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Reconstructing the Bank of Korea's Global Projection Model: Framework and Analysis

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This paper introduces the redevelopment of the Bank of Korea's Global Projection Model (BOK-GPM), a framework originally established in 2014, to incorporate major shifts in the international economic environment and the latest academic research. We extended the estimation period through 2023 to cover the post-pandemic period and expanded the multi-country model to include emerging Asia. The redeveloped model shows strong explanatory power for key macroeconomic variables and provides satisfactory forecast accuracy, even with the inclusion of an exceptional period like the COVID-19 pandemic.

This redevelopment substantially refines the model's three main channels for the cross-country transmission of external shocks: First, the trade channel is re-estimated to better capture the direct and indirect propagation of demand shocks through trade, with updated elasticities reflecting recent structural shifts in global trade; Second, the exchange rate channel now incorporates the U.S. dollar's dominant role as an invoicing currency, allowing the model to capture spillovers from the dollar's fluctuations in addition to traditional real effective exchange rate effects; Third, the financial spillover channel is enhanced by modeling the transmission of shocks from U.S. credit spreads to those of other countries, enabling a more realistic propagation of U.S. financial shocks.

Our analysis shows that Korea's GDP is the most responsive among all modeled economies to demand shocks from the United States and China. While the relative impact of Chinese demand shocks has diminished since 2018, the influence of U.S. demand shocks has intensified.

We also find that the impact of U.S. monetary policy on the Korean economy is now substantially larger, reflecting the model's inclusion of the dollar's key role and financial spillovers. As these policy shocks can contract global trade and tighten financial conditions abroad, the findings highlight the need for heightened vigilance in an externally dependent economy like Korea.

Ultimately, our findings highlight the need to continue diversifying export markets in response to the evolving global trade environment. They also underscore the importance of closely monitoring the U.S. dollar and financial conditions, given their significant influence on both the domestic and global economies.

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BANK OF KOREA

Content

Ⅰ. Introduction

Since the 1980s, the rapid expansion of global trade and capital flows has strengthened both real-financial linkages and the cross-country synchronization of economic variables. More recently, global trade uncertainty has intensified, driven by the COVID-19 pandemic and a trend toward trade fragmentation. These global dynamics are particularly consequential for a small, open economy like Korea, which is highly dependent on external demand. A precise understanding of how external shocks affect the domestic real and financial sectors is therefore essential for improving the accuracy of economic forecasts and policy analysis. This requires continuously refining existing analytical frameworks to incorporate the latest international research, particularly on the economic impact of shifting trade patterns and the global spillovers of U.S. monetary policy. Therefore, this paper first presents the redevelopment of the Bank of Korea's Global Projection Model (BOK-GPM)[1], which was originally built in 2014 based on the IMF's global modeling framework. It then uses the new model to analyze the transmission of key external shocks.

This redevelopment of the BOK-GPM focused on four key enhancements. First, the estimation sample is extended from its original 2000-2010 period to cover data through 2023. This allows the model to better reflect the evolving global trade environment and business cycles, including the pandemic period, and involved re-estimating all parameters. Second, we incorporated the emerging Asia region, one of the key economic partners for Korea, into the model. This addition reflects the growing importance of emerging markets since the 2008 global financial crisis. Third, we enhance the exchange rate channel to reflect the dollar's dominant pricing role in global trade. By adding the U.S. dollar index, the model can now better capture how changes in the dollar's value, often driven by U.S. monetary policy, spill over to other economies[2]. Fourth, the financial channel is enhanced to better model cross-country linkages, using credit spreads as the key transmission mechanism. Overall, the redeveloped BOK-GPM shows a strong fit for key macroeconomic variables like GDP growth and promises to be a versatile tool for analyzing the transmission of diverse external shocks.

This paper proceeds as follows. Section Ⅱ describes the model's structure. Section Ⅲ evaluates its performance and analyzes the transmission of key external shocks using impulse-response functions. The final section concludes by summarizing the results and their policy implications.

1) The BOK-GPM is a semi-structural model: it maintains theoretical coherence by adapting key behavioral equations derived from a DSGE framework to real-world conditions, while enhancing data fit through trend-cycle decomposition of macroeconomic variables and Bayesian estimation of principal parameters. For a detailed description of the original development of the BOK-GPM, see Kang et al. (2014).

2) Whereas the legacy model accounted solely for real effective exchange rate movements, the redeveloped BOK-GPM further incorporates the impact of dollar index fluctuations, reflecting the dollar's uniqe role in international trade.

Ⅱ. BOK-GPM Overview

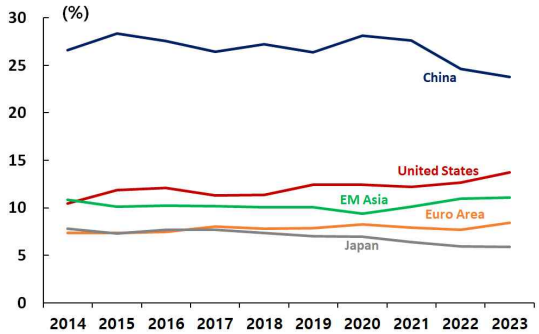
1. Basic Framework of Model

The BOK-GPM is a multi-country model composed of six economies: Korea, the United States, China, the Euro Area, Japan, and emerging Asia. The Euro Area includes 19 member countries, while the emerging Asia region comprises India, Indonesia, Malaysia, the Philippines, Singapore, and Thailand[3]. Collectively, these economies account for approximately 70% of global GDP[4] as of 2023. The five foreign economies also represent 63% of Korea's total trade. A comparison with 2014 data shows that while the trade shares of China and Japan have declined, the U.S. share has risen moderately, and the newly included emerging Asia region now surpasses both the Euro Area and Japan in its trade volume with Korea.

[Figure 1] Economic Size of Countries Included in the Model

Source: IMF WEO

[Figure 2] Each Country's Share[1] of Korea's Exports and Imports



Note: 1) Each country's share of Korea's total exports and imports

Source: IMF DOTS

Each of the six economies in the model consists of several core blocks, including GDP, inflation, interest rates, and exchange rates. The dynamics within each block are governed by three types of equations: an identity that separates a variable (y_t) into its trend and cyclical components; a trend equation that describes the evolution of the trend component ($\bar{y}_t$); and a cycle equation that specifies the dynamic behavior of the cyclical component ($\hat{y}_t$).

$$Identity : y_t = \bar{y}_t + \hat{y}_t$$

$$Trend : \bar{y}_t = \bar{y}_{t-1} + g^{\bar{y}_t}_{4,t}/4 + \epsilon^{\bar{y}}_t$$

$$Cycle : \hat{y}_t = f(\hat{y}_{t-1}, \hat{y}_{t+1}, \Omega_{t-1}, \cdots)$$

The cyclical equations, such as the dynamic IS curve, the Phillips curve, and the Taylor rule, are modified versions of first-order conditions derived from household and firm optimization problems to better fit the data.

3) For aggregate regions such as the Euro Area and emerging Asia, individual country economic variables were aggregated using weights based on PPP-adjusted GDP, as provided by the IMF.

4) The model economies' share of global GDP fell through the early 2010s, largely because non-included Latin American countries such as Brazil were growing rapidly, and then stabilized as growth in those economies slowed in the mid-2010s.

$$GDP\ gap = f(lag\ variables, real\ interest\ rate\ gap, foreign\ variables)$$

$$Inflation = f(lag\ variables, GDP\ gap, foreign\ variables)$$

$$Policy\ rate = f(lag\ variables, nominal\ equilibrium\ interest\ rate, inflation\ gap, GDP\ gap)$$

$$Real\ exchange\ rate = f(real\ interest\ rate\ parity, risk\ premium)$$

Because each economy has unique structural characteristics, the specific form of these equations varies across countries. In total, the BOK-GPM comprises 34 blocks and 198 equations (Table 1).[5]

[Table 1] Blocks and Equations in the BOK-GPM

	Number of Blocks	Number of Equations
South Korea	6	34
United States	6	31
China	6	35
Japan	6	34
Euro Area	6	34
EM Asia	4	30
Total	34	198

2. Transmission Channels of External Shocks

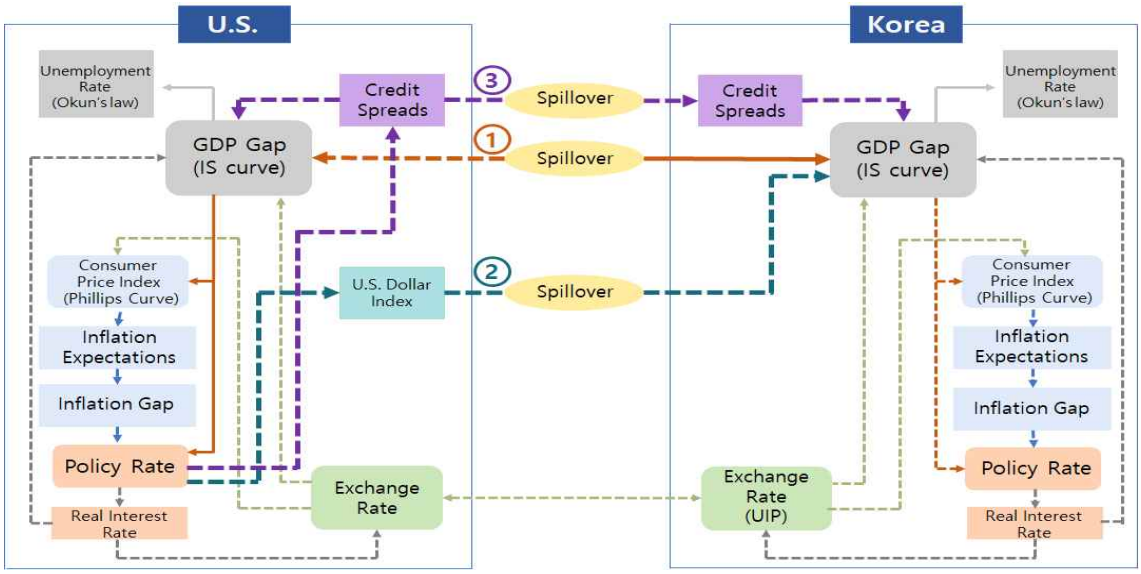
In the BOK-GPM, shocks are transmitted across countries through three main channels: a trade channel, an exchange rate channel, and a financial channel. The redevelopment effort focuses on refining these pathways. First, we enhance the exchange rate channel to incorporate the dollar's dominant role in global trade. Next, we improve the financial channel by using credit spreads as the key transmission mechanism for U.S. financial shocks, replacing the Bank Lending Tightening Index used in the previous model. Figure 3 provides a schematic illustration of the domestic structures and linkages between the Korean and U.S. economies.

(Trade Channel)

The trade channel is a core transmission pathway in the BOK-GPM that captures how a country's demand shifts directly and indirectly affect partner economies through trade. These effects—approximated by considering factors such as relative GDP shares, import-to-GDP ratios, and the value-added from exports—are embedded in the model's spillover coefficient matrix[6]. As part of this redevelopment, we recalculated the matrix using 2023 data to reflect the evolution of global trade patterns since 2010.

5) For detailed specifications of the individual equations, refer to Appendix 2.
6) For a detailed explanation of the spillover coefficient matrix, see Appendix 3.

[Figure 3] Relationship between Korea and U.S. variables in the BOK-GPM



(Exchange Rate Channel)

The traditional exchange rate channel operates through fluctuations in the real effective exchange rate. However, recent research emphasizes that the U.S. dollar's pervasive role as an invoicing currency creates an additional spillover channel.[7][8] We modify the model based on these recent findings as follows: First, each country's dynamic IS curve now incorporates the U.S. dollar index as an explanatory variable to capture its influence on the output gap. Second, the risk premium in the uncovered interest rate parity (UIP) condition is linked to movements in the dollar index. These improvements allow the model to account for both conventional exchange rate effects and the distinct impact of fluctuations in the U.S. dollar's value.

(Financial Channel)

The legacy model used the Bank Lending Tightening index as a proxy for financial conditions[9]. However, this survey-based measure has notable shortcomings, including measurement error and limited availability. To address this issue, the redeveloped model adopts credit spreads[10] as the key transmission mechanism. In the new framework,

7) Recent international literature—such as Gopinath et al. (2020), Bruno and Shin (2023), and Akinci et al. (2024)—emphasizes that, in an environment where the dollar is widely used in global trade and finance, dollar appreciation raises local currency prices of dollar-denominated exports and imports and strains exporters' and importers' dollar-denominated working capital financing, ultimately leading to a contraction in global trade.

8) According to Son (2023), over 80 percent of Korea's trade settlements are denominated in the U.S. dollars, making it a textbook example of dominant-currency pricing. Consequently, Korea's export volumes and importing-country local-currency prices tend to respond more sensitively to the dollar's exchange rate against the partner currency than to the bilateral exchange rate between the Korean won and that currency.

9) Miranda-Agrippino and Rey (2020) point out that U.S. monetary tightening–induced financial distress triggers heightened global risk aversion, reduced global credit flows, and wider corporate bond spreads. In other words, U.S. financial market shocks act as a core driver of the global financial cycle, producing strong co-movements among international financial variables.

the U.S. credit spread responds to U.S. monetary policy, and in turn, influences the credit spreads of other countries. This allows the model to trace how U.S. financial stress propagates through global financial markets.

3. Model Estimation Process

The model's 200 parameters are estimated across its 198 equations using Bayesian techniques[11]. However, the estimation process presents significant challenges. The model is large-scale, yet the post-2000 sample period is relatively short and includes exceptional events like the 2008 global financial crisis and the 2020 pandemic. To address the numerical burden of simultaneous estimation under these conditions, we adopt a staged estimation approach[12], similar to that of Carabenciov et al (2013).

Ⅲ. Results of the Estimated Model

This section assesses the model's goodness of fit and analyzes the impulse responses of each economy to key external shocks.

1. Goodness of Fit

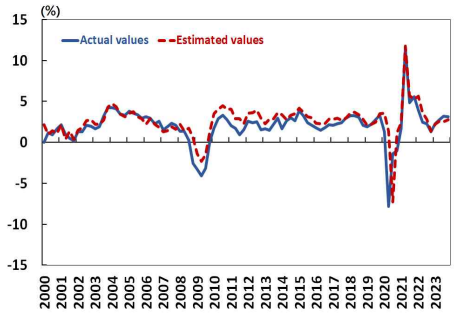
We first evaluate the model's goodness of fit by comparing its estimates for key variables against the actual data. As shown in Figure 4, the model's in-sample fitted values for GDP growth in major economies closely track the realized values, even during exceptional periods like the 2008 global financial crisis and the 2020 pandemic. This demonstrates the model's strong empirical fit and ability to capture actual output fluctuations[13].

Next, we assess the model's medium-term forecasting performance using pseudo out-of-sample unconditional forecasts[14]. For each quarter over the 2014–2023 period, we generated eight-quarter-ahead GDP growth forecasts for each major economy. Excluding the 2020 pandemic episode, the BOK-GPM generally succeeded in predicting the direction of realized growth rates (Figure 5)[15].

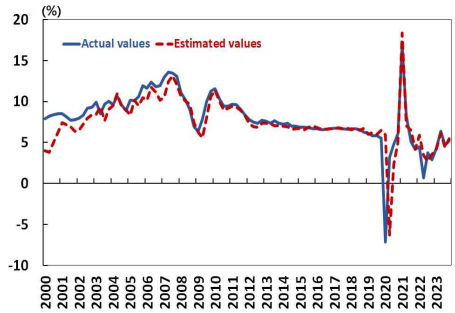
10) Credit spreads are calculated as the difference between yields on same-maturity corporate bonds and government bonds, for each country where data are available.
11) 174 parameters are calibrated using existing literature benchmarks and long-run country-specific data averages.
12) Specifically, we implement a two-stage approach by classifying countries into large economies and small open economies: first estimating and then fixing the parameters for large economies, and subsequently estimating the parameters for the small open economies. This procedure—also employed in Kang et al. (2014)—rests on the block exogeneity assumption that large economies affect small open economies but not vice versa.
13) For the inflation rate of major economies, the model also exhibits a high degree of fit (see Appendix 4).
14) For pseudo out-of-sample forecasting, to alleviate sample size constraints and computational burden, we estimate model parameters once over the full estimation sample and then hold them fixed when generating forecasts for each prediction date.
15) However, the model's predictive accuracy for consumer price inflation (see Appendix 4) is somewhat lower for China and Japan in the post-pandemic period.

[Figure 4] Comparison between Estimated and Actual Values of GDP Growth Rates[1)2)]

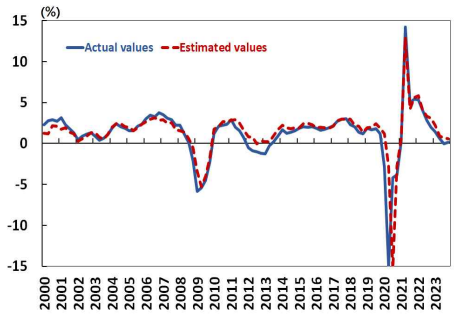
United States



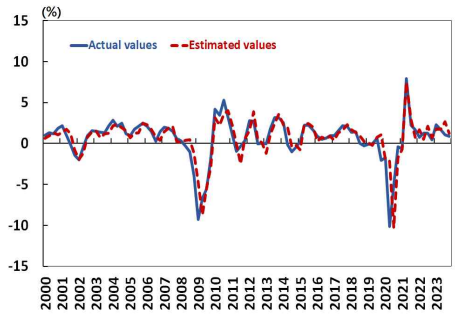
China



Euro Area



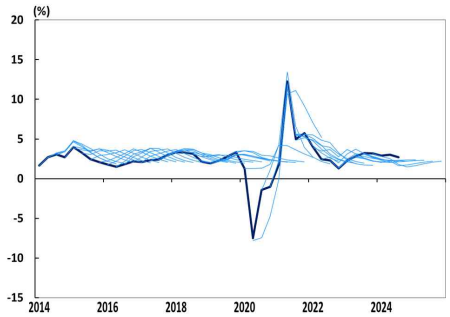
Japan



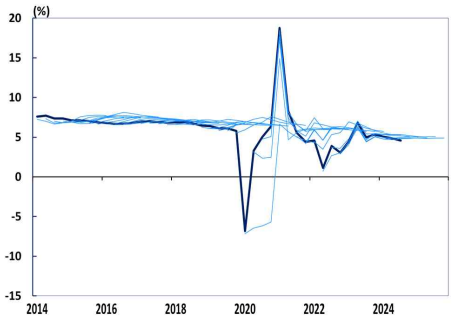
Notes: 1) Year-on-year growth rates
2) The solid line indicates actual values, while the dotted line indicates estimated values from the BOK-GPM

[Figure 5] Unconditional Forecasting of GDP Growth Rates of Major Countries[1)2)]

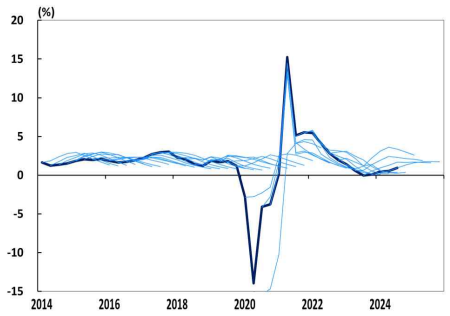
United States



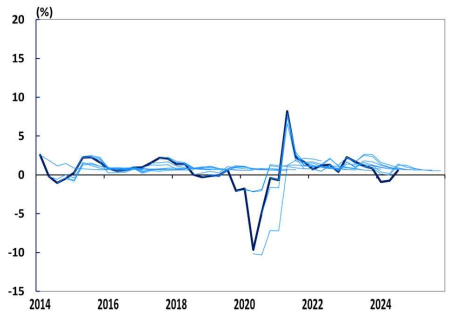
China



Euro Area



Japan



Notes: 1) Year-on-year growth rates
2) The solid line indicates actual values, while the thin line indicates the unconditional forecasting path.

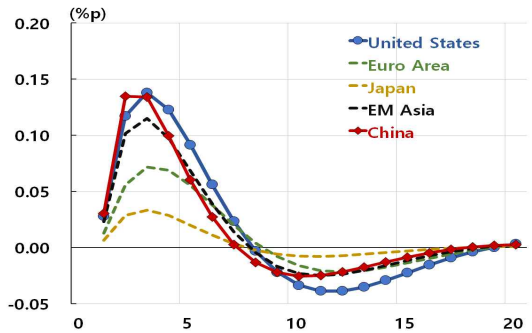
2. Impulse-Response Analysis

This section analyzes the response of Korea's GDP gap to three types of external shocks using the redeveloped BOK-GPM: foreign demand shocks, U.S. monetary policy shocks, and U.S. financial shocks.

(Foreign Demand Shock)

Figure 6 shows Korea's GDP gap response to a 1 percentage-point demand shock from each partner economy. Shocks originating in the United States and China have the largest impact on Korea's output, followed by emerging Asia, the Euro Area, and Japan. This ranking reflects both direct effects (driven by the partner's economic size and trade share) and indirect effects (transmitted through third-country demand). While the initial impact on Korea's GDP from U.S. and Chinese shocks is similar for the first four quarters, the effects of U.S. demand shocks are found to be more persistent.

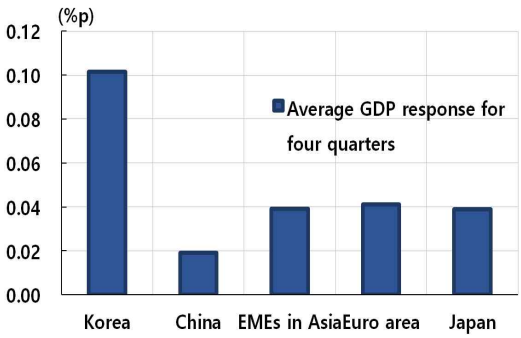
[Figure 6] Korea's GDP Response to External Demand Shocks[1)]



Note: 1) Korea's GDP gap response to a 1%p rise in the GDP gap of other countries.

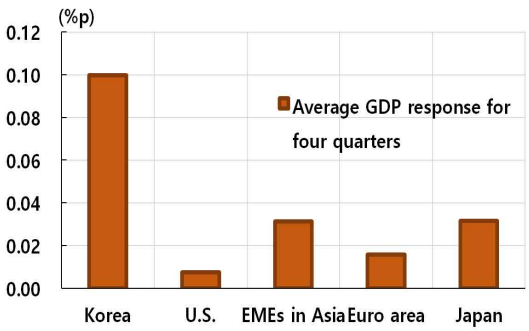
A cross-country comparison reveals that Korea's economy is the most responsive to demand shocks from both the United States and China. Following a U.S. demand shock, Korea's GDP response is substantially larger than that of other countries in the model (Figure 7). Similarly, its response to a Chinese demand shock is more than twice that of neighboring economies like Japan and emerging Asia (Figure 8). These results suggest that the Korean economy is particularly exposed to policy shifts in the U.S. and China.

[Figure 7] Comparing the GDP Responses of Different Countries to U.S. demand shocks[1)]



Note: 1) Average GDP gap responses of countries over four quarters after a 1%p increase in the U.S. GDP gap.

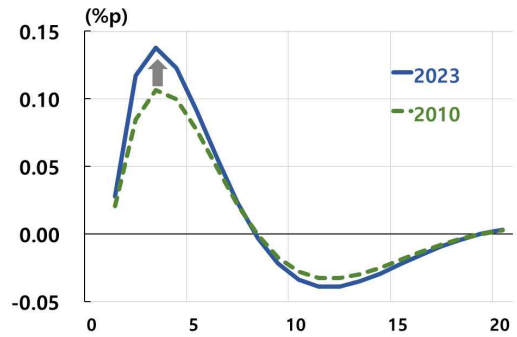
[Figure 8] the GDP Responses to China's demand shocks[1)]



Note: 1) Average GDP gap responses over four quarters after a 1%p increase in China's GDP gap.

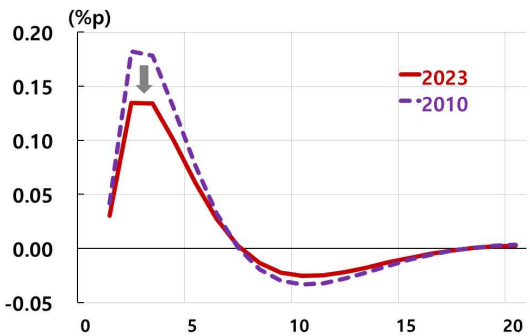
To examine how Korea's exposure to U.S. and Chinese demand shocks has evolved, we compare the model's impulse responses using spillover-coefficient matrices calibrated for both 2010 and 2023. The results show that from 2010 to 2023, the impact of a U.S. demand shock on Korea strengthened modestly, while the effect of a Chinese demand shock diminished (Figures 9 and 10). This evolution likely reflects a shift in Korea's trade patterns, with exports to the U.S. expanding while the relative influence of China has declined due to factors such as global value chain fragmentation (Figure 11).

[Figure 9] Impact of U.S. Demand Shocks on Korea's GDP[1)]



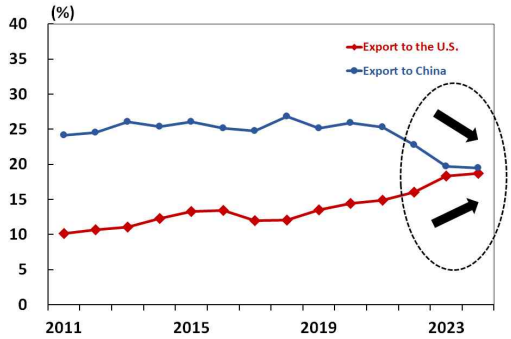
Note: 1) Korea's GDP response to a 1%p rise in U.S. GDP gap by year.

[Figure 10] Impact of China's Demand Shocks on Korea's GDP[1)]



Note: 1) Korea's GDP response to a 1%p rise in China GDP gap by year.

[Figure 11] U.S. and China's Shares of Korea's Exports[1)]



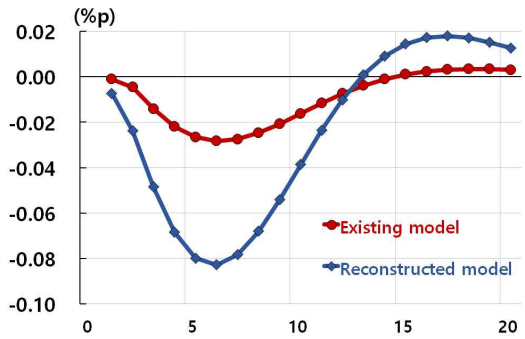
Note: 1) U.S. and China's shares of Korea's exports(customs clearance basis).

Source: Korea Customs Service

(U.S. Monetary Policy Shock)

The redeveloped BOK-GPM incorporates an enhanced exchange rate channel (capturing the dollar's invoicing role) and financial channel (using credit spreads). A comparison with the legacy version shows that these new channels lead to a substantially larger estimated impact of a U.S. monetary policy shock on Korean GDP (Figure 12). While the initial GDP response is similar in both models, the new model's response diverges and deepens after the third quarter. This divergence occurs because the redeveloped framework better captures the dual impacts of a Fed rate hike: dollar appreciation, which dampens global trade, and wider U.S. credit spreads, which worsen financial conditions abroad.

[Figure 12] Impact of U.S. Monetary Tightening on Domestic GDP[1)]

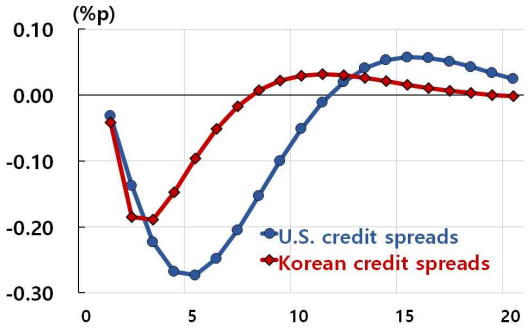


Note: 1) Korea's GDP gap response to a 1%p rise in the U.S. policy rate is compared with and without the inclusion of the U.S. dollar index and credit spread channels.

(U.S. Financial Shock)

Lastly, we examine the impact of a U.S. financial shock, simulated as a 1%p increase in the U.S. credit spread. Figure 13 compares its effect on Korea's GDP gap with that of an equivalent shock to Korea's own credit spread. The U.S. credit spread shock produces a larger and more persistent contraction in Korea's output. This result reflects that U.S. financial stress curtails global dollar liquidity, worsening credit conditions in other economies and thus amplifying the negative impact on their real activity.

[Figure 13] Impact of U.S. Credit Spread Shocks on Domestic GDP[1)]



Note: 1) Responses of Korea's GDP gap to a 1%p rise in U.S. credit spreads and Korean credit spreads.

IV. Summary and Implications

The redeveloped BOK-GPM, updated to reflect shifts in the global economic environment and recent research, demonstrates a strong empirical fit and satisfactory forecast performance.

Our analysis using the model yields two key findings. First, Korea's economy is the most responsive among all modeled economies to demand shocks originating in the United States and China. Second, due to the enhanced exchange rate and financial channels, the estimated impact of U.S. monetary policy on the domestic economy is now substantially larger than in the legacy model.

These findings underscore the importance for Korea's externally oriented economy to continue diversifying its export markets. They also highlight the necessity of closely monitoring the U.S. dollar and U.S. financial conditions, given their significant influence on the domestic and global economies.

BOX 1 Key Variables[16)]

Common to all countries

Variable Name	Definition	Variable Name	Definition
$Y_{i,t}$	GDP	$i_{i,t}$	nominal policy rate
$\overline{Y}_{i,t}$	potential GDP	$r_{i,t}$	real policy rate
$g_{i,t}^{\overline{Y}}$	potential growth rate	$\overline{r}_{i,t}$	equilibrium real interest rate
$y_{i,t}$	GDP gap	$Z_{i,t}$	real exchange rate
$P_{i,t}$	CPI	$Z_{i,t}^{e}$	expected real exchange rate
$\pi_{i,t}$	inflation rate(annualized QoQ)	$\overline{Z}_{i,t}$	trend real exchange rate
$\pi 4_{i,t}$	inflation rate(YoY)		

United States, Euro Area, Japan, China, Korea

Variable Name	Definition	Variable Name	Definition
$U_{i,t}$	unemployment rate	$u_{i,t}$	unemployment gap
$\overline{U}_{i,t}$	natural rate of unemployment	$CS_{i,t}$	credit spread
$g_{i,t}^{\overline{U}}$	change in the natural rate of unemployment		

United States, Japan, Emerging Asia, China, Korea

Variable Name	Definition	Variable Name	Definition
DXY_t	dollar index	dxy_t	dollar index gap
$\overline{DXY}_t$	dollar index trend		

Emerging Asia, China

Variable Name	Definition		
$DOT(\overline{Z}_{i,t})$	long-run exchange rate trend		

16) Level variables are denoted in uppercase; gap variables (i.e., deviations from their trend) and growth rates are denoted in lowercase; and trend variables are indicated with the upper bar.

Box 2 Key Equations

[1] United States ($i = US$)

① GDP block

1. $$y_{US,t} = \{\beta_{US,1} y_{US,t-1} + \beta_{US,2} y_{US,t+1} - \beta_{US,3}(r_{US,t-1} - \bar{r}_{US,t-1})\} + \left\{\beta_{US,4} \sum_{j \neq US} w_{US,j,4} \sum_{k=1}^{4} (Z_{US,j,t-k} - \bar{Z}_{US,j,t-k})/4\right\} + \left\{\beta_{fact} \sum_{j \neq US} w_{US,j,5} y_{j,t-1} + \beta_{factres} \sum_{j} w_{US,j,5} v_{j,t}\right\} - \beta_{US,6}(CS_{US,t-1} - CS_{US,ss}) + \epsilon^{y}_{US,t}$$
2. $$Y_{US,t} = \bar{Y}_{US,t} + y_{US,t}$$
3. $$\bar{Y}_{US,t} = \bar{Y}_{US,t-1} + g^{\bar{Y}}_{US,t}/4 + \epsilon^{\bar{Y}}_{US,t}$$
4. $$g^{\bar{Y}}_{US,t} = \tau_{US} g^{\bar{Y}}_{US,ss} + (1-\tau_{US}) g^{\bar{Y}}_{US,t-1} + \epsilon^{g^{\bar{Y}}}_{US,t}$$
5. $$v_{US,t} = 0.5^{*} v_{US,t-1} + \epsilon^{v}_{US,t}$$

② inflation block

6. $$\pi_{US,t} = \lambda_{US,1} \pi 4_{US,t+4} + (1-\lambda_{US,1}) \pi 4_{US,t-1} + \lambda_{US,2} y_{US,t-1} + \lambda_{US,3} \sum_{j \neq US} w_{US,j,3} (Z_{US,j,t} - Z_{US,j,t-4} - (\bar{Z}_{US,j,t} - \bar{Z}_{US,j,t-4}))/4 - \epsilon^{\pi}_{US,t}$$
7. $$\pi_{US,t} = 4^{*}(P_{US,t} - P_{US,t-1})$$
8. $$\pi 4_{US,t} = P_{US,t} - P_{US,t-4}$$

③ interest rate block

9. $$i_{US,t} = \gamma_{US,1} i_{US,t-1} + (1-\gamma_{US,1})[\bar{r}_{US,t} + \pi 4_{US,t+3} + \gamma_{US,2}(\pi 4_{US,t+3} - \pi^{tar}_{US}) + \gamma_{US,4} y_{US,t}] + \epsilon^{i}_{US,t}$$
10. $$r_{US,t} = i_{US,t} - \pi_{US,t+1}$$
11. $$\bar{r}_{US,t} = \rho_{US} \bar{r}_{US,ss} + (1-\rho_{US})(\bar{r}_{US,t-1} + \bar{r}_{US,t-2} + \bar{r}_{US,t-3} + \bar{r}_{US,t-4})/4 + \epsilon^{\bar{r}}_{US,t}$$

④ unemployment rate block

12. $$u_{US,t} = \alpha_{US,1} u_{US,t-1} + \alpha_{US,2} y_{US,t} + \epsilon^{u}_{US,t}$$
13. $$u_{US,t} = \bar{U}_{US,t} - U_{US,t}$$
14. $$\bar{U}_{US,t} = \bar{U}_{US,t-1} + g^{\bar{U}}_{US,t} + \epsilon^{\bar{U}}_{US,t}$$
15. $$g^{\bar{U}}_{US,t} = (1-\alpha_{US,3}) g^{\bar{U}}_{US,t-1} + \epsilon^{g^{\bar{U}}}_{US,t}$$

⑤ credit spread block

16. $$CS_{US,t} - CS_{US,ss} = \mu_{US,1}(CS_{US,t-1} - CS_{US,ss}) - \mu_{US,2} y_{US,t-1} + \mu_{US,3}(\sum_{k=1}^{4} i_{US,t-k} - 4(\pi^{tar}_{US} + \bar{r}_{US,ss}))/4 + \epsilon^{CS}_{US,t}$$

⑥ dollar index block

17. $$dxy_t = \beta_{dxy,1} dxy_{t-1} + \beta_{dxy,2}(\sum_{k=0}^{3} i_{US,t-k} - 4(\pi^{tar}_{US} + \bar{r}_{US,ss}))/4 - \beta_{dxy,3} \sum_{k=1}^{4} y_{US,t+k}/4 + \epsilon^{dxy}_{t}$$
18. $$DXY_t = \overline{DXY}_t + dxy_t$$
19. $$\overline{DXY}_t = \overline{DXY}_{t-1} + \epsilon^{\overline{DXY}}_{t}$$

[2] Euro Area, Japan, Korea ($i = EZ, JP, KR$)

① GDP block

1. $y_{i,t} = \{\beta_{i,1} y_{i,t-1} + \beta_{i,2} y_{i,t+1} - \beta_{i,3}(r_{i,t-1} - \bar{r}_{i,t-1})\}$
$+ \left\{\beta_{i,4} \sum_{j \neq i} w_{i,j,4} \sum_{k=1}^{4} (Z_{i,j,t-k} - \overline{Z}_{i,j,t-k})/4\right\}$
$+ \left\{\beta_{fact} \sum_{j \neq i} w_{i,j,5} y_{j,t-1} + \beta_{factres} \sum_{j} w_{i,j,5} v_{j,t}\right\}$
$- \beta_{i,5} dxy_t - \beta_{i,6}(CS_{i,t-1} - CS_{i,ss}) + \epsilon_{i,t}^{y}$
2. $Y_{i,t} = \overline{Y}_{i,t} + y_{i,t}$
3. $\overline{Y}_{i,t} = \overline{Y}_{i,t-1} + g_{i,t}^{\overline{Y}}/4 + \epsilon_{i,t}^{\overline{Y}}$
4. $g_{i,t}^{\overline{Y}} = \tau_i g_{i,ss}^{\overline{Y}} + (1-\tau_i) g_{i,t-1}^{\overline{Y}} + \epsilon_{i,t}^{g^{\overline{Y}}}$
5. $v_{i,t} = 0.5^{*} v_{i,t-1} + \epsilon_{i,t}^{v}$

② inflation block

6. $\pi_{i,t} = \lambda_{i,1} \pi 4_{i,t+4} + (1-\lambda_{i,1}) \pi 4_{i,t-1} + \lambda_{i,2} y_{i,t-1}$
$+ \lambda_{i,3} \sum_{j \neq i} w_{i,j,3} (Z_{i,j,t} - Z_{i,j,t-4} - (\overline{Z}_{i,j,t} - \overline{Z}_{i,j,t-4}))/4 - \epsilon_{i,t}^{\pi}$
7. $\pi_{i,t} = 4^{*}(P_{i,t} - P_{i,t-1})$
8. $\pi 4_{i,t} = P_{i,t} - P_{i,t-4}$

③ Interest rate block

9. $i_{i,t} = \gamma_{i,1} i_{i,t-1} + (1-\gamma_{i,1})[\,\bar{r}_{i,t} + \pi 4_{i,t+3} + \gamma_{i,2}(\pi 4_{i,t+3} - \pi_i^{tar}) + \gamma_{i,4} y_{i,t}] + \epsilon_{i,t}^{i}$
10. $r_{i,t} = i_{i,t} - \pi_{i,t+1}$
11. $\bar{r}_{i,t} = \rho_i \bar{r}_{i,ss} + (1-\rho_i)(\bar{r}_{i,t-1} + \bar{r}_{i,t-2} + \bar{r}_{i,t-3} + \bar{r}_{i,t-4})/4 + \epsilon_{i,t}^{\bar{r}}$

④ exchange rate block

12. $(r_{i,t} - r_{US,t}) = 4(Z_{i,t}^{e} - Z_{i,t}) + (\bar{r}_{i,t} - \bar{r}_{US,t}) + \omega_i dxy_t + \epsilon_{i,t}^{UIP}$
13. $Z_{i,t} = S_{i,t} + P_{US,t} - P_{i,t}$
14. $Z_{i,t}^{e} = \phi_i Z_{i,t+1} + (1-\phi_i) Z_{i,t-1}$
15. $\overline{Z}_{i,t} = \overline{Z}_{i,t-1} + \epsilon_{i,t}^{\overline{Z}}$

⑤ unemployment block

16. $u_{i,t} = \alpha_{i,1} u_{i,t-1} + \alpha_{i,2} y_{i,t} + \epsilon_{i,t}^{u}$
17. $u_{i,t} = \overline{U}_{i,t} - U_{i,t}$
18. $\overline{U}_{i,t} = \overline{U}_{i,t-1} + g_{i,t}^{\overline{U}} + \epsilon_{i,t}^{\overline{U}}$
19. $g_{i,t}^{\overline{U}} = (1-\alpha_{i,3}) g_{i,t-1}^{\overline{U}} + \epsilon_{i,t}^{g^{\overline{U}}}$

⑥ credit spread block

20. $CS_{i,t} - CS_{i,ss} = \mu_{i,1}(CS_{i,t-1} - CS_{i,ss}) - \mu_{i,2} y_{i,t-1} + \mu_{i,3}(CS_{US,t} - CS_{US,ss}) + \epsilon_{i,t}^{CS}$

[3] Emerging Asia ($i = EA6$)

① GDP block

1. $y_{EA6,t} = \{\beta_{EA6,1} y_{EA6,t-1} + \beta_{EA6,2} y_{EA6,t+1} - \beta_{EA6,3}(r_{EA6,t-1} - \bar{r}_{EA6,t-1})\}$
$+ \left\{\beta_{EA6,4} \sum_{j \neq EA6} w_{EA6,j,4} \sum_{k=1}^{4} (Z_{EA6,j,t-k} - \bar{Z}_{EA6,j,t-k})/4\right\}$
$+ \left\{\beta_{fact} \sum_{j \neq EA6} w_{EA6,j,5} y_{j,t-1} + \beta_{factres} \sum_{j} w_{EA6,j,5} v_{j,t}\right\}$
$- \beta_{EA6,5} dxy_t + \epsilon^{y}_{EA6,t}$
2. $Y_{EA6,t} = \bar{Y}_{EA6,t} + y_{EA6,t}$
3. $\bar{Y}_{EA6,t} = \bar{Y}_{EA6,t-1} + g^{\bar{Y}}_{EA6,t}/4 + \epsilon^{\bar{Y}}_{EA6,t}$
4. $g^{\bar{Y}}_{EA6,t} = \tau_{EA6} g^{\bar{Y}}_{EA6,ss} + (1-\tau_{EA6}) g^{\bar{Y}}_{EA6,t-1} + \epsilon^{g^{\bar{Y}}}_{EA6,t}$
5. $v_{EA6,t} = 0.5^{*} v_{EA6,t-1} + \epsilon^{v}_{EA6,t}$

② inflation block

6. $\pi_{EA6,t} = \lambda_{EA6,1} \pi 4_{EA6,t+4} + (1-\lambda_{EA6,1}) \pi 4_{EA6,t-1} + \lambda_{EA6,2} y_{EA6,t-1}$
$+ \lambda_{EA6,3} \sum_{j \neq EA6} w_{EA6,j,3} (Z_{EA6,j,t} - Z_{EA6,j,t-4} - (\bar{Z}_{EA6,j,t} - \bar{Z}_{EA6,j,t-4}))/4 - \epsilon^{\pi}_{EA6,t}$
7. $\pi_{EA6,t} = 4^{*}(P_{EA6,t} - P_{EA6,t-1})$
8. $\pi 4_{EA6,t} = P_{EA6,t} - P_{EA6,t-4}$

③ interest rate block

9. $i_{EA6,t} = \gamma_{EA6,1} i_{EA6,t-1}$
$+ (1-\gamma_{EA6,1})[\bar{r}_{EA6,t} + \pi 4_{EA6,t+3} + \gamma_{EA6,2}(\pi 4_{EA6,t+3} - \pi^{tar}_{EA6}) + \gamma_{EA6,4} y_{EA6,t}] + \epsilon^{i}_{EA6,t}$
10. $r_{EA6,t} = i_{EA6,t} - \pi_{EA6,t+1}$
11. $\bar{r}_{EA6,t} = \rho_{EA6} \bar{r}_{EA6,ss} + (1-\rho_{EA6})(\bar{r}_{EA6,t-1} + \bar{r}_{EA6,t-2} + \bar{r}_{EA6,t-3} + \bar{r}_{EA6,t-4})/4 + \epsilon^{\bar{r}}_{EA6,t}$

④ exchange rate block

12. $(r_{EA6,t} - r_{US,t}) = 4(Z^{e}_{EA6,t} - Z_{EA6,t}) + (\bar{r}_{EA6,t} - \bar{r}_{US,t}) + DOT(\bar{Z}_{EA6,t}) + \omega_{EA6} dxy_t + \epsilon^{UIP}_{EA6,t}$
13. $Z_{EA6,t} = S_{EA6,t} + P_{US,t} - P_{EA6,t}$
14. $Z^{e}_{EA6,t} = \phi_{EA6} Z_{EA6,t+1} + (1-\phi_{EA6})(Z_{EA6,t-1} + 2^{*} DOT(\bar{Z}_{EA6,t})/4)$
15. $\bar{Z}_{EA6,t} = \bar{Z}_{EA6,t-1} + DOT(\bar{Z}_{EA6,t})/4 + \epsilon^{\bar{Z}}_{EA6,t}$
16. $DOT(\bar{Z}_{EA6,t}) = \chi_{EA6} DOT(\bar{Z}_{EA6,ss}) + (1-\chi_{EA6}) DOT(\bar{Z}_{EA6,t-1}) + \epsilon^{DOT(\bar{Z})}_{EA6,t}$

[4] China ($i = CN$)

① GDP block

1. $y_{CN,t} = \{\beta_{CN,1} y_{CN,t-1} + \beta_{CN,2} y_{CN,t+1} - \beta_{CN,3}(r_{CN,t-1} - \bar{r}_{CN,t-1})\}$
$+ \left\{\beta_{CN,4} \sum_{j \neq CN} w_{CN,j,4} \sum_{k=1}^{4} (Z_{CN,j,t-k} - \bar{Z}_{CN,j,t-k})/4\right\}$
$+ \left\{\beta_{fact} \sum_{j \neq CN} w_{CN,j,5} y_{j,t-1} + \beta_{factres} \sum_{j} w_{CN,j,5} v_{j,t}\right\}$
$- \beta_{CN,5} dxy_t - \beta_{CN,6}(CS_{CN,t-1} - CS_{CN,ss}) + \epsilon^{y}_{CN,t}$
2. $Y_{CN,t} = \bar{Y}_{CN,t} + y_{CN,t}$
3. $\bar{Y}_{CN,t} = \bar{Y}_{CN,t-1} + g^{\bar{Y}}_{CN,t}/4 + \epsilon^{\bar{Y}}_{CN,t}$
4. $g^{\bar{Y}}_{CN,t} = \tau_{CN} g^{\bar{Y}}_{CN,ss} + (1-\tau_{CN}) g^{\bar{Y}}_{CN,t-1} + \epsilon^{g^{\bar{Y}}}_{CN,t}$
5. $v_{CN,t} = 0.5 * v_{CN,t-1} + \epsilon^{v}_{CN,t}$

② inflation block

6. $\pi_{CN,t} = \lambda_{CN,1} \pi 4_{CN,t+4} + (1-\lambda_{CN,1}) \pi 4_{CN,t-1} + \lambda_{CN,2} y_{CN,t-1}$
$+ \lambda_{CN,3} \sum_{j \neq CN} w_{CN,j,3} (Z_{CN,j,t} - Z_{CN,j,t-4} - (\bar{Z}_{CN,j,t} - \bar{Z}_{CN,j,t-4}))/4 - \epsilon^{\pi}_{CN,t}$
7. $\pi_{CN,t} = 4 * (P_{CN,t} - P_{CN,t-1})$
8. $\pi 4_{CN,t} = P_{CN,t} - P_{CN,t-4}$

③ interest rate block

9. $i_{CN,t} = \gamma_{CN,1} i_{CN,t-1}$
$+ (1-\gamma_{CN,1})[\bar{r}_{CN,t} + \pi 4_{CN,t+3} + \gamma_{CN,2}(\pi 4_{CN,t+3} - \pi^{tar}_{CN}) + \gamma_{CN,4} y_{CN,t}] + \epsilon^{i}_{CN,t}$
10. $r_{CN,t} = i_{CN,t} - \pi_{CN,t+1}$
11. $\bar{r}_{CN,t} = \rho_{CN} \bar{r}_{CN,ss} + (1-\rho_{CN})(\bar{r}_{CN,t-1} + \bar{r}_{CN,t-2} + \bar{r}_{CN,t-3} + \bar{r}_{CN,t-4}) + \epsilon^{\bar{r}}_{CN,t}$

④ exchange rate block

12. $(r_{CN,t} - r_{US,t}) = 4(Z^{e}_{CN,t} - Z_{CN,t}) + (\bar{r}_{CN,t} - \bar{r}_{US,t}) + DOT(\bar{Z}_{CN,t}) + \omega_{CN} dxy_t + \epsilon^{UIP}_{CN,t}$
13. $Z_{CN,t} = S_{CN,t} + P_{US,t} - P_{CN,t}$
14. $Z^{e}_{CN,t} = \phi_{CN} Z_{CN,t+1} + (1-\phi_{CN})(Z_{CN,t-1} + 2 * DOT(\bar{Z}_{CN,t})/4)$
15. $\bar{Z}_{CN,t} = \bar{Z}_{CN,t-1} + DOT(\bar{Z}_{CN,t})/4 + \epsilon^{\bar{Z}}_{CN,t}$
16. $DOT(\bar{Z}_{CN,t}) = \chi_{CN} DOT(\bar{Z}_{CN,ss}) + (1-\chi_{CN}) DOT(\bar{Z}_{CN,t-1}) + \epsilon^{DOT(\bar{Z})}_{CN,t}$

⑤ unemployment rate blcok

17. $u_{CN,t} = \alpha_{CN,1} u_{CN,t-1} + \alpha_{CN,2} y_{CN,t} + \epsilon^{u}_{CN,t}$
18. $u_{CN,t} = \bar{U}_{CN,t} - U_{CN,t}$
19. $\bar{U}_{CN,t} = \bar{U}_{CN,t-1} + g^{\bar{U}}_{CN,t} + \epsilon^{\bar{U}}_{CN,t}$
20. $g^{\bar{U}}_{CN,t} = (1-\alpha_{CN,3}) g^{\bar{U}}_{CN,t-1} + \epsilon^{g^{\bar{U}}}_{CN,t}$

⑥ credit spread block

21. $CS_{CN,t} - CS_{CN,ss} = \mu_{CN,1}(CS_{CN,t-1} - CS_{CN,ss}) - \mu_{CN,2} y_{CN,t-1}$
$+ \mu_{CN,3}(CS_{US,t} - CS_{US,ss}) + \epsilon^{CS}_{CN,t}$

Box 3 Spillover Coefficient Matrix

In the BOK-GPM, the spillover coefficient measures the direct impact of a demand shock in country j on country i's demand ($\Delta Y_i/\Delta Y_j$). It is calculated, using trade-related actual data and findings from previous research, as the product of: 1) the increase in country j's import resulting from a rise in its domestic demand ($\Delta M_j/\Delta Y_j$); 2) the share of country j's total import accounted for by import from country i ($\Delta M_{ji}/\Delta M_j$ (=$\Delta X_{ij}/\Delta M_j$)); 3) the domestic value-added multiplier of country i's export ($\Delta VA_i/\Delta X_{ij}$); 4) the demand-induced effect of an increase in country i's value-added ($\Delta Y_i/\Delta VA_i$).

$$\Delta Y_i/\Delta Y_j = (\Delta Y_i/\Delta VA_i)*(\Delta VA_i/\Delta X_{ij})*(\Delta M_{ji}/\Delta M_j)*(\Delta M_j/\Delta Y_j) \quad \cdots \quad (1)$$

The value-added content parameter $\Delta VA_i/\Delta X_{ij}$ takes larger values for countries whose exports comprise a high share of domestically produced goods and smaller values for economies with a large share of intermediary of processing trade. Meanwhile, the demand-multiplier parameter $\Delta Y_i/\Delta VA_i$ captures a Keynesian-type effect whereby the value-added generated by exports stimulates additional domestic consumption and investment.

Next, using the definition of GDP gap, the following equation can be yielded.

$$\Delta y_i = \Delta(Y_i/\overline{Y}_i - 1) = \Delta Y_i/\overline{Y}_i \;\Rightarrow\; \Delta Y_i/\Delta Y_j = (\Delta y_i/\Delta y_j)*(\overline{Y_i}/\overline{Y_j}) \quad \cdots \quad (2)$$

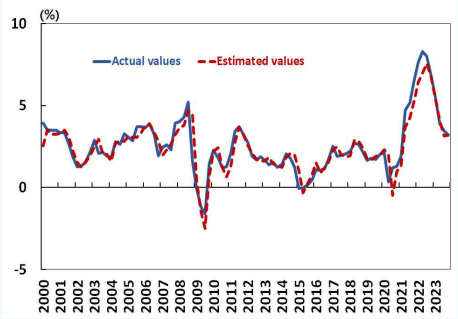
By substituting equation (2) into equation (1), we obtain the transmission of a demand shock in country j to country i as expressed in equation (3) below, in terms of GDP gap.

$$\Delta y_i/\Delta y_j = (\Delta Y_i/\Delta VA_i)*(\Delta VA_i/\Delta X_{ij})*(\overline{Y_j}/\overline{Y_i})*(\Delta M_{ji}/\Delta M_j)*(\Delta M_j/\Delta Y_j) \quad \cdots \quad (3)$$

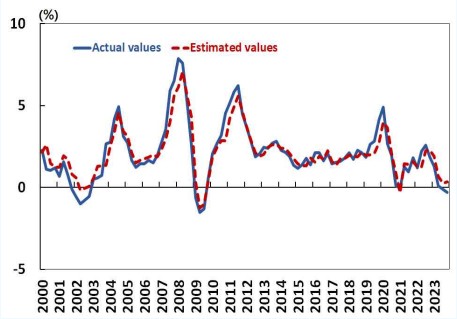
BOX 4 Comparison Between Actual and Estimated Values of Consumer Price Inflation in Major Countries and Unconditional Forecasting

[Figure A1] Actual Estimated Values of Consumer Price Inflation in Major Countries[1)2)]

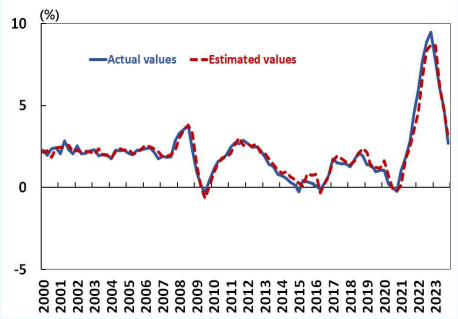
United States



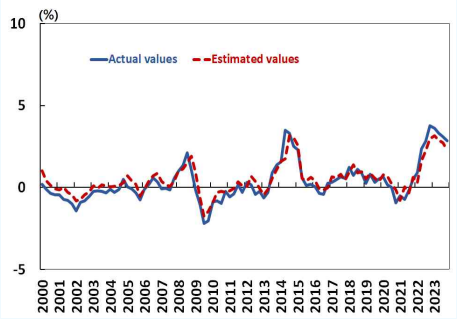
China



Euro Area



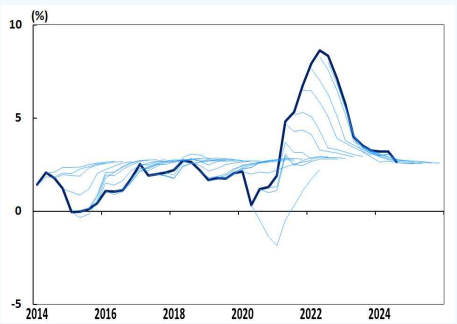
Japan



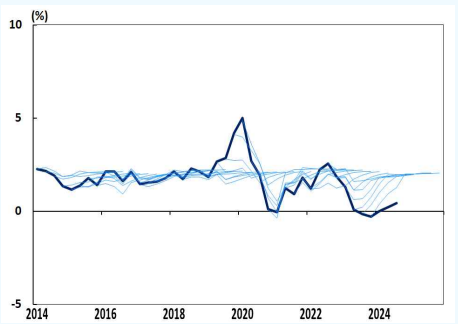
Notes: 1) Year-on-year growth rates
2) The solid line indicates actual values, while the dotted line indicates estimates values of the BOK-GPM

[Figure A2] Results of Unconditional Forecasting (Eight Quarters) of Consumer Price Inflation[1)2)]

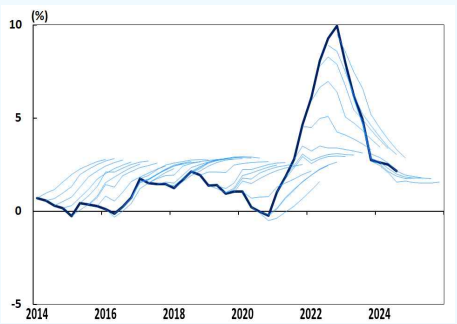
United States



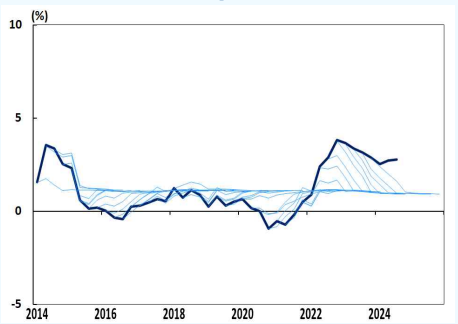
China



Euro Area



Japan



Notes: 1) Year-on-year growth rates
2) The solid line indicates actual values, while the thin line indicates the unconditional forecasting path for the next eight quarters at each quarter.

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