Transmission of U.S. Monetary Policy to Commodity Exporters and Importers

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## Contents

I. Introduction ................................................................. 1

II. Empirical Evidence for the Transmission Mechanism ...... 6

III. Model Description ......................................................... 14

IV. Model Analysis .......................................................... 23

V. Conclusion ................................................................. 36

References ................................................................. 38

Appendix ................................................................. 41
Transmission of U.S. Monetary Policy to Commodity Exporters and Importers

This paper studies international transmission of U.S. monetary policy shocks to commodity exporters and importers. After first showing empirically that the shocks have stronger effects on commodity exporters than on importers, I then augment a standard three-country model to include commodities. Consistent with the empirical evidence, the model indicates that an expansionary monetary policy shock to the U.S. increases the aggregate output of commodity exporters by more than that of importers. This is because the increased U.S. aggregate demand triggered by the shock leads to greater U.S. demand for commodities and higher real commodity prices, and thus the exports of commodity exporters increase relative to those of commodity importers. Furthermore, I show that if commodity exporters’ currencies are pegged to the U.S. dollar, then the U.S. monetary policy shocks have stronger spillovers to commodity exporters and importers. In the event that the U.S. becomes a net energy exporter, the shocks will have weaker effects on commodity exporters and stronger impacts on importers.

**Keywords:** Monetary policy shocks, International transmission, Commodity exporters, Commodity importers, VAR with external instruments

**JEL Classification:** E52, F42, Q43
I. Introduction

U.S. monetary policy has significant effects on prices of commodities such as oil, basic metals, and lumber.\(^1\) Since changes in commodity prices affect commodity-exporting and commodity-importing countries differently (see Bodenstein, Erceg and Guerrieri, 2011 and others), international transmissions of U.S. monetary policy shocks to the two groups may be different as well. I show empirically that in response to an expansionary U.S. monetary policy shock, the aggregate output of commodity-exporting countries increases by more than that of commodity-importing countries. This result can be explained by a rise in commodity prices and a larger increase in the exports of commodity-exporting countries compared to those of commodity-importing countries in response to the shock. Then I construct a three-country dynamic stochastic general equilibrium (DSGE) model that includes commodities while accounting for the idiosyncrasies of country-specific commodity trade structures. According to the simulation results of the model, the aggregate output of commodity-exporting countries rises more compared to that of commodity-importing countries in response to an expansionary U.S. monetary policy shock. Since the shock increases U.S. demand for commodities and hence real commodity prices, the exports of commodity-exporting countries increase by more than those of commodity-importing countries. Therefore, U.S. monetary policy has stronger spillovers to commodity-exporting countries compared to commodity-importing countries, which is consistent with the empirical findings.

The importance of the international transmission of monetary policy through changes in commodity prices has been raised many times in international meetings since 2008. For example, the Delhi Declaration issued at the 2012 BRICS\(^2\) Summit stated that excessive

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1) For details, see Barsky and Kilian (2001), Anzuini, Lombardi and Pagano (2013), etc.
2) Brazil, Russia, India, China and South Africa
liquidity from the aggressive policy actions taken by central banks in advanced countries to stabilize their domestic economies had been spilling over into emerging market economies, fostering excessive volatility in capital flows and commodity prices. According to Takáts and Vela (2014), at the Meeting of Deputy Governors in Basel in 2014, several central banks argued that monetary policies in advanced countries directly affect commodity prices, and hence macroeconomic conditions in emerging economies. From these sources as well as many empirical studies, we can expect that monetary policy in a large economy like the U.S. has strong impacts on commodity prices, and that changes in commodity prices triggered by monetary policy in a large economy affect economic conditions in other countries. As a result, many empirical studies have taken commodity prices into consideration to properly analyze international monetary transmission (e.g. Canova, 2005; Maćkowiak, 2007; Dedola, Rivolta and Stracca, 2017).

To explain the mechanism briefly, an expansionary monetary policy shock in the U.S., a commodity-importing country,\(^3\) will raise its output, which will lead to an increase in its demand for imports of commodities from commodity-exporting countries. In turn, the increased U.S demand for commodities will increase commodity prices. The increase in U.S. demand for commodity imports and the consequent rise in commodity prices will positively affect commodity-exporting countries. The higher commodity prices, however, will have adverse influences on commodity-importing countries. Therefore, U.S. monetary policy would be expected to have stronger effects on commodity-exporting countries than on commodity-importing countries. In accordance with this expectation, an expansionary U.S. monetary policy

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3) The average ratio of net commodity exports to trade (gross exports plus gross imports) in the U.S. was -5.4% during 1995-2011 according to the OECD Trade in Value Added database. I define the commodity sector as the agriculture, hunting, forestry, fishing, mining, quarrying, wood and basic metal industries, following the IMF’s commodity price index.
shock has larger positive effects on the output of commodity-exporting countries than that of commodity-importing countries, as shown by the empirical analysis in Section II.

In order to analyze the international transmission of U.S. monetary policy shocks to commodity-exporting and commodity-importing countries, I add commodities while accounting for different commodity trade structures to a standard three-country DSGE model with nontradable goods, as in Kim (2018). In the model, although country $A$ (representing the U.S.) produces commodities, its production of commodities is not enough to meet domestic demand. Thus, it always imports commodities from commodity-exporting countries. Country $B$ (representing commodity-importing countries among the G7 countries) is the same as country $A$. Country $C$ (representing the major commodity-exporting countries in the world) produces commodities to meet both domestic and overseas demand, and thus always exports commodities. Furthermore, households’ consumption basket includes commodities as a complement to noncommodity consumption goods, and firms producing tradable goods use commodities as an input.

The primary goal of this paper is to examine whether U.S. monetary policy shocks have stronger effects on commodity-exporting countries than on commodity-importing countries. Specifically, the goal is to show that in the model an expansionary monetary policy shock to the U.S. (country $A$) leads to a larger increase in the aggregate output of commodity-exporting countries (country $C$) compared to commodity-importing countries (country $B$), consistent with

4) France, Germany, Italy, Japan and the U.K.
5) Algeria, Angola, Argentina, Australia, Azerbaijan, Bahrain, Belize, Bolivia, Brazil, Brunei Darussalam, Canada, Cambodia, Cameroon, Chile, Colombia, Costa Rica, Côte d’Ivoire, Ecuador, Estonia, Finland, Iceland, Indonesia, Iran, Kazakhstan, Latvia, Luxembourg, Malaysia, Mexico, the Netherlands, New Zealand, Nigeria, Norway, Oman, Paraguay, Peru, Qatar, Russia, Saudi Arabia, South Africa, Ukraine, the U.A.E, Uruguay, Venezuela, Vietnam and Zambia
6) Many empirical studies such as Cooper (2003), Hughes, Knittel and Sperling (2006), Bodenstein, Erceg and Guerrieri (2011) have confirmed that commodity and noncommodity consumption goods (especially energy and nonenergy consumption goods) are complements.
the empirical evidence in Section II.

This paper concludes that, indeed, an expansionary monetary policy shock to the U.S. brings about a bigger increase in the aggregate output of commodity-exporting countries than that of commodity-importing countries. To be specific, an expansionary monetary policy shock to the U.S. increases its aggregate output and consumption, and depreciates its exchange rate. The increased aggregate demand leads to a rise in its demand for imports of commodities and foreign tradable goods from foreign countries. The depreciation makes commodities and foreign tradable goods more expensive. Owing to the increased price, U.S. consumption of foreign tradable goods decreases, and hence its imports of foreign tradable goods fall. However, despite the increased price, U.S. commodity consumption goes up thanks to the complementarity between commodities and noncommodity goods in consumption. Conversely, since the depreciation makes U.S. tradable goods cheaper, consumptions of U.S. tradable goods in all three countries increase, which causes a large increase in the output of U.S. tradable goods. U.S. imports of commodities for tradable production jump, which leads to a rise in the exports of commodity-exporting countries. In contrast, the exports of commodity-importing countries fall due to the decreased demand for their tradable goods. As a consequence, the aggregate output of commodity-exporting countries goes up by more than that of commodity-importing countries.

Furthermore, according to the simulation results, if commodity-exporting countries adopt pegged exchange rate regimes—i.e., their currencies are pegged to the U.S. dollar—U.S. monetary policy shocks have stronger impacts on both commodity-exporting and commodity-importing countries than when the exchange rate regimes of commodity-exporting countries are floating. If the U.S. becomes a net energy exporter as per the expectations of the U.S. Energy Information Administration (EIA), the effects of the shocks on commodity-exporting countries will become weaker but those on
commodity-importing countries will become stronger.

The policy implications from the analysis are clear. Since the outputs of commodity-exporting countries are more greatly affected by U.S. monetary policy than those of commodity-importing countries, their policymakers, especially those in commodity-exporting countries whose currencies are pegged to the U.S. dollar, should monitor U.S. economic conditions and monetary policy more carefully to stabilize their economies. Furthermore, if the U.S. becomes a net energy exporter as per the EIA’s expectation, U.S. monetary policy will have stronger effects on commodity-importing countries than now, which means that U.S. economic conditions and monetary policy are becoming more and more important to policymakers in commodity-importing countries in stabilizing their economies.

This paper is closely related to the literature on international monetary transmission. The most well-known framework for this is the Mundell-Fleming-Dornbusch (MFD) model. According to the MFD model, a monetary loosening in the home country leads to a rise in domestic demand, which boosts the home country’s imports from the foreign country (the demand-augmenting effect). However, the monetary loosening also brings about an exchange rate depreciation, which increases the foreign country’s imports from the home country (the expenditure-switching effect). Since these two effects are opposite, the net effect of monetary policy in one country on the other country is ambiguous. The other popular frameworks were developed by Svensson and van Wijnbergen (1989) and Obstfeld and Rogoff (1995). Their theoretical frameworks with micro-foundations have become the main analytical machinery of international monetary transmission. These models emphasize that a monetary loosening in the U.S. increases future U.S. price levels, making future goods more expensive relative to current goods. This brings about intertemporal substitution in favor of current goods, including current foreign goods, which has positive effects on foreign output. With regard to empirical studies, many papers
(e.g. Kim, 2001; Faust and Rogers, 2003; Dedola, Rivolta and Stracca, 2017) show that U.S. monetary policy has positive spillover effects on other countries. For instance, Kim (2001) concludes that since a monetary expansion in the U.S. decreases the world real interest rate and increases the world aggregate demand for U.S. and foreign goods, foreign output grows, which is suggested by some versions of the models of Svensson and van Wijnbergen (1989) and Obstfeld and Rogoff (1995).

This paper is organized as follows. Section II empirically investigates the transmission mechanism by which U.S. monetary policy shocks have stronger effects on commodity-exporting countries than on commodity-importing countries. Section III describes the three-country DSGE model with commodities. Section IV presents the model calibration and analyzes how U.S. monetary policy shocks affect commodity-exporting and commodity-importing countries differently. It also analyzes how the effects of U.S. monetary policy shocks change if commodity-exporting countries adopt pegged exchange rate regimes and the U.S. becomes a net energy exporter. I then present policy implications drawn from the analysis. Section V concludes.

II. Empirical Evidence for the Transmission Mechanism

In this section, I investigate empirically the mechanism of how U.S. monetary policy shocks affect the outputs of commodity-exporting and commodity-importing countries differently through changes in commodity prices and the exports of the two groups. Specifically, I empirically examine whether an expansionary U.S. monetary policy shock leads to a rise in commodity prices, and larger increases in the exports and industrial production of commodity-exporting countries than those of commodity-importing countries.

I use the two-step approach of Romer and Romer (2004) and
Dedola, Rivolta and Stracca (2017). The first step is to identify U.S. monetary policy shocks using the vector autoregression (VAR) model with external instruments developed by Stock and Watson (2012) and Mertens and Ravn (2013). The second step is to estimate the effects of the shocks on commodity prices, and on the exports and industrial production of commodity-exporting and commodity-importing countries by using autoregressive distributed lag models in which the lagged values of the shocks are included. Then, I investigate the robustness of the results from the two-step approach by using an open economy VAR.

The reasons why I use the two-step approach as main evidence rather than the open economy VAR model are as follows. Although the two-step approach is known to be sensitive to the lag length of autoregressive distributed lag models (Coibion, 2012), the VAR has the same shortcoming as well, i.e., it is very sensitive to the lag structure. Furthermore, to properly model an open economy VAR, we should model both the U.S. and foreign economies in the VAR, which means many variables of the U.S. and foreign countries should be included in the VAR. However, a large number of variables in the VAR leads to the well-known “curse of dimensionality.” In other words, when we add one more variable in the VAR, the number of parameters to estimate increases quadratically, which causes inefficient estimators. Due to these shortcomings, many open economy VARs that analyze international transmission of U.S. monetary policy shocks in the literature do not properly model the U.S. economy, but include only U.S. monetary policy indicators such as the federal funds rate in VARs (e.g. Kim and Roubini, 2000; Gerko and Rey, 2017). In this paper, I use the open economy VAR of Gerko and Rey (2017) for the robustness check.
1. Methodology

The first step is to obtain U.S. monetary policy shock series. I use the VAR with external instruments of Gertler and Karadi (2015) in which high frequency surprises around policy announcements are used as external instruments and government bond rates are used as the policy indicator. According to Gertler and Karadi (2015), shocks to forward guidance need to be included in the measure of policy innovation since, during the recent crisis when short-term interest rates reached the zero lower bound, forward guidance became the only means by which the central bank could influence market rates, absent unconventional credit market interventions. They point out that the government bond rate is appropriate as the policy indicator because innovations of the government bond rate include both the effects of surprises in the current federal funds rate and shocks to forward guidance. Moreover, since their VAR includes various interest rates, a simultaneity problem between the policy innovation and the interest rates arises. Thus they address the problem using the high frequency surprises as external instruments.

Following Gertler and Karadi (2015), my VAR includes six U.S. variables and one instrument. The six variables are the log industrial production, the log CPI index, the one-year government bond rate (the policy indicator), the excess bond premium of Gilchrist and Zakrajšek (2012), the mortgage rate spread and the commercial paper spread. The instrument is the unexpected changes in the three month ahead monthly federal funds futures within a 30-minute window of the Federal Open Market Committee (FOMC) announcement. The mortgage rate spread is defined as the difference between the 30-year conventional mortgage rate and the 10-year constant maturity treasury rate, and the commercial paper spread is the difference between the

7) It is well known that monetary policy has impacts on financial variables and responds endogenously to changes in financial variables at the same time.
3-month AA nonfinancial rate and the 3-month treasury rate. Since the excess bond premium of Gilchrist and Zakrajšek (2012) is only available to August 2016, I expand the data set of Gertler and Karadi (2015) to July 1979 to August 2016 (full sample) by using FRED data other than the instrument which is only available from January 1991 to June 2012. Therefore, I use the full sample in estimating coefficients and reduced form shocks, and then use the instrument and the estimated reduced form shocks for the corresponding period (January 1991 to June 2012) to find the relationship between the reduced form and structural form shocks. The lag length is 12 months. Appendix A presents the detailed methodology of the VAR with external instruments, while Appendix B shows impulse responses to a monetary policy shock in the VAR for the first step.

The second step is to compute the impact of an expansionary U.S. monetary policy shock. I estimate the following autoregressive distributed lag model for each variable and country to obtain the impact:

$$
\Delta y_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{j=1}^{q} \gamma_j \Delta S_{t-j} + e_t,
$$

where $y$ is the log commodity price index,\(^8\) the log industrial production of each country or the exports of goods of each country.\(^9\) $S$ is the U.S. monetary policy shocks obtained in the first step. $p$ and $q$ are the numbers of lags of $y$ and $S$, respectively. I include 12 lags for $y$ ($p=12$) and 24 lags for $S$ ($q=24$).\(^{10}\) The sample countries are 16

\(^8\) The source of the commodity price index is the IMF. Since the natural gas price, whose weight in the IMF’s commodity price index is 6.9%, starts from 1992, I exclude it from the commodity price index. I then construct the commodity price index by using the weight assigned to each commodity price in the IMF’s commodity price index.

\(^9\) The sources of the exports of goods and the industrial production of each country, which are seasonally adjusted, are the OECD monthly Main Economic Indicators, and the exports are scaled by the average of the sum of imports and exports over the sample period.

\(^{10}\) Since the results are sensitive to the lag length, for robustness I also estimate equation (1) with $p=24$ and
OECD countries whose monthly data for the sample period is available from the OECD monthly Main Economic Indicators. Among them, 4 countries are commodity-exporting countries whose net commodity exports from the OECD Trade in Value Added are positive: Canada, Mexico, the Netherlands and Norway. 12 countries are commodity-importing countries: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Spain, Sweden and the U.K.

The cumulative effect of a one percentage point increase in $S$ on $y$ can be calculated from equation (1) as in Romer and Romer (2004). The effect on $y$ after one month is $\gamma_1$, that after two months is $\gamma_1 + (\gamma_2 + \gamma_1\beta_1)$, and so on.

Finally, since the lag length in the VAR in the first step is 12 months, the U.S. monetary policy shock series start from July 1980. Therefore, the full sample of the second step is July 1980 to August 2016.

### 2. Results

The cumulative impacts on variables of an expansionary U.S. monetary policy shock are presented in Figure 1. For the cumulative impacts on the exports and industrial production of commodity-exporting and commodity-importing countries, I take the average cumulative impacts across the country groups. Consistent with other studies, there is a significant increase in commodity prices. The shock increases the exports of commodity-exporting countries by more than those of commodity-importing countries. The shock also leads to a significant increase in the industrial production of commodity-exporting countries, but the rise in the industrial production of commodity-importing countries is barely statistically significant and is slightly smaller.

\[ q=36, \text{ which are used in Romer and Romer (2004), and with } p=24 \text{ and } q=24. \text{ The estimated impacts of the two cases are very similar to the case with } p=12 \text{ and } q=24. \]
The main conclusion derived from this analysis is that the positive effects of an expansionary U.S. monetary policy shock on the industrial production of commodity-exporting countries tend to be stronger than those on the industrial production of commodity-importing countries. A rise in commodity prices and a larger increase in the exports of commodity-exporting countries compared to those...
of commodity-importing countries in response to the shock may explain the stronger effects on the industrial production of commodity-exporting countries. The DSGE model in this paper tries to capture these main mechanisms by which U.S. monetary policy shocks have different effects on commodity-exporting and commodity-importing countries.

3. Robustness

To check the robustness of the results from the two-step approach, I use the open economy VAR with external instruments of Gerko and Rey (2017). Specifically, I use the same policy indicator and external instruments as those in Gertler and Karadi (2015) for U.S. monetary policy shocks, and estimate impulse responses of variables of commodity-exporting and commodity-importing countries to an expansionary U.S. monetary policy shock.

The VAR includes the U.S. one-year government bond rate as the U.S. policy indicator, the log commodity price index, and the log real effective exchange rate,\(^{11}\) exports of goods, short-term interest rate\(^{12}\) and log industrial production of each country. As an external instrument, unexpected changes in the three month ahead monthly federal funds futures within a 30-minute window of the FOMC announcement are used. I use the dataset of Gertler and Karadi (2015) for the instrument. Although the instrument is only available for January 1991 to June 2012, the full sample is January 1980 to August 2016.

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11) The source of the real effective exchange rate of each country is the BIS.
12) Central bank rate (Austria, Canada, Denmark, Finland and Japan), interbank rate less than 24 hours (France, Germany, Mexico, Spain, Sweden and the U.K.), 3-month interbank rate (Belgium, Italy, the Netherlands and Norway) or money market rate (Ireland) is used as the short-term interest rate. The source of the central bank rate, interbank rate less than 24 hours, and 3-month interbank rate is the FRED, and that of the money market rate is the IMF IFS.
I estimate each VAR for each country. For the impulse responses of commodity prices, I use the average impulse response of all countries, and for the impulse responses of the variables of commodity-exporting and commodity-importing countries, I take the average impulse response across the country groups. The lag length is 12 months.
Figure 2 presents the impulse responses of the variables in the system to an expansionary U.S. monetary policy shock. They are very similar to the results of the two-step approach. In response to the shock, commodity prices increase. The exports of commodity-exporting and commodity-importing countries also increase, and the rise in the exports of the former group is larger than that of the latter group. The shock brings about a significant increase in the industrial production of commodity-exporting countries, but the response of the industrial production of commodity-importing countries is not statistically significant. These results mean that U.S. monetary policy shocks have stronger effects on commodity-exporting countries than on commodity-importing countries, as in the results of the two-step approach.

III. Model Description

In this section, I describe the three-country DSGE model.\textsuperscript{13) The model is close to the sticky price version of Kim (2018), who extends the two-country model of Stockman and Tesar (1995) by adding commodities and different commodity trade structures. I mainly extend his two-country model to a three-country version.}\textsuperscript{14) To be specific, the world economy consists of three countries: country A (the U.S., commodity-importing country), country B (commodity-importing country), and country C (commodity-exporting country). Although countries A and B produce commodities, they cannot produce them in sufficient quantities to meet domestic demand and thus they import commodities from country C. Country C produces enough commodities to meet domestic demand for commodities and the other countries' demand for imports, and hence it exports commodities to the other two

\textsuperscript{13) See Appendix C for the equilibrium conditions for the model.  
\textsuperscript{14) The main difference between this model and Kim (2018)'s model is that in his model the commodity-importing country does not produce commodities, whilst in this model not only the commodity-exporting country but also the commodity-importing countries produce commodities.}
countries. Labor is mobile between sectors but immobile between countries, and capital is sector-specific. Asset markets are complete.

1. Households

The utility function of the representative household in country \( i \in \{A, B, C\} \), which allows for habit formation in consumption, is

\[
U^i = E_0 \sum_{t=0}^{\infty} \beta^t \left( \ln(C^t_i - bC^t_{i-1}) - \frac{L^t_{i+1}}{1+\chi} \right),
\]

(2)

where \( E \) is the expectations operation, \( \beta \) is the discount factor, \( C^t_i \) is the composite of tradable, nontradable and commodity consumption goods, \( b \) is the habit parameter, \( L^t_i \) is the labor supply by households, and \( \chi \) is the inverse of Frisch elasticity of labor supply.

The corresponding budget constraint is

\[
C^t_i + E_t\{Q^i_{t,t+1}D^i_{t+1}\} = W^i_tL^i_t + D^i_t + \Pi^i_t,
\]

(3)

with \( L^i_t = \sum_s L^i_{s,t}, s \in \{T, N, X\} \) where \( T, N \) and \( X \) denote the tradable, nontradable and commodity sectors, respectively, and \( L^i_{s,t} \) is the labor supply to sector \( s \). \( Q^i_{t,t+1}, D^i_{t+1}, W^i_t \) and \( \Pi^i_t \) denote the stochastic discount factor for one-period ahead real payoffs relevant to the household, the real payoff in period \( t+1 \) of the portfolio held at the end of period \( t \), the real wage and the real profits remitted by firms, respectively. \( E_t\{Q^i_{t,t+1}\} \) can be expressed by the risk free rate, \( R^i_t \), i.e.,

\[
E_t\{Q^i_{t,t+1}\} = 1/R^i_t.
\]

The composite of consumption goods, \( C^t_i \), is defined by

15) In this paper, the superscript and subscript \( i \), and the subscript \( s \) denote countries and sectors, respectively.
noncommodity consumption goods, $C_{NC,t}^i$, and commodity consumption goods, $C_{X,t}^i$, using the constant elasticity of substitution (CES) aggregator.

$$C_t^i = \left( (1 - \gamma_0) \frac{\eta}{\eta_0} C_{NC,t}^i + \gamma_0 C_{X,t}^i \right)^{-\frac{\eta_0}{\eta - 1}}.$$  (4)

Assuming that the commodities produced in each country are homogeneous, commodity consumption goods, $C_{X,t}^i$, are the sum of domestically produced commodities, $C_{X,i,t}^i$, and imported commodities from country $C$, $C_{X,C,t}^i$.

$$C_{X,t}^i = C_{X,i,t}^i + C_{X,C,t}^i.$$  (5)

Since countries $A$ and $B$ are net commodity-importing countries, I further assume that they can produce only a fraction of the domestic demand for commodity consumption goods ($C_{X,i,t}^i = (1 - \gamma) C_{X,t}^i$, $i = A, B$). This means that they need to import commodities from country $C$ ($C_{X,C,t}^i = \gamma C_{X,t}^i$, $i = A, B$). The production of country $C$ can fully meet its domestic demand for commodity consumption goods ($C_{X,C,t}^C = C_{X,t}^C$) so it does not need to import commodities. Furthermore, country $C$ can also produce commodities to satisfy demand for imports of commodities from countries $A$ and $B$ ($C_{X,C,t}^A + C_{X,C,t}^B$).

The noncommodity consumption goods, $C_{NC,t}^i$, in turn, consist of tradable, $C_{T,t}^i$, and nontradable consumption goods, $C_{N,t}^i$.

$$C_{NC,t}^i = \left( (1 - \gamma_1) \frac{\eta}{\eta_1} C_{T,t}^i + \gamma_1 C_{N,t}^i \right)^{-\frac{\eta_1}{\eta - 1}}.$$  (6)

Tradable consumption goods, $C_{T,t}^i$, are a function of tradable
consumption goods produced in country \(i\), \(C_{i,t}^i\), tradable consumption goods produced in country \(l \neq i\), \(C_{l,t}^i\), and tradable consumption goods produced in country \(m \neq i, l\), \(C_{m,t}^i\). It is assumed that the weights of \(C_{i,t}^i\) and \(C_{m,t}^i\) in \(C_{T,t}^i\) are equal for all \(i\).

\[
C_{T,t}^i = \left\{ \left(1 - \gamma_2^i \right) \frac{1}{\eta_2} C_{i,t}^i + \left( \frac{\gamma_2^i}{2} \right) \frac{1}{\eta_2} C_{l,t}^i + \left( \frac{\gamma_2^i}{2} \right) \frac{1}{\eta_2} C_{m,t}^i \right\}^{\frac{\eta_2}{\eta_2 - 1}}. \tag{7}
\]

\(P_t^i\) (CPI), \(P_{X,t}^i\) (price of commodity consumption goods), \(P_{NC,t}^i\) (price of noncommodity consumption goods) and \(P_{T,t}^i\) (price of tradable consumption goods), are defined by

\[
P_t^i = \left(1 - \gamma_0^i \right) P_{NC,t}^i + \gamma_0^i P_{X,t}^i \right\}^{\frac{1}{1 - \eta_0}}, \tag{8}
\]

\[
P_{X,t}^i = \left(1 - \gamma_1^i \right) P_{X,i,t}^i + \gamma_1^i P_{X,C,t}^i, \tag{9}
\]

\[
P_{NC,t}^i = \left(1 - \gamma_1^i \right) P_{T,t}^i + \gamma_1^i P_{NC,t}^i \right\}^{\frac{1}{1 - \eta_1}}, \tag{10}
\]

\[
P_{T,t}^i = \left(1 - \gamma_2^i \right) P_{i,t}^i + \frac{\gamma_2^i}{2} P_{l,t}^i + \frac{\gamma_2^i}{2} P_{m,t}^i \right\}^{\frac{1}{1 - \eta_2}}, \tag{11}
\]

where \(P_{X,i,t}^i\) is the price of domestically produced commodities, \(P_{X,C,t}^i\) is the price of imported commodities from country \(C\), \(P_{X,t}^i\) is the price of nontradable consumption goods, \(P_{i,t}^i\) is the price of domestically produced tradable consumption goods, \(P_{l,t}^i\) is the price of tradable consumption goods produced in country \(l \neq i\), and \(P_{m,t}^i\) is the price of tradable consumption goods produced in country \(m \neq i, l\).
2. Firms

2.1. Final Goods Firms

In each sector, there is a continuum of intermediate goods firms indexed by \( j \in [0, 1] \). They produce differentiated intermediate goods, \( Y_{s,t}^i(j) \), at prices \( P_{s,t}^i(j) \). Final goods firms bundle intermediate goods to produce final goods according to the following CES technology:

\[
Y_{s,t}^i = \left( \int_0^1 Y_{s,t}^i(j)^{\frac{\varepsilon-1}{\varepsilon}} d\bar{j} \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{12}
\]

where \( \varepsilon > 1 \) is the elasticity of substitution among intermediate goods.

From the profit maximization problem, the demand for each intermediate good is

\[
Y_{s,t}^i(j) = \left( \frac{P_{s,t}^i(j)}{P_{s,t}^i} \right)^{-\frac{\varepsilon}{\varepsilon-1}}, \tag{13}
\]

and the corresponding price index is

\[
P_{s,t}^i = \left( \int_0^1 P_{s,t}^i(j)^{1-\varepsilon} d\bar{j} \right)^{\frac{1}{1-\varepsilon}}. \tag{14}
\]

2.2. Intermediate Goods Firms

Nontradable and commodity intermediate goods are produced using labor and capital as inputs, while commodities in addition to labor and capital are used in the production of tradable intermediate goods. All three countries produce tradable, nontradable and commodity intermediate goods with the same production function. Firms purchase capital at the
end of period $t-1$ to produce goods in period $t$, and sell the remaining capital back to capital goods producers at the end of period $t$.

### 2.2.1. Nontradable Intermediate Goods Producers

Nontradable intermediate goods producers produce output using labor and capital, and all three countries produce nontradable intermediate goods with the same production function,

$$Y^{i}_{N,t}(j) = A_{N,t}^{i} K_{N,t}^{i}(j)^{\alpha_N} L_{N,t}^{i}(j)^{1-\alpha_N},$$

(15)

where $Y^{i}_{N,t}(j)$ is the output of firm $j$, $A_{N,t}^{i}$ is the common productivity in the sector, $K_{N,t}^{i}(j)$ is the capital input of the firm, $L_{N,t}^{i}(j)$ is the labor input of the firm, and $1-\alpha_N$ is the labor share of income.

### 2.2.2. Tradable Intermediate Goods Producers

Producing tradable intermediate goods requires producers to use commodities together with capital and labor as inputs. The production function is a nested CES as in Kim and Loungani (1992):

$$Y^{i}_{T,t}(j) = A_{T,t}^{i} \left\{ (1-a) K_{T,t}^{i}(j)^{-\nu} + a x^{i}(j)^{-\nu} \right\}^{-\frac{\alpha}{\nu}} L_{T,t}^{i}(j)^{1-\alpha},$$

(16)

where $Y^{i}_{T,t}(j)$, $A_{T,t}^{i}$, $K_{T,t}^{i}(j)$, $x^{i}(j)$ and $L_{T,t}^{i}(j)$ denote the output of firm $j$, the common productivity in the sector, the capital input of the firm, the commodity input of the firm and the labor input of the firm, respectively. $1-\alpha$ is the labor share of income. $a$ is related to the weight of commodities. $\nu = \frac{1-\zeta}{\zeta}$, where $\zeta$ means the elasticity of substitution between capital and commodities.

Like commodity consumption goods, commodity input is the sum of domestically produced commodities and imported commodities from
2.2.2. Commodity Intermediate Goods Producers

Commodity intermediate goods producers use capital and labor as inputs to produce goods. The production function is Cobb-Douglas as in Kim (2018) and Huynh (2016):

\[
Y_{i,t}(j) = A_{i,t} K_{i,t}^{\alpha_X} L_{i,t}^{1-\alpha_X},
\]

(17)

where \(Y_{i,t}(j), A_{i,t}, K_{i,t}^{\alpha_X}, L_{i,t}^{1-\alpha_X}\) are the output of firm \(j\), the common productivity in the sector, the capital input of the firm and the labor input of the firm, respectively. \(1 - \alpha_X\) is the labor share of income.

2.2.2. Price Setting

Firms in each sector set prices based on Calvo price-setting. In each period, a fraction, \(1 - \theta\), of firms adjust their prices. This means that the probability a firm will be stuck with a price for one period is \(\theta\). Thus, the first-order condition for the optimal reset price in sector \(s\), \(P_{s,t}^{i,O}\), is

\[
P_{s,t}^{i,O} = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{h=0}^{\infty} (\beta \theta)^h \lambda_h Y_{s,t+h}^{i} P_{s,t+h}^{i} - P_{s,t+h}^{i-1} Y_{s,t+h}^{i}}{E_t \sum_{h=0}^{\infty} (\beta \theta)^h \lambda_h Y_{s,t+h}^{i} P_{s,t+h}^{i} - P_{s,t+h}^{i-1} Y_{s,t+h}^{i}},
\]

(18)

where \(mc_{s,t}^{i}\) is the real marginal cost in sector \(s\), and \(\lambda_t^{i}\) is the marginal value of an extra unit of income.

Accordingly, the price index in sector \(s\) evolves according to
\[ P^{i}_{s,t} = \left[ (1 - \theta)P^{i}_{s,t-1} + \theta P^{i-1}_{s,t-1} \right]^{\frac{1}{1-c}}. \]  

(19)

2.3. Capital Goods Producers

Final goods in each sector can be converted to capital goods by capital goods producers. In each period, capital goods producers buy \( L^i_{s,t} \) of final goods at price \( p^i_{s,t} \) and \( (1 - \delta)K^i_{s,t} \) of used capital at price \( Q^i_{s,t} \). Then, by using technology \( F^i \) they produce new capital goods, \( K^i_{s,t+1} \). The capital goods producers’ problem is thus

\[
\max_{\ell^i_{s,t}} \sum_{h=0}^{\infty} \chi^i_{t+h} [Q^i_{s,t+h} (1 - F^i_{s,t,h} \ell^i_{s,t,h})] \ell^i_{s,t+h} - p^i_{s,t} \ell^i_{s,t+h},
\]

(20)

subject to the law of motion for capital

\[
K^i_{s,t+1} = (1 - \delta)K^i_{s,t} + \left( 1 - F^i_{s,t-1} \ell^i_{s,t-1} \right) \ell^i_{s,t},
\]

(21)

where \( \delta \) is the depreciation rate, \( p^i_{s,t} \) is the real price of final goods in sector \( s \), and \( F^i_{s,t} \ell^i_{s,t-1} = \frac{\ell^i_{s,t}}{2} \left( \frac{\ell^i_{s,t}}{\ell^i_{s,t-1}} - 1 \right)^2 \).

3. Monetary Policy and Resource Constraints

The monetary authority in country \( i \) follows a standard Taylor-type rule,

\[
i^i_t = (1 - \rho^i_t)i^i_t + \rho^i_t i^i_{t-1} + (1 - \rho^i_t)\left\{ \phi^i_n \pi^i_t - \pi^i_t \right\} + \phi^i_Y (\ln Y^i_t - \ln Y^i) + u^i_t,
\]

(22)

where \( i^i_t \) is the nominal interest rate, \( u^i_t \) is an exogenous monetary policy shock, \( \pi^i_t \) is the CPI inflation, and \( Y^i_t \) is the aggregate output.
The variables without time subscript \( t \) denote their steady state values. The Fisher equation, \( R_i^t = E_t \left[ i_t^t / \pi_t^t+1 \right] \), gives the relationship between the nominal and real interest rates.

Finally, I complete the model description with a set of resource constraints. The output of nontradable goods in each country has to be the same as the sum of the country’s consumption of nontradable goods and its investment.

\[
Y^i_{N,t} = C^i_{N,t} + I^i_{N,t}. \tag{23}
\]

The output of tradable goods in each country must be equal to the sum of the world demand for the tradable goods produced in the country and its investment.

\[
Y^i_{i,t} = C^i_{i,t} + C^i_{i,t} + C^m_{i,t} + I^i_{T,t}, \quad l \neq i, \quad m \neq i, \quad l. \tag{24}
\]

In countries \( A \) and \( B \), the commodity output is equal to the sum of investment and domestically produced commodities for consumption and for tradable goods production. The commodity output of country \( C \) has to equate with the sum of the world demand for commodities produced in it for consumption and for tradable goods production, and its investment.

\[
Y^i_{X,t} = C^i_{X,i,t} + x^i_{i,t} + I^i_{X,t}, \quad i = A, \quad B, \tag{25}
\]

\[
Y^C_{X,t} = C^A_{X,C,t} + C^B_{X,C,t} + C^C_{X,t} + x^A_{C,t} + x^B_{C,t} + x^C_{C,t} + I^C_{X,t}. \tag{26}
\]
Ⅳ. Model Analysis

1. Calibration

The parameter values for the model are given in Table 1. The values are based on U.S. quarterly data and symmetric in the three countries with the exception of the commodity trade structures.

Some parameter values are the same as those in the standard literature. As in Galí and Monacelli (2005), the discount factor, $\beta$, is 0.99, the inverse of Frisch elasticity of labor supply, $\chi$, is set to 3, the elasticity of substitution between intermediate inputs, $\varepsilon$, is 6, and the probability that a price does not adjust, $\theta$, is assumed to be 0.75. Following Christiano, Eichenbaum and Evans (2005), I assume that the habit parameter, $b$, is 0.65 and the value for the parameter associated with the investment adjustment costs, $\xi$, is 2.5. I set the labor shares of income in the nontradable $(1-\alpha_Z)$ and tradable $(1-\alpha)$ sectors to 0.56 and 0.61, respectively, as in Stockman and Tesar (1995), and the labor share of income in the commodity sector $(1-\alpha_X)$ is assumed to be 0.66. The depreciation rate of capital, $\delta$, is 0.025 as in the standard literature. I borrow the parameter values in the monetary policy from Clarida, Galí and Gertler (1999), and Smets and Wouters (2005, 2007). The autoregressive parameter for the monetary policy rule, $\rho_p$, is 0.8, the policy weight on inflation, $\phi_z$, is set to 1.5, and the policy weight on the output gap, $\phi_y$, is 0.1. The correlation of the monetary policy shocks across countries is assumed to be 0.15.
Table 2. Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>Discount factor</td>
</tr>
<tr>
<td>$\chi$</td>
<td>3</td>
<td>Inverse of Frisch elasticity of labor supply</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>6</td>
<td>Elasticity of substitution between intermediate inputs</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.75</td>
<td>Probability that price cannot be adjusted</td>
</tr>
<tr>
<td>$b$</td>
<td>0.65</td>
<td>Habit parameter</td>
</tr>
<tr>
<td>$\xi$</td>
<td>2.5</td>
<td>Parameter associated with investment adjustment costs</td>
</tr>
<tr>
<td>$1-\alpha_X$</td>
<td>0.56</td>
<td>Labor share in the nontradable sector</td>
</tr>
<tr>
<td>$1-\alpha$</td>
<td>0.61</td>
<td>Labor share in the tradable sector</td>
</tr>
<tr>
<td>$1-\alpha_X$</td>
<td>0.66</td>
<td>Labor share in the commodity sector</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.025</td>
<td>Depreciation rate of capital</td>
</tr>
<tr>
<td>$\rho_t$</td>
<td>0.8</td>
<td>Autoregressive parameter for the monetary policy rule</td>
</tr>
<tr>
<td>$\phi_s$</td>
<td>1.5</td>
<td>Policy weight on inflation</td>
</tr>
<tr>
<td>$\phi_Y$</td>
<td>0.1</td>
<td>Policy weight on output gap</td>
</tr>
<tr>
<td>$1/(\nu+1)$</td>
<td>0.59</td>
<td>Elasticity of substitution between commodities and capital in tradable production</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.044</td>
<td>Parameter related to the weight of commodities in tradable production</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.72</td>
<td>Fraction of imported commodities in commodity consumption goods and commodity inputs</td>
</tr>
<tr>
<td>$\gamma_0$</td>
<td>0.081</td>
<td>Weight of commodities in the composite of consumption goods in countries $A$ and $B$</td>
</tr>
<tr>
<td>$\eta_0$</td>
<td>0.3</td>
<td>Elasticity of substitution between commodity and noncommodity consumption goods</td>
</tr>
<tr>
<td>$\gamma_1$</td>
<td>0.544</td>
<td>Weight of nontradable goods in noncommodity consumption goods</td>
</tr>
<tr>
<td>$\eta_1$</td>
<td>0.44</td>
<td>Elasticity of substitution between tradable and nontradable goods</td>
</tr>
<tr>
<td>$\gamma_2$</td>
<td>0.338</td>
<td>Weight of foreign tradable goods in tradable consumption goods in countries $A$ and $B$</td>
</tr>
<tr>
<td>$\eta_2$</td>
<td>1</td>
<td>Elasticity of substitution between home and foreign tradable goods</td>
</tr>
<tr>
<td>$\gamma^C_0$</td>
<td>0.138</td>
<td>Weight of commodities in the composite of consumption goods in country $C$</td>
</tr>
<tr>
<td>$\gamma^C_2$</td>
<td>0.947</td>
<td>Weight of foreign tradable goods in tradable consumption goods in country $C$</td>
</tr>
</tbody>
</table>
The elasticity of substitution between capital and commodities in tradable production, $1/(1 + \nu)$, is set to 0.59, as in Kim and Loungani (1992). I use 44 as the steady state ratio of capital to commodity inputs in tradable production, $K_T^i/x^i$. Accordingly, the weight of commodities in tradable production, $a$, is 0.044, which is consistent with the values of $\nu$, $K_T^i/x^i$, $\beta$ and $\delta$.\(^{16}\) The fraction of imported commodities in commodity consumption goods and commodity input in countries $A$ and $B$, $\gamma$, is set to be 0.72, and I assume that the weight of commodity consumption goods in the composite of consumption goods in those countries, $\gamma_0$, is 0.081. These parameter values closely match 12% of the steady state ratio of commodity expenditure to GDP, $(C^X X^i + x^i)/Y^i, i = A, B.$\(^{17}\) 6% of the steady state ratio of commodity inputs to GDP, $x^i/Y^i, i = A, B.$\(^{18}\) 6% of the steady state ratio of commodity consumption to GDP, $C^X_i/Y^i, i = A, B$, and 4% of the steady state ratio of commodity output to GDP, $Y^i_X/Y^i, i = A, B.$\(^{19}\)

With regard to the other parameters associated with consumption, I set the elasticity of substitution between commodity and noncommodity consumption goods, $\eta_0$, to be 0.3, following Natal (2012). The weight of nontradable consumption goods in noncommodity consumption goods, $\gamma_1$, is assumed to be 0.544. Considering that commodities are also tradable, $\gamma_1=0.544$ implies that the steady state ratio of consumption of all tradable goods (commodities and tradable goods in the model) to nontradable consumption goods, $(C_T^X + C_X^A)/C_N^A$, is 1, which is equal to

---

16) Using the first-order conditions of households and firms in the steady state, $a = [1 + (1/\beta - 1 + \delta(K_T^i/x^i)^{1/\gamma})^{-1}].$

17) The average ratio of end-use energy expenditure to GDP during 1997-2015 is about 7% based on EIA data. Since the weight of energy in the IMF’s commodity price index is 0.631, 12% seems to be appropriate as the ratio of commodity expenditure to GDP.

18) This value is based on the fact that the average ratio of energy consumption (energy expenditure of the residential sector and motor gasoline) to end-use energy expenditure for 1997-2015 is approximately 51%, according to EIA data.

19) During 1997-2015, the average ratio of commodity output to GDP in the U.S. is around 4%, according to NIPA data.
Stockman and Tesar (1995)’s assumption. I set the value of the elasticity of substitution between tradable and nontradable consumption goods, $\eta_1$, to be 0.44, as in Stockman and Tesar (1995). The weight of tradable consumption goods produced in the foreign countries in the tradable consumption goods in countries $A$ and $B$, $\gamma_2$, is assumed to be 0.338, which ensures that the steady state ratio of imported commodity and tradable consumption goods to total tradable consumption goods is 0.4, $(C^A_C + C^B_C + C^A_C)/(C^A_C + C^A_C) = 0.4$. This ratio is the same as that in Galí and Monacelli (2005). The elasticity of substitution between home and foreign tradable consumption goods, $\eta_2$, is 1, as in Stockman and Tesar (1995). The weight of commodity consumption goods in the composite of consumption goods in country $C$, $\gamma_C^C$, is 0.138, and the weight of tradable consumption goods produced in the foreign countries in the tradable consumption goods in country $C$, $\gamma_C^F$, is 0.947, which is a result of the assumptions that the steady state values of consumption and labor aggregates in the three countries are the same.

Under this parameterization, the steady state ratio of aggregate output in country $A$ to that in country $B$, $Y^A/Y^B$, is equal to 1, and the steady state ratio of aggregate output in country $C$ to that in country $A$, $Y^C/Y^A$, is 0.97. These values closely match the average ratio of U.S. GDP to the aggregate GDP of commodity-importing G7 countries (1.03) and the average ratio of the aggregate GDP of major commodity-exporting countries in the world to U.S GDP (0.93) for 2003-2016,\textsuperscript{20} using data from the IMF World Economic Outlook data.

\textsuperscript{20} Some countries’ GDPs are not available before 2003.
2. Transmission of U.S. Monetary Policy Shocks

In this section, I present the responses of variables in the model to a negative 25bp monetary policy shock to country A (the U.S.). In order to analyze how commodity-exporting and commodity-importing countries are affected differently by the shock, I compare the responses of countries B (commodity-importing country) and C (commodity-exporting country).

Figure 3. Responses of Aggregate Variables to an Expansionary Monetary Policy Shock to Country A

Figure 3 shows the responses of aggregate variables in the three countries to an expansionary monetary policy shock to country A.21)

21) For the responses of other variables, see Appendix D.
The shock decreases the nominal interest rate in country $A$, $i^A$, and thus its real interest rate, $R^A$. Accordingly, the aggregate output ($Y^A$), aggregate consumption ($C^A$), and aggregate investment ($I^A$) of country $A$ increase as usual.

The shock has positive spillovers to the other two countries. The aggregate outputs ($Y^B$ and $Y^C$), aggregate consumptions ($C^B$ and $C^C$), and aggregate investments ($I^B$ and $I^C$) of countries $B$ and $C$ go up. However, the increases in the aggregate variables of country $C$ are larger than those of country $B$. Therefore, according to the model, U.S. monetary policy shocks have stronger impacts on commodity-exporting countries than on commodity-importing countries.

2.1. How Commodity Exporters and Importers Are Affected Differently

I now investigate the mechanism by which U.S. monetary policy shocks have stronger influences on commodity-exporting countries compared to commodity-importing countries. Figure 4 presents the responses of several variables of countries $B$ and $C$ that play key roles in explaining the different effects of an expansionary U.S. monetary policy shock.

First, consider country $B$ (commodity-importing country). An expansionary monetary policy shock to country $A$ (the U.S.) raises its aggregate demand and depreciates its currency against the other two countries' currencies. The increased aggregate demand causes a rise in its demand for imports of foreign tradable goods. The currency depreciation has two effects. It offsets the increased demand for imports of foreign tradable goods in country $A$ by making foreign tradable goods more expensive. Thus, in the model, country $A$'s imports of tradable goods produced in countries $B$ and $C$ fall. Conversely, the prices of country $A$'s tradable goods in countries $B$ and $C$ become cheaper thanks to the depreciation, which leads to a decline in country $C$'s imports of tradable goods produced in country $B$, and vice versa.
Consequently, the exports of country $B$ drop. The second effect is that the depreciation leads the import price in country $B$ to fall, which brings about a decrease in its CPI inflation. Owing to the decreased CPI inflation together with the positively correlated monetary policy shocks with country $A$, the nominal interest rate in country $B$ falls according to the monetary policy rule,\footnote{Even if the monetary policy shocks to the three countries are not correlated, the decreased CPI inflations in countries $B$ and $C$ bring about falls in their nominal interest rates following the monetary policy rule.} which has positive effects on country $B$’s aggregate demand. Since the second effect is larger, its aggregate output increases in response to a monetary expansion in country $A$.

With regard to country $C$ (commodity-exporting country), there is one more positive transmission channel through commodities. Specifically, an expansionary monetary policy shock to country $A$ raises its demand for imports of commodities for consumption as well as of foreign tradable goods. Similarly, the price of foreign commodities becomes more expensive due to the depreciation of U.S. currency, which leads to a rise in commodity prices in the U.S. Differently from tradable goods, however, despite the increased commodity prices, U.S. consumption of commodities rises thanks to the complementarity between commodity and noncommodity consumption goods ($\eta_0 < 1$). Moreover, because all countries’ consumptions of tradable goods produced in country $A$ increase, country $A$’s output of tradable goods rises, which leads to a jump in country $A$’s commodity input in the production of tradable goods. Thus, the U.S. imports more commodities from country $C$. As a consequence, although country $C$’s exports of its tradable goods fall, its total exports increase thanks to a large rise in exports of commodities. Accordingly, commodity output in country $C$ goes up, which together with the increased real commodity prices\footnote{Because nominal commodity prices rise and CPI inflation falls, real commodity prices go up. Alternatively, since the U.S. demand for imports of commodities from country $C$ increases due to the shock, the real prices of commodities produced in country $C$ rise.} enables its aggregate output to rise by more than that of country $B$. Therefore, in
the model the expansionary monetary policy shock to the U.S. has stronger positive spillovers to commodity-exporting countries than to commodity-importing countries.

Figure 4. Responses to an Expansionary Monetary Policy Shock to Country A

In short, an expansionary monetary policy shock to the U.S. increases its aggregate demand, and thus its demand for commodities and real commodity prices go up. Therefore, commodity-exporting countries’ exports of commodities to the U.S. jump. The increased exports of commodities and higher real commodity prices enable the aggregate output of commodity-exporting countries to increase by more than that of commodity-importing countries.

Finally, the model captures the empirical mechanism explained in
Section Ⅱ well, namely that an increase in commodity prices and a bigger rise in the exports of commodity-exporting countries compared to those of commodity-importing countries in response to an expansionary U.S. monetary policy shock explain the larger rise in the output of commodity-exporting countries compared to that of commodity-importing countries. Specifically, in the model commodity prices increase and the exports of commodity-exporting countries go up by more than those of commodity-importing countries in response to an expansionary U.S. monetary policy shock, which leads to a larger rise in the output of commodity-exporting countries compared to that of commodity-importing countries.

3. Further Experiments

In this section, I consider two scenarios: the commodity-exporting country adopting a pegged exchange rate regime and the U.S. becoming a net energy-exporting country. These reflect the facts that the currencies of many emerging commodity-exporting countries such as Saudi Arabia and Venezuela are pegged to the U.S. dollar, and that according to the EIA, the U.S. could become a net energy-exporting country by 2026. Therefore, these two cases should be considered.

3.1. Commodity–exporting Country Adopting a Pegged Exchange Rate Regime

Since many emerging commodity-exporting countries such as Saudi Arabia, Qatar and Venezuela have adopted pegged exchange rate regimes, the case in which the currency of country $C$ (commodity-exporting country) is pegged to the U.S. dollar and the exchange rate regime of country $B$ (commodity-importing country) is floating should be analyzed.

If country $C$’s currency is pegged to country $A$’s currency, the
nominal exchange rate expressed by country $A$’s currency per country $C$’s currency, $s_t^C$, does not change.

$$s_t^C = s_{t-1}^C. \quad (27)$$

From the uncovered interest rate parity, the pegged exchange rate also requires that the monetary authority in country $C$ sets its nominal interest rate to be equal to that of country $A$ ($i_t^A = i_t^C$).

Figure 5. Responses of Countries $B$ and $C$ to an Expansionary Monetary Policy Shock to Country $A$

Figure 5 shows the responses of countries $B$ and $C$ to an expansionary monetary policy shock to country $A$ in the model in which the currency of country $C$ is pegged to the currency of country $A$ and the model in which it is floating. First of all, even if country $C$
adopts a pegged exchange rate regime, the shock has stronger effects on country $C$ than on country $B$, i.e., the main results of the model are maintained. Nevertheless, when $s^C_i$ is fixed, in response to the shock, the aggregate output of country $C$ increases by more than in the model in which country $C$’s exchange rate regime is floating, which is consistent with the conventional wisdom that a flexible exchange rate regime helps insulate the domestic economy from external shocks. Moreover, country $B$’s aggregate output also goes up by more when country $C$’s exchange rate regime is pegged. Hence, if commodity-exporting countries adopt pegged exchange rate regimes, U.S. monetary policy shocks will have stronger impacts on both commodity-exporting and commodity-importing countries compared to the case in which commodity-exporting countries have floating exchange rate regimes.

To explain, since the currency of country $C$ (commodity-exporting country) is pegged to that of country $A$ (the U.S.), it depreciates against the currency of country $B$ (commodity-importing country) like country $A$. Furthermore, the nominal interest rates of countries $A$ and $C$ fall by the exact same degree. The depreciations of the currencies of countries $A$ and $C$ lead to a larger fall in imported prices in country $B$, which causes a greater decline in country $B$’s CPI inflation. According to the monetary policy rule, country $B$ cuts its nominal interest rate by more, which enables its aggregate output to increase by more compared to the model in which country $C$’s exchange rate regime is floating. With regard to country $C$, the depreciation of its currency makes tradable goods and commodities produced in the country cheaper, which brings about a larger increase in its exports. The greater rise in exports together with the larger decline in the nominal interest rate enables the aggregate output in country $C$ to go up by more compared to the case in which country $C$ adopts a floating exchange rate regime.
3.2. The U.S. as a Net Energy Exporter

According to the EIA’s Annual Energy Outlook 2017, the EIA expects that the U.S. could become a net energy-exporting country by 2026. Since the U.S. is a net importing country of other commodities such as basic metals and lumber, even if the U.S. becomes a net energy-exporting country, it will not become a net commodity-exporting country. Rather, the U.S. is likely to shift from a major commodity-importing country to a minor commodity-importing country. This case can be considered by increasing the fraction of commodities that country A produces in its commodity consumption goods and commodity input, \((1-\gamma)\). To consider this case, I raise country A’s \((1-\gamma)\) from 0.28 to 0.5, and maintain country B’s \((1-\gamma)\) as 0.28.

Figure 6 presents the responses of countries B and C to an expansionary monetary policy shock to country A in the models in which the U.S. is a net energy-exporting country (a minor commodity-importing country) and a major commodity-importing country. Even if the U.S. is a minor commodity-importing country rather than a major commodity-importing country, the main results of the model are maintained, i.e., the shock has stronger effects on commodity-exporting countries than on commodity-importing countries. Nonetheless, when the U.S. is a minor commodity-importing country, the aggregate output in country B (commodity-importing country) increases by more, and that in country C (commodity-exporting country) rises by less compared to the model in which the U.S. is a major commodity-importing country. Therefore, if the U.S. becomes a minor commodity-importing country, U.S. monetary policy shocks will have stronger spillovers to commodity-importing countries but weaker spillovers to commodity-exporting countries compared to the case in which the U.S. is a major commodity-importing country.
More specifically, since the U.S. can produce more commodities in the model in which the U.S. is a minor commodity-importing country, its demand for imports of commodities rises by less in response to the shock, which means that the real prices of commodities produced in country $C$ go up by less. This leads to a smaller rise in the aggregate output of country $C$ compared to the case in which the U.S. is a major commodity-importing country. In contrast, the smaller rise in real commodity prices benefits commodity-importing countries. Therefore, country $B$’s aggregate output increases by more compared to the case in which the U.S. is a major commodity-importing country.

4. Policy Implications

Important policy implications can be drawn from the analysis. Given that commodity-exporting countries are more vulnerable to U.S. monetary policy than commodity-importing countries, policymakers in commodity-exporting countries need to carefully monitor U.S. economic conditions and monetary policy in order to stabilize their economies. Considering that the economies of commodity-exporting countries whose currencies are pegged to the U.S. dollar fluctuate by much more in response to U.S. monetary policy, their policymakers are required to...
consider U.S. economic conditions and monetary policy more carefully. Specifically, because the Fed has been raising the federal funds rate since the end of 2015, commodity-exporting countries are more likely to be adversely affected. Policymakers in commodity-exporting countries should take this into account when conducting economic policies.

Furthermore, according to the simulation results, if the U.S. becomes a net energy-exporting country as per the expectations of the EIA, U.S. monetary policy will have stronger effects on commodity-importing countries than now. This also has important policy implications for policymakers in commodity-importing countries, as U.S. economic conditions and monetary policy are becoming more and more important in stabilizing their economies.

V. Conclusion

In this paper, I analyze the international transmission of U.S. monetary policy shocks to commodity-exporting and commodity-importing countries. I first show empirically that an expansionary U.S. monetary policy shock tends to have stronger influences on commodity-exporting countries than on commodity-importing countries. This is because in response to the shock commodity prices rise and the exports of commodity-exporting countries go up by more than those of commodity-importing countries. Then, I set up a three-country DSGE model in which the commodities and idiosyncratic commodity trade structures of countries are considered, and show that the responses of the model to an expansionary monetary policy shock in the U.S. capture the empirical mechanism well. Specifically, the increased aggregate demand in the U.S. triggered by the shock leads to a rise in its demand for commodities and higher real commodity prices. Hence, commodity-exporting countries’ exports of commodities to the U.S. increase, which leads to a larger increase in the exports of commodity-exporting countries than those of commodity-importing countries.
Consequently, the aggregate output of commodity-exporting countries goes up by more compared to commodity-importing countries.

Furthermore, I show that if commodity-exporting countries' currencies are pegged to the U.S. dollar, U.S. monetary policy shocks will affect both commodity-exporting and commodity-importing countries by more than when the exchange rate regimes of commodity-exporting countries are floating. Moreover, if the U.S. becomes a net energy-exporting country, meaning that the U.S. shifts from a major commodity-importing country to a minor commodity-importing country, U.S. monetary policy shocks will have weaker effects on commodity-exporting countries and stronger impacts on commodity-importing countries.

From the analysis, I draw several policy implications. Policymakers in commodity-exporting countries, especially in those that have adopted pegged exchange rate regimes, should monitor U.S. economic conditions and monetary policy more carefully. In addition, as the U.S. becomes a net energy-exporting country, U.S. economic conditions and monetary policy will be a more important factor in the economic stability of commodity-importing countries.
References


Appendix

A. Methodology of the VAR with External Instruments

Let $y_t$ be an $n \times 1$ vector where $n$ is the number of variables. Then, the general structural form of the VAR is

$$Ay_t = \sum_{j=1}^{p} C_j y_{t-j} + \epsilon_t,$$

(A.1)

where $A$ is an $n \times n$ matrix of coefficients, $C_j, j = 1, 2, \cdots, p$ are $n \times n$ matrices of coefficients, and $\epsilon_t$ is an $n \times 1$ vector of structural shocks. By multiplying both sides of equation (A.1) by $A^{-1}$, the reduced form can be obtained:

$$y_t = \sum_{j=1}^{p} B_j y_{t-j} + u_t,$$

(A.2)

where $u_t$ is an $n \times 1$ vector of reduced form shocks. From equations (A.1) and (A.2), the relationship between $u_t$ and $\epsilon_t$ can be written as

$$Au_t = \epsilon_t, \quad u_t = S\epsilon_t,$$

(A.3)

where $S = A^{-1}$. Since $E[\epsilon_t \epsilon_t^T] = I$ where $I$ is an $n \times n$ identity matrix and the superscript $T$ denotes transpose, the $n \times n$ variance-covariance matrix of the reduced form is

$$\Sigma = E[u_t u_t^T] = E[S\epsilon_t \epsilon_t^T S^T] = E[SS^T].$$

(A.4)

Let the first element of $y_t$ ($y_t^1$) be the policy indicator. Then the first element of $\epsilon_t$ ($\epsilon_t^1$) is the associated policy shock. To obtain the impulse responses of variables to the policy shock, we need to identify
only the first columns of $S = [s^1, s^2, \ldots, s^n]^T$, since we can obtain estimates of $B_j$ by using least squares estimation of equation (A.2).

Let $z_t$ be the instrumental variable for the policy shock. In order for $z_t$ to be a valid instrument, the following conditions should be satisfied:

$$E[z_t \varepsilon_t^1] \neq 0, \quad E[z_t \varepsilon_t^2] = E[z_t \varepsilon_t^3] = \cdots = E[z_t \varepsilon_t^n] = 0,$$

where $\varepsilon_t^k$, $k = 2, 3, \ldots, n$ means the $k$th element of $\varepsilon_t$.

Let $\hat{u}_t$ be the estimate of $u_t$ by OLS of equation (A.2), and let $\hat{u}_t^h$, $h = 1, 2, \ldots, n$ be the $h$th element of $\hat{u}_t$. To obtain estimates of $[s^1, s^2, \ldots, s^n]^T$, first, regress $\hat{u}_t^1$ on $z_t$ and obtain the fitted value of $\hat{\varepsilon}^1_t$. By doing this, we can isolate the variations in $\hat{u}_t^1$ owing to the structural policy shock ($\varepsilon_t^1$). Then, regress $\hat{u}_t^k$, $k = 2, 3, \ldots, n$ on $\hat{\varepsilon}^1_t$. Since the coefficient of this regression means the variation of $\hat{u}_t^k$ caused by the variations in $\hat{u}_t^1$ owing to $\varepsilon_t^1$, it is $s^k/s^1$.

$$u_t = \frac{s^k}{s^1} \hat{u}_t^1 + \zeta_t.$$

If we can find $s^1$, other elements of the first column of $S$ are easily found from the estimates of equation (A.6). $s^1$ can be obtained from equations (A.4) and (A.6). First, partition $S$ and $\Sigma$. Then, from equation (A.4),

$$S = \begin{pmatrix} s^1 & s_{1,2} \\ s_{2,1} & s^2 \end{pmatrix}, \quad \Sigma = \begin{pmatrix} \Sigma_{1,1} & \Sigma_{1,2} \\ \Sigma_{2,1} & \Sigma_{2,2} \end{pmatrix} = \begin{pmatrix} s^1 & s_{1,2} \\ s_{2,1} & s^2 \end{pmatrix}^T \begin{pmatrix} s^1 & s_{1,2} \\ s_{2,1} & s^2 \end{pmatrix}. \tag{A.7}$$
Then, \( (s^1)^2 = \Sigma_{1,1} - s_{1,2} s_{1,2}^T \) where \( s_{1,2} s_{1,2}^T = (\Sigma_{2,1} - \frac{s_{2,1}}{s_{1,1}} \Sigma_{2,1} \Sigma_{2,1}^T)^T Q^{-1} (\Sigma_{2,1} - \frac{s_{2,1}}{s_{1,1}} \Sigma_{2,1} \Sigma_{2,1}^T) \) with \( Q = \frac{s_{2,1}}{s_{1,1}} \Sigma_{2,1} \frac{s_{2,1}}{s_{1,1}} \Sigma_{2,1}^T - (\Sigma_{2,1} \frac{s_{2,1}}{s_{1,1}} \Sigma_{2,1}^T + \frac{s_{2,1}}{s_{1,1}} \Sigma_{2,1} \Sigma_{2,1}^T) + \Sigma_{2,2} \). Therefore, the ordering of variables is arbitrary in this framework.

Nonetheless, to identify the policy shocks we need to find the values of elements in the first row of \( A, [a_{11}, a_{12}, \ldots, a_{1n}] \), with \( a_{11} = 1 \) due to a normalization. The method to obtain these values is explained well in Ramey (2016). First, regress \( \hat{z}_h^h, h = 2, 3, \ldots, n \) on \( \hat{u}_t^1 \) using the instrument \( z_t \), which yields unbiased estimates of the elements in the first column of \( A, -a_{21}, -a_{31}, \ldots, -a_{n1} \). Then, regress \( \hat{z}_h^1 \) on \( \hat{z}_h^h, h = 2, 3, \ldots, n \) using \( \hat{v}_t^h, h = 2, 3, \ldots, n \) as instruments where \( \hat{v}_t^h, h = 2, 3, \ldots, n \) are residuals of previous regressions. This gives unbiased estimates of \( -a_{12}, -a_{13}, \ldots, -a_{1n} \). Therefore, the estimate of the policy shocks can be obtained from

\[
\hat{\epsilon}_t = \hat{u}_t - a_{12}\hat{u}_t - a_{13}\hat{u}_t - \ldots - a_{1n}\hat{u}_t.
\] (A.8)
B. Impulse Responses to an Expansionary Monetary Policy Shock in the First Step

Note: The solid lines are the median effect, and the dashed lines are 68% confidence intervals obtained by bootstrapping with 5,000 draws.
C. Equilibrium Conditions of the Model

In this appendix, I present the equilibrium system of the three-country DSGE model with commodities and different commodity trade structures of countries described in Section III.

- Households' intertemporal problem:

\[
\lambda^i_t = \frac{1}{C^i_t - bC^i_{t-1}} - \beta b E_t \left[ \frac{1}{C^i_{t+1} - bC^i_t} \right],
\]  
(A.9)

\[
1 = \beta E_t \left[ \frac{\lambda^i_{t+1}}{\lambda^i_t} R^i_t \right],
\]  
(A.10)

\[
\lambda^i_t W^i_t = L^i_t,
\]  
(A.11)

\[
\lambda^i_t = \partial e^i_t \lambda^i_t, \ l \in \{B, C\},
\]  
(A.12)

where \(e^i_t\) denotes the real exchange rate between countries A and \(l \in \{B, C\}\), and \(L^i_t = \sum_s L^i_s\).

- Households' consumption allocation:

\[
C^i_{NC,t} = (1 - \gamma^i_0)p^i_{NC,t} C^i_t,
\]  
(A.13)

\[
C^i_{X,t} = \gamma^i_0 p^i_{X,t} C^i_t,
\]  
(A.14)

\[
C^i_{X,i,t} = (1 - \gamma)C^i_{X,t}, \ i \in \{A, B\},
\]  
(A.15)

\[
C^C_{X,C,t} = C^C_{X,t},
\]  
(A.16)

\[
C^i_{X,C,t} = \gamma C^i_{X,t}, \ i \in \{A, B\},
\]  
(A.17)

\[
C^i_{T,t} = (1 - \gamma^i_1) \left( \frac{p_{T,t}^i}{p_{NC,t}} \right)^{-\eta^i} C^i_{NC,t},
\]  
(A.18)
\[ C_N^t = \gamma_0 \left( \frac{p_{N,t}}{p_{NC,t}} \right)^{-\eta_1} C_{NC,t}^t, \quad \text{(A.19)} \]
\[ C_i^t = (1 - \gamma_2) \left( \frac{p_{i,t}}{p_{T,t}} \right)^{-\eta_2} C_{T,t}^i, \quad \text{(A.20)} \]
\[ C_{B,t}^i = \frac{\gamma_2}{2} \left( \frac{p_{i,t}}{p_{T,t}} \right)^{-\eta_2} C_{T,t}^i, \quad l \neq i, \quad \text{(A.21)} \]
\[ C_{C,t}^i = \frac{\gamma_2}{2} \left( \frac{p_{m,t}}{p_{T,t}} \right)^{-\eta_2} C_{T,t}^i, \quad m \neq i, l. \quad \text{(A.22)} \]

- **Price indices:**

\[ 1 = (1 - \gamma_1) p_{NC,t}^j + \gamma_0 p_{X,t}^j, \quad \text{(A.23)} \]
\[ p_{X,t}^j = (1 - \gamma) p_{X,i,t}^j + \gamma p_{X,C,t}^j, \quad i \in \{A, B\}, \quad \text{(A.24)} \]
\[ p_{X,t}^C = p_{X,C,t}^C, \quad \text{(A.25)} \]
\[ p_{NC,t}^j = (1 - \gamma_1) p_{NC,t}^j + \gamma_1 p_{N,t}^j, \quad \text{(A.26)} \]
\[ p_{T,t}^j = (1 - \gamma_1) p_{i,t}^j + \frac{\gamma_2}{2} p_{t,t}^j + \frac{\gamma_2}{2} p_{m,t}^j, \quad l \neq i, m \neq i, l. \quad \text{(A.27)} \]

- **Laws of one price:**

\[ p_{A,t}^A = e_t^B p_{A,t}^B, \quad \text{(A.28)} \]
\[ p_{B,t}^A = e_t^B p_{B,t}^B, \quad \text{(A.29)} \]
\[ p_{C,t}^A = e_t^B p_{C,t}^B, \quad \text{(A.30)} \]
\[ p_{X,t}^A = e_t^B p_{X,t}^B, \quad \text{(A.31)} \]
\[ p_{A,t}^A = e_t^C p_{A,t}^C, \quad \text{(A.32)} \]
\[ p_{B,t}^A = e_t^C p_{B,t}^C, \quad (A.33) \]
\[ p_{C,t}^A = e_t^C p_{C,t}^C, \quad (A.34) \]
\[ p_{X,C,t}^A = e_t^C p_{X,C,t}^C. \quad (A.35) \]

- Nontradable intermediate good producing firms’ optimality conditions and price setting:

\[ Y_{N,t}^i, v_{N,t}^{p,i} = A_{N,t}^i K_{N,t}^i L_{N,t}^{j-n_x}, \quad (A.36) \]
\[ W_t^A = (1 - \alpha_N^N) m c_{N,t}^j v_{N,t}^{p,i} Y_{N,t}^i \]
\[ R_{t-1}^i = \frac{1}{Q_{N,t-1}^i} \left\{ (1 - \delta) Q_{N,t}^i + \alpha_N^N m c_{N,t}^j v_{N,t}^{p,i} Y_{N,t}^i \right\}, \quad (A.38) \]
\[ v_{N,t}^{p,i} = (1 - \theta) \left[ \frac{\epsilon}{\epsilon - 1} \frac{\Delta_{1,N,t}^i}{p_{N,t}^i \Delta_{2,N,t}^i} \right]^{1-\epsilon} + \theta v_{N,t-1}^{p,i} \pi_{N,t}^f, \quad (A.39) \]
\[ \pi_{N,t}^i = (1 - \theta) \left[ \frac{\epsilon}{\epsilon - 1} \frac{\pi_{N,t}^i}{\Delta_{1,N,t}^i} \right]^{1-\epsilon} + \theta, \quad (A.40) \]
\[ \Delta_{1,N,t}^i = \lambda_i^i Y_{N,t}^i m c_{N,t}^j + \beta_0 E_t \left[ \Delta_{1,N,t+1}^i \pi_{N,t+1}^f \right], \quad (A.41) \]
\[ \Delta_{2,N,t}^i = \lambda_i^j Y_{N,t}^i + \beta_0 E_t \left[ \Delta_{2,N,t+1}^i \pi_{N,t+1}^f \right], \quad (A.42) \]
\[ \pi_{N,t}^i = \pi_{t-1}^i \frac{p_{N,t}^i}{\pi_{N,t-1}^i}, \quad (A.43) \]

where \( v_{s,t}^{p,i} \) denotes the price dispersion term in sector \( s \).
- Tradable intermediate good producing firms’ optimality conditions and price setting:

\[ Y^j_{i,t} p^j_{i,t} = A^i_{T,t} \left\{ (1 - a) K^{i,j}_t + ax^i_t \right\}^{-\alpha} L^{i,j}_t, \]  
\[ W^i_t = (1 - a) mc^j_{i,t} \frac{v^j_{T,t} Y^j_{i,t}}{L^i_{i,t}}, \]  
\[ R^j_{i,t-1} = \frac{1}{Q^j_{T,t-1}} \left\{ (1 - \delta) Q^j_{T,t} + \alpha (1 - a) mc^j_{i,t} K^{i,j}_t \frac{v^j_{T,t} Y^j_{i,t}}{(1 - a) K^{i,j}_t + ax^i_t} \right\}. \]  

\[ p^{j,i}_{X,t} = \alpha mc^{j,i}_{T,t} x^{i,j}_t \frac{v^{j,i}_{T,t} Y^{j,i}_{i,t}}{(1 - a) K^{i,j}_t + ax^{i,j}_t}, \]  
\[ x^{i,j}_{i,t} = (1 - \gamma) x^{i,j}_t, \quad i \in \{A, B\}, \]  
\[ x^{C,j}_{C,t} = x^C, \]  
\[ x^{j,i}_{C,t} = \gamma x^{j,i}_t, \quad i \in \{A, B\}, \]  
\[ v^{p,i}_{T,t} = (1 - \theta) \left[ \frac{\varepsilon}{\varepsilon - 1} \frac{\Delta^i_{1,t,T}}{p^{i,j}_{i,t} \Delta^i_{2,t,T}} \right]^{-\varepsilon} + \theta v^{p,i}_{T,t-1} \pi^{i,j}_{i,t}, \]  
\[ \pi^{i,j}_{i,t} = (1 - \theta) \left[ \frac{\varepsilon}{\varepsilon - 1} \frac{\pi^{i,j}_{i,t}}{p^{i,j}_{i,t} \Delta^i_{2,t,T}} \right]^{1-\varepsilon} + \theta, \]  
\[ \Delta^i_{1,T,t} = \lambda^i_t Y^i_{i,t} mc^j_{T,t} + \beta \theta E_t \left[ \Delta^i_{1,t,T-1} \pi^{i,j}_{i,t-1} + 1 \right], \]  
\[ \Delta^i_{2,T,t} = \lambda^i_t Y^i_{i,t} + \beta \theta E_t \left[ \Delta^i_{2,t,T-1} \pi^{i,j}_{i,t-1} \right], \]  
\[ \pi^{i,j}_{i,t} = \pi^{i,j}_{i,t-1} \frac{p^{j,i}_{i,t}}{p^j_{i,t-1}}. \]
- Commodity intermediate good producing firms’ optimality conditions
and price setting:

\[ Y^i_{X,t} v^{p,i}_{X,t} = A^i_X K^{i \gamma}_{X,t} L^{i \gamma}_{X,t}, \]  
\[ (A.56) \]

\[ W^i_t = (1 - \alpha_X) mc^{i \gamma}_{X,t} v^{p,i}_{X,t} Y^i_{X,t}, \]
\[ (A.57) \]

\[ R^i_{t-1} = \frac{1}{Q^i_{X,t-1}} \left\{ (1 - \delta) Q^i_{X,t} + \alpha_X mc^{i \gamma}_{X,t} \frac{v^{p,i}_{X,t} Y^i_{X,t}}{K^i_{X,t}} \right\}, \]
\[ (A.58) \]

\[ v^{p,i}_{X,t} = (1 - \theta) \left[ \frac{\varepsilon}{\varepsilon - 1} \frac{\Delta^i_{1,X,t}}{p^i_{X,i,t} \Delta^i_{2,X,t}} \right]^{-\varepsilon} + \theta v^{p,i}_{X,t-1} \pi^{i \gamma}_{X,i,t}, \]
\[ (A.59) \]

\[ \pi^{i \gamma}_{X,i,t} = (1 - \theta) \left[ \frac{\varepsilon}{\varepsilon - 1} \frac{\pi^{i \gamma}_{X,i,t} \Delta^i_{1,X,t}}{p^i_{X,i,t} \Delta^i_{2,X,t}} \right]^{1-\varepsilon} + \theta, \]
\[ (A.60) \]

\[ \Delta^i_{1,X,t} = \lambda^i_Y Y^i_{X,t} mc^{i \gamma}_{X,t} + \beta \theta E_t \left[ \Delta^i_{1,X,t+1} \pi^{i \gamma}_{X,i,t+1} \right], \]
\[ (A.61) \]

\[ \Delta^i_{2,X,t} = \lambda^i_Y Y^i_{X,t} + \beta \theta E_t \left[ \Delta^i_{2,X,t+1} \pi^{i \gamma}_{X,i,t+1} \right], \]
\[ (A.62) \]

\[ \pi^{i \gamma}_{X,i,t} = \frac{p^i_{X,i,t}}{p^i_{X,i,t-1}}. \]
\[ (A.63) \]

- Laws of motion for capital:

\[ K^{i \gamma}_{X,t+1} = \left[ 1 - \frac{\xi}{2} \left( \frac{I^i_{X,t}}{I^i_{X,t-1}} - 1 \right) \right] I^i_{X,t} + (1 - \delta) K^{i \gamma}_{X,t}, \]
\[ (A.64) \]

\[ K^{i \gamma}_{T,t+1} = \left[ 1 - \frac{\xi}{2} \left( \frac{I^i_{T,t}}{I^i_{T,t-1}} - 1 \right) \right] I^i_{T,t} + (1 - \delta) K^{i \gamma}_{T,t}, \]
\[ (A.65) \]

\[ K^{i \gamma}_{X,t+1} = \left[ 1 - \frac{\xi}{2} \left( \frac{I^i_{X,t}}{I^i_{X,t-1}} - 1 \right) \right] I^i_{X,t} + (1 - \delta) K^{i \gamma}_{X,t}. \]
\[ (A.66) \]
- Optimal investment:

\[
p^i_{N,t} = Q^i_{N,t} \left[ 1 - \frac{\xi}{2} \left( \frac{I^i_{N,t}}{I^i_{N,t-1}} - 1 \right)^2 \right] - \xi Q^i_{N,t} \frac{p^i_{N,t}}{I^i_{N,t-1}} \left( \frac{I^i_{N,t}}{I^i_{N,t-1}} - 1 \right)
\]

\[+ \beta \xi E_t \left[ \frac{\lambda_{i+1}}{\lambda^i_t} \frac{I^2_{N,t+1}}{I^2_{N,t}} \left( \frac{I^i_{N,t+1}}{I^i_{N,t}} - 1 \right)Q^i_{N,t+1} \right], \tag{A.67}\]

\[
p^i_{T,t} = Q^i_{T,t} \left[ 1 - \frac{\xi}{2} \left( \frac{I^i_{T,t}}{I^i_{T,t-1}} - 1 \right)^2 \right] - \xi Q^i_{T,t} \frac{p^i_{T,t}}{I^i_{T,t-1}} \left( \frac{I^i_{T,t}}{I^i_{T,t-1}} - 1 \right)
\]

\[+ \beta \xi E_t \left[ \frac{\lambda_{i+1}}{\lambda^i_t} \frac{I^2_{T,t+1}}{I^2_{T,t}} \left( \frac{I^i_{T,t+1}}{I^i_{T,t}} - 1 \right)Q^i_{T,t+1} \right], \tag{A.68}\]

\[
p^i_{X,t} = Q^i_{X,t} \left[ 1 - \frac{\xi}{2} \left( \frac{I^i_{X,t}}{I^i_{X,t-1}} - 1 \right)^2 \right] - \xi Q^i_{X,t} \frac{p^i_{X,t}}{I^i_{X,t-1}} \left( \frac{I^i_{X,t}}{I^i_{X,t-1}} - 1 \right)
\]

\[+ \beta \xi E_t \left[ \frac{\lambda_{i+1}}{\lambda^i_t} \frac{I^2_{X,t+1}}{I^2_{X,t}} \left( \frac{I^i_{X,t+1}}{I^i_{X,t}} - 1 \right)Q^i_{X,t+1} \right]. \tag{A.69}\]

- Resource constraints:

\[
Y^i_{N,t} = C^i_{N,t} + I^i_{N,t}, \tag{A.70}\]

\[
Y^i_{i,t} = C^i_{i,t} + C^m_{i,t} + I^i_{T,t}, \quad l \neq i, m \neq i, l, \tag{A.71}\]

\[
Y^i_{X,t} = C^i_{X,t} + x^i_{i,t} + I^i_{X,t}, \quad i \in \{A, B\}, \tag{A.72}\]

\[
Y^C_{X,t} = C^A_{X,t} + C^B_{X,t} + C^C_{X,t} + x^A_{C,t} + x^B_{C,t} + x^C_{t} + I^C_{X,t}. \tag{A.73}\]

- Monetary policy and Fisher equations:

\[
i^i_t = (1 - \rho_i) \bar{i}^i + \rho_i i^i_{t-1} + (1 - \rho_i) \left\{ \phi_\pi (\pi^i_t - \pi^i) + \phi_Y (\ln Y^i_t - \ln Y^i) \right\} + u^i_t, \tag{A.74}\]

\[
R^i_t = E_t \left[ \frac{i^i_t}{\pi^i_{t+1}} \right]. \tag{A.75}\]
D. Responses of the Model to an Expansionary Monetary Policy Shock to Country A

(a) Nontradable Output
(b) Nontradable Consumption
(c) Investment in Nontradable Sector

(d) Tradable Output
(e) Tradable Consumption
(f) Investment in Tradable Sector

(g) Commodity Output
(h) Commodity Consumption
(i) Investment in Commodity Sector
Transmission of U.S. Monetary Policy to Commodity Exporters and Importers

(i) Consumption of $A$’s Tradables

(k) Consumption of $B$’s Tradables

(l) Consumption of $C$’s Tradables

(m) Commodity Input for Production

(n) Real Price of Nontradables

(o) Real Commodity Price

(p) Real Price of $A$’s Tradables

(q) Real Price of $B$’s Tradables

(r) Real Price of $C$’s Tradables
미국의 통화정책이 원자재 수출국과 수입국에 미치는 영향

김명현*

본고는 미국의 통화정책이 원자재 수출국과 수입국에 미치는 영향에 대해 분석하였다. 먼저 실증분석을 통해 미국의 확장적 통화정책 충격이 원자재 수입국에 비해 수출국에 더 큰 영향을 미친 것을 보였다. 원자재가 포함된 3국 모형을 구축한 후 시뮬레이션을 실시한 결과도 실증분석 결과와 동일하였다. 이러한 결과는 미국의 확장적 통화정책에 따른 미국의 총수요 증가로 미국의 원자재에 대한 수요가 늘어나고 국제원자재가격이 상승함에 따라 원자재 수출국의 수출이 수입국에 비해 더 크게 증가하기 때문인 것으로 나타났다. 한편 3국 모형내의 원자재 수출국이 고정 환율제를 채택할 경우 미국의 통화정책의 원자재 수출국 및 수입국에 대한 영향이 더욱 커지며, 미국이 에너지 순수출국이 될 경우에는 미국의 통화정책의 수출국에 대한 영향은 줄어들고 수입국에 대한 영향은 확대되는 것으로 분석되었 다.

핵심 주제어: 통화정책 충격의 파급효과, 원자재 수출국, 원자재 수입국, 도구변수를 이용한 VAR

JEL Classification: E52, F42, Q43

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이 연구내용은 집필자의 개인의견이며 한국은행의 공식견해와는 무관합니다. 따라서 본 논문의 내용을 보도하거나 인용할 경우에는 집필자명을 반드시 명시하여주시기 바랍니다.
 Korean Bank for International Cooperation (KOF) Economic Review

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한국은행 경제연구원에서는 Working Paper인『BOK 경제연구』를 수시로 발간하고 있습니다.『BOK 경제연구』는 주요 경제 현상 및 정책 효과에 대한 직관적 설명 뿐 아니라 깊이 있는 이론 또는 실증 분석을 제공함으로써 엄밀한 논증에 초점을 두는 학술논문 형태의 연구이며 한국은행 직원 및 한국은행 연구용역사업의 연구 결과물이 수록되고 있습니다.
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제2015-1 글로벌 금융위기 이후 주요국 통화정책 운영체계의 변화
김병기・김인수

2 미국 장기시장금리 변동이 우리나라 금리기간구조에 미치는 영향 분석 및 정책적 시사점
강규호・오형석

3 직간접 무역연계성을 통한 해외충격의 우리나라 수출입 파급효과 분석
최문정・김근영

4 통화정책 효과의 지역적 차이
김기호

5 수입중간재의 비용효과를 고려한 환율변동과 수출가격 간의 관계
김경민

6 중앙은행의 정책금리 발표가 주식시장 유동성에 미치는 영향
이지은

7 은행 건전성지표의 변동요인과 거시건전성 규제의 영향
강종구

8 Price Discovery and Foreign Participation in The Republic of Korea’s Government Bond Futures and Cash Markets
Jaehun Choi・Hosung Lim・Rogelio Jr. Mercado・Cyn–Young Park

9 규제가 노동생산성에 미치는 영향: 한국의 산업패널 자료를 이용한 실증분석
이동렬・최종일・이종한

10 인구 고령화와 정년연장 연구 (세대 간 중첩모델(OLG)을 이용한 정량 분석)
홍재화・강태수

11 예측조합 및 밀도함수에 의한 소비자물가 상승률 전망
김현학

12 인플레이션 동학과 통화정책
우준명

13 Failure Risk and the Cross-Section of Hedge Fund Returns
Jung-Min Kim

14 Global Liquidity and Commodity Prices
Hyunju Kang・Bok-Keun Yu・Jongmin Yu
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Foreign Ownership, Legal System and Stock Market Liquidity</td>
<td>Jieun Lee · Kee H. Chung</td>
</tr>
<tr>
<td>17</td>
<td>바젤Ⅲ 은행 경기대응완충자본 규제의 기준지표에 대한 연구</td>
<td>서현덕 · 이정연</td>
</tr>
<tr>
<td>18</td>
<td>우리나라 대출 수요와 공급의 변동요인 분석</td>
<td>강종구 · 임호성</td>
</tr>
<tr>
<td>19</td>
<td>북한 인구구조의 변화 추이와 시사점</td>
<td>최지영</td>
</tr>
<tr>
<td>20</td>
<td>Entry of Non-financial Firms and Competition in the Retail Payments Market</td>
<td>Jooyong Jun</td>
</tr>
<tr>
<td>21</td>
<td>Monetary Policy Regime Change and Regional Inflation Dynamics: Looking through the Lens of Sector-Level Data for Korea</td>
<td>Chi-Young Choi · Joo Yong Lee · Roisin O'Sullivan</td>
</tr>
<tr>
<td>23</td>
<td>글로벌 금리 정상화와 통화정책 과제: 2015년 한국은행 국제컨퍼런스 결과보고서</td>
<td>한국은행 경제연구원</td>
</tr>
<tr>
<td>24</td>
<td>The Effects of Global Liquidity on Global Imbalances</td>
<td>Marie-Louise DJIGBENOU-KRE · Hail Park</td>
</tr>
<tr>
<td>25</td>
<td>심물경기를 고려한 내재 유동성 측정</td>
<td>우준명 · 이지은</td>
</tr>
<tr>
<td>26</td>
<td>Deflation and Monetary Policy</td>
<td>Barry Eichengreen</td>
</tr>
<tr>
<td>27</td>
<td>Macroeconomic Shocks and Dynamics of Labor Markets in Korea</td>
<td>Tae Bong Kim · Hangyu Lee</td>
</tr>
<tr>
<td>28</td>
<td>Reference Rates and Monetary Policy Effectiveness in Korea</td>
<td>Heung Soon Jung · Dong Jin Lee · Tae Hyo Gwon · Se Jin Yun</td>
</tr>
<tr>
<td>29</td>
<td>Energy Efficiency and Firm Growth</td>
<td>Bongseok Choi · Wooyoung Park · Bok–Keun Yu</td>
</tr>
<tr>
<td>30</td>
<td>An Analysis of Trade Patterns in East Asia and the Effects of the Real Exchange Rate Movements</td>
<td>Moon Jung Choi · Geun–Young Kim · Joo Yong Lee</td>
</tr>
<tr>
<td></td>
<td>Forecasting Financial Stress Indices in Korea: A Factor Model Approach</td>
<td>Hyeongwoo Kim · Hyun Hak Kim · Wen Shi</td>
</tr>
<tr>
<td>제2016-1</td>
<td>The Spillover Effects of U.S. Monetary Policy on Emerging Market Economies: Breaks, Asymmetries and Fundamentals</td>
<td>Geun-Young Kim · Hail Park · Peter Tillmann</td>
</tr>
<tr>
<td>2</td>
<td>Pass-Through of Imported Input Prices to Domestic Producer Prices: Evidence from Sector-Level Data</td>
<td>JaeBin Ahn · Chang-Gui Park · Chanho Park</td>
</tr>
<tr>
<td>3</td>
<td>Spillovers from U.S. Unconventional Monetary Policy and Its Normalization to Emerging Markets: A Capital Flow Perspective</td>
<td>Sangwon Suh · Byung-Soo Koo</td>
</tr>
<tr>
<td>5</td>
<td>정책금리 변동이 성별·세대별 고용률에 미치는 영향</td>
<td>정성엽</td>
</tr>
<tr>
<td>6</td>
<td>From Firm-level Imports to Aggregate Productivity: Evidence from Korean Manufacturing Firms Data</td>
<td>JaeBin Ahn · Moon Jung Choi</td>
</tr>
<tr>
<td>7</td>
<td>자유무역협정(FTA)이 한국 기업의 기업내 무역에 미친 효과</td>
<td>전봉걸 · 김은숙 · 이주용</td>
</tr>
<tr>
<td>8</td>
<td>The Relation Between Monetary and Macroprudential Policy</td>
<td>Jong Ku Kang</td>
</tr>
<tr>
<td>9</td>
<td>조세피난처 투자자가 투자 기업 및 주식 시장에 미치는 영향</td>
<td>정호성 · 김순호</td>
</tr>
<tr>
<td>10</td>
<td>주택실거래 자료를 이용한 주택부문 거시 건전성 정책 효과 분석</td>
<td>정호성 · 이지은</td>
</tr>
<tr>
<td>11</td>
<td>Does Intra-Regional Trade Matter in Regional Stock Markets?: New Evidence from Asia-Pacific Region</td>
<td>Sei-Wan Kim · Moon Jung Choi</td>
</tr>
<tr>
<td>12</td>
<td>Liability, Information, and Anti-fraud Investment in a Layered Retail Payment Structure</td>
<td>Kyoung-Soo Yoon · Jooyong Jun</td>
</tr>
<tr>
<td>13</td>
<td>Testing the Labor Market Dualism in Korea</td>
<td>Sungyup Chung · Sunyoung Jung</td>
</tr>
<tr>
<td>14</td>
<td>북한 이중경제 사회계정행렬 추정을 통한 비공식부문 분석</td>
<td>최지영</td>
</tr>
<tr>
<td>No.</td>
<td>Title</td>
<td>Authors</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>15</td>
<td>Divergent EME Responses to Global and Domestic Monetary Policy Shocks</td>
<td>Woon Gyu Choi, Byongju Lee, Taesu Kang, Geun-Young Kim</td>
</tr>
<tr>
<td>16</td>
<td>Loan Rate Differences across Financial Sectors: A Mechanism Design Approach</td>
<td>Byoung-Ki Kim, Jun Gyu Min</td>
</tr>
<tr>
<td>17</td>
<td>근로자의 고용형태가 임금 및 소득 분포에 미치는 영향</td>
<td>최충, 정성엽</td>
</tr>
<tr>
<td>18</td>
<td>Endogeneity of Inflation Target</td>
<td>Soyoung Kim, Geunhyung Yim</td>
</tr>
<tr>
<td>19</td>
<td>Who Are the First Users of a Newly-Emerging International Currency? A Demand-Side Study of Chinese Renminbi Internationalization</td>
<td>Hyoung-kyu Chey, Geun-Young Kim, Dong Hyun Lee</td>
</tr>
<tr>
<td>20</td>
<td>기업 취약성 지수 개발 및 기업 부실화에 대한 영향 분석</td>
<td>최영준</td>
</tr>
<tr>
<td>21</td>
<td>US Interest Rate Policy Spillover and International Capital Flow: Evidence from Korea</td>
<td>Jieun Lee, Jung-Min Kim, Jong Kook Shin</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Which Monetary Shocks Matter in Small Open Economies? Evidence from SVARs</td>
<td>Jongrim Ha, Inhwan So</td>
</tr>
<tr>
<td>3</td>
<td>FTA의 물가 안정화 효과 분석</td>
<td>곽노선, 임호성</td>
</tr>
<tr>
<td>4</td>
<td>The Effect of Labor Market Polarization on the College Students’ Employment</td>
<td>Sungyup Chung</td>
</tr>
<tr>
<td>5</td>
<td>국내 자영업의 폐업률 결정요인 분석</td>
<td>남윤미</td>
</tr>
<tr>
<td>6</td>
<td>차주별 패널자료를 이용한 주택담보대출의 연체요인에 대한 연구</td>
<td>정호성</td>
</tr>
<tr>
<td>7</td>
<td>국면전환 확산과정모형을 이용한 콜금리 형태 분석</td>
<td>최승문, 김병국</td>
</tr>
<tr>
<td>제 2017-8</td>
<td>Behavioral Aspects of Household Portfolio Choice: Effects of Loss Aversion on Life Insurance Uptake and Savings</td>
<td>In Do Hwang</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>9</td>
<td>신용공급 충격이 재화별 소비에 미치는 영향</td>
<td>김광환 · 최석기</td>
</tr>
<tr>
<td>10</td>
<td>유가가 손익분기인플레이션에 미치는 영향</td>
<td>김진용 · 김준철 · 임형준</td>
</tr>
<tr>
<td>11</td>
<td>인구구조변화가 인플레이션의 장기 추세에 미치는 영향</td>
<td>강환구</td>
</tr>
<tr>
<td>12</td>
<td>종합적 성장률을 반영한 과다부채 가계의 리스크 요인 분석</td>
<td>이동진 · 한진현</td>
</tr>
<tr>
<td>13</td>
<td>Crowding out in a Dual Currency Regime? Digital versus Fiat Currency</td>
<td>KiHoon Hong · Kyounghoon Park · Jongmin Yu</td>
</tr>
<tr>
<td>14</td>
<td>Improving Forecast Accuracy of Financial Vulnerability: Partial Least Squares Factor Model Approach</td>
<td>Hyeongwoo Kim · Kyunghwan Ko</td>
</tr>
<tr>
<td>15</td>
<td>Which Type of Trust Matters?: Interpersonal vs. Institutional vs. Political Trust</td>
<td>In Do Hwang</td>
</tr>
<tr>
<td>16</td>
<td>기업특성에 따른 연령별 고용행태 분석</td>
<td>이상욱 · 권철우 · 남윤미</td>
</tr>
<tr>
<td>17</td>
<td>Equity Market Globalization and Portfolio Rebalancing</td>
<td>Kyungkeun Kim · Dongwon Lee</td>
</tr>
<tr>
<td>18</td>
<td>The Effect of Market Volatility on Liquidity and Stock Returns in the Korean Stock Market</td>
<td>Jieun Lee · KeeH.Chung</td>
</tr>
<tr>
<td>19</td>
<td>Using Cheap Talk to Polarize or Unify a Group of Decision Makers</td>
<td>Daeyoung Jeong</td>
</tr>
<tr>
<td>20</td>
<td>패스트트랙 기업회생절차가 법정관리 기업의 이자보상비율에 미친 영향</td>
<td>최영준</td>
</tr>
<tr>
<td>21</td>
<td>인구고령화가 경제성장에 미치는 영향</td>
<td>안병권 · 김기호 · 윤승환</td>
</tr>
<tr>
<td>22</td>
<td>고령화에 대응한 인구대책: OECD사례를 중심으로</td>
<td>김진일 · 박경훈</td>
</tr>
<tr>
<td>제2017-23</td>
<td>인구구조변화와 경상수지</td>
<td>김경근・김소영</td>
</tr>
<tr>
<td>24</td>
<td>통일과 고령화</td>
<td>최지영</td>
</tr>
<tr>
<td>25</td>
<td>인구고령화가 주택시장에 미치는 영향</td>
<td>오강현・김솔・윤재준・안상기・권동휘</td>
</tr>
<tr>
<td>26</td>
<td>고령화가 대외투자에 미치는 영향</td>
<td>임진수・김영래</td>
</tr>
<tr>
<td>27</td>
<td>인구고령화가 가계의 자산 및 부채에 미치는 영향</td>
<td>조세형・이용민・김정훈</td>
</tr>
<tr>
<td>28</td>
<td>인구고령화에 따른 우리나라 산업구조 변화</td>
<td>강종구</td>
</tr>
<tr>
<td>29</td>
<td>인구구조 변화와 재정</td>
<td>송호신・허준영</td>
</tr>
<tr>
<td>30</td>
<td>인구고령화가 노동수급에 미치는 영향</td>
<td>이철희・이지은</td>
</tr>
<tr>
<td>31</td>
<td>인구 고령화가 금융산업에 미치는 영향</td>
<td>윤경수・차재훈・박소희・강선영</td>
</tr>
<tr>
<td>32</td>
<td>금리와 은행 수익성 간의 관계 분석</td>
<td>한재준・소인환</td>
</tr>
<tr>
<td>33</td>
<td>Bank Globalization and Monetary Policy Transmission in Small Open Economies</td>
<td>Inhwan So</td>
</tr>
<tr>
<td>34</td>
<td>기존 경영자 관리인(DIP) 제도의 회생기업 경영성과에 대한 영향</td>
<td>최영준</td>
</tr>
<tr>
<td>35</td>
<td>Transmission of Monetary Policy in Times of High Household Debt</td>
<td>Youngju Kim・Hyunjoon Lim</td>
</tr>
<tr>
<td>제2018-1</td>
<td>4차 산업혁명과 한국의 혁신역량: 특허자료를 이용한 국가기술별 비교 분석, 1976-2015</td>
<td>이지홍・임현경・정대영</td>
</tr>
<tr>
<td>2</td>
<td>What Drives the Stock Market Comovements between Korea and China, Japan and the US?</td>
<td>Jinsoo Lee・Bok-Keun Yu</td>
</tr>
<tr>
<td>3</td>
<td>Who Improves or Worsens Liquidity in the Korean Treasury Bond Market?</td>
<td>Jieun Lee</td>
</tr>
<tr>
<td>No.</td>
<td>Title</td>
<td>Author(S)</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>4</td>
<td>Establishment Size and Wage Inequality: The Roles of Performance Pay and Rent Sharing</td>
<td>Sang-yoon Song</td>
</tr>
<tr>
<td>5</td>
<td>가계대출 부도요인 및 금융업권별 금융취약성: 자영업 차주들 중심으로</td>
<td>정호성</td>
</tr>
<tr>
<td>6</td>
<td>직업훈련이 청년취업률 제고에 미치는 영향</td>
<td>최충⋅김남주⋅최광성</td>
</tr>
<tr>
<td>7</td>
<td>재고투자와 경기변동에 대한 동직 분석</td>
<td>서병선⋅장근호</td>
</tr>
<tr>
<td>8</td>
<td>Rare Disasters and Exchange Rates: An Empirical Investigation of South Korean Exchange Rates under Tension between the Two Koreas</td>
<td>Cheolbeom Park⋅Suyeon Park</td>
</tr>
<tr>
<td>9</td>
<td>통화정책과 기업 설비투자 - 자산가격경로와 대차대조표경로 분석 -</td>
<td>박상준⋅육승환</td>
</tr>
<tr>
<td>10</td>
<td>Upgrading Product Quality: The Impact of Tariffs and Standards</td>
<td>Jihyun Eum</td>
</tr>
<tr>
<td>11</td>
<td>북한이탈주민의 신용행태에 관한 연구</td>
<td>정승호⋅민병기⋅김주원</td>
</tr>
<tr>
<td>12</td>
<td>Uncertainty Shocks and Asymmetric Dynamics in Korea: A Nonlinear Approach</td>
<td>Kevin Larcher⋅Jaebeom Kim⋅Youngju Kim</td>
</tr>
<tr>
<td>13</td>
<td>북한경제의 대외개방에 따른 경제적 후생 변화 분석</td>
<td>정혁⋅최창용⋅최지영</td>
</tr>
<tr>
<td>14</td>
<td>Central Bank Reputation and Inflation–Unemployment Performance: Empirical Evidence from an Executive Survey of 62 Countries</td>
<td>In Do Hwang</td>
</tr>
<tr>
<td>15</td>
<td>Reserve Accumulation and Bank Lending: Evidence from Korea</td>
<td>Youngjin Yun</td>
</tr>
<tr>
<td>16</td>
<td>The Banks' Swansong: Banking and the Financial Markets under Asymmetric Information</td>
<td>Jungu Yang</td>
</tr>
<tr>
<td>제2018-17</td>
<td>E-money: Legal Restrictions Theory and Monetary Policy</td>
<td>Ohik Kwon · Jaevin Park</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>18</td>
<td>글로벌 금융위기 전후 외국인의 채권투자 결정요인 변화 분석: 한국의 사례</td>
<td>유복근</td>
</tr>
<tr>
<td>19</td>
<td>설비자본재 기술진보가 근로유형별 임금 및 고용에 미치는 영향</td>
<td>김남주</td>
</tr>
<tr>
<td>20</td>
<td>Fixed–Rate Loans and the Effectiveness of Monetary Policy</td>
<td>Sung Ho Park</td>
</tr>
<tr>
<td>21</td>
<td>Leverage, Hand–to–Mouth Households, and MPC Heterogeneity: Evidence from South Korea</td>
<td>Sang–yoon Song</td>
</tr>
<tr>
<td>22</td>
<td>선진국 수입수요가 우리나라 수출에 미치는 영향</td>
<td>최문정 · 김경근</td>
</tr>
<tr>
<td>23</td>
<td>Cross–Border Bank Flows through Foreign Branches: Evidence from Korea</td>
<td>Youngjin Yun</td>
</tr>
<tr>
<td>24</td>
<td>Accounting for the Sources of the Recent Decline in Korea’s Exports to China</td>
<td>Moon Jung Choi · Kei–Mu Yi</td>
</tr>
<tr>
<td>25</td>
<td>The Effects of Export Diversification on Macroeconomic Stabilization: Evidence from Korea</td>
<td>Jinsoo Lee · Bok–Keun Yu</td>
</tr>
<tr>
<td>26</td>
<td>Identifying Uncertainty Shocks due to Geopolitical Swings in Korea</td>
<td>Seohyun Lee · Inhwan So · Jongrim Ha</td>
</tr>
<tr>
<td>27</td>
<td>Monetary Policy and Income Inequality in Korea</td>
<td>Jongwook Park</td>
</tr>
<tr>
<td>28</td>
<td>How the Financial Market Can Dampen the Effects of Commodity Price Shocks</td>
<td>Myunghyun Kim</td>
</tr>
<tr>
<td>30</td>
<td>Do Korean Exports Have Different Patterns over Different Regimes?: New Evidence from STAR–VECM</td>
<td>Sei–Wan Kim · Moon Jung Choi</td>
</tr>
<tr>
<td>31</td>
<td>기술진보와 청년고용</td>
<td>심명규 · 양희승 · 이서현</td>
</tr>
<tr>
<td>페이지</td>
<td>제목</td>
<td>저자</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>-----</td>
</tr>
<tr>
<td>32</td>
<td>북한지역 장기주택수요 및 연관주택건설투자 추정</td>
<td>이주영</td>
</tr>
<tr>
<td>33</td>
<td>기업규모간 임금격차 원인 분석</td>
<td>송상윤</td>
</tr>
<tr>
<td>34</td>
<td>우리나라 고용구조의 특징과 과제</td>
<td>장근호</td>
</tr>
<tr>
<td>35</td>
<td>창업의 장기 고용효과: 시군구 자료 분석</td>
<td>조성철, 김기호</td>
</tr>
<tr>
<td>36</td>
<td>수출입과 기업의 노동수요</td>
<td>음지현, 박진호, 최문정</td>
</tr>
<tr>
<td>37</td>
<td>청년실업의 이력현상 분석</td>
<td>김남주</td>
</tr>
<tr>
<td>38</td>
<td>노동시장 이중구조와 노동생산성: OECD 국가를 중심으로</td>
<td>최충, 최광성, 이지은</td>
</tr>
<tr>
<td>39</td>
<td>한국과 일본의 청년실업 비교분석 및시사점</td>
<td>박상준, 김남주, 장근호</td>
</tr>
<tr>
<td>40</td>
<td>노동시장의 이중구조와 정책대응: 해외사례 및 시사점</td>
<td>전병우, 황인도, 박광용</td>
</tr>
<tr>
<td>41</td>
<td>최저임금이 고용구조에 미치는 영향</td>
<td>송현재, 임현준, 신우리</td>
</tr>
<tr>
<td>42</td>
<td>최저임금과 생산성: 우리나라 제조업의 사례</td>
<td>김규일, 육승환</td>
</tr>
<tr>
<td>43</td>
<td>Transmission of U.S, Monetary Policy to Commodity Exporters and Importers</td>
<td>Myunghyun Kim</td>
</tr>
</tbody>
</table>
Transmission of U.S. Monetary Policy to Commodity Exporters and Importers

Myunghun Kim