Financial Cycles and The Natural Rate of Interest in a Small Open Economy: The Case of Korea

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ABSTRACT: By extending the semi-structural model of Laubach and Williams (2003), we analyse the impact of domestic and global financial cycles on the natural rate of interest in Korea. We find that, along with domestic household credit to GDP ratio, global financial cycle proxies such as foreign portfolio investments and VIX and MOVE volatility measures are important factors in the fluctuation of output gap and the natural interest rate. While Korea's natural interest rate has fallen substantially after the global financial crisis as in many advanced economies, our finance-neutral estimates have fallen less than the conventional estimate based on the inflation dynamics only. Furthermore, our findings suggest that the substantial reduction in the US bond term premium has brought about significant spill-over effects in open emerging economies such as Korea through its impact on the natural interest rate.

KEY WORDS: natural rate of interest; potential growth; financial cycle; monetary policy; Korea

JEL CLASSIFICATION: E43, E52, F42

1. Introduction

Since the seminal work of Laubach and Williams (2003, LW hereafter), the natural real interest rate has received increasing attention in both academia and policy circles as a benchmark guidepost in conducting monetary policy. The natural rate of interest is interpreted as the short-term equilibrium real interest rate that is consistent, in the long-run, with output at potential, unemployment at its natural rate, and inflation at the monetary authorities' target level (Wicksell 1936, LW 2003, Kiley 2015). LW and early empirical studies employed statistical models that focus on inflation dynamics in order to identify unobservable natural rate and output gaps. However, with the occurrence of the global financial crisis, a growing volume of research has paid attention to the linkage between financial cycle and business cycle. According to this view, early semi-structural models of the natural rate of interest such as LW may suffer potentially serious misspecification problems as they exclude financial variables relevant in characterizing the output dynamics (Kiley 2015, Cukierman 2016, Taylor and Wieland 2016).

A strand of recent research has extended the LW model by explicitly incorporating financial variables in the semi-structural model and found evidence supporting the role of financial factors as determinants of the natural rate of interest. For instance, Kiley (2015) employed financial variables such as corporate bond spread and private credit growth along with fiscal policy variable in his IS and Phillips curves, and found that these cyclical variables have important effects on estimates of the natural interest rate. Juselius et al. (2016) considered leverage gap and debt service ratio gap variables in their semi-structural model, and found that the natural rate of interest has declined less than the LW estimate in the US since 2000 when including financial factors in their model. Hakkio and Smith (2017) considered government bond term

premium and corporate bond spread and found that the term premium is a significant determinant of the natural interest rate in the US. They argued that a reduction in bond premiums in financial cycle booms increases the natural rate of interest as lower premiums provide additional accommodative effects by reducing funding costs of firms and households. They also argued that a reduction in term premiums causes long-term interest rates to fall and hence, the neutral level of short-term policy rate of monetary authorities must increase in order to maintain long-term equilibrium interest rate at the previous level.[1)] More recently Krustev (2018) employed private credit growth and corporate spread in his semi-structural model, and found that the natural rate of interest in the US has been significantly affected by financial cycle variables.

Relative to the growing volume of research on the natural rate of interest in advanced economies, there exists relatively little research on the natural rate in open economy setting especially on its relationship with financial cycles. For instance, Wynne and Zhang (2017) provided a two-country open economy framework and estimated the natural rate of interest without considering the role of financial cycles. Grintzalis *et al*. (2017) estimated the impact of both domestic and global credit cycles on output gaps of emerging market economies. They found that financial cycle information captured by both domestic and global credit aggregates is significantly associated with output dynamics in emerging market countries. However, they did not estimate the natural rate of interest.

In the present paper, we follow the above literature and extend the LW model by explicitly allowing for the role of financial cycle in estimating output gaps and the natural rate of interest in open emerging economies such as Korea. Our contributions to

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[1] Note also that, in DSGE models such as Smets and Wouters (2007) and Curdia and Woodford (2016), bond term premiums and credit spreads are negatively related with the neutral interest rate implied by the optimal monetary policy.

existing literature are twofold. First, we distinguish domestic financial cycle factors from global financial cycle factors, and explore their respective roles in characterizing financial conditions and the natural interest rate in Korea. As Rey (2015) emphasized, there is a global financial cycle in which capital flows, asset prices and credit growth tend to co-move, which in turn greatly affect financial condition and business cycle in open emerging economies. Notwithstanding potentially significant spill-over effects of global financial cycles to small open emerging economies such as Korea, there exists little empirical research on this front. Kim and Park (2013) estimated Korea's natural real interest rate, but they did not consider financial cycle effects. Park *et al*. (2013) applied the model of Borio et al. (2013) to Korea and estimated finance-neutral output gaps. However, they did not estimate the natural rate of interest.

Second, we extend Hakkio and Smith (2017) to open emerging economies by considering the term premium in the US long-term bond along with the domestic term premium as a potentially important determinant of the natural rate of interest in Korea. Indeed, bond markets have become increasingly integrated across countries and cross-border investment flows constitute an important channel of monetary policy spill-over across countries. As Turner (2014) argued, the global reduction in bond term premiums triggered by the large scale asset purchase programs in the US and other advanced countries have exerted significant spill-over effects on the monetary and financial conditions of emerging market countries through cross-border bond investment flows. According to Gagnon et al. (2011), the first round of quantitative easing (QE1) reduced the US bond term premium by 50 basis points. Abrahams et al. (2016) also estimated that all three rounds of QEs reduced the US term premium by about 110 points on a cumulative basis. Duca et al. (2016) found that QEs in the US led to the expansion of global corporate bond issuance. In particular their empirical analysis indicates that the

reduction in the US term premium is a significant factor that has caused the expansion of bond issuance in both advanced and emerging market economies. Korea is not an exception in this regard. As we argue below, Korea's long-term bond yields and term premiums have declined substantially along with the fall in the US term premium. We explicitly incorporate and investigate this channel of spill-over effects via capital flows and term premiums in bond markets.

Our empirical investigation indicates that, along with the domestic household credit cycle, external financial cycle variables such as portfolio investment flows into Korea as well as uncertainty measures in global financial markets such as VIX and MOVE indices are important factors in the fluctuation of output gap and the natural interest rate in Korea. While Korea's natural interest rate has fallen substantially after the global financial crisis as in many advanced economies, our finance-neutral estimates have fallen less than the conventional LW estimate based on the inflation dynamics only. In particular, our estimation results show that the recent substantial reduction in the US term premium has brought about significant spill-over effects in open emerging economies such as Korea in that, the resulting low long-term interest rates and accommodative financial conditions have exerted upward pressure on the natural rate of interest.

The remainder of the present paper is organized as follows. Section 2 describes our semi-structural model of the natural rate of interest, which explicitly incorporates the role of financial cycle factors. We also discuss estimation method in this section. Section 3 presents our empirical results obtained. We report our estimates of finance-adjusted output gaps as well as finance neutral real interest rates. This section also explores relative importance of domestic and global financial cycle factors as

determinants of output and interest rate dynamics in Korea. Finally Section 4 summarizes our findings and concludes.

2. The Model and Estimation Method

We extend the semi-structural model of LW in a way that captures the role of both domestic and global financial cycles. The financial cycles are linked to the natural rate of interest via two channels. The first channel is through real-financial linkage in which the output gap is affected by the financial cycle. The second channel captures more direct impacts of financial conditions on the natural rate of interest, and we employ domestic and foreign bond premiums as important financial cycle variables that exert impacts on the natural interest rate following the spirit of Bernanke (2006) and Hakkio and Smith (2017).[2] As noted above, with other factors held constant, a reduction in long-term bond term premiums caused by either domestic shocks or global contagion would induce more accommodative financial conditions in open emerging economies as it lowers financing costs of firms and households. Lower long-term interest rates along with accommodative financial conditions would in turn exert upward pressure on the short-term neutral interest rates.

Our model consists of four groups of equations. The first group of equations summarizes the investment-saving (IS) relation which links the output gap to the interest rate gap and the financial cycle gap, along with the dynamics of potential outputs.

$$(\mathrm{y_t} - y_t^*) = \beta_1(\mathrm{y_{t-1}} - y_{t-1}^*) - \beta_2[(r_{t-1} - r_{t-1}^*) + (r_{t-2} - r_{t-2}^*)]/2 + \hat{f}_t + \epsilon_t^{\hat{y}} \quad (1)$$

[2] Bernanke (2006) discusses potential factors leading to the dramatic fall in the US bond term premium in the mid-2000s, and argues that, to the extent that the lower long-term yield reflects a declining term premium, the implications for future economic activity are positive rather than negative, and the monetary policy rate associated with a given degree of financial stimulus would be higher than usual.

$$y_t^* = 2\, y_{t-1}^* - y_{t-2}^* + \epsilon_t^{y^*} \tag{2}$$

where y_t is logged output, y_t^* is its potential level, r_t is real short-term interest rate, r_t^* is the natural real rate of interest, $\hat{f}_t$ is the financial cycle gap, and $\epsilon_t^{\hat{y}}$, $\epsilon_t^{y^*}$ are the error terms. In equation (1), the output gap increases above its potential level if the real rate of interest falls below the natural rate of interest or if the financial cycle gap is positive, namely, financial condition is accommodative. To capture the interest rate effect on the output gap, we employ a two period moving average of the lagged real interest rate gaps as in LW (2013). The log potential output is assumed to follow a double unit root process and thus potential output growth rate is random walk as postulated in most semi-structural models.

The second group of equations describes the financial cycle dynamics, $\hat{f}_t$, which consists of domestic and global financial cycles. Specifically, financial cycles are characterized by the following equations.

$$\sigma_t = \sigma_t^* + \hat{\sigma}_t, \qquad \sigma_t^* = c_\sigma + cr_{t-1}^* + \epsilon_t^{cr^*} \tag{3}$$

$$\hat{\sigma}_t = \eta_1 \hat{\sigma}_{t-1} - \eta_2[(r_t - r_t^*) + (r_{t-1} - r_{t-1}^*)]/2 + \epsilon_t^{c\hat{r}} \tag{4}$$

$$\widehat{fc}_t = fc_t - fc_{t-1} \tag{5}$$

$$\hat{f}_t = \beta_3(\hat{\sigma}_{t-1} + \hat{\sigma}_{t-2})/2 + \beta_4\left(\widehat{fc}_{t-1} + \widehat{fc}_{t-2}\right)/2 \tag{6}$$

where σ_t and σ_t^* are domestic financial cycle factor and its trend, respectively, fc_t represents the foreign financial cycle factor, and $\epsilon_t^{c\hat{r}}$, $\epsilon_t^{cr^*}$ are the error terms. In equation (4) the domestic financial cycle gap is negatively linked with the interest rate gap. Since we consider a small open economy, the global financial cycle gap is assumed not directly affected by domestic factors such as the interest rate gap.

The third group of equations describes the dynamics of the natural rate of interest. In equation (7), along with the annualized potential output growth rate, financial factors c_t that directly affect the natural rate of interest are included, and z_t describes other unobservable determinants of natural interest rate such as households' rate of time preference and demographic changes. We assume that z_t follows a random walk process. As argued above, we consider the 10 year government bond term premiums of Korea (tp_t^{kr}) and the US (tp_t^{us}) as potential candidate variables for c_t.

$$\mathrm{r}_t^* = c\,(4 \cdot \Delta y_t^*) - c_t + z_t + \epsilon_t^{r^*} \tag{7}$$

$$\mathrm{c}_t = c_{tp}\, tp_t^{kr} + c_{tpf}\, tp_t^{us} \tag{8}$$

Finally, equation (9) denotes the Phillips curve in which the deviation of inflation from the target inflation π_t^* is linked with the output gap. Core CPI is used to obtain inflation.

$$(\pi_t - \pi_t^*) = \gamma_1(\pi_{t-1} - \pi_{t-1}^*) + \gamma_2(y_t - y_t^*) + \epsilon_t^{\pi} \tag{9}$$

In attempts to illuminate the diverse effects of domestic and global financial cycle factors and bond term premiums in more detail, we estimate six alternative model specifications described in Table 1.

[Table 1 near here]

Actual estimation needs to employ domestic and global financial cycle proxy variables. As for the domestic financial cycle proxy, we use the household credit to GDP ratio. During our sample period the household debt to GDP ratio has increased dramatically from 49% to 92%, while the increase in the corporate debt to GDP ratio has been modest (from 51% to 65%). The strong credit growth in housing sector has been partly driven by the relaxation of prudential regulatory measures such as the loan

to value (LTV) and debt service to income (DTI) ratios by the supervisory authority along with the accommodative monetary policies of the central bank. The fast growing household leverage has been widely noted as representing accumulation of financial imbalances in Korea. Note that Borio *et al.* (2013) and Juselius *et al.* (2017) also employed household credit growth in their IS equation.

As for the global financial cycle proxy, we employ the log of foreigners' portfolio investment holdings of stocks and bonds in Korea. As noted in numerous studies such as Rey (2015) and Grintzalis *et al.* (2017), the magnitude and direction of cross-border portfolio capital flows in emerging market countries would most vividly reflect the fluctuation in global financial cycle. As an alternative global financial cycle proxy, we also employ the weighted average of VIX and MOVE indices in global financial markets, which reflect changing uncertainty and risk attitudes of international investors. For the term premium measures in the US 10 year government bond yield, we use the estimates provided by Adrian *et al*. (2013). By applying the Adrian *et al*. (2013)'s three-step regression method, we obtained similar term premium measures for the 10 year government bond in Korea.

We use Bayesian method in estimating the models above. It is well known that the maximum likelihood estimators in LW type models are subject to the pile-up problem of Stock and Watson (1996). Namely, the estimated variance of permanent component in time series is biased toward zero. LW mitigated this problem by pre-imposing some signal-to-noise ratios using the median unbiased estimators as Stock and Watson (1996) suggested. However, Kim and Kim (2013) found that the pile-up problem is much less severe in Bayesian estimation. Based upon their findings and following many authors such as Kiley (2015), we estimate our models using Bayesian method in which the priors of all the coefficients are gamma distributed with the same

mean and variance as in Juselius *et al*. (2017). We use quarterly data and the data spans from the first quarter of 2000 through the first quarter of 2018 due to the availability of Korea's bond term premium data. All the variables used except for the interest rate are seasonally adjusted. Appendix Tables A1~A3 report our priors and posterior estimation results for respective model specifications in Table 1.

3. Empirical Findings

3.1. Financial Cycle Indicators and Term Premiums

Figure 1 shows the trends of domestic and global financial cycle gap measures. As described above, the domestic financial cycle gap is the cyclical component of the household credit to GDP ratio and shows positive values during the periods 2002~2004 and 2006~2008. It fell into the negative range after the global financial crisis and has turned again into positive values since 2015 along with the relaxation of housing finance regulations such as LTV and DTI in Korea. The global financial cycle gap in Figure 1 is the cyclical component of the foreigners' portfolio investments in Korea which shows relatively more volatile movements. It sporadically fell into the negative range during the global financial crisis in 2008~2009, taper tantrum in 2013, and China's stock market turbulence in 2015, but then it has turned into positive gaps from 2016 onwards.

[Figure 1 near here]

The second panel of Figure 1 shows the trends of bond term premiums in Korea and the US, another set of potentially important financial variables that may have direct impacts on the natural rate of interest. As we can see from the figure, the relationship between the two countries' term premiums had not been so close and tight in the pre-crisis period. However, in the post-crisis period, those two term premiums have shown a

strong positive co-movement, and fallen substantially together along with the implementation of the Fed's large-scale asset purchase programs. As noted before, the fall in the US term premium has brought about significant reductions in long-term bond yields in both advanced and open emerging economies (Duca *et al.* 2016). In order to explore the significance of the linkage between the US term premium and Korea's long-term interest rate, we run a simple bi-variate vector auto-regression between those two variables. The cumulative impulse responses summarized in Figure 2 indicate that a unit standard deviation shock to the US term premium tends to have a significant positive impact to Korea's 10 year Treasury bond yield. This finding strongly suggests that the recent dramatic decline in US term premiums may have influenced the natural rate of interest as well in Korea through its impact on long-term bond yields and by bringing in accommodative financial conditions in Korea.[3]

[Figure 2 near here]

3.2. Finance-Neutral Potential Growth and Output Gaps

Figure 3 shows our estimates of potential output growth rates obtained from our financial cycle augmented models with alternative proxies for global financial cycle. We also show the potential growth rate for the benchmark LW model without including financial cycle variables. As the panels in Figure 3 show, both the LW and finance-neutral potential growth rates have fallen substantially during the sample period, which is consistent with the observation that the neutral rates of interest have fallen in major countries after the global financial crisis (Holston, Laubach and Williams 2017). Note however that, relative to finance-neutral potential growth rates, the LW growth rate fell

[3] A bilateral Granger causality test between the US term premium and Korea's 10 year bond yield also confirms that a significant causal relationship exists from the US term premium to Korea's long-term bond yield but not the other way around. We don't report these results to save space.

more sharply in the aftermath of the global financial crisis reflecting the impact of contractionary financial conditions. On the contrary, during the recent period of accommodative financial cycle since 2015, finance-neutral potential growth rates have fallen more to a level below the LW growth rate, suggesting that conventional measures of potential growth rates based upon the inflation neutrality such as the LW estimate could be biased upward due to the effect of financial cycle boom. Note also that the difference between finance-neutral potential growth rates and the LW growth rate becomes larger in models with global financial cycle gaps compared to the model with only domestic financial cycle gap.

[Figure 3 near here]

The finance-adjusted output gap estimates reported in Figure 4 also confirm findings above. Output gap measures in both financial cycle augmented and the baseline LW models had been increasing and significantly positive before the global financial crisis, but then they fell sharply into the negative range in the aftermath of the crisis. Note that, during the recent recovery period since 2015, the negative output gaps have been closed and turned to positive earlier in our global financial cycle augmented models than in the LW model. The evidence is consistent with the findings above that, if there were no positive spill-over effects from lax global financial cycle movements since 2016, the potential growth rate would have fallen more and thus output gaps would have been smaller or even positive.

[Figure 4 near here]

3.3. Finance-Neutral Natural Rate of Interest

The estimates of our finance-neutral natural interest rate are reported in Figure 5. Note that compared to the LW natural rate, the estimates of finance-neutral natural interest

rate show in general more cyclicality due to financial cycle effects, which is consistent with the finding of Hakkio and Smith (2017) and others discussed above. At the onset of the global financial crisis, reflecting the accommodative effect of financial cycle boom, finance-neutral natural real rates had been higher than the LW natural rate in Korea. The finance-neutral natural rates fell substantially along with the LW natural rate in the aftermath of the global financial crisis. However, while the LW rate continued to fall since the crisis, the finance-neutral natural real interest rates fluctuated at a level higher than the LW rate in recent expansionary financial cycle period since 2015.

[Figure 5 near here]

Our findings are consistent with the observation that the natural rate of interest has fallen significantly since the global financial crisis in both advanced and emerging market countries. The fall in the natural rate of interest in Korea would reflect both domestic factors such as aging demography and global factors such as high precautionary saving and declining relative price of investment goods. However, as argued by Kiley (2015) and Juselius *et al.* (2016), the magnitude of the fall in natural real interest rate may have been exaggerated due to financial cycle effect, and if the financial cycle effect is adjusted, the natural rate of interest may be a bit higher than the conventional estimates based on inflation dynamics only.

In Korea, along with the domestic household credit boom since 2015, lax global financial cycle reflected in sustained portfolio capital inflows and favourable risk attitudes of international investors have contributed to improvement of output gaps and thus have indirectly affected natural interest rates in Korea. Note that term premiums have a more direct impact on the finance-neutral natural rate in Korea. In our natural interest rate equations, the coefficients of both Korea and US term premiums were negative as predicted. In particular, the US term premium seems to exert economically

significant negative impacts on the natural interest rate in Korea. This result also suggests that unusually low US term premiums and resulting accommodative global financial cycle have brought about significant spill-over effects through bond markets on financial conditions and thus natural real interest rate in Korea.

3.4. Relative Contribution of Domestic and Global Financial Cycles

Figure 6 shows the decomposition of quarter to quarter changes in finance-neutral natural interest rates estimated from our financial cycle augmented models which include both Korea and the US term premiums in the natural rate equation. As the potential output growth rate has fallen persistently during the sample period, its impact on the change in natural rate of interest is mostly negative. It is interesting to note that, while the domestic term premium plays a limited role, the US term premium has exerted economically significant impacts on the quarter to quarter change in finance-neutral natural interest rate in Korea. During the taper tantrum in 2013, the increase in the US term premium caused Korea's natural interest rate to fall, but in most of the recent period, the reductions in the US term premium tended to yield upward pressure for Korea's natural interest rate, except in sporadic periods of financial turmoil such as China's stock market turbulences in 2015.

[Figure 6 near here]

In a similar vein, Figure 7 shows the decomposition of output gap estimates. In the figures, the contribution of the autoregressive component was excluded. Note that the Bank of Korea's accommodative monetary policies and downward adjustments of benchmark policy rate since 2014 onwards had contributed positively to the output gap in Korea. The household credit cycle had contributed negatively to the output gap before 2016, but its contribution turned to positive from 2016 reflecting the positive

domestic credit cycle gap. As for the impact of global financial cycle factors, the contribution of portfolio capital inflows to the output gap in Korea has been mostly positive except in the periods of global financial turbulences. However, when using the VIX and MOVE volatility measures as a proxy of global financial cycle, its contribution to Korea's output gap had been mostly negative before 2013, but then it turned positive and its positive contribution has expanded significantly during the recent episode.

[Figure 7 near here]

4. Conclusion

This study empirically investigates the impact of domestic and global financial cycles on the natural real rate of interest and output gap in Korea. Following the recent attempts to account for the linkage between financial variables and the natural interest rate, we extend the benchmark semi-structural model of Laubach and Williams (2003) by incorporating both domestic and global financial cycle gap measures in the IS curve, and domestic and the US bond term premiums in the neutral rate equation.

Empirical results indicate that both domestic and global financial cycle factors have significantly influenced Korea's output gap and natural rate of interest in directions predicted by the model. More specifically, we find that the domestic household credit boom and sustained portfolio capital inflows along with unusually low global bond term premiums have brought about accommodative financial conditions in Korea in the recent period since 2016. In this recent expansionary financial cycle period, the accommodative financial conditions have positively contributed to the output gap. When we account for the financial cycle effect, our finance-neutral potential output growth rates are lower and finance-neutral natural interest rates are higher than conventional measures based on inflation dynamics only.

In particular, we find that there exists a significant spill-over channel of global financial cycle through globally integrated bond markets. The unusually low and negative term premiums in global bond markets partly triggered by the large scale asset purchase programs in the US and other advanced countries have led to the low and negative long-term bond term premiums in Korea. Resulting accommodative financial conditions have exerted upward pressure on the natural rate of interest.

Our study yields important policy implications for open emerging economies. When conducting monetary policy, financial cycles must be considered carefully along with conventional inflation dynamics especially when financial cycle booms are not accompanied with inflationary pressures. With inflationary pressures subdued, monetary policies under conventional inflation targeting, may lead to accumulation of financial imbalances especially when the finance-neutral natural interest rate diverges with conventional inflation based natural interest rate. In particular, policymakers in open emerging market economies may need to carefully consider the nature and magnitude of spill-over effects from the global financial cycle in addition to domestic credit and asset price movements when they try to achieve both price stability and financial stability.

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Table 1: Specifications of Semi-structural Models

		IS Equation	
		domestic financial cycle only ($\beta_4 = 0$)	both domestic and global financial cycles
Natural Interest Rate Equation	domestic term premium only ($c_{tpf} = 0$)	D-K	DF-K
	US term premium only ($c_{tp} = 0$)	D-U	DF-U
	both domestic and US term premiums	D-KU	DF-KU

[Appendix]

Table A1: Bayesian Estimation Results (Domestic Financial Cycle Only)

Model D-KU

		priors			posteriors	
		distribution	mean	s.d.	mean	s.d.
IS Equation	β_1	Gamma	0.7	0.2	0.730	0.074
	β_2	Gamma	0.3	0.2	0.152	0.056
	β_3	Gamma	0.3	0.2	0.102	0.025
Natural Rate of Interest	c	Gamma	0.5	0.2	0.630	0.224
	c_{tp}	Gamma	0.5	0.2	0.000	0.146
	c_{tpf}	Gamma	0.3	0.2	0.261	0.173
Phillips Curve	γ_1	Gamma	0.7	0.2	0.397	0.082
	γ_2	Gamma	0.3	0.2	0.049	0.027
Financial Cycle	η_1	Gamma	0.7	0.2	0.917	0.045
	η_2	Gamma	0.3	0.2	0.172	0.073

Model D-K

		priors			posteriors	
		distribution	mean	s.d.	mean	s.d.
IS Equation	β_1	Gamma	0.7	0.2	0.735	0.075
	β_2	Gamma	0.3	0.2	0.141	0.051
	β_3	Gamma	0.3	0.2	0.101	0.031
Natural Rate of Interest	c	Gamma	0.5	0.2	0.582	0.217
	c_{tp}	Gamma	0.3	0.2	0.000	0.150
Phillips Curve	γ_1	Gamma	0.7	0.2	0.397	0.082
	γ_2	Gamma	0.3	0.2	0.048	0.027
Financial Cycle	η_1	Gamma	0.7	0.2	0.917	0.045
	η_2	Gamma	0.3	0.2	0.152	0.073

Model D-U

		priors			posteriors	
		distribution	mean	s.d.	mean	s.d.
IS Equation	β_1	Gamma	0.7	0.2	0.759	0.081
	β_2	Gamma	0.3	0.2	0.042	0.030
	β_3	Gamma	0.3	0.2	0.035	0.026
Neutral Rate of Interest	c	Gamma	0.5	0.2	0.638	0.216
	c_{tpf}	Gamma	0.3	0.2	0.242	0.100
Phillips Curve	γ_1	Gamma	0.7	0.2	0.401	0.082
	γ_2	Gamma	0.3	0.2	0.056	0.031
Financial Cycle	η_1	Gamma	0.7	0.2	0.915	0.042
	η_2	Gamma	0.3	0.2	0.182	0.086

Table A2: Bayesian Estimation Results (Capital Flows as Foreign Financial Cycle)

Model DF-KU (Capital Flow)

		priors			posteriors	
		distribution	mean	s.d.	mean	s.d.
IS Equation	β_1	Gamma	0.7	0.2	0.683	0.072
	β_2	Gamma	0.3	0.2	0.063	0.050
	β_3	Gamma	0.3	0.2	0.034	0.025
	β_4	Gamma	0.3	0.2	0.051	0.010
Neutral Rate of Interest	c	Gamma	0.5	0.2	0.654	0.203
	c_{tp}	Gamma	0.5	0.2	0.000	0.149
	c_{tpf}	Gamma	0.3	0.2	0.197	0.183
Phillips Curve	γ_1	Gamma	0.7	0.2	0.417	0.085
	γ_2	Gamma	0.3	0.2	0.040	0.028
Financial Cycle	η_1	Gamma	0.7	0.2	0.915	0.053
	η_2	Gamma	0.3	0.2	0.185	0.108

Model DF-K (Capital Flow)

		priors			posteriors	
		distribution	mean	s.d.	mean	s.d.
IS Equation	β_1	Gamma	0.7	0.2	0.697	0.069
	β_2	Gamma	0.3	0.2	0.050	0.040
	β_3	Gamma	0.3	0.2	0.032	0.024
	β_4	Gamma	0.3	0.2	0.051	0.010
Natural Rate of Interest	c	Gamma	0.5	0.2	0.581	0.214
	c_{tp}	Gamma	0.3	0.2	0.059	0.050
Phillips Curve	γ_1	Gamma	0.7	0.2	0.416	0.085
	γ_2	Gamma	0.3	0.2	0.041	0.028
Financial Cycle	η_1	Gamma	0.7	0.2	0.908	0.052
	η_2	Gamma	0.3	0.2	0.160	0.089

Model DF-U (Capital Flow)

		priors			posteriors	
		distribution	mean	s.d.	mean	s.d.
IS Equation	β_1	Gamma	0.7	0.2	0.684	0.071
	β_2	Gamma	0.3	0.2	0.065	0.051
	β_3	Gamma	0.3	0.2	0.034	0.025
	β_4	Gamma	0.3	0.2	0.051	0.010
Neutral Rate of Interest	c	Gamma	0.5	0.2	0.675	0.203
	c_{tpf}	Gamma	0.3	0.2	0.273	0.145
Phillips Curve	γ_1	Gamma	0.7	0.2	0.418	0.085
	γ_2	Gamma	0.3	0.2	0.040	0.028
Financial Cycle	η_1	Gamma	0.7	0.2	0.916	0.052
	η_2	Gamma	0.3	0.2	0.192	0.111

Table A3: Bayesian Estimation Results (Volatility Index as Foreign Financial Cycle)

Model DF-KU (Volatility)

		priors			posteriors	
		distribution	mean	s.d.	mean	s.d.
IS Equation	β_1	Gamma	0.7	0.2	0.374	0.074
	β_2	Gamma	0.3	0.2	0.107	0.069
	β_3	Gamma	0.3	0.2	0.058	0.034
	β_4	Gamma	0.3	0.2	0.311	0.112
Neutral Rate of Interest	c	Gamma	0.5	0.2	0.671	0.217
	c_{tp}	Gamma	0.5	0.2	0.047	0.040
	c_{tpf}	Gamma	0.3	0.2	0.267	0.141
Phillips Curve	γ_1	Gamma	0.7	0.2	0.410	0.083
	γ_2	Gamma	0.3	0.2	0.045	0.028
Financial Cycle	η_1	Gamma	0.7	0.2	0.913	0.045
	η_2	Gamma	0.3	0.2	0.188	0.089

Model DF-K (Volatility)

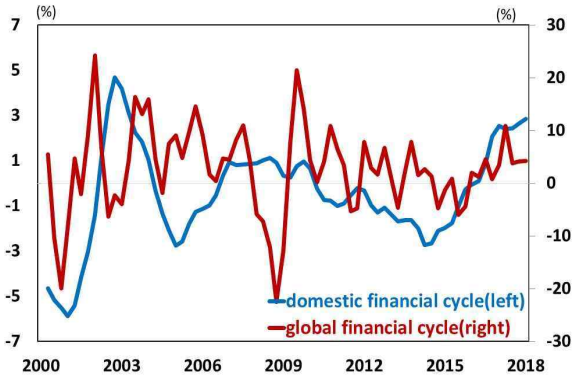
		priors			posteriors	
		distribution	mean	s.d.	mean	s.d.
IS Equation	β_1	Gamma	0.7	0.2	0.674	0.073
	β_2	Gamma	0.3	0.2	0.105	0.064
	β_3	Gamma	0.3	0.2	0.058	0.034
	β_4	Gamma	0.3	0.2	0.319	0.112
Natural Rate of Interest	c	Gamma	0.5	0.2	0.604	0.213
	c_{tp}	Gamma	0.3	0.2	0.054	0.046
Phillips Curve	γ_1	Gamma	0.7	0.2	0.410	0.083
	γ_2	Gamma	0.3	0.2	0.044	0.028
Financial Cycle	η_1	Gamma	0.7	0.2	0.913	0.043
	η_2	Gamma	0.3	0.2	0.161	0.077

Model DF-U (Volatility)

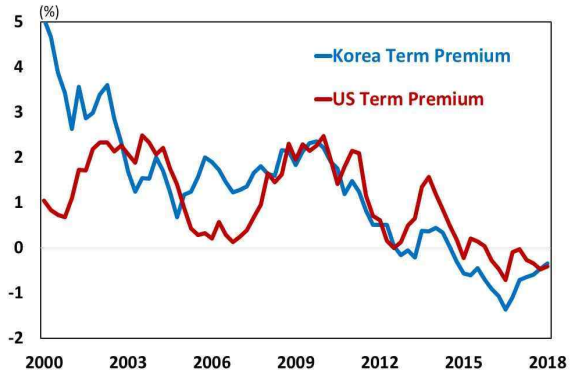
		priors			posteriors	
		distribution	mean	s.d.	mean	s.d.
IS Equation	β_1	Gamma	0.7	0.2	0.677	0.073
	β_2	Gamma	0.3	0.2	0.110	0.070
	β_3	Gamma	0.3	0.2	0.055	0.033
	β_4	Gamma	0.3	0.2	0.317	0.110
Neutral Rate of Interest	c	Gamma	0.5	0.2	0.675	0.206
	c_{tpf}	Gamma	0.3	0.2	0.281	0.141
Phillips Curve	γ_1	Gamma	0.7	0.2	0.400	0.082
	γ_2	Gamma	0.3	0.2	0.051	0.027
Financial Cycle	η_1	Gamma	0.7	0.2	0.914	0.044
	η_2	Gamma	0.3	0.2	0.188	0.090

Figure 1: Financial Cycle Gaps and Term Premiums

Domestic and global financial cycle gaps

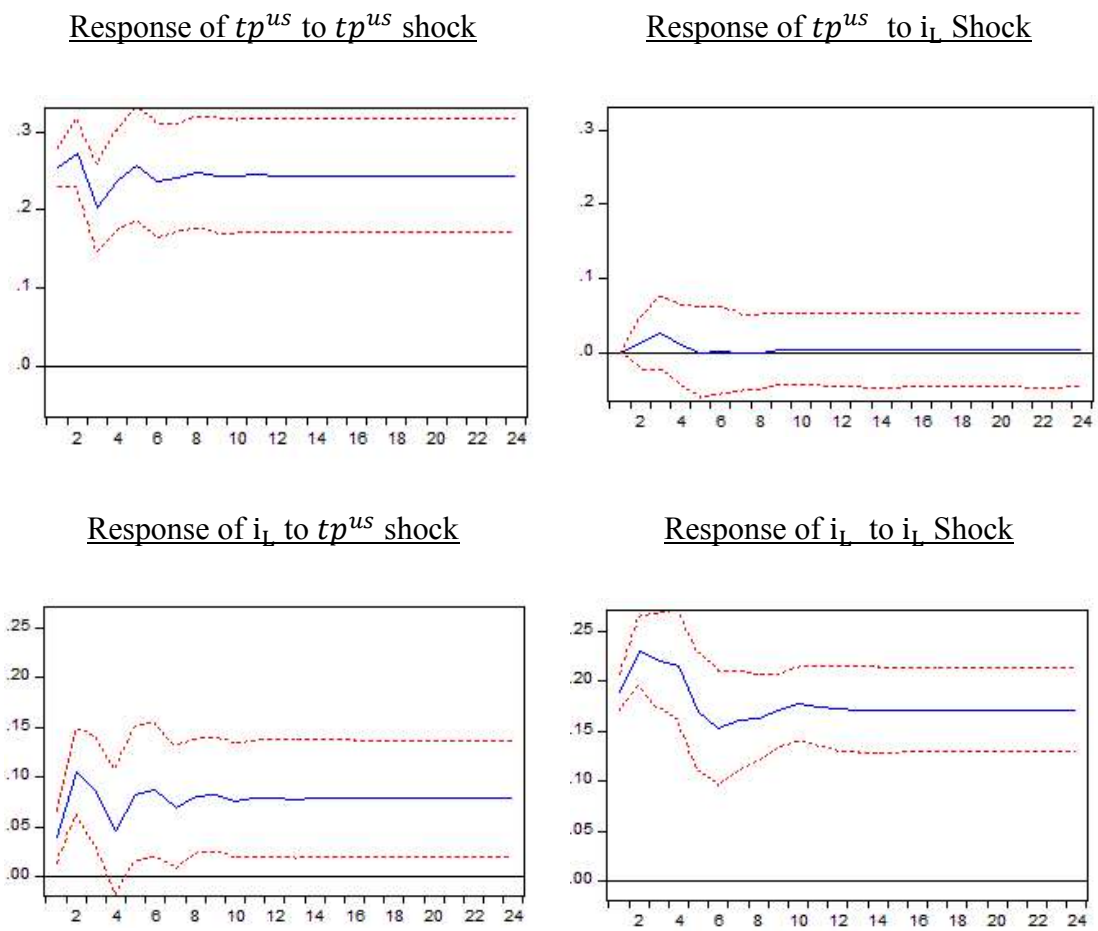


Korea and the US term premiums



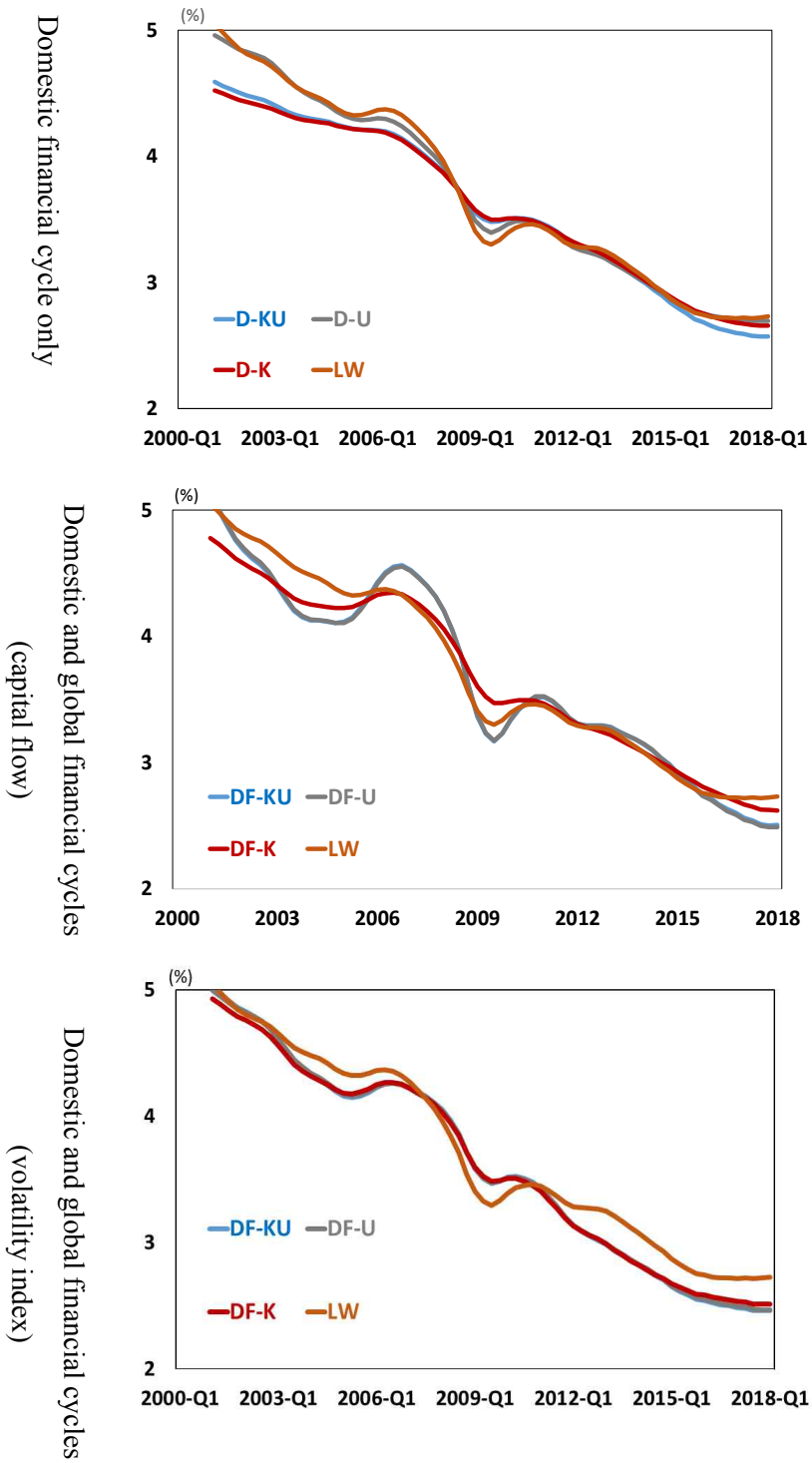
Note: Domestic financial cycle gap denotes the cyclical component of household credit to GDP ratio in Korea, and global financial cycle gap is the rate of change in foreign portfolio investment holdings in Korea. Term premiums are estimated from the 10 year Treasury bonds in Korea and the US, respectively.

Figure 2: Korea's Long term Interest Rate and US Bond Term Premium



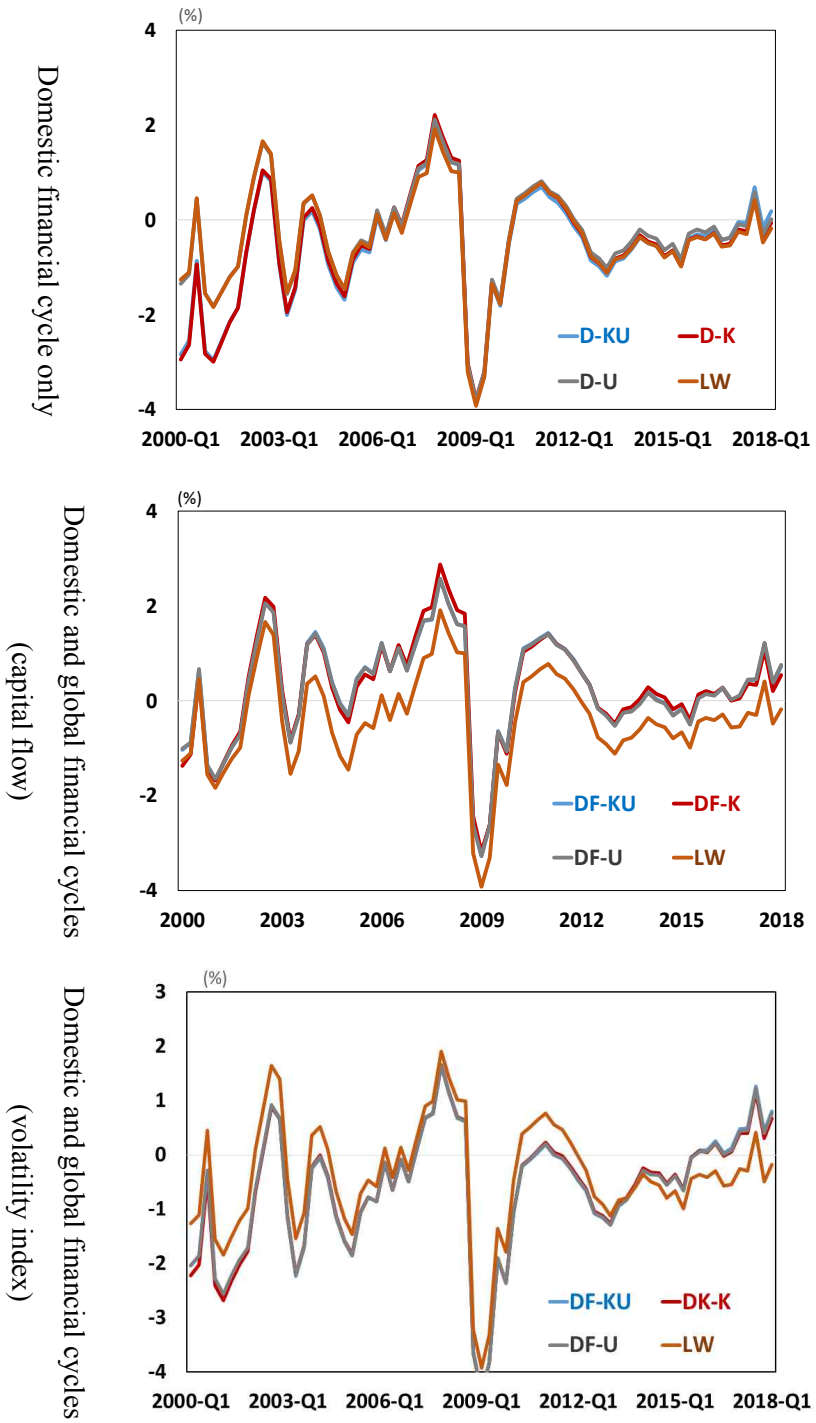
Note: This figure summarizes the cumulative impulse responses from a bi-variate vector auto-regression between the 10 Treasury bond yield in Korea (i_L) and the term premium in 10 year US Treasury bond (TP^{us}).

Figure 3: Estimates of Finance-Neutral Potential Growth



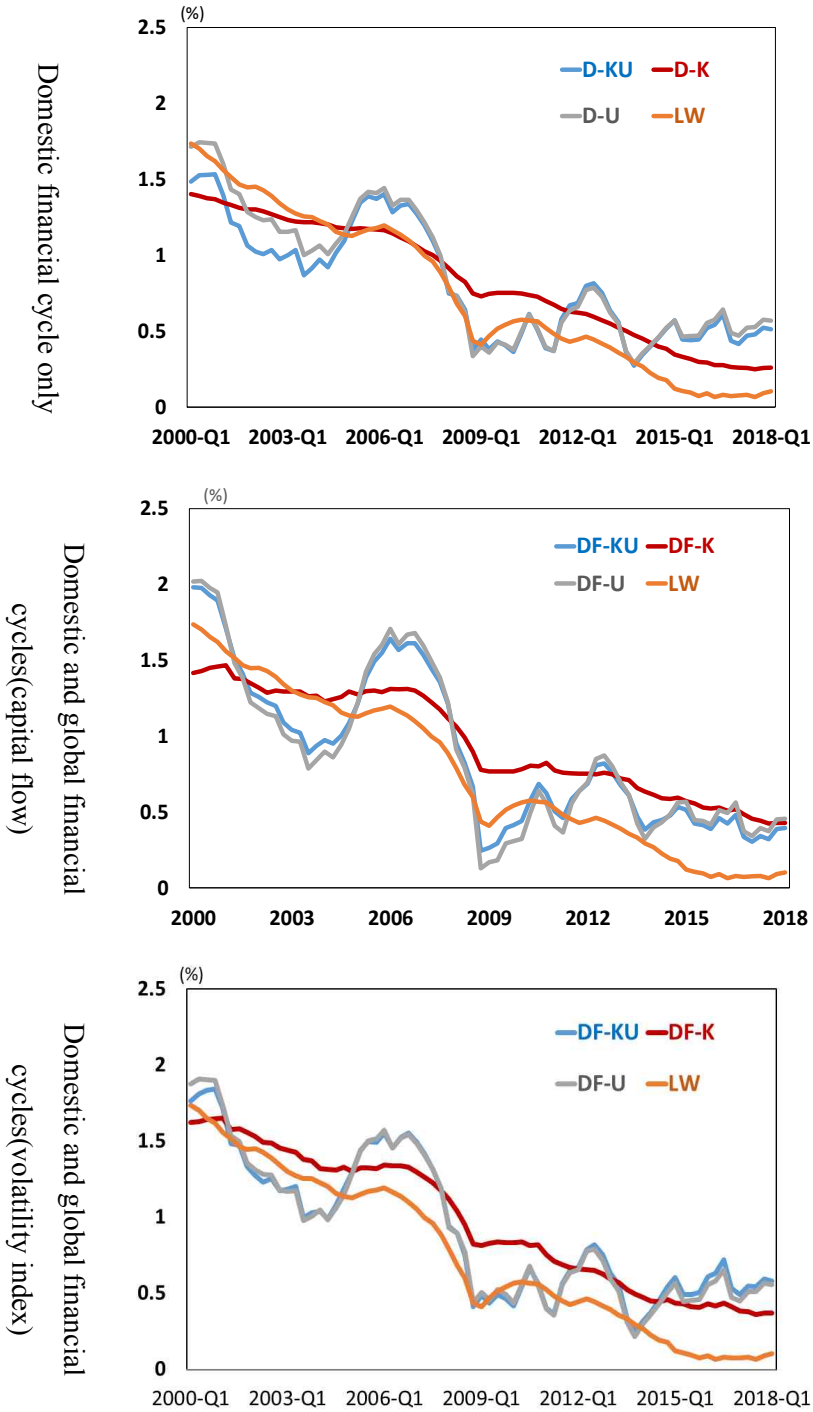
Note: The LW model denotes the baseline model that does not include financial cycle gap variables in both IS curve and the natural rate of interest equation.

Figure 4: Estimates of Finance-adjusted Output Gaps



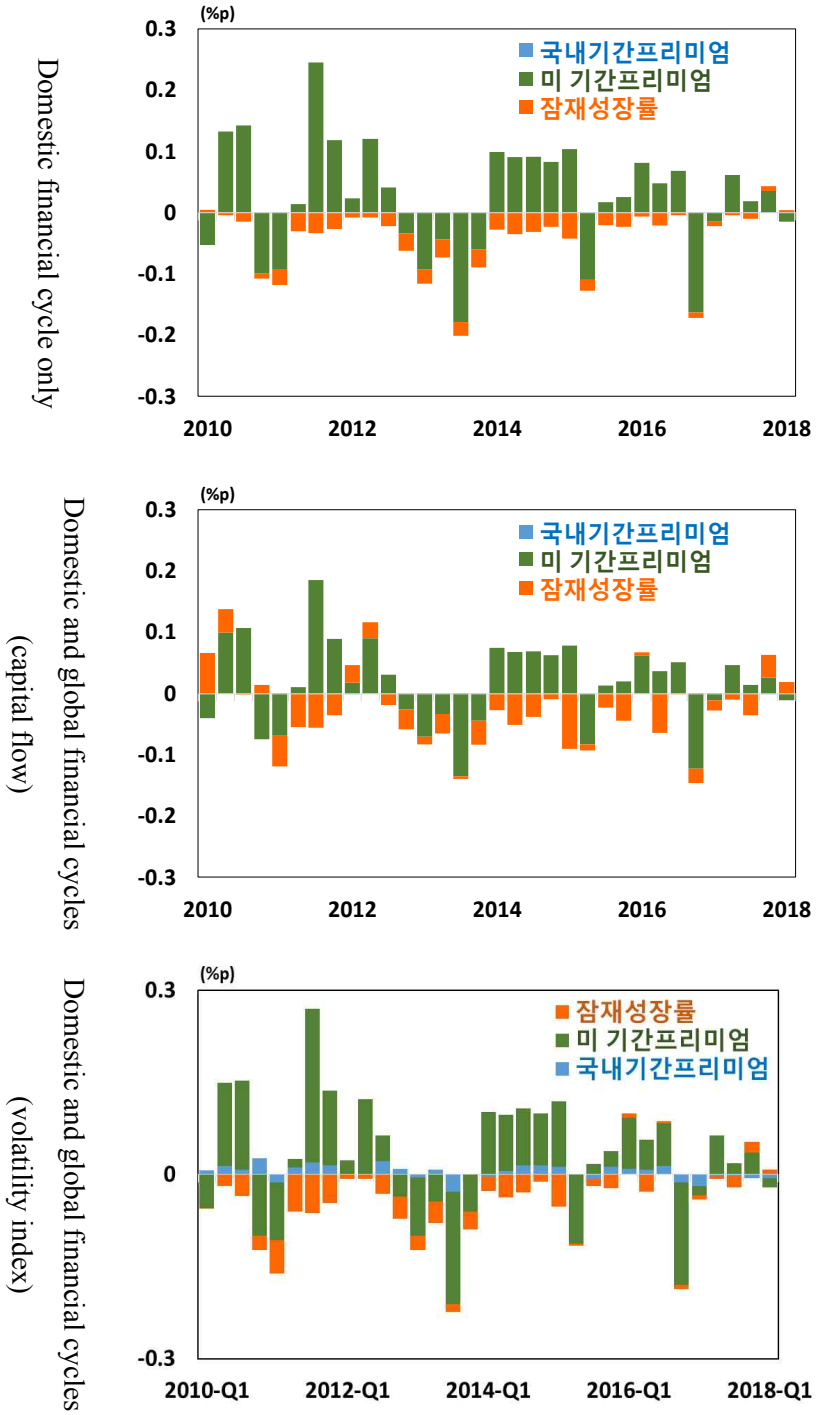
Note: The LW model denotes the baseline model that does not include financial cycle gap variables in both IS curve and the natural rate of interest equation.

Figure 5: Estimates of Finance-neutral Natural Real Interest Rate



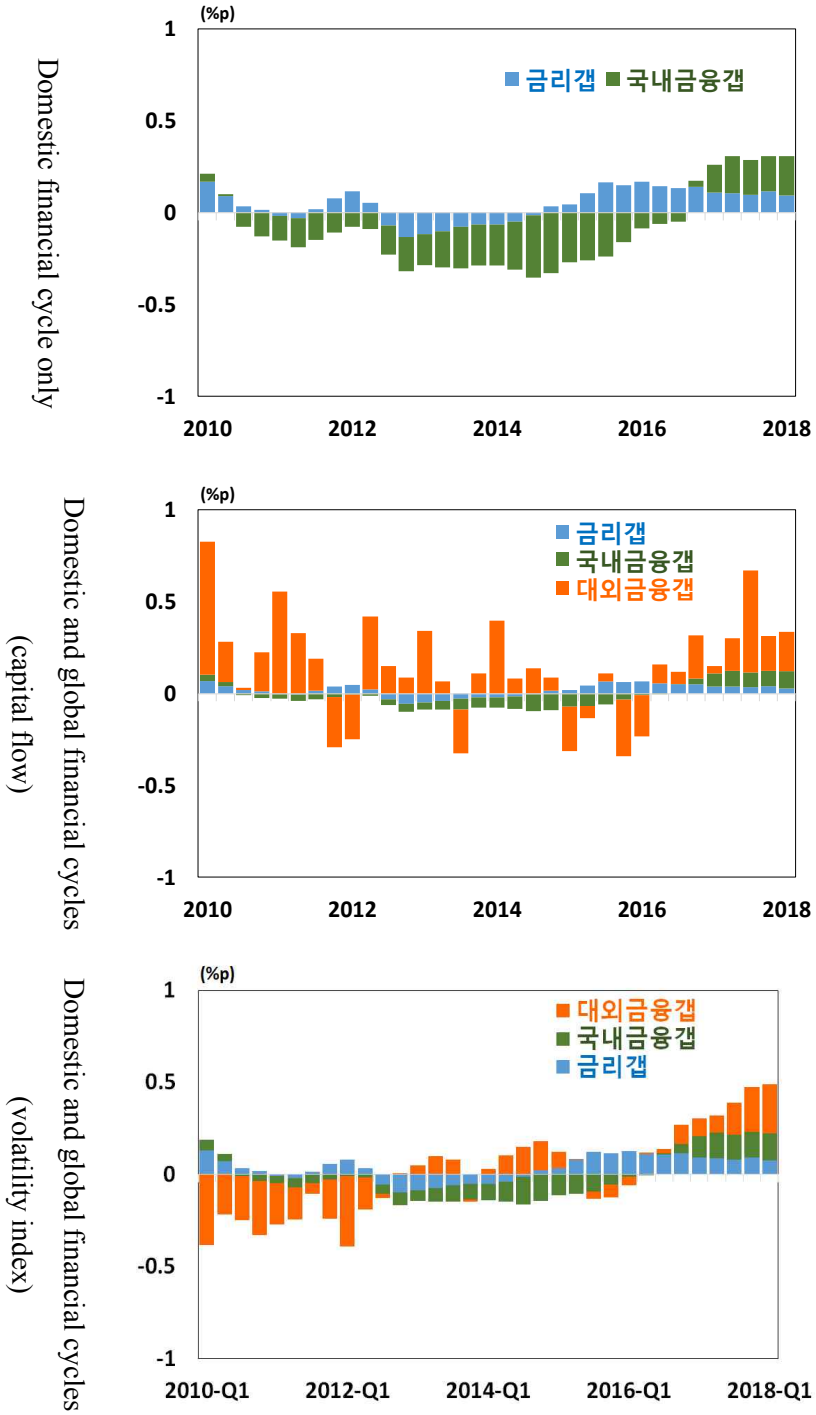
Note: The LW model denotes the baseline model that does not include financial cycle gap variables in both IS curve and the natural rate of interest equation.

Figure 6: Factor Decompositions of Natural Real Interest Rate



Note: This figure shows the decomposition of the quarter-to-quarter change in the natural real interest rate from our estimation of the natural interest rate equation with both Korea and the US term premiums.

Figure 7: Factor Decompositions of Output Gap



Note: This figure shows the decomposition of the finance-adjusted output gap from our estimation of the model with both Korea and the US term premiums. In the figures, the auto-regressive component was excluded.