a measure of inflation (output).

Table 1 shows the mean and standard deviation of six variables: inflation rate, output growth, money supply (M1, M2) growth, exchange rate growth, and short-term interest rate. It can be seen that the inflation rate showed a relatively low mean in most countries, ranging from 2 to 5%. Romania and Turkey had high rates of inflation, 9.08 and 14.28%, respectively. Brazil and South Africa had moderate inflation rates, approximately 6.32% and 5.21%, respectively. The mean of output growth was slightly different between emerging economies. Compared with other countries, Brazil and South Africa had a relatively low rate of output growth, about 1%. Similarly, the mean of M1 and M2 growth was not much different between countries with the exception of Romania and Turkey, where the figures were twice or three times greater than other countries. It seems that high money growth was a cause of high inflation in Romania and Turkey. Furthermore, the mean of exchange rate growth was negative, indicating the depreciation of the domestic currency in emerging economies.

Table 2 shows the ADF test for the stationarity of various variables. As observed, the interest rate is stationary at level, except for Hungary, where it is stationary at first difference. For other variables, they are stationary at a level in a few cases: output for Turkey; prices for Mexico, Romania, and Turkey; M1 and M2 for the Philippines; exchange rate for Hungary, Poland, Romania, and Turkey. Overall, variables are stationary at first difference. Hence, we enter the first difference of all variables but interest rate into the VAR model to satisfy the stationary condition of the VAR model and reduce the complexity in the estimation. Interest rate appears in its level form.

Table 1. Mean and standard deviation of selected variables

	Inflation rate	Output growth	Exchange rate growth	M1 growth	M2 growth	Interest rate
Brazil	6.32	1.11	-3.26	10.69	12.54	13.64
	(2.5)	(6.39)	(18.37)	(7.89)	(7.13)	(4.45)
Chile	3.14	2.19	-1.11	12.65	10.25	4.26
	(2)	(5.31)	(11.14)	(5.74)	(5.96)	(2.31)
Colombia	4.98	2.32	-2.76	13.19	12.06	6.36
	(1.99)	(5.5)	(13.88)	(6.46)	(4.15)	(2.38)
Mexico	4.52	0.95	-3.63	12.79	10.91	7.14
	(1.51)	(3.78)	(9.33)	(3.71)	(3.08)	(3.47)
Hungary	4.26	3.15	-1.13	11.50	8.21	5.02
	(2.82)	(8.94)	(5.43)	(7.44)	(4.98)	(3.08)
Poland	2.54	5.05	-0.01	11.85	9.25	5.47
	(2.42)	(5.83)	(8.99)	(6.01)	(4.35)	(4.63)
Romania	9.08	4.24	-5.67	22.80	16.09	12.10
	(10.26)	(6.51)	(10.19)	(22.2)	(10.65)	(13.35)
Turkey	14.28	5.17	-12.67	27.52	25.60	21.68
	(12.98)	(8.98)	(18.62)	(17.66)	(16.68)	(19.31)
Korea	2.51	4.87	0.43	9.53	7.29	3.19
	(1.16)	(7.47)	(10.55)	(8.49)	(2.91)	(1.27)
Philippines	3.76	2.92	-1.48	1.93	6.99	5.44
	(1.9)	(10.56)	(7.62)	(63.97)	(80.01)	(2.62)
Thailand	2.08	4.00	0.83	8.29	6.37	2.19
	(1.96)	(9.92)	(6.57)	(4.38)	(3.05)	(1)
South Africa	5.21	0.90	-4.02	10.77	10.48	7.56
	(2.67)	(5.5)	(17.35)	(5.75)	(5.17)	(2.18)

Source: Author's estimation.
Notes: Standard deviation is in the parentheses.

Table 2. ADF test for the stationarity of variables

	LY	LCPI	LM1	LM2	LEX	R
Brazil	-7.94***	-6.48***	-7.74***	-6.14***	-8.28***	-1.38(a)***
Chile	-8.77***	-5.44***	-7.32***	-3.62***	-8.88***	-3.53(a)***
Colombia	-12.71***	-7.21***	-7.12***	-5.67***	-7.64***	-4.04(a)***
Mexico	-8.99***	-3.14(a)***	-7.77***	-7.57***	-8.47***	-3.62(a)***
Hungary	-4.81***	-5.37***	-4.82***	-11.54***	-3.42(a)***	-11.1***
Poland	-9.36***	-4.78***	-3.9***	-3.54***	-3.13(a)***	-3.81(a)***
Romania	-4.17***	-3.92(a)***	-3.93***	-4.11***	-3.79(a)***	-2.54(a)***
Turkey	-3.34(a)***	-5.74(a)***	-12.98***	-15.8***	-3.24(a)***	-2.31(a)***
Korea	-5.88***	-5.84***	-4.76***	-5.13***	-6.38***	-1.56(a)***
Philippines	-8.02***	-4.37***	-4.15(a)***	-3.67(a)***	-9.02***	-1.47(a)***
Thailand	-8.29***	-8.16***	-5.79***	-3.5***	-7.16***	-2.81(a)***
South Africa	-5.5***	-7.33***	-9.6***	-15.4***	-9.54***	-2.58(a)***

Source: Author's estimation.
Notes: The table describes the ADF test for the stationarity at first difference. (a) indicates that variables are stationary at the level. The optimal lag is selected by the AIC criterion.
, **, * denote the significance at 1%, 5%, and 10% level respectively.*

Empirical results

Country evidence: Granger causality analysis

This section discusses how money supply and interest rate Granger cause inflation in emerging economies that follow inflation targeting. The Granger causality analysis is of importance because it indicates whether changes in monetary policy indicators can predict changes in inflation. It also complements the disadvantage of the correlation analysis in previous studies. However, it should be noted that Granger causality analysis cannot specify the direction of changes in monetary policy objectives such as inflation after a decision of monetary authorities. Therefore, Granger causality evidence works as a supplement for the analysis of impulse response function in the next section.

To account for the fact that variables are integrated at different levels, we use the augmented Granger causality test proposed by Toda and Yamamoto (1995). As shown in Table 3, the maximum order of integration is one in most cases and the optimal lag selected by the AIC criterion varies across specifications. Overall, the results show that the causal relationship between monetary policy indicators and inflation is strong. The interest rate has a bidirectional Granger causality with inflation in most countries except for Chile, Thailand, and the Philippines. While the Granger causality from interest rate to inflation is not statistically significant for Chile and Thailand, the reverse Granger causality is not statistically significant for the Philippines. For M1, it has a bidirectional causality with inflation in all countries. For M2, it does not cause inflation in the Philippines and South Africa. According to the conventional theory, it is likely that a rise in

the money supply can lead to a rise in inflation. In reverse, changes in inflation can cause changes in the money supply. One channel happens through changes in wages. Higher inflation causes a rise in wages, which leads to a rise in production costs and a reduction in production. To avoid contraction in production and related economic activities, monetary authorities can increase the money supply. Another channel is the inflation expectation. In times of high inflation, the public can establish a high level of inflation expectation, which calls for a contraction in the supply of money.

Table 3. Granger causality between monetary policy indicators on inflation

	$R \rightarrow \pi$	$\pi \rightarrow R$	$M1 \rightarrow \pi$	$\pi \rightarrow M1$	$M2 \rightarrow \pi$	$\pi \rightarrow M2$
Brazil	26.43***	18.17**	30***	42.51***	34.18***	27.17***
	(10-1)	(10-1)	(12-1)	(12-1)	(10-1)	(10-1)
Chile	5.79	51.9***	35.63***	32***	25.75***	20.77**
	(8-0)	(8-0)	(12-1)	(12-1)	(11-1)	(11-1)
Colombia	17.55**	37.46***	42.2***	48.54***	38.89***	28.39***
	(12-0)	(12-0)	(12-1)	(12-1)	(12-1)	(12-1)
Mexico	26.09***	20.16**	67.26***	26.12**	19.1**	14.6**
	(9-0)	(9-0)	(12-1)	(12-1)	(8-1)	(8-1)
Hungary	15.97**	25.67***	30.35***	27.98***	23.34**	34.72***
	(9-1)	(9-1)	(12-1)	(12-1)	(12-0)	(12-0)
Poland	22.37***	27.35***	20.61**	31.17***	21.99**	12.64**
	(8-0)	(8-0)	(12-1)	(12-1)	(12-1)	(12-1)
Romania	2.07**	7.67**	17.17**	9.37**	33.2***	32.1***
	(2-1)	(2-1)	(7-1)	(7-1)	(12-0)	(12-0)
Turkey	66.27***	49.11***	42.74***	7**	23.98***	7.08**
	(12-1)	(12-1)	(7-0)	(7-0)	(7-0)	(7-0)
Korea	5.02**	8.78**	20.32**	32.6***	5.27**	8.41**
	(4-1)	(4-1)	(12-1)	(12-1)	(4-1)	(4-1)
Philippines	15.42**	3.13	5.85**	7.21**	7.23	20.94**
	(6-1)	(6-1)	(4-0)	(4-0)	(9-0)	(9-0)
Thailand	3.68	94.85***	13.16**	32.84***	26.06***	31.35***
	(7-1)	(7-1)	(12-1)	(12-1)	(8-1)	(8-1)
South Africa	11.93***	2.46**	20.34**	51.08***	0.14	1.52**
	(3-1)	(3-1)	(9-1)	(9-1)	(2-1)	(2-1)

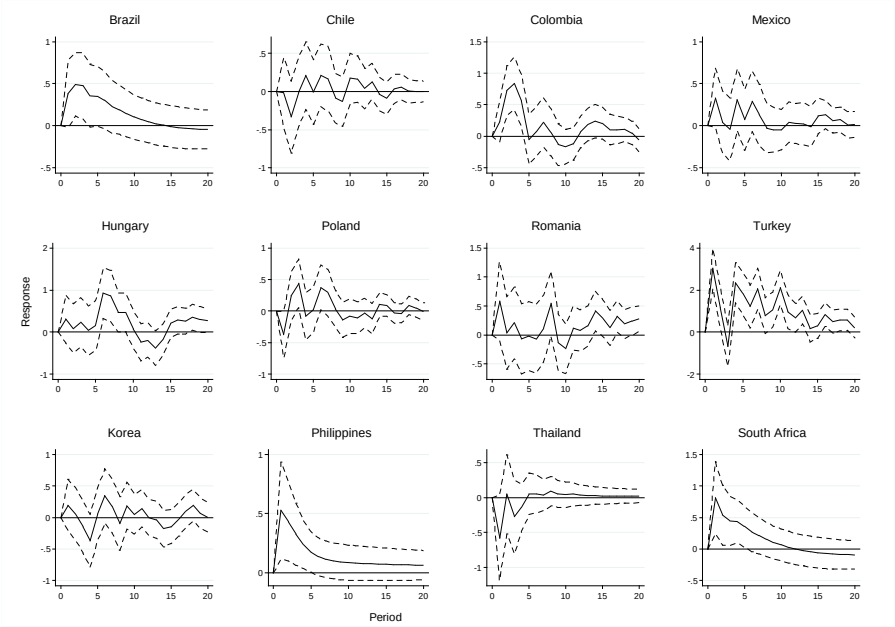
Source: Author's estimation.
Notes: *, **, *** denotes significance at 1%, 5%, and 10% respectively. The optimal lag and maximum integration order are in the parentheses.

Country evidence: Impulse response analysis

We proceed by separately investigating the effect of interest rate and money supply on inflation. Figure **Chyba! Nenalezen zdroj odkazů.**1 shows that the interest rate weakly affects inflation in emerging economies. Such a finding is in line with Acosta-Ormaechea and Coble (2011) in the sense that monetary policy weakly transmits

through the traditional interest rate channel in emerging economies. A low degree of monetization, underdeveloped financial markets, and capital controls are factors that can lower the effectiveness of interest rate policy in emerging economies.

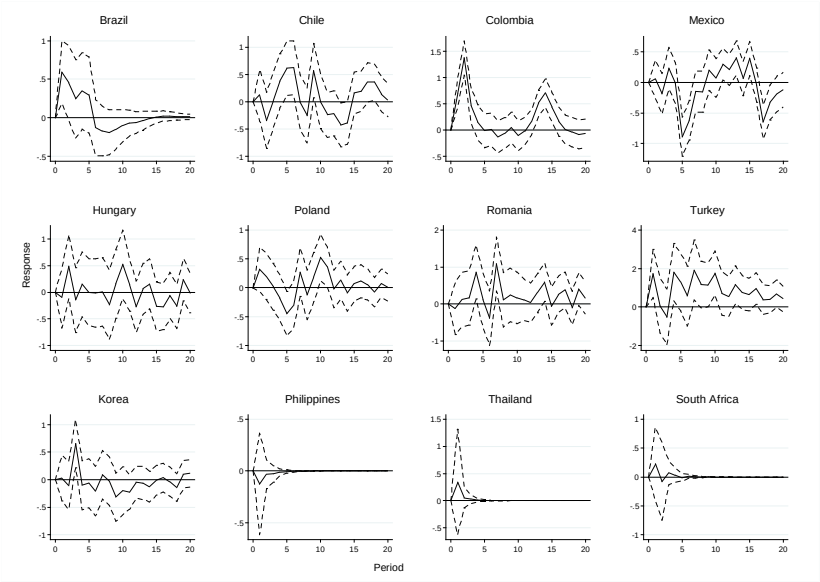
Figure 1. Response of inflation to interest rate shocks



Source: Authors' construction

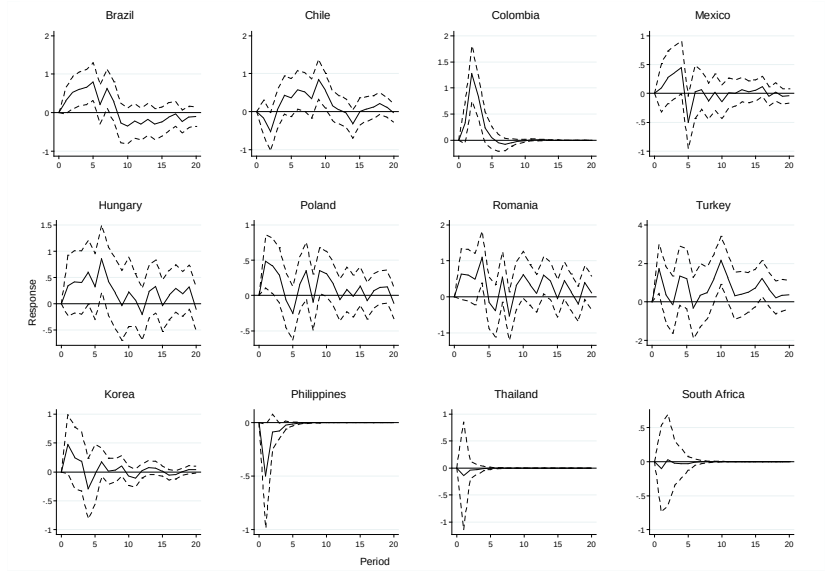
Furthermore, the interest rate has a positive effect on inflation in most countries, which has been termed as the price puzzle (Sims, 1992). For Poland and Thailand, interest rate negatively affects inflation in the first few months, which is consistent with the findings for advanced economies and most theoretical models. The presence of the price puzzle has some possible interpretations. Firstly, the interest rate is weak in representing the stance of monetary policy in emerging economies. To put it differently, a rise in interest rate cannot fully capture the expansionary and contractionary stance of monetary policy in emerging economies. Other variables such as money supply can play a role in measuring monetary policy. This problem is likely to emerge because monetary authorities in emerging economies use multiple instruments to achieve many objectives, including price stability, output growth, financial stability, exchange rate stability, and the adequacy of international reserves. Furthermore, the segmentation of credit markets can also reduce the representation of interest rates as an indicator of monetary policy in emerging economies. In summary, it is crucial to consider information from other indicators such as money supply when measuring the stance of monetary policy for emerging economies,

Figure 2. Response of inflation to money supply M1



Source: Authors' construction

Figure 3. Response of inflation to money supply M2



Source: Authors' construction

Secondly, the presence of the price puzzle can stem from the specification bias. The small-scaled nature of the VAR model may lead to the exclusion of important information for inflation forecast (Bernanke and Mihov, 1998; Sims, 1992). Therefore, a remedy to solve the price puzzle is to add variables such as commodity or oil prices (Bernanke and Mihov, 1998; Sims, 1992). However, the robustness tests in section "Robustness test" does not support the speculation that the price puzzle is owning to the misspecification.

Thirdly, the price puzzle can result from other reasons. One is the influence of monetary policy on the supply side of the economy (Barth and Ramey, 2001). Changes in interest rates can affect borrowing costs and then lead to changes in prices. If the effect of monetary policy on production costs dominates the effect on aggregate demand, prices are likely to increase rather than decrease following a monetary policy contraction. Moreover, information asymmetry can also lead to the price puzzle. Imperfect information may cause monetary policy responses to be insufficient or too late to control inflation. As a result, raising the interest rate will increase rather than decrease inflation (Walsh, 2010). Furthermore, high inflation expectation can lead to the weak response of inflation to a monetary policy restriction and lengthen the period of disinflation (Mackiewicz-Łyziak, 2016).

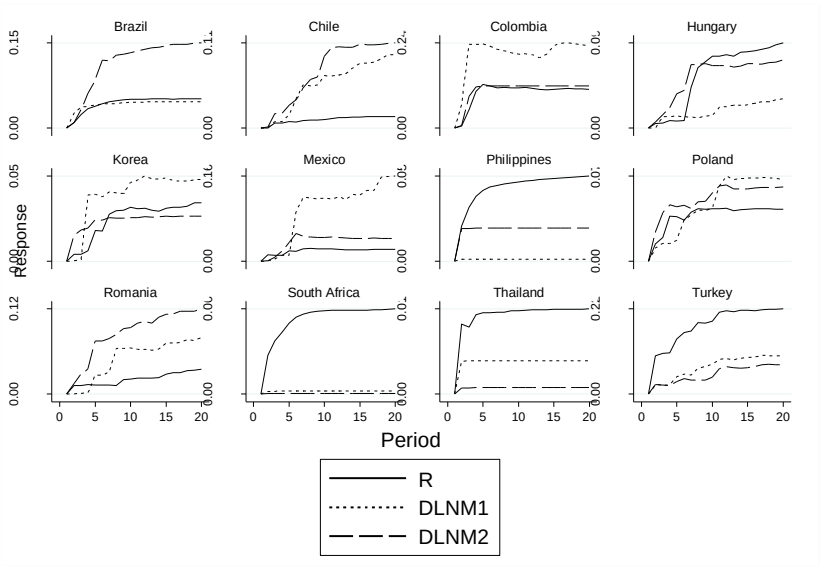
Turning to M1 and M2, Figure 2 and Figure 3 show that inflation positively reacts to shocks of M1 and M2 in most emerging economies. Such a positive effect shows a quick reduction and becomes neutral in the medium term. The finding is in line with the traditional conceptualization. However, it should be noted that the results are quite different for Romania and the Philippines, whereby M1 has a negative effect on inflation. For M2, the negative response of inflation is visible in the Philippines. Last but not least, the effect of monetary aggregates on inflation is statistically insignificant in most emerging economies. This finding suggests that changes in money supply can contain information about changes in monetary policy, but this role seems to be weak.

Country evidence: FEVD analysis

This section presents the contribution of monetary policy indicators to inflation variation (see Figure 4). It can be seen that the interest rate explains a greater part of the variation of inflation than the money supply does in few countries (Philippines, South Africa, Thailand, and Turkey). In many countries, M1 and M2 explain more about the variation of inflation than interest rate does. In Colombia, Hungary, Korea, and Poland, interest rates and M2 have similar explanatory power on inflation variation. Overall, the money supply has a stronger power in explaining inflation variation than the interest rate.

In summary, the country evidence about the response of inflation to both money supply and interest rate suggests some interpretations. One, misspecification causes difficulties in distinguishing the endogenous and exogenous components of monetary policy changes. However, the robustness tests below show that this is less likely to happen. Two, neither interest rate nor money supply can fully capture the stance of monetary policy. The empirical results, especially Granger causality and FEVD, are supportive of the speculation that monetary policy is not fully captured by using a single indicator.

Figure 4. FEVD contribution of monetary policy indicators to inflation



Source: Authors' construction

Panel evidence

We also examine the effectiveness of money supply and interest rate as a measure of monetary policy using the panel context. We perform the Dumitrescu and Hurlin (2012) test to determine whether both indicators Granger cause the movement of inflation. As observed, the panel VAR evidence is to some degree consistent with the country evidence (see Table 4). Monetary aggregates are useful to predict the inflation movement. However, the interest rate is not a useful predictor of inflation.

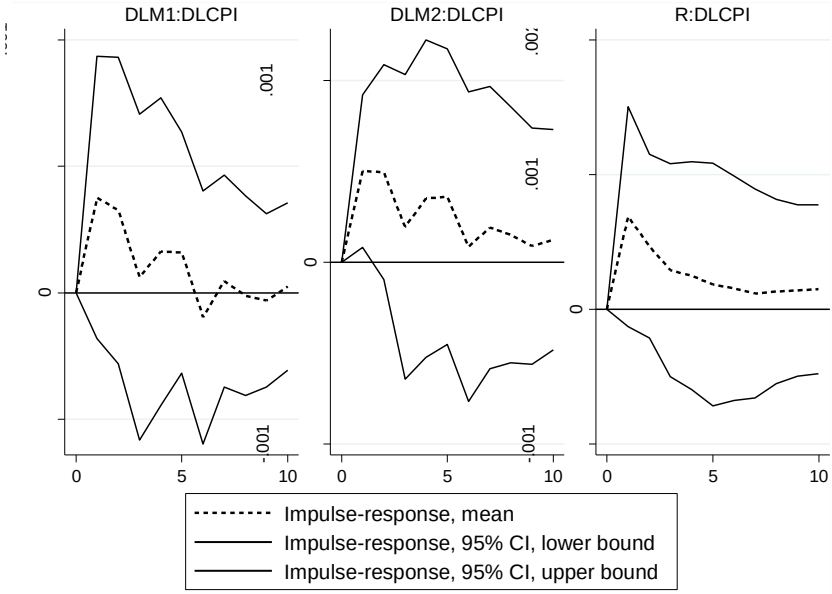
Table 4. The causal effect of monetary policy indicator on inflation

	$\bar{W}$	$\bar{Z}$	$\bar{Z}$ p-value
R	58.72	-0.38	0.70
DLM1	30.20	-2.92	0.00
DLM2	33.00	-2.67	0.01

Source: Authors' calculation

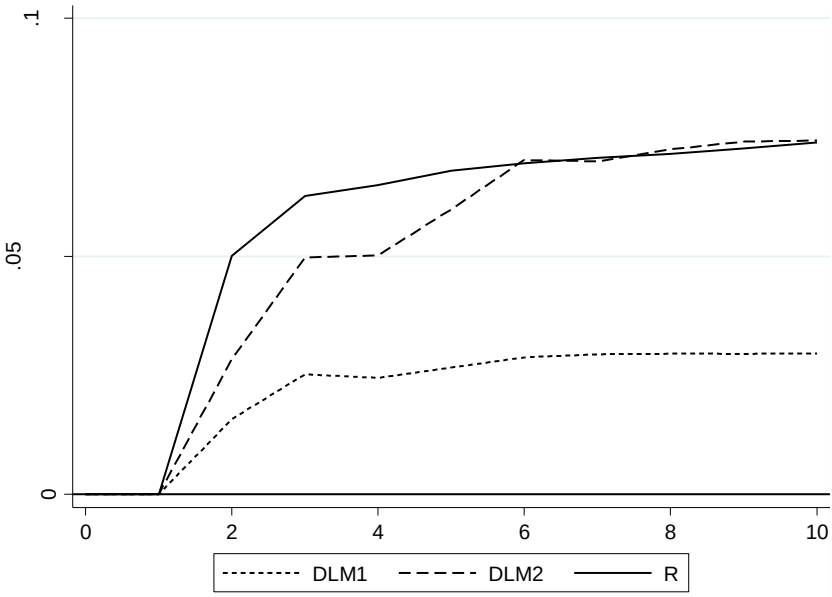
Figure 5 indicates the response of inflation to shocks of interest rate and money supply. Accordingly, the interest rate has a temporary and positive effect on inflation, which is in line with the country evidence. However, the effect of interest rate is statistically insignificant, which is consistent with the time-series results of most of emerging economies. With respect to the money supply, both M1 and M2 have a positive effect on inflation, which is in line with theory. However, it should be noted that the response of inflation to shocks of M2 is statistically significant in the short run. The finding implies finance development can make a significant contribution to the implementation of monetary policy in emerging economies.

Figure 5. Response of inflation to shocks of monetary policy indicators



Source: Authors' construction

Figure 6. FEVD of inflation to monetary policy indicators



Source: Authors' construction

Figure 6 indicates the contribution of monetary policy indicators to inflation variation. Among indicators, the interest rate contributes the most to the variance of inflation, which doubles in size when comparing with M1. On the other hand, the money supply explains a smaller percentage of inflation variance. Since the line of DLM2 stands above the line of DLM1 over the study period, M2 explains more about the variation of inflation than M1. This finding implies that finance development has a positive effect on the contribution of the money supply to inflation variation.

Overall, the panel evidence, to a certain degree, supports the country evidence. The results of impulse response and FEVD indicate that it is not possible to determine the superiority of interest rate.

Robustness test

Since the price puzzle happens because of the exclusion of important information for inflation forecasts (Bernanke and Mihov, 1998; Sims, 1992). Therefore, an important robustness test of equation (4) is to add variables that can influence inflation expectation, such as commodity or oil prices. Since emerging economies are small and open, they are considered price takers. Therefore, commodity or oil prices are considered as exogenous, and thus, they stay before other domestic variables in equation (4). To preserve the degree of freedom, we include these variables one at a time. The results (not shown) indicate that the inflation response is similar to those shown in previous sections. Particularly, the price puzzle is still present. Money supply has a positive effect on inflation, which is consistent with the theories. Hence, the analysis indicates that the price puzzle does not stem from the failure of the VAR model in capturing important information in forecasting inflation. In other words, the price puzzle may be conditional on other factors such as the low representative power of interest rate in measuring the stance of monetary policy.

Following Acosta-Ormaechea and Coble (2011), we use the differential between domestic inflation and US inflation to replace the original measure of inflation in the equation (4). Since domestic prices are influenced by the movement of prices in large economies such as the US, the use of inflation differential can help isolate domestic inflation from external inflation. Another reason for the selection of the US inflation is that the US dollar is considered as an anchor currency and the US has a significant impact on emerging economies. The results indicate that the effectiveness of this solution is quite limited. The price puzzle does not disappear. Moreover, the empirical evidence is not supportive of the superiority of either interest rate or money supply.

The recent Global financial crisis had a significant effect on the global economy. Therefore, it is of interest to investigate whether the crisis affects the response of inflation to various indicators of monetary policy. The results indicate that interest rate policies show small changes after the recent crisis. The price puzzle is still present. Turning to M1 and M2, there is minor changes after the crisis.

In the panel setting, the empirical results are robust to the inclusion of commodity prices, oil prices, or inflation differential. Moreover, changing the ordering of variables in the equation (4) does not alter the general conclusion of the analysis. This gives more evidence indicating that the price puzzle does not stem from the specification bias.

In summary, there is robust evidence supporting the argument that the price puzzle is not owning to misspecification. Since both interest rate and money supply have comparable power in explaining the movement of inflation in emerging economies, it is likely that the price puzzle stems from the low representation of interest rate in measuring the stance of monetary policy. Hence, a composite index may be better than any one of the two variables in measuring monetary policy. There are several ways to construct this composite index. One example is the monetary condition index which is the weighted average of changes in the exchange rate and interest rate relative to a benchmark level (Batini and Turnbull, 2002; Qayyum, 2002). Another example is to use the component derived from the Principal component analysis of various monetary policy instruments (Memon and Jabeen, 2018).

Conclusion

What should be the representative indicator of monetary policy: interest rate or money supply? While the literature is vast for advanced economies, it is quite limited for emerging economies. The objective of this paper is to investigate how money supply and interest rate act as a measure of monetary policy through the analysis of Granger causality, impulse response function, and forecast error variance decomposition. The empirical results indicate that both money supply and interest rate have a significant causal effect on inflation. Moreover, both have a comparable power in explaining inflation variation. However, in most emerging economies, the inflation response to the interest rate is weak and of unexpected sign whereas money supply has a positive and expected effect on inflation.

The existence of the price puzzle suggests some explanations and policy recommendations. One, the interest rate cannot fully capture the stance of monetary policy. This means that part of monetary policy intention is included in the change of other monetary policy instruments. It is highly likely to happen in emerging economies where monetary authorities use multiple instruments, which stems from the influence of other objectives than price stability and the incomplete knowledge about the structure of the economy. Since both money supply and interest rate contain information about changes in monetary policy, a composite indicator can be a better measure of monetary policy. Another suggestion is to explicitly consider the influence of money supply in the interest rate reaction function.

Two, interest rate policies may have a limited impact on inflation. To increase the effectiveness of interest rate policy, monetary authorities should put emphasis on the objective of price stability. This requires greater independence of the central bank, and thus more reforms should be implemented in the financial system. Future reforms should allow monetary authorities to have more power in determining objectives and instruments of monetary policy as well as specify penalties when not fulfilling inflation targets. Another suggestion is to improve the forecast of inflation. The reason is that underestimating inflation expectation reduces the response of interest rate to inflation, leading to the fact that a rise in interest rate is not high enough to reduce inflation. Therefore, the performance of the inflation forecast is crucial to improve interest rate policies. There are several tools to obtain a better forecast of inflation: (1) understanding the drivers of inflation and the structure of the Phillips curve and (2) using forward

guidance to improve the transparency of monetary policy (Mackiewicz-Łyziak, 2016). Finally, improvements in the financial system can contribute to the effective implementation of monetary policy. A greater volume of financial instruments and a higher level of financial development can improve the transmission effect of the interest rate channel.

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