The Impact of U.S. Interest Rate Changes
on Emerging Market Countries
under cost-push shocks and natural rate shocks

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Abstract
This paper analyzes the impact of U.S. interest rate changes under cost-push shocks and natural rate shocks as well as these shocks’ transmission to emerging market countries. The theoretical model of a small open economy finds that changed exchange rate (exchange rate channel) is negative - USD depreciation under cost-push shock, while positive - USD appreciation under natural rate shock. The differences under the two shocks are amplified through domestic bonds (financial market channel) and terms of trade (trade market channel). Then, the real output of the emerging economy with PPI-based Taylor rule is positive under both shocks and less volatile under cost-push shock, given the same magnitude of shocks. This paper also uses Bayesian local projections to test empirical sample that consists of five emerging and five developed countries. As the model predicts, the exchange rate channel has significant and different effects under both shocks. The empirical results reveal that cost-push shocks cause more substantial volatility than natural rate shocks for each country due to their characteristics - significant deviation and less persistence. Under natural rate shocks, consumptions tend to be more volatile than outputs in emerging economies, while the former is less volatile than the latter in developed economies. However, consumptions are roughly volatile as outputs under cost-push shocks in both emerging and developed economies.

1 Introduction
During the 2008 financial crisis, the U.S. Federal Reserve used both conventional and unconventional monetary policies to set the federal funds rate at the zero lower bound, ensure
market liquidity, and boost market confidence. Given the economic outlook, on December 16, 2015, the Federal Open Market Committee (FOMC) decided to raise the target range for the federal funds rate from a range of 0% to 0.25% to a range of 0.25% to 0.5%. The rate hike was a small one, while it would affect not only millions of Americans but also other economies. Since then, the FOMC has been gradually increasing its target range to fulfill the Federal Reserve’s goals of maximum employment, low inflation, stable economic growth, and moderate long-term interest rates. However, the frequent changes in the Fed’s monetary policy would have spillover effects on other economies.

In some previous episodes, the Fed raised rates to fight inflation, such as cost-push shocks. Due to the oil crisis in the 1970s, the inflation rate of the U.S. rose to a peak of 11% in early 1980. The Fed, after that, pursued tight monetary policy, rising interest rate, to lower inflation - Volcker disinflation. The Fed brought the inflation rate down to 4% by the end of 1983, but the disinflationary monetary policy also caused the U.S. 1981-1982 recession. The interest rate hike also increased debt cost (denominated in the U.S. currency), which made it harder for Latin Americans to pay back their debts. Because the petroleum-exporting countries earned much money and invested that money in international banks, during the oil price surge in 1973-1980, Latin American governments could easily borrow loans from international banks for their economic development. After the risky accumulation of foreign debts over a couple of years, the Latin American debt crisis happened in 1982. The spillover effect of U.S. interest rate hike under this cost-push shock impacted the Latin American economy, which triggered the purchasing power erosion by inflation, high unemployment rate, slumping imports and income, and stagnated economic growth\(^1\).

What’s more, the natural rate of interest also affects how the Fed steers interest rates, such as the natural rate shocks. The natural rate of interest, also called the neutral rate of interest or the long-run equilibrium interest rate, is the rate that would maintain the economy at full employment and stable inflation. The natural rate of interest is determined by structural features of the economy and is not observable. In addition, it may vary over time due to fluctuations in trends of productivity growth, changing demographics, and other structural shifts of the economy\(^2\). As a monetary policy guided by Taylor [1993] and Taylor [1999] - the Taylor Rule, the natural rate of interest could measure whether a change in the federal funds rate is low enough to stimulate or is high enough to dampen economic activi-

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\(^1\)Bernal and Cristina [1991] introduced economic history of Latin America.
\(^2\)The Fed’s Monetary Policy Report (July 2018) also emphasized academic studies have estimated the longer-run value of the natural rate of interest using statistical techniques to capture the variations among inflation, interest rates, real gross domestic product, unemployment, and other data series.
ties. For instance, the 2008 financial crisis shifted the structure of the U.S. economy. Facing the natural rate shocks, the Fed not only decreased the federal funds rate to the zero lower bound but also used unconventional policies that had put downward pressure on longer-term interest rates and helped make broader financial conditions more accommodative. Williams [2012] presented the Federal Reserve to use two types of unconventional monetary policies to stimulate the U.S. economy: forward policy guidance and large-scale asset purchases, after the 2008 financial crisis. Since households and investors make saving and investment decisions depend on what they expect interest rates would be in the future, the Fed’s views on the natural rate of interest have meaningful importance. The spillover effect of the lower U.S. interest rate under this natural rate shock impacted the world economy. Firstly, a depreciating dollar would enhance the competitiveness of U.S. goods at home and abroad. In other words, the non-U.S. exporters will suffer loss because their products will become more expensive. Secondly, an interest rate drop could also prompt a fresh flow of capital into high-yield but risky investments in the emerging markets and away from dollar-denominated bonds and instruments.

Figure 1: All rates are quarterly data at the annual level from 1964Q3-2017Q4; Shaded areas indicate U.S. recessions from NBER recession data; 3-month interbank rate is from the OECD database; the inflation rate is calculated by GDP deflator from the OECD database; the natural rate of interest is estimated by Laubach and Williams [2003].

Therefore, what is the impact of the U.S. interest rate changes under different shocks
(cost-push shocks and natural rate shocks), as shown in Figure 1, on emerging market countries’ real output and inflation? What are the critical transmission channels of the impact? How could the emerging market countries deal with the impact? This paper, focusing on these issues, provides theoretical and empirical results to understand emerging market countries in response to the impact of U.S. interest rate changes. Table 1 briefly presents the different effects on other economies through various transmission channels. If the Fed follows the Taylor Rule, cost-push shocks will cause the price level to increase, then the federal funds rate hikes against high inflation and real output drops by the restrictive monetary policy. High inflation is more likely to have a significant adverse effect, rather than an apparent positive effect, on a U.S. currency’s value and foreign exchange rate. For the financial market channel, the U.S. interest hikes would lead other economies to pay more for debts denominated in the U.S. currency and get less foreign capital inflow. Furthermore, if the expenditure-switching effect is more significant than the income absorption effect to the U.S., there would be more export for other economies. But if the exchange rate depreciation effect is more prominent than the price hike effect, the U.S. will reduce import that harms the benefits of other foreign exporters. Unlike cost-push shocks, natural rate shocks are determined by the structural shifts of the U.S. economy. If the Fed would not need to stimulate or slow the economy by monetary policy, the federal funds rate is the natural rate of interest. As Janet Yellen said, during an interview with The International Economy Magazine in 2005, monetary policy should be at neutral only when economic conditions are “just right”. So, if the interest rate hikes by a positive natural rate shock, the real output would decrease to the new real potential output without significant effects on the price level. For the trade market channel, if the value of the U.S. currency is raised due to an increase in interest rate, one can expect the terms of trade to be improved with an appreciated exchange rate. As a result, even though exporters in the U.S. are enjoying a high price, they may be challenging to sell their goods in the international trade market. That means other economies face a higher import price and a more considerable export amount. Generally, the impact of U.S. interest rate changes on emerging market countries’ real output and inflation is ambiguous because of the reaction of their central banks and governments, such as the inflation targeting policy or the pegged exchange rate regime. The above brief analysis is the motivation of this paper to study these issues.
Transmission | Cost-push shocks ↑ | Natural rate shocks ↑  
---|---|---  
U.S. condition | $i^{us} \uparrow$, $Y^{us} \downarrow$, $P^{us} \uparrow$ | $i^{us} \uparrow$, $Y^{us} \downarrow$  
The exchange rate channel | $S^{o/us} \downarrow$ | $S^{o/us} \uparrow$  
The financial market channel | $B^{o}_{us} \downarrow$ | $B^{o}_{us} \downarrow$  
The trade market channel | $P^{m}_{o} \uparrow$, $X^{o} \uparrow$ | $P^{m}_{o} \uparrow$, $X^{o} \uparrow$  
or $P^{m}_{o} \downarrow$, $X^{o} \downarrow$  

Table 1: How would U.S. interest rate hikes by different shocks affect other economies

2 Literature Review

Previous papers and researches focus on empirical and quantitative work for the impact of U.S. (or Euro area) monetary policy shocks on other countries. For developed countries, Kim [2001] revealed empirical evidence on the international transmission of U.S. monetary policy shocks for the G-6 countries (excluding the U.S.) with a flexible exchange rate regime using VAR models and found the world real interest rate is a crucial transmission instead of trade balance. Holman and Neumann [2002] emphasized the importance of the transmission of monetary shocks between the U.S. and Canada using time-series techniques and examined the impact of a monetary shock in one country on real activity in both countries, such as consumption, investment, employment, and the bilateral trade balance. Jannsen and Klein [2011] analyzed the international transmission effects of Euro area monetary policy shocks into other western European countries, using a structural VAR model and concluded a broadly similar change in the interest rate and GDP in these other western European countries, unlike insignificant effects on their exchange rates and trade balances. Their results suggested that the income absorption effect of being more critical than the expenditure switching effect in the international transmission of monetary policy and that exchange rate stabilization seems to be of some concern to monetary policymakers in small open economies. Rey [2016] presented evidence that U.S. monetary policy shocks are transmitted internationally and affect financial conditions even in inflation targeting economies with large financial markets, which means flexible exchange rates are not enough to guarantee monetary autonomy in a world of large capital flows.

For emerging economies, Mackowiak [2007] found that U.S. monetary policy shocks affect quickly and sharply interest rates and the exchange rate in a typical emerging market. The price level and real output in a typical emerging market respond to U.S. monetary policy shocks by more than the price level and real output in the U.S. itself. Employing the structural VAR, Xiao and Zhao [2012] showed that the effect of transmission of short-term
international capital flows is stronger than the balance of trade and the world commodity prices index. Also, the exchange rate of RMB has the weakest transmission effect. Ramos-Francia and García-Verdú [2014] tested whether an EME has undergone a structural change in the policy rate, exchange rate, or long-term rate channels, facing U.S. monetary policy shocks. Although the evidence was not uniform across the various tests, they concluded an increase in the sensitivity of EMES to U.S. monetary policy shocks could lead to higher dependence on U.S. economic developments and accordingly to a higher impact of U.S. policy on EMES’ policy cycles. Edwards [2015] analyzed whether local central banks’ policy rates of three Latin American countries with flexible exchange rates, inflation targeting, and capital mobility - Chile, Colombia, and Mexico - are impacted by Federal Reserve actions, and found that these countries tend to “import” Fed policies.

In short, the U.S. monetary policy shocks could cause significant “policy contagion” to developed countries and emerging market economies. Miniane and Rogers [2003] tested the effect of U.S. monetary shocks on the exchange rate and foreign country (developed and developing) interest rates, and found countries with less open capital accounts do not exhibit systematically smaller responses. However, the exchange rate regime or degree of dollarization explains more of the cross-country differences in responses. Feldkircher and Huber [2016] illustrated international spillovers of expansionary U.S. aggregate demand and supply shocks, and a contractionary U.S. monetary policy shock to international output through the financial channel (i.e., interest rates) and the trade channel (i.e., the real effective exchange rate), using Bayesian global vector autoregressions. Also, they argued that the shocks emanating from abroad are less critical in advanced economies compared to domestic shocks. By contrast, external shocks play a vital role for economies in Latin America, Asia, and emerging Europe.

This paper uses a New Keynesian Small Open Economy Model and employs a Bayesian Local Projection (BLP) estimation to analyze the “policy contagion” by the U.S. Federal Reserve actions. First of all, this paper decomposes U.S. monetary policy rate changes from different sources: cost-push shocks and natural rate shocks, as mentioned in the introduction. Sometimes, the Fed rate rises by cost-push shocks: uncontrollably rising wages, the OPEC oil-price increases, and droughts or poor harvests. Alternatively, the Fed changes the monetary policy rate according to natural rate shocks. Bullard [2018] explained that it is vital for policymakers to know the natural rate of interest to determine whether the current policy rate setting is accommodative, neutral, or restrictive. He noted that the Fed could influence the real rate of interest but not the trend in the real rate of interest, which
is viewed as driven by fundamental factors.

Furthermore, this paper involves three main transmission channels: the exchange rate, the international trade market, and the international financial market. As the above literature reviews, although each paper explored the impact of U.S. monetary policy shocks on other countries with different data sets and VAR methods to get mixed results, the effects significantly exist through transmission channels, which are the crucial part to link U.S. economy to other economies. Some theoretical papers use different models to explain these transmission effects. The primary and traditional Mundell-Fleming-Dornbusch (MFD) model focuses on international trade channels, as Dornbusch [1980], Obstfeld and Stockman [1985], and Obstfeld and Rogoff [1996]. The MFD model predicts that a positive U.S. monetary shock leads to other countries’ terms of trade deterioration or exchange rate depreciation, which causes an improvement in other countries’ trade balance and output (the expenditure-switching effect). However, a decrease in U.S. income following a federal funds rate hike reduces its import demand, which may worsen other countries’ trade balance and output (the income-absorption effect). Despite that, Kim [2001] and Canova [2005] found strong evidence for the international financial channel and less for the international trade channel. Since the U.S. plays a pivotal role in global financial markets, an increase in the federal funds rate is likely to trigger movements in other countries’ interest rates (international financial channel). Neumeyer and Perri [2005] decomposed the interest rate to an international rate and a country risk component with a neo-classical small open economy model. They found that in a sample of emerging economies, business cycles are more volatile than in developed ones, real interest rates are countercyclical and lead the cycle, consumption is more volatile than output, and net exports are strongly countercyclical. Their model generated business cycles consistent with Argentine data. Also, the intertemporal model (equipped with sticky price or/and sticky wage) emphasizes the forward-looking intertemporal decisions of economic agents, as Cardia [1991], Kollman [1997], Kollman [1999], Betts and Devereux [2000], and Betts and Devereux [2001]. A positive U.S. monetary policy shock triggers a temporary decrease in the world aggregate demand for current goods, so that the trade balance and output of other countries may worsen, also due to their consumption smoothing. However, the intertemporal model also comprises the expenditure-switching effect, so that the trade balance and output of other countries may improve. In brief, all three main transmission channels are essential to analyze the “policy contagion”.

Last but not least, this paper considers that other countries’ exchange rate regimes and international reserves may explain more of the cross-country differences in responses to the
U.S. monetary policy changes. Miniane and Rogers [2003], Broda [2004], Shambaugh [2004], and Jannsen and Klein [2011] showed the exchange rate regime is significant in determining how the exchange rate and the interest rate respond to U.S. monetary policy shocks. Broda [2004] found the flexible exchange rate regimes could insulate the economy (the fluctuation of output, exchange rate, and price) more effectively against terms of trade disturbances than pegged regimes. Shambaugh [2004] observed significant differences between pegged regimes and flexible regimes in the way domestic interest rates respond to changes in foreign interest rates. Additionally, Arifovic and Masson [2004], Arifovic and Maschek [2012], and Kato et al. [2018] argued that international investors consider a shortage of the domestic economy’s foreign currency reserves as a signal of increasing country risk. Policymakers in emerging economies have adopted accumulating international reserves strategy as an insurance policy against a sudden stop when there is no credible lender of last resort in the international monetary system. Concisely, the choice of exchange rate regime and precautionary saving (international reserves) is other countries’ reaction in case of external shocks through international markets. The remainder of this paper is structured as follows: Section 3 describes the model setup and theoretical results; Section 4 is Bayesian Local Projection estimation and empirical results; The conclusions and policy recommendations are in Section 5.

3 New Keynesian Small Open Economy Model

3.1 Model Setup

This section describes the baseline model. The model is mostly based on a New Keynesian model of a small open economy that includes one representative household, one final goods firm, intermediate goods firms, foreign part, government, and central bank. The change of the U.S. interest rate goes through three channels - the exchange rate, the international trade market, and the international financial market to influence emerging market economies. Due to secure evidence for the international financial channel, as mentioned in the literature review, this paper adds working capital to the model. It means firms’ inputs must be financed by short term loans, so changes in the interest rate affect the economy by changing firms’ variable production costs and domestic price level to influence economy, as Fuerst [1992], Christiano et al. [2005] and Adolfson et al. [2007]. Final good firms use intermediate goods to produce homogeneous domestic goods, so this assumption makes working capital costs significant, as Basu [1995]. Because of the uncovered interest parity puzzle, this paper involves a risk premium for UIP to provide a connection between the U.S. interest rate and
domestic interest rate. In the view of Arifovic and Masson [2004], Arifovic and Maschek [2012], and Kato et al. [2018], the risk premium depends on international reserves which provide confidence motive to foreign investors. This paper provides sterilization bonds to collect international reserves for the central bank. Alla et al. [2017] said sterilized intervention consists of the central bank purchasing or selling foreign currency-denominated assets (international reserves) with corresponding sales or purchases of domestic currency assets in order to leave the money supply unchanged. If foreign exchange intervention is not sterilized, then it does not constitute a separate instrument from monetary policy. Under foreign exchange sterilized intervention, the domestic central bank could simultaneously adopt other monetary policies\(^3\) in response to U.S. interest rate changes. The shocks cause U.S. interest rate changes: cost-push shocks from the U.S. Phillips curve and natural rate shocks from the U.S. Taylor rule.

1. Household

Domestic household consumes domestic goods \(C^d_t\) and imported goods \(C^m_t\), provides labor \(N_t\) to intermediate goods firms, and involves wage payment \(W_t\), lump-sum tax \(T_t\), and profit \(\Pi_t\). Households can borrow and lend using domestic bonds \(D_t\). The \(B^s_t\) are sterilization bonds sold by the central bank. However, we assume that domestic households can only use domestic bonds, contrary to foreign investors who can buy either domestic or foreign bonds. Here, \(\chi\) specifies that the preference weight of labor in utility, and the Frisch elasticity for labor supply is \(\frac{1}{\psi}\).

\[
\max E_0 \sum_{t=0}^{\infty} \beta^t (\log C_t - \frac{\chi N^\psi_t}{1 + \psi})
\]

\[
s.t. P_tC_t + D_t + B^s_t \leq i_{t-1}(D_{t-1} + B^s_{t-1}) + W_tN_t - T_t + \Pi_t
\]

The consumption - composite goods \(C_t\) follows the constant elasticity of substitution (CES) form, where \(\eta\) is the elasticity of substitution of consumption between imported and domestic

\(^3\)Galí and Monacelli [2005] evaluated the welfare losses under the central bank choosing different monetary policy rules (domestic inflation and CPI-based Taylor rules, and an exchange rate peg). They concluded a Taylor rule generally leads to excess volatility of nominal variables, and excess smoothness of real variables, but a pure exchange rate peg seems to have better stabilization properties than a Taylor rule. Also, Clarida et al. [1999] and Christiano et al. [2011] introduced some DSGE models for monetary policy analysis.
goods, and \( \omega \) is the weight household places on imported consumption.

\[
\begin{align*}
\min P_t^d C_t^d + P_t^m C_t^m \\
\text{s.t. } C_t &= \left[ (1 - \omega) \frac{1}{\eta} \left( C_t^d \right)^{\frac{\eta-1}{\eta}} + \omega \frac{1}{\eta} \left( C_t^m \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}
\end{align*}
\]

\( P_t \) is the consumer price; \( P_t^m \) is the imported goods price; \( P_t^d \) is the domestic goods price, where \( p_t \equiv \frac{P_t}{P_t^d} \), \( \tilde{p}_t^m \equiv \frac{P_t^m}{P_t^d} \).

\[
p_t = \left[ (1 - \omega) + \omega (p_t^m)^{1-\eta} \right]^{\frac{1}{1-\eta}}
\]

2. Firms

The final goods firm uses intermediate goods with working capital costs to produce homogeneous domestic goods for domestic households and foreign countries. Final goods firm maximizes profits:

\[
\begin{align*}
\max P_t^d Y_t - \int_0^1 P_{j,t}^d Y_{j,t} dj \\
\text{s.t. } Y_t &= \left[ \int_0^1 Y_{j,t}^{\frac{1}{1-\epsilon}} \frac{1}{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}}
\end{align*}
\]

where \( Y_t \) is the final goods firm’s output, and \( Y_{j,t} \) is each intermediate goods firm’s output as materials inputs of final goods firm with each intermediate goods price \( P_{j,t}^d \).

Materials inputs:

\[
Y_{j,t} = Y_t \left( \frac{P_t^d}{P_{j,t}^d} \right)^\epsilon
\]

\[
P_t^d = \left[ \int_0^1 (P_{j,t}^d)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}}
\]

Intermediate goods firms use labor with working capital costs to produce intermediate goods, facing Calvo price setting frictions. Intermediate goods producers with productivity \( Z \):

\[
Y_{j,t} = Z N_{j,t}
\]

Real marginal cost of production \( mc_t \), where \( \delta \) is a fraction of input costs that must be
financed in advance:

\[
\min \frac{(1 - \delta + \delta i_t)W_t}{P^d_t} N_{j,t} + mc_t(Y_{j,t} - ZN_{j,t})
\]

Therefore,

\[
mc_t = \frac{(1 - \delta + \delta i_t)W_t}{Z P^d_t}
\]

Calvo price setting frictions

- Intermediate goods firms with probability \( \theta \) cannot change price: \( P^d_{j,t} = P^d_{j,t-1} \);
- Intermediate goods firms with probability \( 1 - \theta \) set price optimally: \( P^d_{j,t} = \tilde{P}^d_t \);

where stochastic discount factor \( \Delta_{i,t+i} = \beta^i \frac{C_t}{C_{t+i}} \).

\[
\max E_t \sum_{i=0}^{\infty} \theta^i \Delta_{i,t+i} \left[ \frac{P^d_{j,t} Y_{j,t+i} - mc_{t+i} Y_{j,t+i}}{P^d_{t+i}} \right]
\]

Therefore,

\[
\tilde{P}^d_t = \frac{\tilde{P}^d_t}{P^d_t} = \frac{K_t}{F_t}
\]

\[
K_t = \frac{\epsilon}{\epsilon - 1} \frac{Y_t}{C_t} mc_t + \beta \theta E_t (\pi^d_{t+1})^\epsilon K_{t+1}
\]

\[
F_t = \frac{Y_t}{C_t} + \beta \theta E_t (\pi^d_{t+1})^{\epsilon-1} F_{t+1}
\]

Aggregate price (domestic price):

\[
P^d_t = [(1 - \theta)(\tilde{P}^d_t)^{1-\epsilon} + \theta (P^d_{t-1})^{1-\epsilon}]^{\frac{1}{1-\epsilon}}
\]

\[
\tilde{P}^d_t = \left[ \frac{1 - \theta (\pi^d_t)^{\epsilon-1}}{1 - \theta} \right]^{\frac{1}{\epsilon}}
\]
Aggregate output (final output):

\[ Y_t^* \equiv \int_0^1 Y_{j,t} \, dj = \int_0^1 Z_{N_j,t} \, dj = ZN_t \]

\[ Y_t^* = \int_0^1 Y_t \left( \frac{P_t}{P^d_j} \right) \epsilon \, dj = Y_t (P_t^d)^\epsilon (P_t^d)^{-\epsilon} \]

\[ P_t^{ds} \equiv \left[ \int_0^1 \left( P^d_j \right)^{-\epsilon} \, dj \right]^{-\frac{1}{\epsilon}} = \left[ (1 - \theta) (P^d_t)^{-\epsilon} + \theta (P_{t-1}^{ds})^{-\epsilon} \right]^{-\frac{1}{\epsilon}} \]

\[ p_t^{ds} \equiv \left( \frac{P_t^{ds}}{P^d_t} \right)^\epsilon = \left[ (1 - \theta) \left( \frac{1 - \theta (\pi_t^d)^{-1}}{1 - \theta} \right)^{-\frac{1}{\epsilon}} + \theta \left( \frac{\pi_t^d}{p_{t-1}^{ds}} \right)^{-\frac{1}{\epsilon}} \right]^{-\frac{1}{\epsilon}} \]

\[ Y_t = p_t^{ds} Y_t^* = p_t^{ds} ZN_t \]

where \((p_t^{ds})^{-1} \geq 1\), price dispersion means more has to be produced to achieve a given level of \(Y_t\).

3. Foreign part

The foreign part sets imported goods price with working capital cost and needs exports from the final goods firm. Foreign investors hold domestic bonds from government and foreign bonds (UIP with risk premium). Assume \(C_t^m\) is produced by the foreign competitive firm, which sets price equal to marginal cost, where \(\delta^f\) is a fraction of input costs that must be financed in advance, and \(P_t^f\) is the foreign currency price of foreign goods.

\[ P_t^m = S_t P_t^f (1 - \delta^f + \delta^f i_t^f) \]

\[ p_t^m = p_t q_t (1 - \delta^f + \delta^f i_t^f) \]

\[ \frac{q_t}{q_{t-1}} = s_t \frac{\pi_t^f}{\pi_t} \]

where real exchange rate \(q_t \equiv \frac{p_t^f}{P_t^x}\), and changed nominal exchange rate \(s_t \equiv \frac{S_t}{S_{t-1}}\).

Foreign demand for exports, where \(Y_t^f\) is the foreign output, \(\frac{P_t^x}{P_t^f} \equiv p_t^x\):

\[ X_t = \left( \frac{P_t^x}{P_t^f} \right)^{-\eta_f} Y_t^f = (p_t^x)^{-\eta_f} Y_t^f \]

\(X_t\) is produced by the final goods firm, where \(\delta^x\) is a fraction of intermediate goods costs...
that must be financed in advance.

\[ S_t P_t^x = P_t^d (1 - \delta^x + \delta^x i_t) \]

\[ q_t p_t^x = 1 - \delta^x + \delta^x i_t \]

Foreign investors are sophisticated agents. The rate of return on domestic bonds, taking into account the risk premium \( \phi_t \), should be equal to the rate of return in foreign bonds.

\[ \frac{\dot{i}_t}{\phi_t} = \frac{S_{t+1}^{f^f}}{S_t^{i_t}} \]

Assume the foreign country puts a negligible weight on the goods imported from (exported to) the small economy and market clearing condition \( Y_t^f = C_t^f \), which would be as a standard closed economy model.

New Keynesian Phillips curve with cost-push shock:

\[ \hat{\pi}_t^f = \beta^f E_t \hat{\pi}_{t+1}^f + \kappa^f (1 + \psi^f) \hat{y}_t^f + \hat{u}_t^f \]

where \( \kappa^f \equiv \frac{(1-\theta^f)(1-\beta^f \theta^f)}{\beta^f} \), \( \hat{y}_t^f \equiv \dot{Y}_t^f - \dot{Y}_t^f \) is the foreign output gap and \( \hat{u}_t^f \) is the cost-push shock.

Cost-push shock:
It is a shock that changes the output-inflation trade-off and drives a wedge between marginal cost and the output gap. Assume that it follows an AR(1).

\[ \hat{u}_t^f = \rho^f \hat{u}_{i-1}^f + \epsilon_{u,t}^f \]

New Keynesian IS curve with natural rate of interest:

\[ \hat{y}_t^f = E_t \hat{y}_{t+1}^f - (\hat{i}_t^f - E_t \hat{\pi}_{t+1}^f - \hat{r}_{i-t}^f) \]

where \( \dot{Y}_t^f = E_t \dot{Y}_{t+1}^f - (\dot{\pi}_t^f - E_t \dot{\pi}_{t+1}) \equiv E_t \dot{Y}_{t+1}^f - \dot{r}_t^f \) and \( \dot{r}_{i-t}^f \) is the natural rate of interest that would be obtained if prices are fully flexible, so \( \beta^f = \frac{1}{\rho^f} \).

Natural rate shock:
The flexible price level of output evolves exogenously in line with the level of technology \( \dot{Y}_t^f = \dot{Z}_t^f \). If the technology obeys an AR(1), then the flexible price equilibrium level of output as following the same AR(1) \( \dot{Y}_t^f = \rho_z \dot{Y}_{t-1}^f + \epsilon_{z,t}^f \).

\[ \dot{\pi}_{i-t}^f = \rho_z \dot{\pi}_{i-t}^f + (\rho_z - 1) \epsilon_{z,t}^f \]
Policy with modified Taylor rule:

\[ \hat{i}_t^f = \hat{r}_t^f + \rho_\pi \hat{\pi}_t^f + \rho_y \hat{y}_t^f \]

4. Government

Government sells bonds to domestic investors \( D_t \) and foreign investors \( D_t^f \), where \( G_t \) is government spending.

\[ \frac{i_t-1}{\phi_{t-1}} D_{t-1}^f + i_{t-1} D_{t-1} + P_t^d G_t = D_t^f + D_t + T_t \]

Foreign demand for domestic bonds \( D_t^{f*} \equiv \frac{D_t^f}{P_t} \):

\[ D_t^{f*} = \mu \left( \frac{i_t}{E_t \pi_{t+1}^f} \frac{1}{i_t^f} \frac{1}{\phi_t} \right) = \mu \left( \frac{E_t q_{t+1}}{q_t} \right) \]

Risk premium:

\[ \phi_t = \zeta \left( \frac{R_t^*}{R_{t-1}^*} \right)^\gamma \]

where \( R_t^* \equiv \frac{R_t}{P_t^f} \) is real international reserves, and \( \tau \) implies the risk premium \( \phi_t \) is responsive to changes in \( \frac{R_t^*}{R_{t-1}^*} \)

5. Central bank

Central bank chooses the interest rate and performs sterilized foreign exchange intervention, offsetting any increase in reserves by issuing sterilization bonds \( B_t^* \).

Balance sheet:

\[ S_t R_t - S_t i_{t-1}^f R_{t-1} = B_t^* - i_{t-1} B_{t-1}^* \]

Policy with Taylor rule \( (\rho_t = 0) \):

\[ \log\left( \frac{i_t}{i_t^f} \right) = \rho_t \log\left( \frac{i_{t-1}}{i_{t-1}^f} \right) + (1 - \rho_t) \left[ \rho_\pi \log\left( \frac{\pi_t}{\pi} \right) + \rho_y \log\left( \frac{Y_t}{Y} \right) \right] \]
6. Equilibrium

Balance of payment:
Cash outflow - Domestic country would buy foreign assets \( S_t R_t \), import goods \( P_t^m C_t^m = P_t^m \omega(\frac{p_t}{p_t^m})^\eta C_t \) and pay \( \frac{i_{t-1}}{\phi_{t-1}} D_{t-1}^f \) to foreign investors who hold domestic bonds.
Cash inflow - Domestic country would sell export goods \( S_t P_t^x X_t \), receive existing foreign assets return \( S_t i_{t-1}^f R_{t-1} \) and sell domestic bonds \( D_t^f \) to foreign investors.

\[
S_t R_t + P_t^m C_t^m + \frac{i_{t-1}}{\phi_{t-1}} D_{t-1}^f = S_t P_t^x X_t + S_t i_{t-1}^f R_{t-1} + D_t^f
\]

\[
q_t p_t R_t^* + p_t^m \omega(\frac{p_t}{p_t^m})^\eta C_t + \frac{i_{t-1}}{\phi_{t-1} \pi_t} p_t D_{t-1}^f
\]

\[
= q_t p_t^x X_t + \frac{i_{t-1}}{\pi_t} q_t p_t R_{t-1}^* + p_t D_{t-1}^f
\]

Final goods market clearing:

\[
S_t R_t - S_t i_{t-1}^f R_{t-1} = B_t^s - i_{t-1} B_{t-1}^s
\]

\[
\frac{i_{t-1}}{\phi_{t-1}} D_{t-1}^f + i_{t-1} D_{t-1} + P_t^d G_t = D_t^f + D_t + T_t
\]

\[
P_t C_t + D_t + B_t^s \leq i_{t-1} (D_{t-1} + B_{t-1}^s) + W_t N_t - T_t + \Pi_t
\]

Then,

\[
P_t C_t + S_t R_t - S_t i_{t-1}^f R_{t-1} + \frac{i_{t-1}}{\phi_{t-1}} D_{t-1}^f + P_t^d G_t = D_t^f + W_t N_t + \Pi_t
\]

Therefore,

\[
Y_t = C_t^d + X_t + G_t = (1 - \omega)p_t^\eta C_t + X_t + G_t
\]

\[
p_t^d Z N_t = (1 - \omega)p_t^\eta C_t + X_t + G_t
\]
### Table 2: Calibration for the baseline model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
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<td>Weight of imported consumption in the gross consumption</td>
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<tr>
<td>Fraction of intermediate goods costs that must be financed in advance</td>
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<td>Preference weight of labor in utility</td>
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<td>Frisch elasticity for labor supply</td>
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<td>Probability cannot change price</td>
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<td>Elasticity of demand for domestic intermediate goods</td>
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<td>Fraction of government spending</td>
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<td>Fraction of reserves over import</td>
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<tr>
<td>Monetary policy rule weight on inflation rate</td>
<td>( \rho_\pi )</td>
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<td>Monetary policy rule weight on output</td>
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<td>Responsiveness of foreign investors</td>
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<td>Risk premium</td>
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<td>Productivity</td>
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<tr>
<td>Discount factor</td>
<td>( \beta )</td>
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<tr>
<td>Target inflation</td>
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<td>Nominal interest rate</td>
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<td>(1.02)(1.02)(^{1/4} )</td>
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<tr>
<td>Steady state output</td>
<td>( Y )</td>
<td>0.3485</td>
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<td>Steady state reserves</td>
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<td>Steady state reserves in domestic currency</td>
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<td>Fraction of input costs that must be financed in advance (foreign)</td>
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<td>Elasticity of demand for exports as function of relative price (foreign)</td>
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<td>Foreign output gap</td>
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<td>Foreign natural rate of interest</td>
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<td>Foreign nominal interest rate</td>
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<td>Autocorrelation coefficient of foreign cost-push shocks</td>
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<td>Autocorrelation coefficient of foreign natural rate shocks</td>
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<tr>
<td>Standard deviation of foreign natural rate shocks</td>
<td>( \sigma^f_\tau )</td>
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</table>

#### 3.2 Calibration

The parameters in the baseline model are calibrated to mimic the economy of developing countries or taken from other studies. The data set includes Argentina, Brazil, Korea, Mexico, and South Africa, as observed in 1978Q1-2017Q4. For the elasticity of substitution between imported and domestic consumption, Ostry and Reinhart [1992] estimated \( \eta \) for a panel of 13 developing countries. Arellano et al. [2009] estimated the weight of imported
consumption in the gross consumption $\omega$ for a small open economy. This paper assumes all working capital costs - the fractions of domestic input costs, intermediate goods costs, and foreign input cost that must be financed in advance - are 10%. The preference weight of labor in utility, sticky price probability of Calvo price setting frictions (domestic and foreign), target inflation (domestic and foreign), foreign Frisch elasticity for labor supply, foreign productivity (normalized to 1), foreign output gap, foreign natural rate of interest (quarterly), foreign nominal interest rate (quarterly) and elasticity of demand for domestic intermediate goods (foreign) are taken from standard model parameters. For the Frisch elasticity for labor supply, Boz et al. [2012] estimated it for emerging markets. Christiano et al. [2005] provided value to the elasticity of demand for domestic intermediate goods and elasticity of demand for exports as a function of relative price (foreign). The fraction of government spending is calculated by the average of real government spending over real GDP. The fraction of reserves over import follows the rule of thumb - reserves cover three-month import ($1/4$ of quarterly import)$^4$. Monetary policy rule weight on the historical interest rate, inflation rate, and output are taken from Taylor [1993]. Following the related equations in the baseline model, the responsiveness of foreign investors $\tau$, risk premium $\zeta$, and productivity $Z$ are estimated by panel data under a fixed effect. Discount factor, nominal interest rate, and steady state value (output, reserves, reserves in domestic currency) depend on steady state equations to be calculated. For detrended variables (data: energy commodity prices index and natural rate of interest from 1961Q1 to 2017Q4), this paper adopts the method from Hamilton [2017] instead of the Hodrick-Prescott filter. This paper uses the energy commodity prices index in the World Bank dataset$^5$ to calculate the related inflation. Then, the detrended energy inflation shows the autocorrelation and standard deviation of U.S. cost-push shocks ($\rho_k^{\pi} = 0.16$, $\sigma_f^{\pi} = 0.673$). Also, this paper detrends the natural rate of interest estimated by Laubach and Williams [2003] to find the autocorrelation and standard deviation of U.S. natural rate shocks ($\rho_f^{r} = 0.83$, $\sigma_f^{r} = 0.003$). However, this paper assumes that both shocks’ standard deviations are 1%. Table 2 summarizes all the parameters used in the calibration.

3.3 Impulse Response Functions

The impulse responses for the different variables to a one percent innovation in U.S. cost-push or natural rate shock are displayed in Figure 2 to Figure 10 with different monetary

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$^4$The developed countries’ data set (Australia, Canada, Netherlands, New Zealand, and Sweden) shows the average fraction of reserves over import 0.22. However, the average fraction is 0.47 for developing countries. This paper treats the $1/4$ of quarterly imports as a minimum requirement.

$^5$The energy commodity prices index includes coal (Australia, Colombia, South Africa), crude oil (U.K., Dubai or Saudi Arabian, U.S.), and natural gas (Europe, U.S., Japan).
policy rules. The U.S. interest rates (US FFR) increase by around 1% under two shocks, but natural rate shock causes a more persistent effect than the other. Under the CPI-based Taylor rule in Figure 2 to Figure 4, outputs and working hours (hours) under two shocks decrease on impact and then are followed by a hump-shaped pattern, but output and working hours under cost-push shock are more muted and less persistent. CPI inflation increases under natural rate shock and then start immediately to revert to steady state, unlike that under cost-push shock. However, PPI inflation rates under two shocks increase firstly and are followed by a hump-shaped pattern, because domestic sticky prices need time to adjust external shocks. Why do they have different patterns and effects? The exchange rate channel shows that the changed exchange rate is negative under cost-push shock (positive under natural rate shock), which is consistent with the initial analysis of this paper. High inflation by cost-push shock is more likely to have a significant adverse effect on a U.S. currency’s value and foreign exchange rate. The uncovered interest parity implies the transmission between the U.S. interest rate and the domestic interest rate. There are nominal interest rate hikes under two shocks. According to a negative change in the exchange rate, the impact on the nominal interest rate under cost-push shock is weak. For financial market channel, because the U.S. interest hikes would lead to other economies pay more for debt denominated in the U.S. currency and get less foreign capital inflow, domestic bonds by foreigners decreases under two shocks. The less effect on domestic bonds under cost-push shock is due to negative changed exchange rates (U.S. currency’s value depreciates). A similar intuition is for international reserves. Pina [2017] found global interest rate hikes increase reserve transfers, defined as the change in international reserves net of the interest earned on reserves, if the central bank manages international reserves to smooth inflation over time, as this paper’s positive hump-shaped patterns in international reserves. The slight fall in initial international reserves under cost-push shock also because of U.S. dollar depreciation. The risk premium is negative correlation with international reserves. For the trade market channel, the terms of trade get worse under natural rate shock than those under cost-push shock because of an appreciated U.S. currency. Therefore, import amounts decrease under two shocks with high import price and low income. However, export amounts increase under two shocks, because the expenditure-switching effect is larger than the income absorption effect for U.S. households. For the rest variables, facing the higher price and lower income

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6In figures, the title name with * means variables are the U.S. deflator adjusted real terms, instead of domestic deflator, such as $R^*_t$ and $\frac{D^*_t}{q_t}$.

7An improvement of domestic terms of trade benefits this country, which means it can buy more imports for any given level of exports. The nominal exchange rate could affect the terms of trade because an appreciation in the country’s currency lowers its import prices but may not directly influence the export prices.
or contractionary monetary policy (higher domestic interest rate), consumption decreases under two shocks. The government spending has similar patterns as outputs because of the passive assumption - fixed ratio between government spending and output for this model. In shorts, the different patterns and effects under two shocks are significantly amplified through the exchange rate channel.

Figure 2: Cost-push shock v.s. Natural rate shock with CPI-based Taylor rule
In Figure 5 to Figure 7, the central bank chooses the pegged exchange rate regime, so two shocks do not affect the nominal exchange rate. However, the differences under two shocks go through the real exchange rate channel. For the financial market channel, facing two shocks, the central bank should use international reserves to keep the pegged exchange
rate regime. This is the reason why international reserves decrease immediately under two shocks. The risk premium is negative correlation with international reserves. On the one hand, the increasing risk premium would cause a decrease in domestic bonds by foreigners. On the other hand, given uncovered interest parity with risk premium, U.S. interest rate hikes trigger that domestic nominal interest rate increases. For the trade market channel, import price (increase more) and export price rise under cost-push shock, but export price falls under natural rate shock. Hence, terms of trade get worse under natural rate shock than those under cost-push shock, although the nominal exchange rate does not change. Then, import amounts decrease under two shocks with low income. Because of lower domestic price, the effect on import amount is more significant under natural rate shock. Under cost-push shock, the expenditure-switching effect is more substantial than the income absorption effect for U.S. households, so the export amount increases. However, as a result of the expenditure-switching effect is less than the income absorption effect for U.S. households under natural rate shock, the export amount falls. Therefore, output, hours, consumption, and government spending decrease under natural rate shock and then start immediately to revert to steady state. Conversely, they slightly decrease and then are followed by a hump-shaped pattern under cost-push shock. The CPI inflation and PPI inflation rise initially under cost-push shock, unlike those under natural rate shock.
Figure 5: Cost-push shock v.s. Natural rate shock with Pegged exchange rate
If the central bank implements the PPI-based Taylor rule from Figure 8 to Figure 10, the exchange rate channel would be similar to one with the CPI-based Taylor rule. The variables, including international reserves, domestic bonds by foreigner, and risk premium, have the same pattern through the financial market channel, but the impacts on them are
larger than those with the CPI-based Taylor rule, due to the less response of the central bank to external shocks. For the trade market channel, the intuition is the same as one under the CPI-based Taylor rule for terms of trade and import amount. Moreover, the expenditure-switching effect is significantly larger than the income absorption effect for U.S. households, so positive impact on export amount with larger magnitude under two shocks than those with the CPI-based Taylor rule. However, the output (also government spending) and hours are positive responses under two shocks, unlike the other two policies, although the magnitude is small. Because of PPI smoothness, the CPI inflation has a larger deviation than one with the CPI-based Taylor rule. Conversely, the PPI inflation has less deviation than one with the CPI-based Taylor rule. Hence, two shocks less impact on the nominal interest rate hike with the PPI-based Taylor rule. In general, consumption under two shocks also decreases, because domestic households face increased price.

Figure 8: Cost-push shock v.s. Natural rate shock with PPI-based Taylor rule
After comparing results under two different shocks in each monetary policy regime, this paper also illustrates the differences in monetary policy regimes. Monetary policy analysis points to the presence of a trade-off between the stabilization of the nominal exchange rate (exchange rate channel), domestic bonds (financial market channel) and the terms of trade.
(trade market channel) on the one hand, and the stabilization of the output and the PPI inflation on the other. For instance, PPI-based Taylor rule, which achieves a simultaneous stabilization of both the output and the PPI inflation, causes a substantially larger volatility of the nominal exchange rate, domestic bonds, and the terms of trade through each channel relative to the CPI-based Taylor rules and the pegged exchange rate regime. Generally, a CPI-based Taylor rule delivers equilibrium dynamics that lie somewhere between the PPI-based Taylor rule and the pegged exchange rate regime.\textsuperscript{8} Due to the excess smoothness of the nominal exchange rate, the pegged exchange rate regime generates significantly higher welfare losses (such as output and consumption) than two Taylor rules. On the contrary, the PPI-based Taylor rule delivers higher welfare than the similar CPI-based Taylor rule.

4 Bayesian Local Projection Empirical Estimation

4.1 Data Description

The data are obtained from the Organization for Economic Co-operation and Development (OECD), International Monetary Fund (IMF), Federal Reserve Economic Data (FRED), World Bank, and local national accounts sources (see the Data appendix for more details). The data set includes emerging market countries - Argentina (ARG), Brazil (BRA), Korea (KOR), Mexico (MEX) and South Africa (ZAF), and developed countries - Australia (AUS), Canada (CAN), Netherlands (NLD), New Zealand (NZL) and Sweden (SWE) as observed in 1978Q1-2017Q4.\textsuperscript{9} Due to the model’s implication, data set collects real value variables - output, consumption, government spending, export, import. This paper uses working hours or the employed population to measure the labor market. The data set also has price index - GDP deflator, assets (denominated in the U.S. currency) - international reserves and debt securities, and nominal rates - exchange rates and interest rates. The cost-push and natural rate shocks are calculated in the model section.

The following results reported in Table 3 and Table 4 are based on time series detrended using the method from Hamilton [2017] instead of the Hodrick-Prescott filter. The unconditional correlation between each variable and cost-push shock or natural rate shock has shed some light on the problem. First of all, both shocks are positively correlated with FFR, but domestic interest rates of emerging economies show a negative correlation. Second, com-

\textsuperscript{8}Galí and Monacelli [2005] presented the similar dynamic effects of a domestic productivity shock on a number of macroeconomic variables with different monetary policy rules.

\textsuperscript{9}The data set is available for ARG between 1993Q1 and 2017Q4, for BRA between 1991Q1 and 2017Q4.
paring with natural rate shock, cost-push shock is more likely to have a significant negative effect, rather than an obvious positive effect, on a U.S. currency’s value and foreign exchange rate. Third, in contrast to developed economies, assets of emerging market economies in the financial market under natural rate shock are cyclical, due to lack of openness and a number of international aids. Fourth, export deviations of emerging economies are more sensitive to cost-push shock, while developed economies’ are more responsive to natural rate shock, because of differences in export product attributes. Finally, the natural rate shock - the structural shock of the U.S. has a substantial effect on developed countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Y</th>
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<th>C</th>
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Table 3: Correlation with U.S. cost-push shocks

Table 4: Correlation with U.S. natural rate shocks

Table 5 are also based on time series detrended using the method from Hamilton [2017]. Association rule learning finds interesting relations between variables in the data set. For emerging economies, if positive cost-push shocks, positive FFR, and negative foreign exchange rate happen together, they are likely to also have the positive output, export, import, or reserves. However, there is only the positive export under natural rate shocks. In other words, emerging economies are more sensitive to cost-push shock, while developed economies are more responsive to natural rate shock. This method can show some interesting associations.
consequents with specific antecedents, but it ignores the magnitude effect and time influence.

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<th>Consequents</th>
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Table 5: Association Rule Learning

4.2 Bayesian Local Projection Method

Miranda-Agrippino and Ricco [2017] provided a flexible econometric method - Bayesian local projections robust to misspecifications that bridges between vector autoregressions (VARs) and local projections (LPs). The VARs produce IRFs by iterating up to the relevant horizon the coefficients of a one-step-ahead model. However, because of a small-size information set, underestimated lag order, and non-linearities, misspecified VARs can fail to capture all of the dynamic interactions. $y_{t+1} = C + B_1 y_t + \ldots + B_p y_{t-p+1} + \epsilon_{t+1}$ The LPs, Jordà [2005], estimate the IRFs from the coefficients of direct projections of variables onto their lags at the relevant horizon. However, due to the moving average structure of residuals, and the
risk of over parametrization, LPs are likely to be less efficient, and hence subject to volatile and imprecise estimates. $y_{t+h} = C + B_1 y_t + \ldots + B_p y_{t-p+1} + \epsilon_{t+h}$ Therefore, choosing between iterated and direct methods involves a sharp trade-off between bias and estimation variance: the VAR produces more efficient parameter estimates than the LP, but it is prone to bias if the one-step-ahead model is misspecified.

Miranda-Agrippino and Ricco [2017] proposed a regularization for LP-based IRFs which builds on the prior that a VAR can provide, in first approximation, a decent description of the behavior of most variables. As the horizon grows, however, BLPs are allowed to optimally deviate from the restrictive shape of VAR-based IRFs, whenever these are poorly supported by the data. This, while the discipline imposed by the prior, allows to retain reasonable estimation uncertainty at all horizons. Hence, BLP can sensibly reduce the impact of compounded biases over the horizons, effectively dealing with model misspecifications.

### 4.3 Empirical Results

The main results of this section are that impulse response functions (IRFs) with the following VAR ($\epsilon^f_{i,t}$ includes two shocks) in these two groups of countries, facing cost-push and natural rate shocks, differ along some important dimensions. Figure 11 to Figure 15 show emerging market countries’ IRFs under cost-push shocks (Figure 21 to Figure 25 for developed countries). Figure 16 to Figure 20 display emerging market countries’ IRFs under natural rate shocks (Figure 26 to Figure 30 for developed countries).\(^{10}\) In contrast to developed countries, the emerging market countries are more volatile, due to the lack of the well established market system and macro-control. Under natural rate shocks, consumption tends to be more volatile than output in emerging economies, while consumption is less volatile than output in developed economies. However, consumption is roughly as volatile as output under cost-push shocks in both emerging and developed economies. Furthermore, cost-push shocks cause larger volatility than natural rate shocks for each country, because of the characteristics of two shocks (cost-push shock $\rho^f_\pi = 0.16$, $\sigma^f_\pi = 0.673$ and natural rate shock $\rho^f_r = 0.83$, $\sigma^f_r = 0.003$).

\(^{10}\) All IRFs have a 90% confidence interval. Variables and cointegrated variables pass the augmented Dickey-Fuller test and conclude a stationary process. Akaike’s information criterion (AIC), Schwarz’s Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC) lag order selection statistics provide an optimal lag number 4. Please see the IRFs appendix for more details with other methods - VARs and LPs.
\[ M_{12 \times 12} = \begin{bmatrix} Y_t \\ P_t \\ C_t \\ G_t \\ X_t \\ C^m_t \\ N_t \\ R^*_t \\ D^*_t \\ S_t \\ i_t \\ \epsilon^f_{i,t} \end{bmatrix} = B_0 + B_1 \begin{bmatrix} Y_{t-1} \\ P_{t-1} \\ C_{t-1} \\ G_{t-1} \\ X_{t-1} \\ C^m_{t-1} \\ N_{t-1} \\ R^*_{t-1} \\ D^*_{t-1} \\ S_{t-1} \\ i_{t-1} \\ \epsilon^f_{i,t-1} \end{bmatrix} + \cdots + B_4 \begin{bmatrix} Y_{t-4} \\ P_{t-4} \\ C_{t-4} \\ G_{t-4} \\ X_{t-4} \\ C^m_{t-4} \\ N_{t-4} \\ R^*_{t-4} \\ D^*_{t-4} \\ S_{t-4} \\ i_{t-4} \\ \epsilon^f_{i,t-4} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ \epsilon_f \end{bmatrix} \]

Figure 11: Cost-push shock with BLP method - ARG
Figure 12: Cost-push shock with BLP method - BRA

Figure 13: Cost-push shock with BLP method - KOR
In either emerging market or developed countries, the exchange rate channel shows cost-push shocks would cause a negative effect on the exchange rate (USD depreciation), while natural rate shocks would trigger a positive effect on the exchange rate (USD appreciation), which are consistent with the predictions of the model (the CPI-based Taylor rule or the PPI-based Taylor rule). Also, domestic interest rate hikes are more significant and less volatile for developed countries under two shocks, due to well established foreign exchange
markets.

Figure 16: Natural rate shock with BLP method - ARG

Figure 17: Natural rate shock with BLP method - BRA
Figure 18: Natural rate shock with BLP method - KOR

Figure 19: Natural rate shock with BLP method - MEX
For financial market channel, one interesting finding is that the U.S. deflator adjusted international reserves of developed economies have significantly negative effects after natural rate shocks, unlike those after cost-push shocks, because international reserves as precautionary savings could smooth consumption with USD appreciation condition, which can explain that consumption is less volatile than output in developed economies (consumption is roughly as volatile as output under cost-push shocks). On the contrary, the U.S. deflator adjusted international reserves of emerging market economies have insignificant and ambiguous effects after natural rate shocks, due to the accumulation of reserves behavior. Under cost-push shocks, the predictions of the model and BLP IRFs show similar results. However, the patterns of U.S. deflator adjusted international debt securities for emerging market economies are not consistent with predictions of the model under both shocks. First, these variables measure the amount outstanding of international debt securities for issuers in the general government sector with all maturities, which are stock values instead of flow values. Second, emerging market countries tend to increase their public debts continuously. For instance, since 2014, Brazil’s public debt as a share of GDP has jumped some 20% points to its present level of around 75%. Third, the model assumes the passive assumption - fixed ratio between government spending and output. Due to the above, the model does not capture the explosive path on public debts of emerging market economies. Unlike emerging market countries, most developed countries show significant negative patterns of international debt securities under two shocks.
Figure 21: Cost-push shock with BLP method - AUS

Figure 22: Cost-push shock with BLP method - CAN
Figure 23: Cost-push shock with BLP method - NLD

Figure 24: Cost-push shock with BLP method - NZL
For the trade market channel, the model predicts export amount increases and then decreases; while import amount decreases, and then increases under cost-push shocks with CPI or PPI-based Taylor rule. The empirical results show consistent patterns for real export, but only positive responses for real import (only South Africa shows consistent pattern as model) under cost-push shocks. What’s more, the natural rate shocks positively impact on the export amount and display negative effects on the import amount, according to the model. However, IRFs give insignificant positive responses for real exports (some significant ones, such as Canada, Netherlands, South Africa) and lagged negative responses for real imports. In addition, the model also presents a negative impact on terms of trade. In other words, export price decreases, and import price increases. The data of real export and import are measured by volume estimates with reference year 2010, which does not include any information about terms of trade. Finally, there are no significant differences between emerging and developed countries.
Figure 26: Natural rate shock with BLP method - AUS

Figure 27: Natural rate shock with BLP method - CAN
Figure 28: Natural rate shock with BLP method - NLD

Figure 29: Natural rate shock with BLP method - NZL
Through three channels - exchange rate, financial market, and trade market channels, IRFs also reveal other economic indicators’ responses. This paper uses either total working hours or the employed population to measure the labor market. The emerging market countries only have a significant and consistent up-down pattern under cost-push shocks as the model with the PPI-based Taylor rule, but an insignificant and unclear pattern under natural rate shocks. In contrast to emerging market countries, developed countries have a significant and unclear pattern under cost-push shocks, but a significant and consistent up-down pattern under natural rate shocks. The model assumes a fixed ratio between government spending and output, but the empirical test treats government spending as an endogenous variable. A positive response is showed under cost-push shocks for the emerging market economy and negative response for the developed economy. The price index - GDP deflator most likely involves a positive response under both shocks. For real output, Argentina, Mexico, South Africa, Australia, Canada, Netherlands, and Sweden have significant and consistent up-down patterns under both shocks as the prediction of model with the PPI-based Taylor rule. However, IRFs of real consumption under different countries and shocks present inconsistent results, comparing with the prediction of the model.
5 Conclusion

This paper analyzes the impact of U.S. interest rate changes under cost-push shocks and natural rate shocks as well as these shocks’ transmission to emerging market countries. The results are two-fold: First, the theoretical model of a New Keynesian small open economy finds that changed exchange rate (exchange rate channel) is negative - USD depreciation under cost-push shock, while positive - USD appreciation under natural rate shock. The differences under the two shocks are amplified through domestic bonds (financial market channel) and terms of trade (trade market channel). Then, the real output of the emerging economy with the PPI-based Taylor rule is positive under both shocks and less volatile under cost-push shock, given the same magnitude of shocks. The model also illustrates the differences in monetary policy regimes. Monetary policy analysis presents the trade-off between the stabilization of the nominal exchange rate (exchange rate channel), domestic bonds (financial market channel) and the terms of trade (trade market channel) on the one hand, and the stabilization of the output and the PPI inflation on the other. As a result, the PPI-based Taylor rule, which achieves a simultaneous stabilization of both the output and the PPI inflation, causes a substantially larger volatility of the nominal exchange rate, domestic bonds and the terms of trade through each channel relative to the CPI-based Taylor rules and the pegged exchange rate regime. Generally, the CPI-based Taylor rule delivers equilibrium dynamics that lie somewhere between the PPI-based Taylor rule and the pegged exchange rate regime.

Second, the empirical test uses Bayesian local projections to analyze the sample that consists of five emerging and five developed countries. As the prediction of the model, the exchange rate channel has significant and different effects under both shocks. A country with a lower inflation rate than others would see an appreciation in the value of its currency. The empirical results reveal that cost-push shocks cause larger volatility than natural rate shocks for each country, due to their characteristics - significant deviation and less persistence. Under natural rate shocks, consumption tends to be more volatile than output in emerging economies, while consumption is less volatile than output in developed economies. However, consumption is roughly as volatile as output under cost-push shocks in both emerging and developed economies. Other interesting findings include domestic interest rate hikes are more significant and less volatile for developed countries under two shocks, due to well established foreign exchange markets; the U.S. deflator adjusted international reserves of developed economies have significantly negative effects after natural rate shocks, but the result doesn’t hold for emerging economies in the financial market; there are no significant

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differences between emerging and developed countries in the trade market under two shocks. Understanding the above mechanisms could be the fundamental basis to design monetary policies or promote financial market reforms, which help central banks or governments stabilize emerging economies.
References


Appendices

A Model

The model in full: Endogenous control variables include \( p_t, p^m_t, q_t, \pi_t, \pi^d_t, p^d_t, s_t, p^d_{it}, N_t, C_t, X_t, R_t^d, D_t^f, \phi_t, K_t, F_t, i_t, G_t, \pi^f_t, y^f_t, Z^f_t, u^f_t, r^f_{it} \). Exogenous variables includes \( \epsilon^f_{u,t}, \epsilon^f_{z,t} \).

Price setting equations

\[
\frac{p^d_t}{p^d_{t-1}} = \left(1 - \theta\right)\left(\frac{1 - \theta(\pi^d_t)^{\epsilon-1}}{1 - \theta}\right)^{-\frac{1}{\epsilon}} + \theta\frac{(\pi^d_t)^{\epsilon}}{p^d_{t-1}} \tag{1}
\]

\[
K_t = \frac{\epsilon^f}{\epsilon - 1} \frac{t}{1 - \delta} \chi N_t^\psi + 1 + \frac{p^d_t p_t}{\pi^f_t} + \beta \theta E_t (\pi^d_{t+1})^{\epsilon} K_{t+1} \tag{2}
\]

\[
F_t = \frac{p^d_t ZN_t}{C_t} + \beta E_t (\pi^d_{t+1})^{\epsilon-1} F_{t+1} \tag{3}
\]

Household intertemporal Euler equation

\[
\frac{1}{C_t} = \beta E_t \frac{1}{C_{t+1}} \frac{i_t}{\pi_{t+1}} \tag{5}
\]

Relative price equations

\[
p_t = [(1 - \omega) + \omega (p^m_t)^{1-\eta}]^{\frac{1}{1-\eta}} \tag{6}
\]

\[
p^m_t = p_t q_t (1 - \delta^f + \delta^f i^f_t) \tag{7}
\]

\[
\pi_t = \frac{P_t}{P_{t-1}} = \frac{p^{d t}}{P^{d}_{t-1} p_{t-1}} = \pi^d_t \left[\frac{(1 - \omega) + \omega (p^m_{t-1})^{1-\eta}}{(1 - \omega) + \omega (p^m_{t-1})^{1-\eta}}\right]^{\frac{1}{1-\eta}} \tag{8}
\]

\[
q_t p_t p^d_t = 1 - \delta^x + \delta^x i_t \tag{9}
\]

\[
\frac{q_t}{q_{t-1}} = \frac{s_t}{\pi^f_t} \tag{10}
\]
UIP equation

\[
\frac{i_t}{\phi_t} = s_{t+1} i_t^f
\]  

Aggregate resource condition

\[
p_t^d Z N_t = (1 - \omega)p_t^d C_t + X_t + G_t
\]

Balance of payment

\[
q_t R^*_t + \omega \left( \frac{p_t}{p_t^m} \right)^{\eta-1} C_t + \frac{i_t-1}{\phi_{t-1} \pi_t} D^f_{t-1} = q_t p_t^x X_t + \frac{i_{t-1}^f}{\pi_t} q_t R^*_{t-1} + D^f_t
\]

Government spending

\[
G_t = \eta_g p_t^d Z N_t
\]

Central bank policy

\[
\log(i_t) = \rho_i \log(i_{t-1}) + (1 - \rho_i)[\rho_s \log(\pi_t) + \rho_y \log(\frac{Y_t}{Y})]
\]

Risk premium

\[
\phi_t = \zeta \left( \frac{R^*_t}{R_{t-1}} \right)^{\gamma}
\]

Foreign demand for exports

\[
X_t = (p_t^x)^{-\eta_f} \left( \frac{1}{\epsilon_f} - 1 \right) \frac{1}{\epsilon_f + \psi} Z_t^f y_t^f
\]
Foreign demand for domestic bonds

\[ D_t^f = \mu \left( \frac{E_t q_{t+1}}{q_t} \right) \] (18)

Foreign New Keynesian Phillips curve

\[ \log(\frac{\pi^f_t}{\pi^f_{t-1}}) = \beta^f E_t \log(\frac{\pi^f_{t+1}}{\pi^f_{t-1}}) + \kappa^f (1 + \psi^f) \log(\frac{y^f_t}{y^f_{t-1}}) + \hat{u}^f_t \] (19)

where \( \kappa^f \equiv \frac{(1-\theta^f)(1-\beta^f\theta^f)}{\theta^f} \) and \( \beta^f = \frac{1}{r^f} \).

Foreign New Keynesian IS curve

\[ \log(\frac{y^f_t}{y^f_{t-1}}) = E_t \log(\frac{y^f_{t+1}}{y^f_{t-1}}) - \log(\frac{i^f_t}{i^f_{t-1}}) \] (20)

Foreign policy with Taylor rule

\[ \log(\frac{i^f_t}{i^f_{t-1}}) = \rho^a \log(\frac{\pi^f_t}{\pi^f_{t-1}}) + \rho^y \log(\frac{y^f_t}{y^f_{t-1}}) + \log(\frac{r^f_{t-1}}{r^f_{t-1}}) \] (21)

Foreign cost-push shocks

\[ \hat{u}^f_t = \rho^u \hat{u}^f_{t-1} + \epsilon^f_{u,t} \] (22)

Foreign natural rate of interest shocks

\[ \log(\frac{r^f_{t-1}}{r^f_{t-1}}) = \rho^f \log(\frac{r^f_{t-1}}{r^f_{t-1}}) + (\rho^f - 1) \epsilon^f_{z,t} \] (23)

Foreign technology shocks

\[ \log(\frac{Z^f_t}{Z^f_{t-1}}) = \rho^f \log(\frac{Z^f_t}{Z^f_{t-1}}) + \epsilon^f_{z,t} \] (24)
## B Data

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<td>1961Q1-2017Q4</td>
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<tr>
<td>Private final consumption-expenditure</td>
<td>OECD</td>
<td>National currency (Millions), volume estimates, reference year 2010, annual levels, seasonally adjusted</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>General government final consumption expenditure</td>
<td>OECD</td>
<td>National currency (Millions), volume estimates, reference year 2010, annual levels, seasonally adjusted</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>Exports of goods and services</td>
<td>OECD</td>
<td>National currency (Millions), volume estimates, reference year 2010, annual levels, seasonally adjusted</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>Imports of goods and services</td>
<td>OECD</td>
<td>National currency (Millions), volume estimates, reference year 2010, annual levels, seasonally adjusted</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>Hours worked per worker</td>
<td>OECD</td>
<td>(Hours), annual levels (not available for ARG, BRA, ZAF)</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>Employed population</td>
<td>OECD</td>
<td>(Thousands), aged 15 and over, seasonally adjusted (not available for ARG, ZAF)</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>GDP deflator</td>
<td>OECD</td>
<td>Index, reference year 2010, seasonally adjusted</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>International reserves</td>
<td>IMF</td>
<td>US Dollar (Millions), official reserve assets, official gold price</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>Exchange rates</td>
<td>OECD</td>
<td>National currency USD, average of daily rates</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>International debt securities</td>
<td>FRED</td>
<td>US Dollar (Millions), issues in general government sector, all maturities</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>Interest rates</td>
<td>OECD</td>
<td>3-month interbank rates, annual levels (available for AUS, CAN, SGD, NZD, SWE, ZAF, USA)</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>Interest rates</td>
<td>IMF</td>
<td>3-month deposit rates, annual levels (available for ARG, BRA)</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>Interest rates</td>
<td>FRED</td>
<td>3-month government securities rates, annual levels (available for KOR)</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>Interest rates</td>
<td>OECD</td>
<td>3-month treasury securities rates, annual levels (available for SBR)</td>
<td>1961Q1-2017Q4</td>
</tr>
<tr>
<td>Natural rate of Interest</td>
<td>Laubach &amp; Williams</td>
<td>Estimates of the baseline LW model, one-sided estimates, annual levels</td>
<td>1961Q1-2017Q4</td>
</tr>
</tbody>
</table>

Table 6: Data Sources

Argentina’s consumption, government spending, export, import data is available from 1993Q1 to 2003Q4 in local national accounts sources and from 2004Q1 to 2017Q4 in the OECD data set. Brazil’s output, consumption, government spending, export, import data is available from 1991Q1 to 1995Q4 in local national accounts sources and from 1996Q1 to 2017Q4 in the OECD data set. For hours worked per worker (adjusted to annual level), Argentina has semester data from 1986S2 to 2002S2 and quarter data from 2003Q3 to 2017Q4 in local national accounts sources (ILOSTAT). Brazil has quarter data from 1992Q1 to 2001Q4 and month data from 2002M1 to 2017M12 in local national accounts sources. South Africa has semester data from 2000S1 to 2007S2 and quarter data from 2008Q1 to 2017Q4 in local national accounts sources (ILOSTAT). Also, for the employed population (aged 15 and over), Argentina has semester data from 1980S1 to 2002S1 and quarter data from 2003Q3 to 2017Q4 in local national accounts sources (ILOSTAT). South Africa has semester data from 2000S1 to 2007S2 and quarter data from 2008Q1 to 2017Q4 in local national accounts sources (ILOSTAT). GDP deflator of Argentina has some missing data from 1993Q1 to 2003Q4, collected from IMF data sources for supplement. International reserves and international debt securities are adjusted by U.S. GDP deflator to change nominal terms to real terms. For interest rates, Brazil’s 3-month deposit rates are more volatile due to the high variability of local inflation. The quarterly energy commodity price indices are the average of monthly indices.
C  IRFs

Figure 31: Cost-push shock with all methods - ARG

Figure 32: Cost-push shock with all methods - BRA
Figure 33: Cost-push shock with all methods - KOR

Figure 34: Cost-push shock with all methods - MEX
Figure 35: Cost-push shock with all methods - ZAF

Figure 36: Natural rate shock with all methods - ARG
Figure 37: Natural rate shock with all methods - BRA

Figure 38: Natural rate shock with all methods - KOR
Figure 39: Natural rate shock with all methods - MEX

Figure 40: Natural rate shock with all methods - ZAF
Figure 41: Cost-push shock with all methods - AUS

Figure 42: Cost-push shock with all methods - CAN
Figure 43: Cost-push shock with all methods - NLD

Figure 44: Cost-push shock with all methods - NZL
Figure 45: Cost-push shock with all methods - SWE

Figure 46: Natural rate shock with all methods - AUS
Figure 47: Natural rate shock with all methods - CAN

Figure 48: Natural rate shock with all methods - NLD
Figure 49: Natural rate shock with all methods - NZL

Figure 50: Natural rate shock with all methods - SWE