The Effect of Quantitative Easing on Inflation in Korea[*]

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This paper evaluates the whole impact of quantitative easing on inflation in Korea
implemented by the central banks in four major advanced economies, the U.S., Euro Area,
U.K. and Japan. According to the analysis employing a VAR-X model with the security
holdings of those central banks an exogenous variable, quantitative easing is estimated to
exert downward pressures on inflation in Korea. Considering the impulse responses of
Korean macroeconomic variables to a quantitative easing shock, the spillover effect is
transmitted through exchange rate channel while trade channel turns out to be ineffective.
In an additional analysis assessing the impact of each quantitative easing program of the
central banks, only those of the Fed and European Central Bank are estimated to be
significant. The empirical results prove to be robust even if using long-term interest rates
as an alternative indicator of quantitative easing.

Keywords: Quantitative Easing, Security Holdings, Spillover Effects, Exchange Rate
and Trade Channel, Inflation in Korea, VAR-X
JEL Classification: E31, E58, F42

I. INTRODUCTION

For the purpose of providing further stimulus to the economic recovery after the
U.S. sub-prime crisis in 2008 while adding corporate bonds issued by private
enterprises residing in the Euro area to the list of purchasable assets. The Fed began
the first round of quantitative easing (QE) as early as in November 2008, and the QE
programs of the Bank of England (BOE) and European Central Bank (ECB) ensued
in March and June 2009, respectively. The Bank of Japan (BOJ) started the Asset
Purchase Program in October 2010. The QE programs (henceforth QEs) in those

advanced economies are regarded as effective in achieving the intended aim of reducing domestic long-term interest rates.[1] On the other hand, the QEs brought about unintended international spillover effects by creating excessive global liquidity (Korniyenko and Loukoianova, 2015). Continuous capital outflows from the advanced economies likely affected the financial conditions of emerging market economies (EMEs).[2] The spillover effects of the QEs have been empirically substantiated by numerous studies (Takáts and Vela, 2014; Bhattarai et al., 2015; Bowman et al., 2015; Chen et al., 2016; Tillmann, 2016; Anaya et al., 2017).[3]

Among those studies, Anaya et al. (2017) find economic growth accelerates and real exchange rates decrease in EMEs following the Fed's QE using data on portfolio outflows from the U.S. as a proxy for QE. Miyajima et al. (2014) estimate the effects of the Fed's QE on five Asian economies including Korea. Their empirical results reveal that exchange rates do not respond significantly to a decline in 10-year U.S. Treasury yield while inflation pressure diminishes substantially. Chen et al. (2016) evaluate the average effects of the Fed's QE on major advanced economies and fourteen EMEs. The results of their analysis indicate that, in Asian EMEs, appreciation pressures on local currency intensify and inflation decreases responding to a QE shock from the U.S. Bhattarai et al. (2015) find an expansionary U.S. QE shock exerts a significant influence on financial variables in EMEs.[4] Tillmann (2016) also finds each of the three rounds of QE and the Maturity Extension Program (MEP) immediately expands capital flows into EMEs and induce appreciation in their currency value.

While the research on the impacts of the Fed's QE on financial variables in EMEs have been burgeoning, macroeconomic variables in EMEs have not been paid due attention in the literature. Even in the several, if any, studies which include output and inflation in EMEs in the variable set of interest, those variables are treated as a secondary

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[1] Numerous studies have provided the empirical results that QE induced long-term interest rates to fall. Earlier studies such as Christensen and Rudebusch (2012), Gagnon et al. (2011) and Joyce et al. (2011) estimate long-term interest rates to decrease by between 50 and 100 basis points in the U.S. and U.K.

[2] A number of studies, *inter alia*, Fratzscher et al. (2016) and Tillmann (2016), empirically verify the positive impact of the Fed's QE on capital flows into EMEs.

[3] Another strand of research such as Gambacorta et al. (2014) focuses on the effects of QE inside the advanced economies.

[4] Bhattarai et al. (2015) use the security holdings of the Fed as an indicator of the QE which directly reflect the liquidity effect of the large-scale asset purchase (LSAP) instead of long-term interest rates or term spreads widely employed in the research.

concern. In particular, the estimated effect of the Fed's QE on inflation in EMEs is insignificant or negligible at the most.

Against this backdrop, the role of QE has been nearly overlooked in explaining the downward phase of inflation in Korea from 2011 to 2014. Meanwhile, as the reasons for that, researchers have suggested anemic expenditure on consumption and investment on the demand side and decreases in the prices of crude oil and intermediate goods on the supply side. However, considering the prevalent results from existing studies that the Fed's QE led to appreciation in the currency value of EMEs, the QEs of the central banks in advanced economies as a whole might amplify the aforementioned downward pressures arising from weak aggregate demand and lower input prices on inflation through exchange rate channel.[5]

Motivated by these considerations, this paper aims to estimate the spillover effect of the QEs on inflation in Korea implemented by the central banks of four major advanced economies, namely, the U.S., Euro Area, Japan and U.K. on inflation in Korea through estimating a VAR-X model with the security holdings of those central banks an exogenous variable. The paper has two important distinctions compared to the existing studies in the same strand. First, since only Korean data is used for the analysis, the impact of the QEs unique to Korea can be identified instead of the average impact on EMEs. Second, unlike previous studies focusing their attention only on the Fed's QE, the paper takes into account all the QEs implemented by the central banks of the major advanced economies (henceforth, *the major central banks*).

The empirical results of the analysis uncover that the QEs as a whole exert additional downward pressures on inflation in Korea through appreciation in the currency value. On the other hand, transmission of QEs through trade channel enlarging aggregate demand in EMEs turns out to be ineffective. Comparing the impacts of the individual QE programs on inflation in Korea, only those of the Fed and ECB are estimated to be significant. As regards the robustness of the empirical results, the results of an alternative estimation using long-term interest rates instead of the security holdings as an alternative indicator of QE remain in line with the baseline results.

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[5] According to Gong et al. (2014), if the exchange rate of Korean Won against U.S. dollar declines by 10% on a year-on-year basis, inflation measured by Consumer Price Index falls by 0.3 percentage point. Kim (2012) verifies the positive relationship between exchange rate and consumer price inflation. Earlier, Kim (2006) also finds changes in exchange rate are passed onto consumer prices through import prices and producers' prices.

The remainder of the paper is organized as follows. Section II provides an overview of each QEs of the major central banks. Section III elaborates on possible transmission channels through which the QEs affect inflation in Korea. Section IV presents the results of empirical analysis. Section V concludes with a summary and policy implications.

II. OVERVIEW OF QUANTITATIVE EASING IN ADVANCED ECONOMIES

This section presents a brief overview of the QEs implemented by the Fed, ECB, BOJ and BOE following the sub-prime crisis.

Firstly, the Fed conducted three rounds of QE consecutively from November 2008 to October 2014 as shown in Table 1 to induce long-term interest rates to fall while lowering the target range for the federal funds rate to the zero lower bound in December 2008.[6] The Fed purchased mainly agency mortgage-backed securities (MBS) and long-term treasury bonds totalling approximately 4 trillion U.S. dollars (henceforth *dollars*). In the meantime, it also implemented the Maturity Extension Program (MEP) to extend the average maturity of its assets by replacing short-term securities with longer-term ones aiming at adding further downward pressures on long-term interest rates.[7]

Table 1. Quantitative Easing by the Fed

(billion dollars)

Program	Implementation Period	Purchased Asseets	Purchase Amount
QE1	Nov. 2008 – Mar. 2010	Long-term Treasury Bond	3,000
		MBS	12,500
		Agency Debt	1,750
QE2	Nov. 2010 – Jun. 2011	Long-term Treasury Bond	6,000
QE3	Sep. 2012 – Oct. 2014	Long-term Treasury Bond	7,900
		MBS	8,400

Source: Federal Reserve

[6] Academic attempts have been accumulated to quantify the effects of the Fed's QE and MEP on long-term interest rates. According to Bonis et al. (2017), yields on 10-year Treasury would be higher by 100 basis points without QE.

[7] Under the MEP, the Fed sold short-term Treasury securities maturing less than three years to buy long-term ones. The program resulted in the purchase of an additional 267 billion dollars in Treasury securities.

The ECB also embarked on a series of QE programs from June 2009 as shown in Table 2. Whereas the Fed's QE was meant to lower long-term interest rates from the very beginning, the ECB's initial QE programs, the first two rounds of Covered Bond Purchase Programme (CBPP) and the Securities Markets Programme (SMP), were intended to supply sufficient liquidity for easing credit conditions in the Euro Area. However, as inflation continued to hover far below the targeted level of *below but close to 2%* and economic recovery remained at a standstill because of the sovereign debt crisis originating from southern European countries, the ECB launched a series of expanded asset purchase program in March 2015. Under the Public Sector Purchase Programme (PSPP), the ECB purchased the sovereign bonds issued by the governments of all the member states less than 60 billion euros every month.[8] Moreover, introducing the Corporate Sector Purchase Programme (CSPP) in 2016, it elevated the ceiling on monthly purchase amount to 80 billion euros while adding to the list of purchasable assets for purchasing corporate bonds issued by private enterprises residing in the Euro Area.

Table 2. Quantitative Easing by the ECB

(billion euros)

Program	Implementation Period	Purchased Asseets	Purchase Amount
CBPP1	Jan. 2009 – Jun. 2010	Mortgage-backed CB	60
CBPP2	Nov. 2011 – Oct. 2012	Mortgage-backed CB	16
SMP	May 2010 – Sep. 2012	Sovreign Debt of Countries in Fiscal Crisis	218
CBPP3	Oct. 2014 – present	CB issued by Financial Institutions	261
ABSPP	Nov. 2014 – present	ABS issued by Non-banking Institutions	28
PSPP	Mar. 2015 – present	Dedt of Government and Government Agency	2,068
CSPP	Jun. 2016 – present	Corporate Bonds	164

Notes: 1) The acronyms in the table stand for what is in the following parentheses: CB (Covered Bond), CBPP (Covered Bond Purchase Programme), SMP (Securities Markets Programme), ABSPP (Asset-backed Securities Purchase Programme), PSPP (Public Sector Purchase Program), CSPP (Corporate Sector Purchase Programme).
        2) The purchase amount is in net as of June 2018.
Source: ECB

[8] Under the PSPP, the range of eligible assets for purchase also included, alongside government securities, governmental agency debts and euro-denominated securities issued by international organizations residing in the Euro Area.

The BOJ, having already lowered policy rates to 0.5% even before the sub-prime crisis, launched the Asset Purchase Program (APP) in 2010 to expand the scope of policy for boosting the economy. As shown in Table 3, the BOJ purchased 76 trillion yen under the APP in various debts including government bonds, corporate bonds and commercial papers from October 2010 through March 2013. However, as deflation persisted even after implementing the APP, the BOJ entered the new phase of QE in 2013. The bank introduced the price stability target of 2% in January 2013 and subsequently launched the Quantitative and Qualitative Monetary Easing (QQE) in April the same year as a means to achieving the inflation target. It set the target for annual purchase of Japanese government bonds (JGBs) as 50 trillion yen while aiming to extend the average remaining maturity of the government bonds it held to about seven years. The BOJ has maintained the QQE regime modifying the main components of the policy framework.[9]

Table 3. Quantitative Easing by the Bank of Japan

(trillion yen)

Program	Implementation Period	Purchased Asseets	Purchase Amount
APP	Oct. 2010 – Mar. 2013	Government Bond, Corporate Bond, etc.	76
QQE	Apr. 2013 – present	Governmnet Bond	342
		Exchange Traded Fund	19
		J-REIT	0.4
		Commercial Paper	0.1
		Corprorate Bond	0.2

Notes: 1) APP and QQE stand for the Asset Purchase Program and Quantitative and Qualitative Monetary Easing, respectively. REIT refers to Real Estate Investment Trust.
2) The purchase amount of the QQE is in net as of June 2018.
Source: Bank of Japan

The BOE carried out QE through the Asset Purchase Facility (APF) established in March 2009 purchasing mainly medium- and long-maturity gilts, the government bond of the U.K. Initially, the ceiling on total asset purchase was set as 200 billion

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[9] The BOJ changed the original version of QQE to QQE *with a Negative Interest Rate* in January 2016 and then to QQE *with Yield Curve Control and inflation-overshooting commitment* in September of the same year.

pounds by outstanding standard and was increased gradually to 435 billion since medium-term forecasts for inflation remained below the inflation target of 2% for too long. In September 2016, the Corporate Bond Purchase Scheme (CBPS) was newly introduced for buying additional 10 billion pounds in corporate bonds.

Table 4. Quantitative Easing by the Bank of England

(billion pounds)

Program	Implementation Period	Purchased Asseets	Purchase Amount
APF	Mar. 2009 – present	Government Bond, Commercial Paper, Corporate Bond, etc	435
CBPS	Sep. 2016 – present	Corprorate Bond	10

Note: APF and CBPS stand for Asset Purchase Facility and Corporate Bond Purchase Scheme, respectively.
Source: Bank of England

As a consequence of those large-scale asset purchases, the security holdings of the central banks increased rapidly and long-term interest rates in the advanced economies fell appreciably as can be seen in Figure 1. Table 5 below presents the increment and growth rate of the security holdings between 2008 and 2014. The Fed's security holdings increased by 3.7 trillion dollars, roughly seven times during the period of QE implementation from the end of 2008 to October 2014. During the same period, the BOJ expanded its balance sheet by 2.1 trillion dollars, the ECB by 1.1 trillion dollars and the BOE by 0.6 trillion dollars. Comparing the growth rates of security holdings, the Fed's is the highest as 755.9%, and the ECB and BOJ follow as 671.6% and 294.9%, respectively. The BOE's growth rate is the lowest as 32.7%.

Table 5. Security Holdings of the Central Banks in Advanced Economies

(billion dollars)

	Fed	ECB	BOJ	BOE	Total
Cumulative Increment	3,746	1,101	2,081	585	7,513
Cumulative Growth Rate	755.9%	671.6%	294.9%	32.7%	604.3%

Note: The statistics are calculated for the period between the end of 2008 and the end of 2014.

The average of long-term interest rates in the major advanced economies decreased by 110 basis points cumulatively from 2.3% to 1.2% during the same period as above,

which is in line with the forecasts from the studies conducted at the earlier stage of QE such as Gagnon et al. (2011) and Joyce et al. (2011).

Figure 1. Security Holdings of the Central Banks and Long-term Interest Rates in Major Advanced Economies
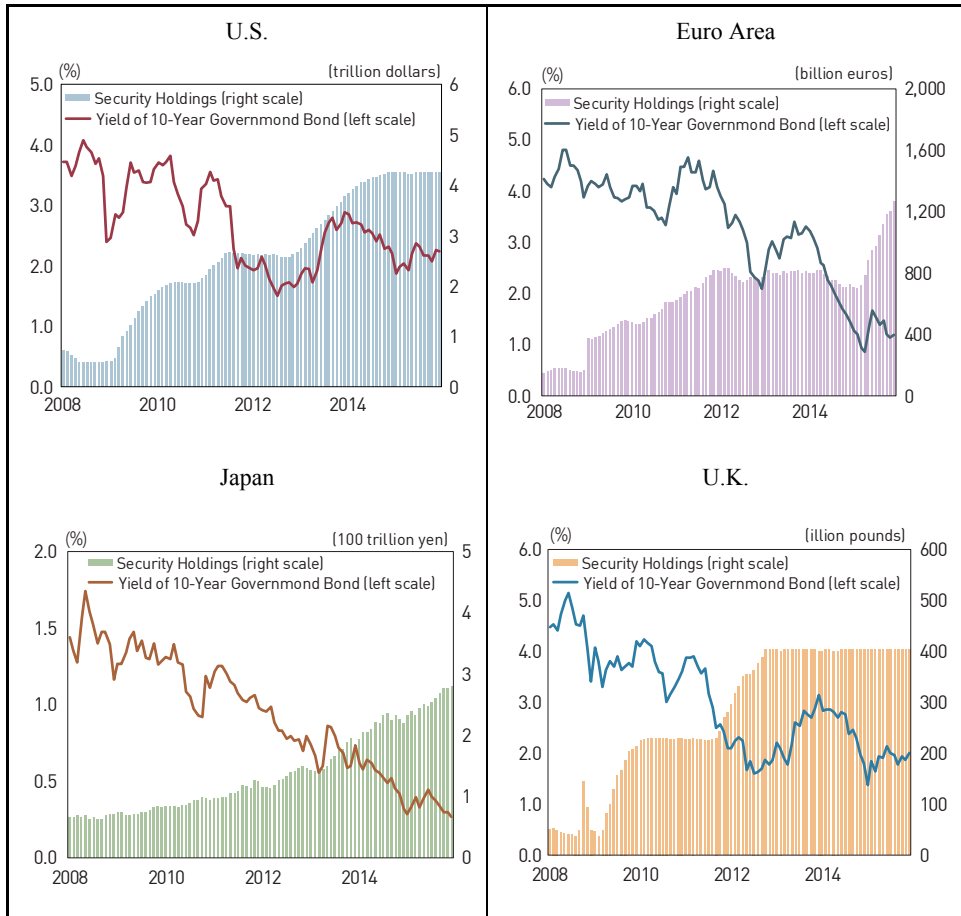
Note: Long-term interest rates in the Euro Area refer to yields on Bund, the German government bond, with the maturity of 10 years.

III. Channels of QE Transmission to Inflation in Korea

QE is theoretically presumed to exert spillover effects on financial and macroeconomic conditions in EMEs through exchange rate channel, trade channel and portfolio-balance channel which are closely intertwined, not mutually exclusive (Bauer and Neely, 2014; Lavigne et al., 2014).

■ Exchange rate channel: QE amplifies liquidity in advanced economies and thereby prompts the superfluous funds to flow into financial markets in EMEs. In the process, the currency value of EMEs remain under continuous appreciation pressure.

■ Trade channel: If QE were effective for boosting economic activities in advanced economies, the demand for imports from EMEs would expand, which in turn leads to larger aggregate demand in EMEs. However, its positive spillover effect on EMEs' exports through trade channel may be offset by appreciation in the currency value of EMEs through exchange rate channel.

■ Portfolio-balance channel: Ampler liquidity created by QE translates into asset price appreciation compressing capital gains in advanced economies. In response to that, global investors rebalance their portfolio increasing their exposure to EMEs to attain higher returns. As a result, the capital relocation causes booms in asset markets of EMEs.

Applying the above reasoning, QE could affect inflation in EMEs through those three channels as follows. First, via exchange rate channel, QE would lessen inflationary pressure in EMEs directly by lowering import prices. Moreover, it might enhance downward pressure on inflation indirectly if exports of EMEs dwindle because of currency appreciation through the same channel. Second, if the demand in advanced economies for the products of EMEs expands owing to QE and consequently EMEs' aggregate demand also grows, trade channel would engender upward pressures on inflation. Last, if portfolio rebalancing caused by QE leads to asset price hikes in EMEs and then the accrued capital gains are expended on consumption, in other words, if wealth effect channel operates, inflation would receive upward pressures. However, the causal link running from QE to inflation in EMEs through portfolio-balance channel

appears to be tenuous relative to the other two channels in that the link is more distant and the existence of wealth effect still remains debatable from the empirical viewpoint.[10]

Figure 2. Transmission of QEs to Inflation in EMEs through Exchange Rate Channel and Trade Channel
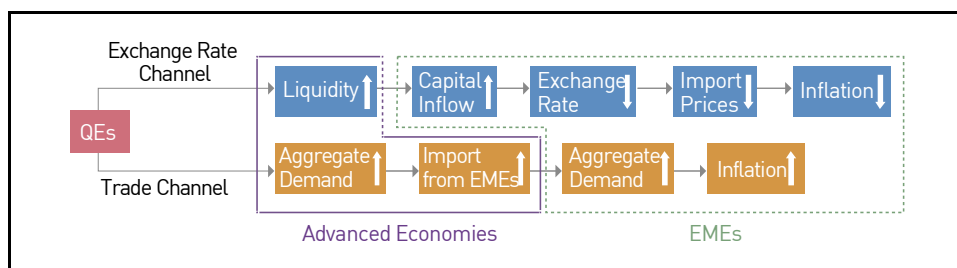
In Korea, exchange rate channel seems to have operated during the period from 2009 to 2014 in which the security holdings of the major central banks grew rapidly allowing for the foreign capital inflows and exchange rate trend. Seeing foreign investments in Korea on International Investment Position (IIP) plotted in Figure 2, capital inflows in net turned positive in 2009 in which the QEs were undertaken in concert among the advanced economies and remained so until 2013.[11] The increment in capital inflows

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[10] The capital gains accrued by QEs through portfolio-balance channel can be considerable since the yield on Korean 10-year government bond decreased from about 5% at the early 2009 to about 2% at the end of 2015 and KOSPI more than doubled from 2009 to 2011. However, how much portion of the capital gains belonged to common households and whether households spent the gains for consumption in practice need to be verified by another serious empirical analysis. Nevertheless, it is worth mentioning that previous empirical findings in Korea broadly support the wealth effect due to increases in stock prices is limited and differential among income groups (Kim and Choi, 2007; Chang, 2009).

[11] By the statistics from the EPFR (Emerging Portfolio Fund Research), the yearly average amount of foreign capital inflows to EMEs from 2005 to 2008 is 19.9 billion USD. It increased more than two times to 47.3 billion USD from 2009 to 2014. During this period, the ratio of the foreign capital inflows to Korea to the total inflows to EMEs hovers in the range of between 10% and 12% per annum.

	2010	2011	2012	2013	2014
Ratio of *Capital Inflows to Korea* to *Total Capital Inflows to EMEs*	10.1%	10.2%	9.3%	11.3%	12.4%

to Korea accounts for roughly 10% of the total inflows to EMEs during that period. The exchange rate of Korean Won (KRW) against U.S. dollar (USD) continued a downward trend most of the time until 2014, which ended in the appreciation of KRW by 14.6% as of the end of 2014 compared to the end of 2008.

Figure 3. Flow of Foreign Investment and Exchange Rate in Korea
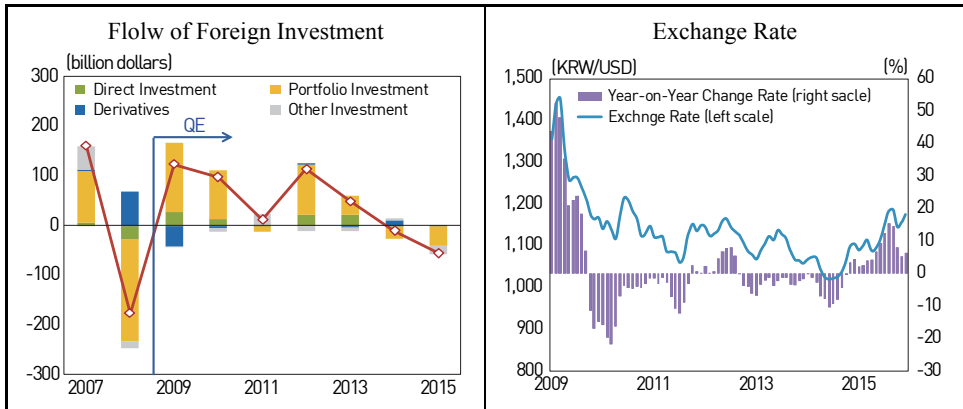
Source: Bank of Korea

A correlation analysis is conducted between the security holdings of the major central banks, the outstanding amount of foreign portfolio investment in Korea and the exchange rate of KRW/USD to examine preliminarily whether exchange rate channel operates during the period from January 2009 to December 2014. As can be seen in Table 6, the security holdings of the major central banks are positively correlated with the outstanding amount of foreign portfolio investment, which in turn is negatively correlated with the exchange rate of KRW/USD. This result suggests a causal chain runs from the QEs to expansion of capital flows to Korea, finally to appreciation in the value of KRW.

Table 6. Coefficients of Correlation between QE, Capital Inflow and Exchange Rate

	Security Holidngs	Foreign Investment	Exchange Rate
Security Holidngs	1.00	0.57	-0.61
Foreign Investment	0.57	1.00	-0.75
Exchange Rate	-0.61	-0.75	1.00

Note: The data used for calculating the correlation coefficients are cyclical components of the variables extracted from the level data during from Jan. 2007 to Dec. 2015 through Hodrick-Prescott filtering.

   In contrast, trade channel looks apparently inoperative in Korea considering the growth rates of the major advanced economies and the exports from Korea to those economies during the period from 2009 to 2014 as shown in Figure 3. Seeing the left panel of the figure, the annual economic growth rate after the sub-prime crisis stays below the pre-crisis average of 2.2% every single year except for 2010. It means the economic recovery was being delayed for a protracted period despite then extremely accommodative financial condition.[12] As a consequence, the exports from Korea to those economies, as shown in the right panel of the same figure, grew to such a limited extent that the QEs might hardly take effect through trade channel.

Figure 4. Economic Growth of Advanced Economies and Korean Exports
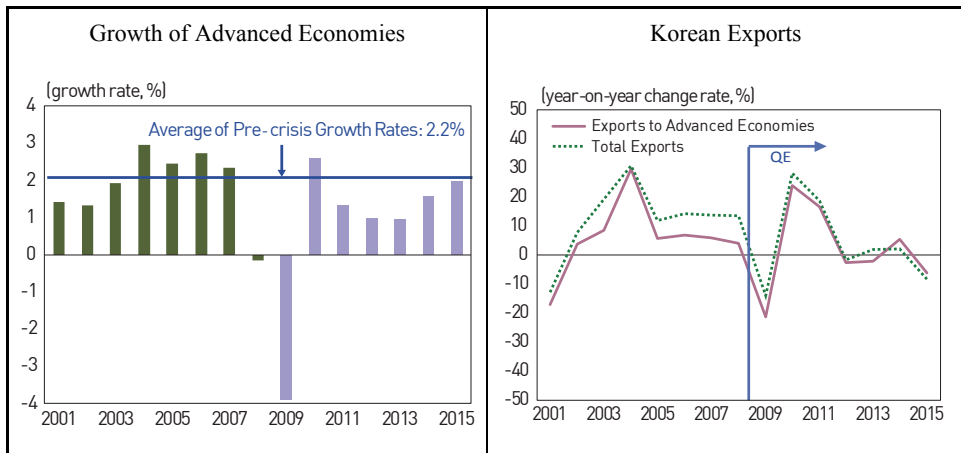
Note: Economic growth rate is the growth rate of the *summed* real GDP in the major advanced economies which is converted into USD by purchasing power parity.
Sources: U.S. Bureau of Economic Analysis, Eurostat, U.K. Office for National Statistics, Japan Cabinet Office, Bank of Korea, Korea International Trade Association

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[12] The sovereign debt crisis of southern European countries such as Greece, Spain, Portugal hampered global economic recovery by amplifying the initial negative shock which originated earlier from the sub-prime crisis in the U.S.

IV. EMPIRICAL ANALYSIS

1. Baseline Model Specification

The baseline model is specified as follows for estimating the influence of the QEs of the major central banks as a whole on inflation in Korea through exchange rate and trade channels.[13]

$$Y_t = c + \sum_{i=1}^{p} \Gamma Y_{t-i} + B Z_t + u_t, \ \ t = 1, \dots, T$$

where Y_t denotes a vector of endogenous macroeconomic variables of Korea including industrial production gap (*IPG*), inflation measured by consumer price index (*INF*), interest rates on certificate of deposit (*CDR*) and the exchange rate of KRW against USD (*EXR*).[14] *IPG* represents the effect of QEs on real activities in Korea through trade channel. *CDR* is included to capture money market condition and monetary policy stance.[15] Γ and B are coefficient matrices and u_t represents shocks. The model specified above is commonly called VAR-X model different from a typical specification of Vector Autoregression (VAR) in that it includes a vector of exogenous variables, Z_t. In an economic sense, the vector Z_t can be interpreted as a given external environment in which the endogenous variables interact with each other. This model framework is similar to those of Bhattarai et al. (2015) and Miyajima et al. (2014) which estimate the spillover effects of the Fed's QE on EMEs.[16] Z_t includes

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[13] Portfolio-balance channel is not reflected based on the consideration that it is hardly justifiable to assume the QEs enlarge inflationary pressure in Korea through taking wealth effect.

[14] Industrial production gap, *IPG*, is defined as percent deviation of industrial production index from its trend component.

[15] By BOK (2015), interest rates on the CD with 91-day maturity, *CDR*, fell by 133 basis points responding to decreases of 125 basis points in policy rates during the period from July 2012 through November 2014, which means changes in policy stance are efficiently transmitted to *CDR*.

[16] Bhattarai et al. (2015) identify QE shocks to U.S. macroeconomic variables through estimating a structural VAR model and subsequently use those shocks as exogenous QE shocks to EMEs. However, it is questionable whether it is appropriate to apply the QE shocks exogenous to the U.S. to EMEs.

three variables, namely, the sum of the securities held by the major central banks, changes in the prices of crude oil and other raw materials, respectively.[17]

The shocks of the baseline model are identified by a standard Cholesky decomposition method. The endogenous variables in Y_t are ordered as below following the existing studies of Eichenbaum and Evans (1995) and Cushman and Zha (1997) which model a small open economy in VAR.[18]

$$Y = [IPG, INF, CDR, EXR]$$

The estimation period is set from January 2009 to December 2014 considering that the Fed's QE terminated in October 2014 and the security holdings of the major central banks grew rapidly during that period.[19] For ensuring the stationarity of the time-series, all the level data except for *IPG* and *CDR* are transformed into the rate of year-on-year change. The maximum lag length of the model is set to three considering the Schwarz information criterion and the loss of freedom to be incurred by estimating the coefficient matrices Γ and B.

2. Empirical Results

The empirical results of the analysis can be summarized as follows. First, exchange rate channel is estimated to be operating during the sample period through which the QEs of the major central banks put downward pressures on inflation in Korea. On the other hand, the effect thorough trade channel turns out to be insignificant. Second, among the QEs of the major central banks, only those of the Fed and ECB turn out to be transmitted to inflation in Korea and especially the Fed's appears to be slightly more potent relative to the ECB's.

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[17] The reason why the prices of crude oil and other raw materials are included in Z_t is for differentiating the effects of the QEs on inflation from those of other global inflation determinants. The data come from the Dubai crude oil prices and the Industrial Input Price Index issued by the International Monetary Fund (IMF).

[18] Even if the endogenous variables ordered differently, the empirical results turn out to be broadly in line with the results obtained thorough this ordering.

[19] By the results of the ADF (Augmented Dicky Fuller) tests, the time series of the endogenous variables are estimated to be stationary during the sample period.

Figure 4 shows the impulse response functions for a shock to the total security holdings of the major central banks. Responding to a positive one standard deviation shock to the growth rate of the security holdings, the rate of change in *EXR*, the exchange rate of KRW, decreases by 1 percentage point upon the shock and then keeps decreasing for 8 months in a row.[20] *INF*, inflation measured by CPI, falls by around 0.2 percentage point for the first two months and continues to decline to a smaller extent afterwards. However, the response of *IPG*, industrial production gap, is somewhat negligible and furthermore statistically insignificant.[21] Taking these impulse responses together, it can be concluded that the QEs of the major central banks do indeed put downward pressures on inflation in Korea mainly through exchange rate channel while not being transmitted through trade channel.[22] These results can be deemed natural in light of the fact that the growth rate of Korean exports to the major advanced economies was subdued as aggregate demand in those economies remained anemic for a long while even after the QEs were implemented. Turning to the response of *CDR* which reflects the liquidity situation of the money market, it decreases by about 0.05 percentage point after arrival of the QE shock. However, the response is insignificant in that its confidence interval includes the zero line over the whole sample period.

Figure 5. Impulse Responses to a Shock to Security Holdings of the Major Central Banks


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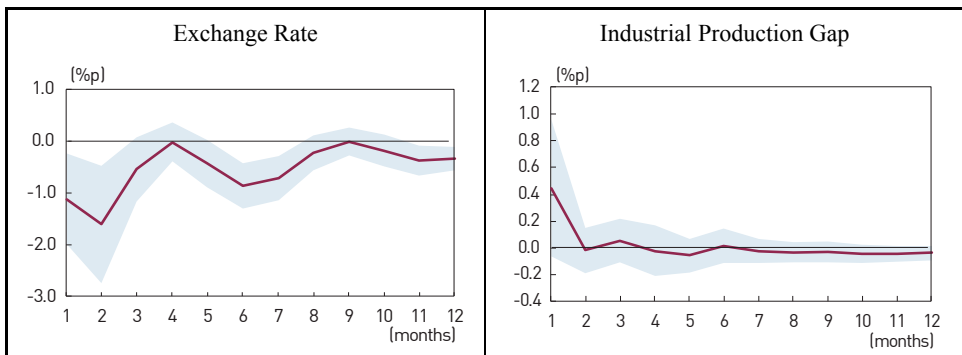
[20] A positive shock to the growth rate of the security holdings corresponds to an increase of 32.0 percentage point in the growth rate.

[21] The average of IPG is -0.01 and its standard deviation is 1.73.

[22] The estimation results of an alternative model including exports in place of industrial production, the growth rate of exports decreases by 2 percentage point upon a shock to QEs, which contradicts the predicted effect through trade channel. The estimated impulse responses are provided in Annex.

Figure 5. Continued
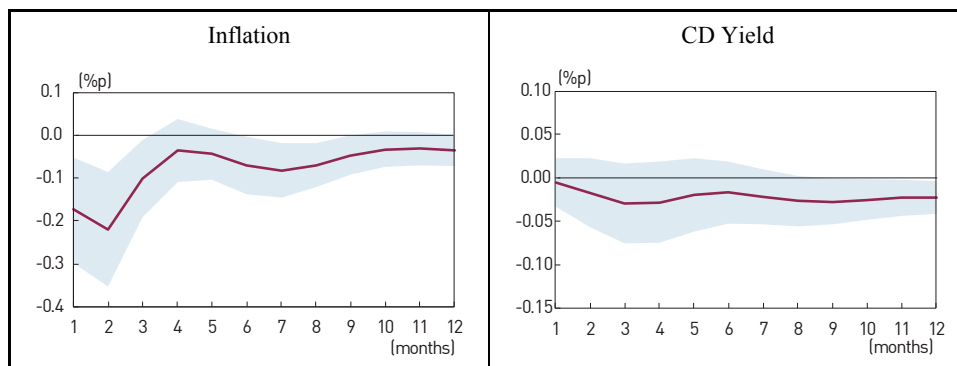
Note: The solid line represents the median response and the shaded area represents 68% confidence interval.

Next, to compare the magnitude of the individual QE program's impact on inflation, the baseline model above is re-estimated using the security holdings of each of, not all, the major central banks. Looking at the results of this additional analysis presented in Figure 5 and 6 which show the impulse responses of *EXR* and *INF* respectively, the effects of the QEs implemented by the Fed and ECB are evident whereas those of the BOJ and BOE are statistically insignificant. In particular, the influence of the Fed's QE on inflation is more pronounced compared with the ECB's. This result is not necessarily surprising allowing for the individual growth rate of each central bank's security holdings. Between 2009 and 2014, the Fed's security holdings grew by 52.7% per month on average and the ECB's did by 38.1% whereas the growth rates for the BOJ and BOE are relatively low as 9.1% and 12.6%, respectively.

Table 7. Descriptive Statistics on Growth Rate of Security Holdings

(%)

	Fed	ECB	BOJ	BOE
Monthly Average	52.7	38.1	22.2	7.8
Standard Deviation	74.7	58.8	9.1	12.6

Note: The statistics are calculated using the data from Jan. 2009 to Dec. 2014. *Monthly Average* means the average of monthly growth rates.

Figure 6. Impulse Responses of Exchange Rate to a Shock to Security Holdings of
Each Central Bank
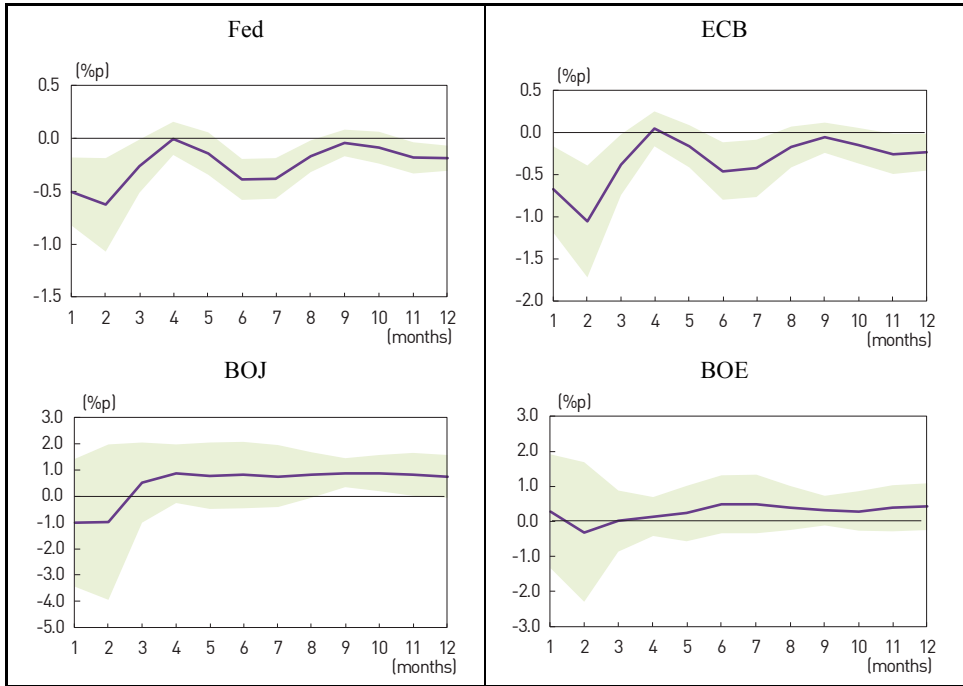
Note: The solid line represents the median response and the shaded area represents 68% confidence interval.

Figure 7. Impulse Responses of Inflation in Korea to a Shock to Security Holdings of
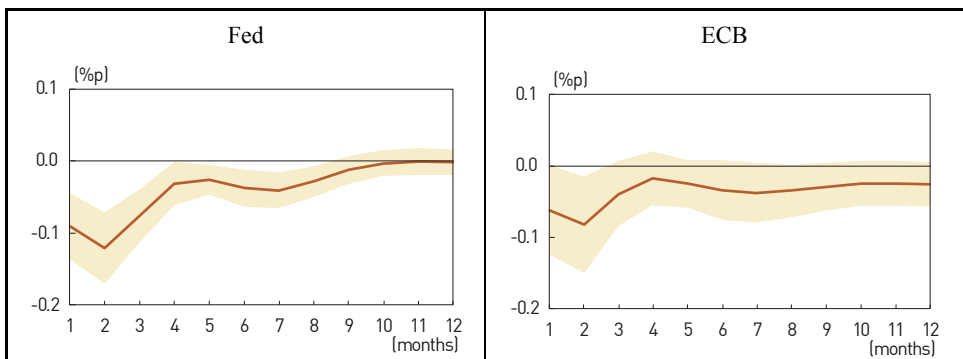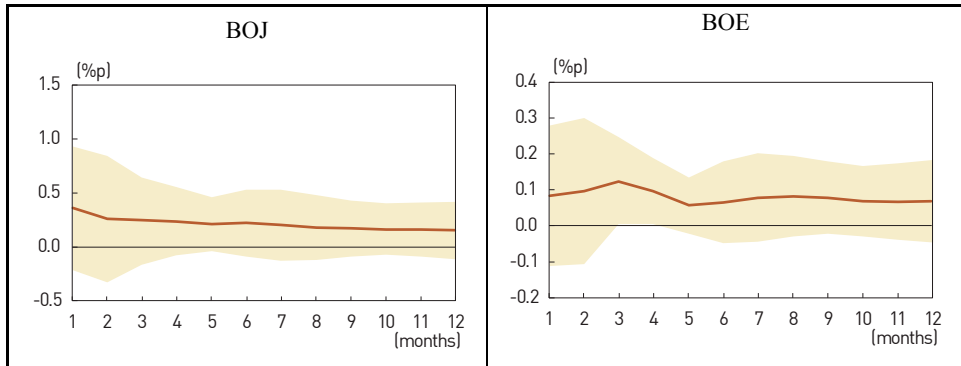Each Central Bank

Figure 7. Continued

Note: The solid line represents the median response and the shaded area represents 68% confidence interval.

3. Alternative Model Specification

Most of the recent studies on the international spillover effects of QE use long-term interest rates or term spread as its statistical indicator instead of the security holdings of the central banks. For checking the robustness of the baseline results presented above, the same VAR-X model is re-estimated replacing the growth rate of the major central banks' security holdings in Z_t with the average of yields on the ten-year government bonds in the major advanced economies.

It can be seen in Figure 7 that the newly estimated impulse responses of the endogenous variables are qualitatively consistent with the baseline results.[23] If the average of the long-term interest rates in the major advanced economies decreases by 50 basis points, the rate of change in *EXR* instantaneously declines by 2.5 percentage point and *INF* keeps falling for the first five months peaking at -0.2 percentage point. The impulse response of *IPG* is insignificant same as in the baseline results. A unique difference between the results of the alternative and baseline models lies in the impulse response of *CDR*. Unlike the baseline results, *CDR* continues to decline slightly for a

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[23] It is also true of another alternative model using term spread between yields on 10-year government bonds and interest rates on overnight inter-bank lending. This result is foreseeable enough considering that overnight interest rates in the major advanced economies were nearly fixed to zero-lower bound most of the time during the sample period while long-term interest rates fluctuated in a wider range reflecting various economic factors including the QEs.

prolonged period. It can be interpreted as an indication that the capital inflows to Korea caused by the QEs rendered the short-term money market condition easier.[24]

Figure 8. Impulse Responses to a Negative Shock to Long-term Interest Rates
in the Advanced Economies
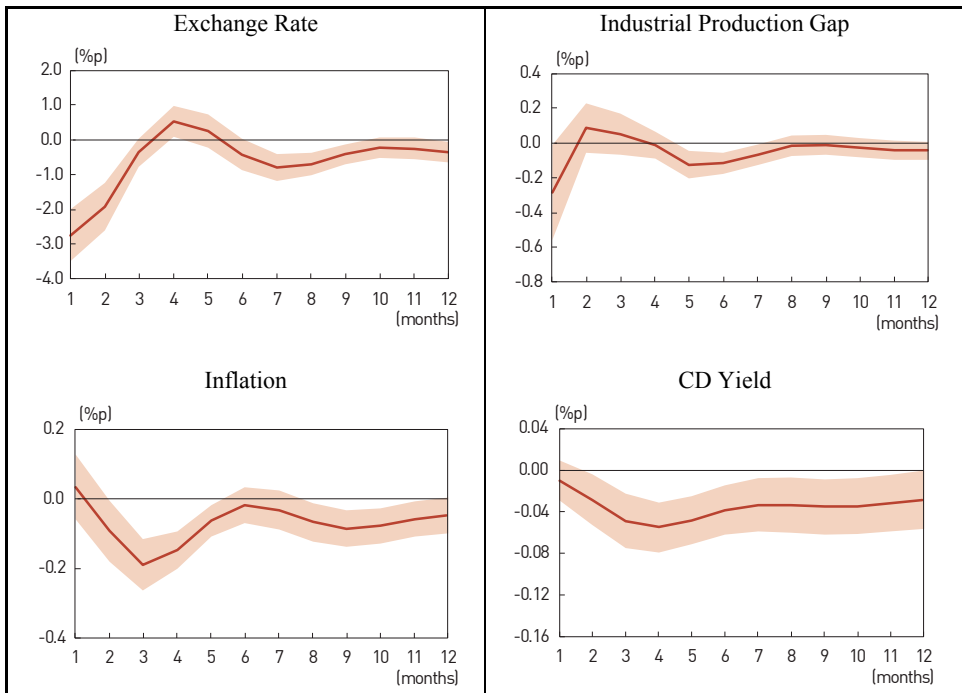
Notes: The graphs represent impulse responses to a negative shock of 50 basis points to the *average* of long-term interest rates in the major advanced economies. The solid line represents the median response and the shaded area represents 68% confidence interval.

V. POLICY IMPLICATIONS

The empirical results of the paper support the hypothesis that the QEs of the central banks in major advanced economies posed additional downward pressures on inflation in Korea through exchange rate channel. That means in practice the QEs amplified the

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[24] However, this inference needs to be verified by a further analysis of how the QEs influenced the liquidity of money market in Korea and thereby short-term interest rates.

impacts of decreasing prices of crude oil and other raw materials on inflation during the disinflationary era from 2011 to 2014. It is considered in general, even in the circle of central bankers, that inflation is determined predominantly by domestic output gap and hence is hardly influenced directly by monetary policy decisions of the central banks in advanced economies. However, the findings of this paper imply that a direct causal relationship may emerge between monetary policy in advanced economies and inflation in EMEs depending on the policy measures and their scale.

A couple of policy implications derive from the empirical results with respect to the central bank's research direction and communication. Firstly, central bankers in EMEs implementing inflation targeting need to be alert to the possibility that monetary policy stance abroad can be transmitted to domestic inflation through the channels considered unlikely in normal situations. In this regard, it is worth intensifying research on the transmission channels through which monetary policy in advanced economies affect inflation in EMEs. The efforts are expected to contribute to forecasting inflation more accurately and thereby to finding an optimal path of policy rates.

Secondly, the central bank needs to reinforce communication to explain the causes of changes in inflation to the public based on related research findings. As verified by existing studies, consumers tend to form inflation expectations in a backward looking way considering mainly past inflation information.[25] However, if the central bank aggressively deliver the results of their research on the evolution of inflation, at least a fraction of consumers likely incorporate the knowledge into the information set used for forming inflation expectations. For example, if consumers in Korea had known that the QEs of the central banks in advanced economies were lowering inflation additionally while having the common knowledge that QEs would terminate in due course, they could have downplayed the apprehension of deflation occurrence which was somewhat prevalent around 2015 and formed inflation expectations at higher level.

Additionally, as a topic of further research in relation to this paper, it is worth studying whether the Fed's balance sheet normalization started in 2007 puts upward pressures on inflation in Korea and that effect is symmetric compared with QE.

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[25] A large number of studies overseas as well as in Korea have empirically shown that consumers' inflation expectations are formed in a backward-looking way. Nam and Go (2017), the most recent study in that strand in Korea, reveal that inflation expectations in Korea closely comove with the average of inflation over the last 12 months and inflation perceptions play a vital role in the process of inflation expectation formation.

Annex

The following figure shows the impulse responses of the alternative model which replaces industrial production gap in the baseline model with the growth rate of total exports.
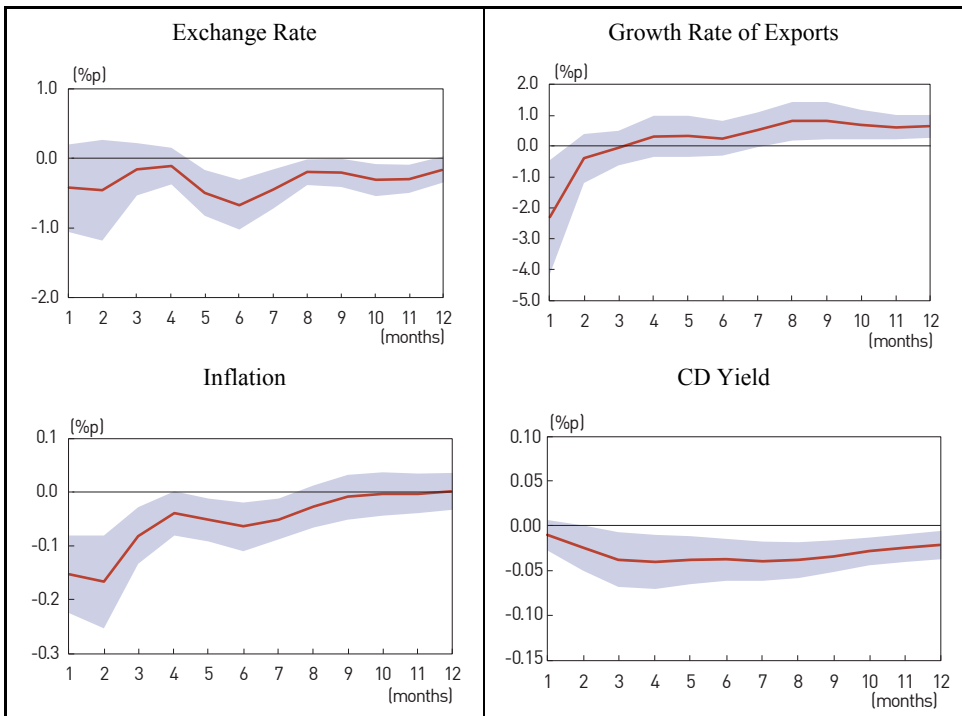
Note: The solid line represents the median response and the shaded area represents 68% confidence interval.

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