Measuring Time-varying Fiscal Multipliers When Monetary Policy Matters

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Motivation

- What is the G multiplier?
- It hinges upon
  (1) source of fiscal financing for initially debt-financed $G\uparrow$: lump-sum taxes vs. distorting income taxes [Uhlig (2010)]
  (2) $G\uparrow$ is anticipated or not: narrative approach [Ramey (2011)] vs. VAR study [Blanchard & Perotti (2002)]
  (3) how monetary policy behaves when $G\uparrow$: normal times (inflation targeting) vs. liquidity trap [Eggertsson(2008); Christiano et al. (2011); Erceg & Lindé (2014)]
- This paper is about (3)
  - is the central bank's policy stance toward inflation a crucial determinant of the size of G multiplier for Korea?

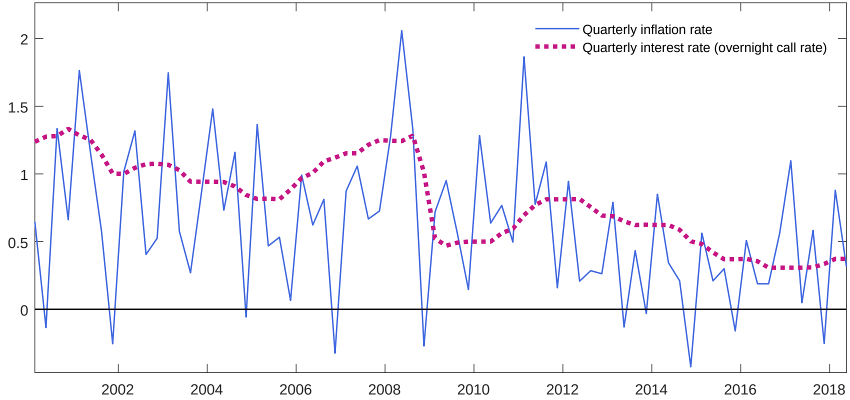
Motivation

- Korea is one of the countries with no zero lower bound (ZLB) constraint has ever been imposed
- The ZLB, however, is regarded as a special case in which CBs' concerns shift away from their central objective (IT) toward other goals, such as output or financial stabilization
  - e.g., Board of Governors of the Federal Reserve System (2009); Bank of England (2009)
- Previous studies demonstrate that expansionary effects of gov't spending are much more pronounced when MP does not increase nominal rates strongly with inflation
  - Kim (2003); Davig & Leeper (2011); Dupor & Li (2015)
  - mechanism through the Fisher equation

What We Do

- Utilize a time-varying coefficient vector autoregressive (TVC-VAR) model
  - as in Primiceri (2005, RES) and Galí and Gambetti (2015, AEJ-Macro)
  - with Korean data for the post-Asian currency crisis period
- In order to identify evidence in data about:
  1. how has G multiplier changed over time?
  2. although often presumed as an IT regime, are there any notable changes in the MP behavior toward inflation?
  3. if any, what are the implications of 2 for 1?

Inflation and Interest Rate

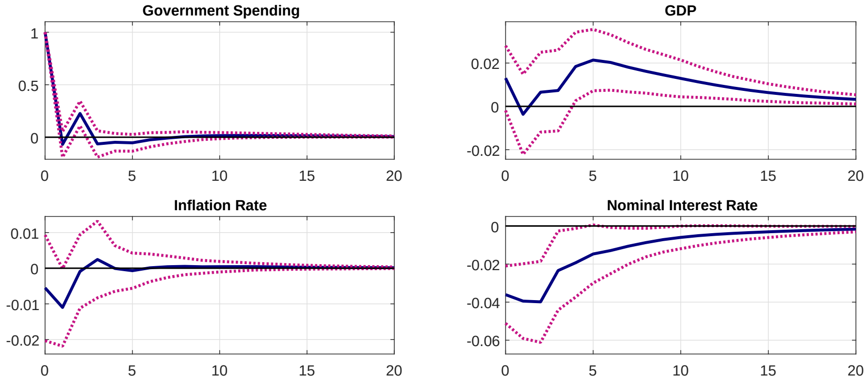


Solid: Quarterly inflation rate; Dashed: Quarterly policy rate

Fixed-coefficient VAR Results

4-variable VAR with a Cholesky ordering of G, Y, π, R

IRF (%) to a 1% government spending shock



Solid: Point estimates; Dashed: 68% bands

What We Find (Preliminary)

1. A clear time-varying pattern is observed in the G multiplier
   - for longer runs, G multipliers start rising from the global financial crisis (GFC) period of 2008-09
2. Responses of inflation and interest rate also vary over time

   2.A. G shocks become less inflationary as time elapses

   2.B. plunges in the interest rate associated with G shocks are more pronounced in the recent sample
3. MP response to inflation has weakened since the GFC
4. The MP stance is a crucial determinant of G multipliers
   - 2.A and 3 jointly result in 2.B
   - 2.B then has a substantial impact on the finding of 1

Econometric Specification

Reduced-form VAR Specification

- A quarterly VAR with time-varying coefficients:

$$z_t = \mu_{0,t} + \mu_1 t + \mu_2 t^2 + D x_t + B_{1,t} z_{t-1} + \ldots + B_{\ell,t} z_{t-\ell} + u_t,$$

  - $\mu_{0,t}$ is a constant, t & t^2 are linear and quadratic time trends
  - x_t: vector of exogenous variables
  - D: coefficients associated with the exogenous variables
  - z_t: vector of endogenous variables
  - $B_{i,t}$'s: matrices of time-varying coefficients
  - u_t: heteroskedastic reduced-form errors with $E(u_t u_t') = \Sigma_{u,t}$

Reduced-form VAR Specification

A quarterly VAR with time-varying coefficients:

$$z_t = \mu_{0,t} + \mu_1 t + \mu_2 t^2 + D x_t + B_{1,t} z_{t-1} + \ldots + B_{\ell,t} z_{t-\ell} + u_t,$$

- x_t contains 4 variables
  - the growth rate of oil price, federal funds rate, and real exchange rate (e.g., Kim (2000)) as well as US output
- z_t consists of 4 variables $\Longrightarrow$ minimal statistic for our research interest
  - government spending (G), GDP (Y), inflation rate (π), and overnight call rate (R)
    - G and Y to measure gov't spending multipliers
    - R decisions conditioning on Y and π (dual mandate)
- set $\ell = 3 \Leftarrow$ based on the information criteria (AIC and BIC)

Corresponding Structural VAR

- The structural VAR model:

$$\begin{aligned} A_t z_t = & A_t \left(\mu_0 + \mu_1 t + \mu_2 t^2 + D x_t\right) \\ & + A_t B_{1,t} z_{t-1} + A_t B_{2,t} z_{t-2} + A_t B_{3,t} z_{t-3} + e_t, \end{aligned}$$

  - A_t: lower-triangular Cholesky decomposition of $\Sigma_{u,t}$
    - assume that government spending is the most exogenous
    - accordingly, the ordering is G, Y, π, and R
  - e_t: structural innovations with $E(e_t e_t') = \Sigma_{e,t}$ where all the off-diagonal elements of $\Sigma_{e,t}$ are zero
    - $A_t u_t = e_t$ and $A_t \Sigma_{u,t} A_t' = \Sigma_{e,t} \Sigma_{e,t}'$

DEFINITIONS OF G AND PV MULTIPLIER

- G: the broadest concept of the government spending
  - G comprises three categories
    - "gov't expenditure on goods and services"
    - "subsidies and current transfers"
    - "capital expenditure"
  - source: Korean Statistical Information Service

- Present value multiplier:

$$\text{Present Value Multiplier}(Q) = \frac{\sum_{t=0}^{Q}(1+\bar{r})^t Y_t}{\sum_{t=0}^{Q}(1+\bar{r})^t G_t} \frac{1}{\bar{Y}/\bar{G}}$$

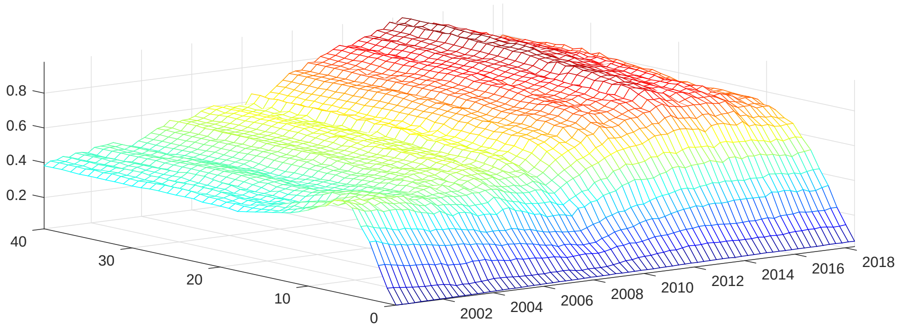
where r is the real interest rate

Data and Estimation

- Sample: 1990:Q1–2018:Q2
  - the 10-year sample 1990:Q1–1999:Q4 is used to initiate the prior distributions
  - the empirical results are for the period 2000:Q1–2018:Q2
- Bayesian inference as in Galí and Gambetti (2015)
  - Gibbs sampling for 22,000 posterior draws
  - with the first 20,000 used as a burn-in period and every 2nd thinned, leaving a sample size of 1,000

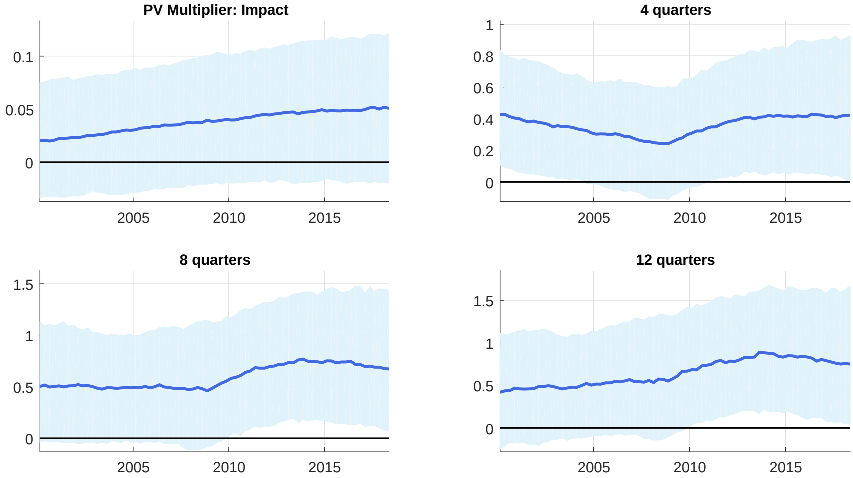
Empirical Results

PRESENT-VALUE MULTIPLIERS



Median PV multiplier estimates

PRESENT-VALUE MULTIPLIERS



PV multiplier, median and 68% band estimates

Present-value Multipliers

	2000:Q2	2004:Q2	2008:Q2	2012:Q2	2016:Q2	2018:Q2
Impact	0.02	0.03	0.04	0.05	0.05	0.05
4 quarters	0.43	0.33	0.39	0.39	0.43	0.42
8 quarters	0.52	0.49	0.29	0.70	0.75	0.67
12 quarters	0.44	0.50	0.15	0.78	0.82	0.75
Peak (QTR)	0.54 (7)	0.51 (11)	0.65 (39)	0.85 (39)	0.88 (30)	0.82 (31)

Summary of the present-value multiplier estimates (in Korean won), median estimates

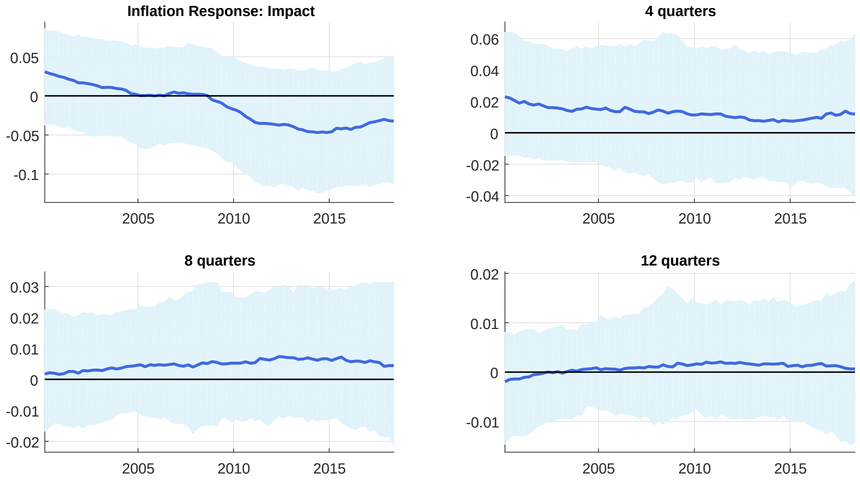
Cross-country Comparisons

	All countries		U.S.		Europe	
	VAR	DSGE	VAR	DSGE	VAR	DSGE
Average	0.9	0.7	1.0	0.7	0.8	0.6
Max	2.1	1.9	2.0	1.6	1.5	1.5
Min	0.4	0.0	0.4	0.0	0.5	0.1

Source: IMF Fiscal Monitor (April 2012)

- Summary of the 1-year PV multipliers for 34 countries, reported in the previous studies between 2002 and 2012

IMPULSE RESPONSES OF π

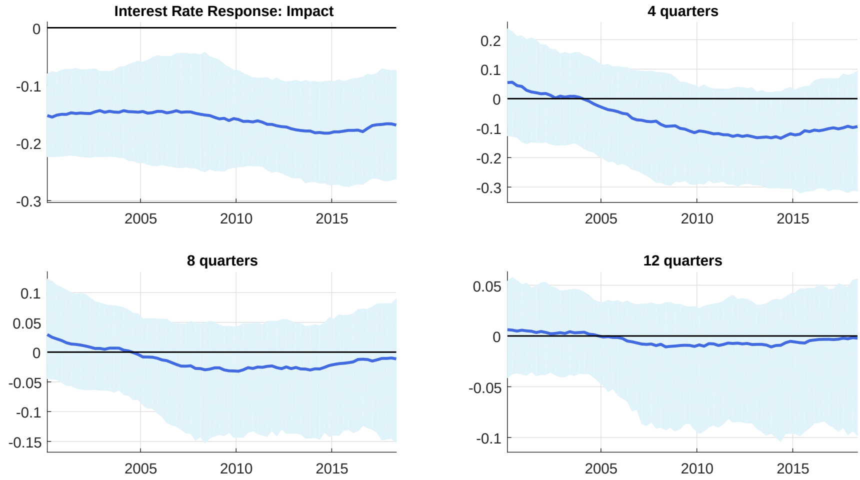


π response (%), median and 68% band estimates

Impulse Responses of π

- Inflationary pressure due to the fiscal expansions is not observed for all horizons considered
- Negative inflation responses to G increases are often documented by the existing VAR studies with US data
  - e.g., Fatás and Mihov (2001); Caldara and Kamps (2008); Mountford and Uhlig (2009)
- A noticeable pattern in the inflation responses at impact
  - a decreasing tendency over time, and negative for the post-GFC period in terms of the median estimates

Impulse Responses of R



R response (%), median and 68% band estimates

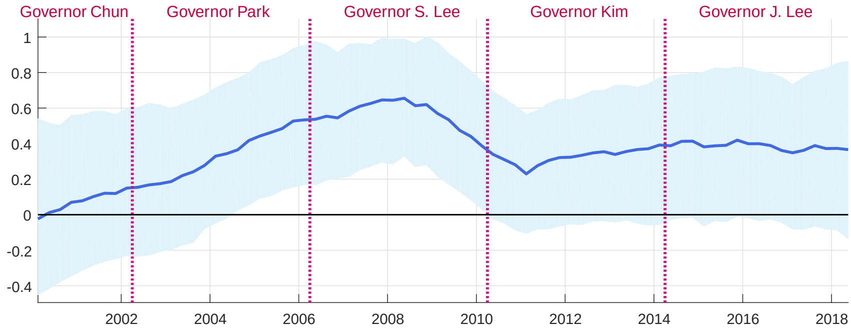
Impulse Responses of R

- The responses at impact are negative and statistically different from zero over the whole sample period
  - consistent with the fixed-coefficient VAR result
- The magnitude of the negative response becomes more pronounced in the 2010s
  - for the recent period, a more accommodative interest-rate policy is associated in times of G expansions

Identifying MP Stance toward Inflation

- Time-varying MP stance toward inflation is measured by the responses of the policy rate to 1% inflation shocks
  - analogous to the Taylor rule inflation coefficient in fully structural models
  - e.g., Primiceri (2005)
- The responses of the policy rate to 1% output shock are not reported herein
  - it turns out that the responses are indifferent from zero with a time-invariant tendency

IDENTIFIED MP STANCE TOWARD INFLATION



R response (%) at impact to 1% inflation shocks,
median and 68% band estimates

Impulse Responses of R: A Reprise

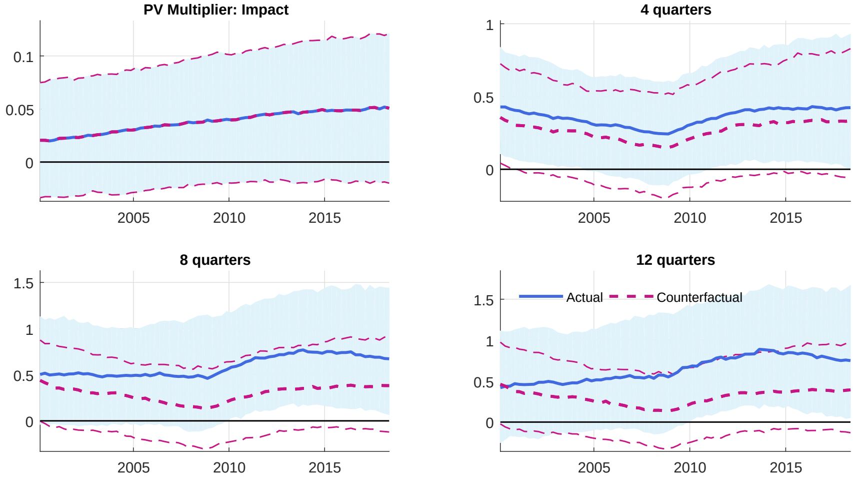
- Key findings in the impulse responses:
  1. G shocks become less inflationary over time
  2. MP response to inflation has weakened in the 2010s
- The time-varying response pattern of the policy rate can be rationalized jointly by 1 and 2
  - for the recent period, a more accommodative interest-rate policy is associated in times of G expansions

Counterfactual Exercise

Counterfactual Impulse Responses

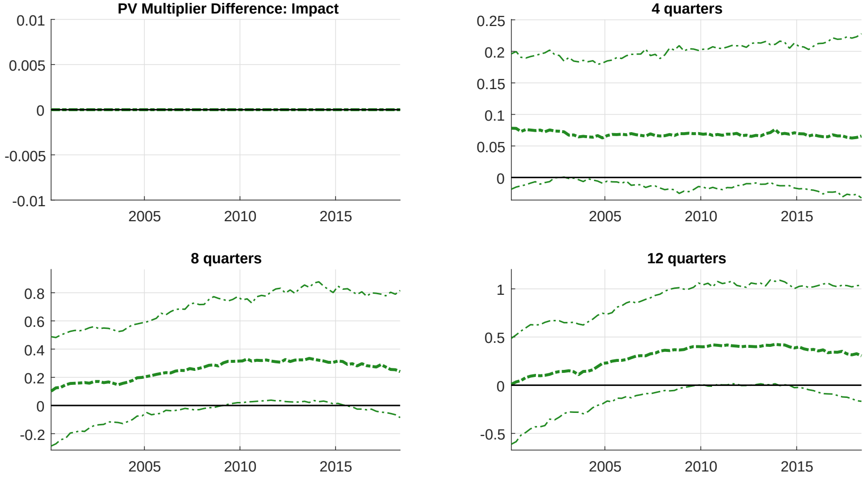
- Conduct a counterfactual experiment to net out how much the fall in the interest rate boosts the spending multiplier
  - the counterfactual assumes that the interest rate did not change in response to a G shock
  - this can be implemented by using the actual VAR estimated coefficients from the other equations, while restricting the coefficients in the interest rate rate equation to be zero
  - e.g., Ramey (2013)

Actual & Counterfactual Multipliers



PV multiplier, actual and counterfactual estimates

Differences in the PV Multipliers



PV multiplier, actual *minus* counterfactual estimates

Differences in the PV Multipliers

	2000:Q2	2004:Q2	2008:Q2	2012:Q2	2016:Q2	2018:Q2
4 quarters	0.08	**0.06**	0.07	0.07	0.06	0.07
	[−0.02, 0.20]	**[0.00, 0.19]**	[−0.02, 0.21]	[−0.01, 0.21]	[−0.03, 0.21]	[−0.03, 0.23]
8 quarters	0.13	0.18	0.28	**0.33**	0.30	0.24
	[−0.27, 0.48]	[−0.10, 0.57]	[−0.02, 0.75]	**[0.03, 0.80]**	[−0.03, 0.81]	[−0.09, 0.82]
12 quarters	0.03	0.16	0.36	**0.40**	0.37	0.30
	[−0.59, 0.52]	[−0.23, 0.69]	[−0.06, 1.00]	**[0.00, 1.02]**	[−0.09, 1.05]	[−0.17, 1.04]

Summary of the present-value multiplier gap estimates (in Korean won), median and [16%, 84%] interval estimates

Actual & Counterfactual Multipliers

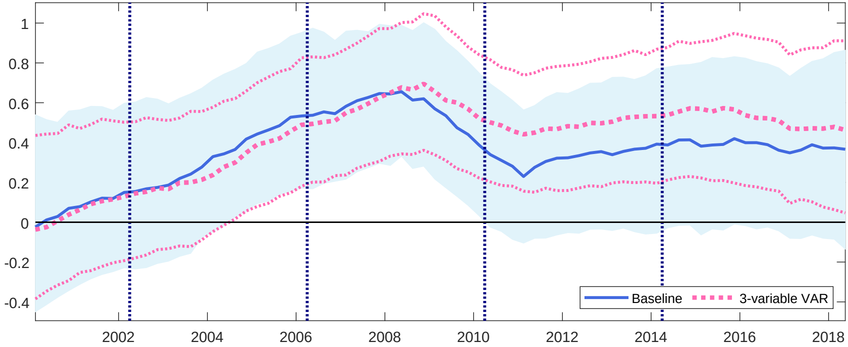
- Rossi and Zubairy (2011)
  - fiscal shocks are relatively more important in explaining medium cycle fluctuations
  - MP shocks are relatively more important in accounting for business cycle fluctuations
- Our finding: the effect of G shocks to output would have been much shorter-lived without the responses of R

Robustness Check

Robustness 1: Drop out G

- The identified MP stance to inflation may be contaminated by the incursion of gov't spending as a model variable
  - MP decisions are likely to be independent of FP actions
- Construct a 3-variable VAR specification without G
  - obtain the responses of the policy rate to 1% inflation shocks
  - compare them to their 4-variable baseline model counterpart

BASELINE VS. 3-VARIABLE VAR



R responses to π shocks, median and 68% band estimates

Solid: Benchmark; Dashed: 3-variable VAR without G

Robustness 2: Augment with Taxes

- Omission of another fiscal instrument, taxes (T), may bias the results
  - the existing literature tends to include T as a model's endogenous variable
  - e.g., Blanchard and Perotti (2002); Ramey (2011)
- The responses of taxes to a gov't spending shock can be crucial for the size of G multipliers
  - if positive (negative), the expansionary effect of G shocks is likely to be mitigated (supplemented) by T responses
- Also, the sign of T responses at impact helps characterize the financing source of the G expansion
  - if positive (negative), the increase in G is initially tax-financed (debt-financed)

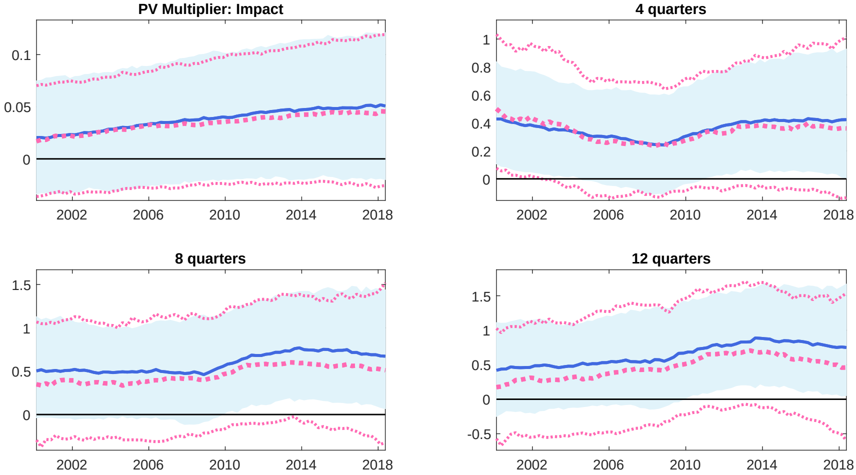
Robustness 2: Augment with Taxes

- Expand the model by including taxes as an endogenous variable
- The 5-variable VAR specification comprises $\{G, Y, \pi, T, R\}$
- The ordering is given as above
  - T after Y and π can be rationalized that, given the tax rate, the tax base is contemporaneously affected by these two variables, and thus tax receipts change
  - Caldara and Kamps (2008)

Baseline vs. 5-variable VAR

T responses to G shocks, median and 68% band estimates

Baseline vs. 5-variable VAR



PV multipliers, median and 68% band estimates

Solid: Benchmark; Dashed: 5-variable VAR augmented with T

Technical Appendix

Appendix 1: Methodology

- Assumptions: states follow random walks

$$B_t = \text{vec}([c_t, B_{1,t}, B_{2,t}, B_{3,t})], \quad B_t = B_{t-1} + \nu_t, \quad \nu_t \sim NID(0, Q)$$

$$\alpha_t = \text{vec}(A_t^{-1}), \quad \alpha_t = \alpha_{t-1} + \zeta_t, \quad \zeta_t \sim NID(0, S)$$

$$\sigma_t = \text{vec}(\text{diag}(\Sigma_{e,t})), \quad \log \sigma_t = \log \sigma_{t-1} + \eta_t, \quad \eta_t \sim NID(0, W)$$

- Informative but diffuse conditional prior distributions
  - calibrated based on 40 initial training samples (90:Q1-99:Q4)
  - OLS estimates parameterize prior means, serve as starting values
- MCMC algorithm to generate sample from unknown joint posterior distribution $p(B^T, \Sigma_u^T, Q, S, W|Z^T)$

Appendix 2: Summary of Gibbs Sampler

1. Initialize A^T, Σ_e^T, hyperparameters Q, S and W
2. Draw coefficients from $p(B^T|Z^T, A^T, Q)$, Carter-Kohn (1994)
3. Draw covariances from $p(A^T|Z^T, \Sigma_e^T, S)$, Carter-Kohn (1994)
4. Draw volatilities from $p(\Sigma_e^T|Z^T, B^T, A^T, W)$, Carter-Kohn (1994)
5. Draw hyperparameters from $p(Q|Z^T, B^T)$, $p(S|Z^T, A^T)$, $p(W|Z^T, \Sigma_e^T)$
6. Go to 2, generate 22k after 20k burn-in iterations

Measuring Time-varying Fiscal Multipliers When Monetary Policy Matters[*]

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ABSTRACT

This paper empirically measures the change of the government spending multipliers since 2000 with a time-varying coefficient vector autoregressive (TVC-VAR) model. While estimating the multipliers, we explicitly take into account the monetary policy response measured by interest rates. The present value fiscal multipliers in the long run have steadily increased after the Global Financial Crisis. Moreover, our counterfactual exercise shows that the accommodative monetary policy stance enhances the long-run stimulus effect of the government spending on output.

Keywords: Time-varying coefficient VAR; Government spending multiplier; Monetary policy

JEL Classifications: C11; E32; E62; E52

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1 INTRODUCTION

The effects of expansionary government spending on macroeconomic aggregates depend on a host of factors: expected sources of future fiscal financing [Uhlig (2010)], whether the implemented policy is anticipated or not [Ramey (2011)], and how monetary policy behaves in times of the fiscal expansion [Eggertsson (2008); Christiano et al. (2011); Erceg and Lindé (2014)]. Among these, the last dimension has received much recent attention, spurred primarily by the fiscal stimuli associated with the Federal Reserve's zero interest rate policy in counteracting the global recession of 2008. A burgeoning theoretical and empirical literature has developed in recent years, demonstrating that fiscal effects are substantially larger at the lower bound for nominal interest rates.

Taken in a more general sense, the zero lower bound is regarded as a special case in which central banks' concerns shift away from their central objective—inflation targeting—toward other goals, such as output or financial stabilization [e.g., Board of Governors of the Federal Reserve System (2009) and Bank of England (2009)]. One of the main characteristics of the policy behavior is that the monetary authority does not increase nominal rates strongly with inflation. A stream of literature, including Kim (2003), Davig and Leeper (2011), and Dupor and Li (2015), documents that expansionary effects of government spending are much more pronounced when this type of policy environment is in place.

This paper attempts to assess empirically how fluctuations in monetary policy behavior affect the stimulus effects of government spending expansions. We particularly take into account Korea as a laboratory for this avenue due to the following reasons. First, a structural break in the Korean macroeconomic aggregates is observed, which may incur potential changes in the monetary policy behavior. Figure 1 shows the series for output, inflation, and the policy interest rate for the period 2000:Q1–2018:Q2. Focusing on output and inflation, the volatilities of these variables decline substantially in the 2010s, compared to their 2010s counterpart. What is more striking, though, is the disparity in the level of inflation across the two decades. Inflation started falling with the beginning of the 2010s so that its overall level for the subsequent period is dramatically lower than that of the 2000s. The policy rate over the sample period tends to fluctuate with the level of inflation. Given the sharp contrast in the levels of inflation, however, the responsiveness of monetary policy toward inflation deserves careful scrutiny.

Second, the behavior of monetary policy in times of fiscal expansions turns out to be quite accommodative over the sample. To inspect this in a formal manner, we estimate a 4-variable vector autoregressive (VAR) model comprising of government spending, output, inflation and the nominal policy rate. The impulse responses to an identified government spending shock are provided in Figure 2.[1] The results show that an increase in government spending stimulates output in the medium to longer runs. Its impacts on inflation are negative for the short horizons, though they are not significantly different from zero at conventional levels. A more notable finding emerges from the interest rate response. An increase in government spending leads to a significant fall in the policy rate, suggesting that the periods of fiscal expansions throughout the sample are on average associated with monetary accommodation.

Based on these features, the contribution of this paper is to identify a time-varying pattern in government spending multipliers of Korea and to net out the contribution of monetary policy in shaping the stimulus effects. We employ a time-varying coefficient VAR (hereafter TVC-VAR) model as in Primiceri (2005) and Galí and Gambetti (2015). The model is estimated with Korean data ranged from 2000:Q1 to 2018:Q2. The selection of the sample period is constrained by the shift in monetary policy occurring in the late 1990s. Brito and Bystedt (2010) and Choi and Hur (2015) document that the post-2000s period corresponds to an inflation targeting regime, whereas this evidence is hardly supported by data in the precedent period.

The results show that monetary policy responses to inflation vary considerably within the sample. The central bank's stance toward inflation turns out to be quite mild during the early years of the sample, whereas the second half of the 2000s is marked with a stronger reaction to inflation over time up to the onset of the global financial crisis (GFC) of 2008-09. For the remainder of the sample, the degree of policy responsiveness bounces back only marginally but not fully compared to its peak in the late 2000s.

A number of notable time-varying patterns in macroeconomic aggregates followed by government spending expansions are observed from the results. First, government spending shocks become less inflationary over time. In particular, the inflation responses become negative for the post-GFC period in terms of the median estimates. Second, the nominal interest rate falls in response to government spending expansions, and the plunges in the interest rate associated with government spending shocks are more pronounced in the recent sample. Together with the aforementioned monetary policy response toward inflation, the first finding may provide an important insight in understanding the accommodative behavior of the interest rate in times of government spending increases. Taken together the findings that monetary policy response to inflation has weakened in the 2010s and that government spending shocks become less inflationary as time elapses, a more accommodative interest-rate policy in the recent period can be associated with increases in government spending.

We demonstrate that the accommodative monetary policy in times of government spending

[1]The empirical procedure used for the results of Figure 2 is detailed in Section 2.

expansions is a critical determinant of the size of government spending multipliers. More specifically, the expansionary effect of government spending on output is a lot more pronounced for the recent period than in the 2000s. For instance, the peak multiplier for 20004:Q2 is 0.51, whereas the 2016:Q2 multiplier turns out to be 0.88, which is more than 50% higher in size. We also find that monetary policy stance matters a lot for the longer-run stimulus effects of government spending than the short-runs.

2 ECONOMETRIC SPECIFICATION

This article utilizes a TVC-VAR model to characterize how the expansionary effects of government spending change over time. In this section, we illustrates the VAR model specification employed in this paper.

2.1 VAR WITH TIME-VARYING COEFFICIENTS

The reduced-form VAR specification is given as

$$z_t = \mu_{0,t} + \mu_1 t + \mu_2 t^2 + Dx_t + B_{1,t} z_{t-1} + \ldots + B_{\ell,t} z_{t-\ell} + u_t, \quad t = 1, \ldots, T, \tag{1}$$

where $\mu_{0,t}$ is an $n \times 1$ vector of time-varying constant terms, and t and t^2 denote linear and quadratic time trends, respectively. x_t is an $m \times 1$ vector of observed exogenous variables with the time-invariant coefficient matrix D. z_t is an $n \times 1$ vector of observed endogenous variables and $B_{i,t}$ with $i = 1, \ldots, \ell$ are $n \times n$ matrices of time-varying coefficients associated with the endogenous variables. u_t are heteroskedastic reduced-form errors with $E(u_t u_t') = \Sigma_{u,t}$. Notice that the reduced-form disturbances are be correlated with each other, i.e., the off-diagonal elements of $\Sigma_{u,t}$ are non-zero.

The choice of the exogenous variables is to reflect the Korean economy's feature as a small open economy. Following Kim (2000), we consider the US federal funds rate, the growth rate of oil prices, and the real exchange rate of Korean won against the US dollar in order to control for the potential factors affecting the central bank's policy decision. In addition, US output is included as a proxy for the world business cycle.[2]

In order to assess the effects of government spending on output conditioning on the monetary policy, we have the minimal set of endogenous variables as $\{g_t, y_t, \pi_t, r_t\}$, where g_t is government spending, y_t is output, π_t is inflation rate, and r_t is the nominal interest rate. g_t and y_t are essential in measuring the expansionary effects of government spending, often referred to as government spending multipliers.[3] The inclusion of inflation and the nominal interest rate is to complete the

[2] Appendix A provides a detailed description of the data used in this paper.

[3] Using these two variables, Caldara and Kamps (2017) demonstrate that the size of government spending multipliers hinges critically upon the identification strategies of government spending shocks.

monetary policy block associated with the central bank's dual mandate—output and price stability. The set of variables $\{y_t, \pi_t, r_t\}$ is often regarded as the minimal sufficient statistic in summarizing the central banks' dual mandate behavior [e.g., Primiceri (2005) and Coibion (2012), among many others]. Based on the information criteria such as AIC and BIC, the lag of the VAR specification is set to be $\ell = 3$.

The corresponding structural VAR is written as

$$A_t z_t = A_t \left(\mu_{0,t} + \mu_1 t + \mu_2 t^2 + D x_t\right) + A_t B_{1,t} z_{t-1} + A_t B_{2,t} z_{t-2} + A_t B_{3,t} z_{t-3} + e_t, \tag{2}$$

At each t, consider the lower-triangular Cholesky decomposition of the covariance matrix $\Sigma_{u,t}$ which yields

$$A_t u_t = e_t, \tag{3}$$

where e_t are the structural innovations with the covariance matrix $E(e_t e_t') = \Sigma_{e,t}$ so that $A_t \Sigma_{u,t} A_t' = \Sigma_{e,t} \Sigma_{e,t}'$ with

$$A_t = \begin{bmatrix} 1 & 0 & 0 & 0 \\ \alpha_{21,t} & 1 & 0 & 0 \\ \alpha_{31,t} & \alpha_{32,t} & 1 & 0 \\ \alpha_{41,t} & \alpha_{42,t} & \alpha_{43,t} & 1 \end{bmatrix}, \qquad \Sigma_{e,t} = \begin{bmatrix} \sigma^2_{e1,t} & 0 & 0 & 0 \\ 0 & \sigma^2_{e2,t} & 0 & 0 \\ 0 & 0 & \sigma^2_{e3,t} & 0 \\ 0 & 0 & 0 & \sigma^2_{e4,t} \end{bmatrix}.$$

In this article, we order the endogenous variables as follows: government spending is ordered first, output is ordered second, inflation is ordered third, and the nominal interest rate is ordered last. This particular ordering has the following implications: (i) government spending is the most exogenous, and thus has no contemporaneous responses to shocks to other variables in the system [e.g., Fatás and Mihov (2001) and Blanchard and Perotti (2002)]; (ii) output does not react to inflation and interest rate shocks in the same period, but is affected contemporaneously by government spending shocks; (iii) inflation does not react contemporaneously to interest rate shocks, but is affected contemporaneously by government spending and output shocks; and (iv) the interest rate is affected contemporaneously by all shocks in the system. Placing output and inflation in front of the nominal interest rate can be justified on the grounds that interest rate-based monetary policy decisions are conditioning on output and inflation of the concurrent period.

2.2 STATE-SPACE REPRESENTATION OF THE VAR SPECIFICATION The reduced-form VAR in (1) has a state-space representation as follows:

$$\text{[Observation equation]} \quad z_t = Z_t' B_t + u_t, \quad Z_t' = I_n \otimes [1, z_{t-1}', \ldots, z_{t-\ell}'], \tag{4}$$

$$\text{[State equation]} \quad B_t = B_{t-1} + \nu_t, \tag{5}$$

where the symbol $\otimes$ denotes the Kronecker product. Following Primiceri (2005) and Galí and Gambetti (2015), we make two assumptions on the time-varying parameters in the model: (i) the elements of the matrices A_t and $\Sigma_{u,t}$ follow an AR(1) process; and (ii) all the innovations in the model are multivariate normal. Thus, the dynamics of the model's time-varying parameter can be summarized as follows:

$$\begin{aligned} \alpha_t =& \alpha_{t-1} + \zeta_t, \qquad \log \sigma_t = \log \sigma_{t-1} + \eta_t, \\ V =& Var\left(\begin{bmatrix} u_t \\ \nu_t \\ \zeta_t \\ \eta_t \end{bmatrix} \right) = \begin{bmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{bmatrix}, \end{aligned}$$

where α_t denotes the column vector of the lower-triangular elements of the matrix A_t stacked by rows, σ_t is the column vector of the diagonal elements of the matrix $\Sigma_{e,t}$, and Q, S, and W are positive definite matrices. In sum, we have following time-varying parameters to be estimated:

$$\begin{aligned} \text{[Coefficients of the reduced-form VAR]} \quad & B^T := \{B_1, \ldots, B_T\}, \\ \text{[Elements of the Cholesky factor]} \quad & A^T := \{A_1, \ldots, A_T\}, \\ \text{[Variances of the structural VAR]} \quad & \Sigma_e^T := \{\Sigma_{e,1}, \ldots, \Sigma_{e,T}\}, \\ \text{[Variance-covariance matrices of the innovations]} \quad & V. \end{aligned}$$

2.3 DATA AND ESTIMATION The aforementioned TVC-VAR model is estimated using quarterly data from 1990:Q1 to 2018:Q2. The first 10-year sample, ranged between 1990:Q1 and 1999:Q4, is used to initiate the prior distributions for the TVC-VAR model so that the actual sample period for empirical analyses is from 2000:Q1 to 2018:Q2. The choice of the sample period for empirical analyses is due primarily to the shift in monetary policy occurring in the late 1990s. Brito and Bystedt (2010) and Choi and Hur (2015) document that the post-2000s period corresponds to an inflation targeting regime, whereas this evidence is hardly supported by data in the precedent period.

The estimation procedure of the TVC-VAR model follows that of Primiceri (2005) and Galí and Gambetti (2015). We employ independent inverse-Wishart prior distributions for the hyperparameters Q, W, and S. The priors for the initial values for B_0, α_0, and $\log \sigma_0$ are assumed to be normally distributed. As a result, the entire sequences of B, α, and $\log \sigma$ are normally distributed conditioned on Q, W, and S. The posterior distributions of the model's parameters are obtained by using Gibbs sampling, which simulates 22,000 posterior draws, with the first 20,000 used as a burn-in period and every 2nd thinned, leaving a sample size of 1,000.[4]

3 EMPIRICAL RESULTS

This section documents the posterior estimates for the impulse responses from the aforementioned TVC-VAR model. To begin, we report the identified central bank's stance toward inflation, which will be critical in shaping the expansionary effects of government spending shocks. We then provide the time-varying pattern in government spending multipliers and unveil their crucial determinant by conducting a counterfactual experiment.

3.1 IDENTIFIED MONETARY POLICY STANCE TOWARD INFLATION Figure 3 reports the time-varying impulse responses of the nominal interest rate *at impact* associated with 1% increases in inflation. To connect this result with narrative accounts of monetary policy history in Korea, we additionally provide the vertical lines indicating the Bank of Korea governor terms. As in Primiceri (2005), notice that the object in this figure can be interpreted as the *contemporaneous* monetary policy stance toward inflation, and thus corresponds to the Taylor rule inflation coefficient of fully structural general equilibrium models.

Monetary policy responses to inflation turn out to be quite mild during the early years of the sample. In order to achieve price stability via an Inflation Targeting system, the Bank of Korea made its policy shift from the money aggregate based approach to the interest rate based policy in 1998. Hence, the weak response during the first half of the 2000s may stem from the monetary policy turning point just prior to the sample period.

The second half of the 2000s is marked with a stronger reaction to inflation over time up to the onset of the global financial crisis (GFC) of 2008-09. Consequently, monetary policy was the most hawkish under the Seongtae Lee's governorship. This upward tendency, however, did not last long. Shortly after, confronting a severe economic downturn associated with the GFC, there were two consecutive cuts of the policy rate in the first quarter of 2009. The interest rate fell from 4.05 (2008:Q4) to 1.88 (2009:Q2) percent per annum, an unprecedented low level in the Korean

[4] Please refer to Galí and Gambetti (2014) for a detailed description of the sampling algorithm used in this article.

monetary policy history. Our TVC-VAR estimates suggest that the central bank's response toward inflation declines with these policy actions.

For the remainder of the sample, the degree of policy responsiveness bounces back only marginally but not fully compared to its peak in the late 2000s. Our estimates indicate that the central bank's stance toward inflation is not much different from its mid-2000s level. Notice, however, that the level of inflation over this period is somewhat lower than that of the 2000s, as depicted in Figure 1. Taken together, the TVC-VAR result shows that the mild reaction to inflation in the recent period can be justified in light of the low inflation environment.

3.2 Effects of Government Spending Shocks

We now inspect the macroeconomic consequences of government spending shocks, associated with the TVC-VAR model. In the existing literature, the expansionary effects of government spending on output are often summarized by a present value multiplier defined as follows:

$$\text{Present Value Multiplier}(Q) = \frac{\sum_{t=0}^{Q}(1+\bar{r})^t y_t}{\sum_{t=0}^{Q}(1+\bar{r})^t g_t}\frac{1}{\overline{Y}/\overline{G}} \tag{6}$$

where $\bar{r}$ and $\overline{G}/\overline{Y}$ denote the sample means of the real interest rate and share of government spending in GDP, respectively.

Figure 4 shows the median estimates of present value multipliers. The figure makes clear that the effects of increases in government spending on output vary substantially over time, pronounced more in the longer horizons. In particular, the longer-run multipliers tend to spike up in the 2010s. As a result, the shape of present value multipliers changes as time elapses—from a hump-shaped response pattern in the early 2000s to a monotonically increasing one after the GFC period. Since present value multipliers represent the full dynamics of discounted future macroeconomic effects caused by exogenous changes in government spending, this finding indicates that an increase in government spending has more persistent effects on output in the recent sample.

To conduct full statistical analyses of the results, Figures 5 through 7 plot the median and 68% band estimates of present value multipliers as well as of the impulse responses of inflation and the nominal interest rate for selected horizons—at impact, and 4, 8 and 12 quarters after government spending shocks. First of all, the sliced present value multipliers are reported in Figure 5. Although neither substantial in size nor statistically different from zero, it turns out that the impact multipliers keep increasing over time. The pattern, however, is quite different for the 4-quarter multipliers as in the second panel of the figure. Present value multipliers show a decreasing tendency from the beginning of the sample to the GFC period, but they bounce back afterward. Accordingly, the early 2000s and most of the 2010s correspond to the periods in which the expansionary effects of government spending become significant in terms of the one-year estimates. For longer horizons, present value multipliers display a similar pattern as they have no trend and remain statistically indifferent from zero throughout the 2000s, and then rise to become significant in the 2010s.

In order to illustrate the differences in dynamics over time, Table 1 reports the median estimates of the present value multipliers for selected periods and horizons. Two findings stand out from the peak multipliers. First, based on the peak multipliers, the expansionary effect of government spending on output is a lot more pronounced for the recent period than in the 2000s. For instance, the peak multiplier for 20004:Q2 is 0.51, whereas the 2016:Q2 multiplier turns out to be 0.88, which is more than 50% higher in size. Second, the persistence effects of government spending on output change over time. In the early 2000s, the peak multipliers appear at relatively shorter horizons. This tendency, however, change dramatically for the remainder of the sample so that it takes more than 30 quarters for the maximum effect of government spending on output to be realized. This finding suggests that government spending shocks tend to have more persistent effects on output in the recent sample.

Figure 6 provides the median and 68% band estimates of inflation impulse responses to government spending shocks for selected horizons. We do not observe any inflationary pressure due to the fiscal expansions for all horizons considered, as the 68% band estimates always include zero. This response pattern of inflation is somewhat puzzling based on a conventional macroeconomic theory such as an IS-LM-type environment. Notice, however, that negative inflation responses to a rise in government spending are often documented by the existing VAR studies with US data including Fatás and Mihov (2001), Caldara and Kamps (2008) and Mountford and Uhlig (2009). Nevertheless, the response pattern at impact deserves further attention. The inflation responses display a decreasing tendency as time elapses, and they become negative for the post-GFC period in terms of the median estimates. Together with the monetary policy response toward inflation described in Figure 3, this finding may provide an important insight into how monetary policy in times of government spending expansions is conducted.

In order to examine this issue in detail, Figure 7 plots the impulse responses of the nominal interest rate to government spending shocks. For the impact period, the responses are negative and statistically different from zero over the whole sample period, consistent with the fixed-coefficient VAR result in Figure 2. When compared to the previous period, it is notable that the magnitude of the negative response becomes more pronounced in the 2010s. The downward trend in the inflation responses is also observed for the 4- and 8-quarter estimates. This response pattern can be rationalized by taking together the findings that monetary policy response to inflation has weakened in the 2010s (Figure 3) and government spending shocks become less inflationary as time elapses

(Figure 6). Hence, a more accommodative interest-rate policy can be associated with increases in government spending. An important implication of the rationale is that the expansionary effects of government spending increases are amplified by the accommodative monetary policy, particularly standing out in the 2010s. The subsequent section takes this issue into consideration by conducting a counterfactual exercise with a hypothetical monetary policy behavior during government spending expansions.

3.3 COUNTERFACTUAL IMPULSE RESPONSES To assess how much the fall in the interest rate intensifies the present value multiplier, we pursue a counterfactual experiment in which the policy rate did not change in response to government spending shocks. This empirical strategy is proposed by Ramey (2013) in controlling for tax changes caused by an exogenous increase in government spending. In a similar vein, we apply the methodology in order to mute the interest rate response followed by government spending shocks. As provided in Ramey (2013), the counterfactual exercise can be implemented by using the actual VAR estimated coefficients from the other equations, while restricting the coefficients in the interest rate rate equation to be zero.

Figure 8 makes a comparison between the actual and counterfactual present value multipliers for selected horizons. The gap across the two types of estimates is substantial, highlighted more as the horizon increases. When associated with the counterfactual scenario, the 4-quarter present value multiplier estimates show a similar time-varying pattern to their actual ones, with a slight decrease in level. This tendency, however, does not hold for the 8- and 12-quarter estimates. The counterfactual multipliers associated with these horizons keep displaying a V-shaped pattern, which is quite different from their actual counterparts.

In order to focus on the differences in dynamics across the two scenarios, Figure 9 reports the median and 68% error bands for the gap between the actual and counterfactual multiplier estimates. As in the first panel of the figure, the gap across the two multipliers is minuscule at impact but increases with horizons. As a result, the counterfactual scenario makes significant differences in the first half of the 2010s based on the 8- and 12-horizon estimates. The only difference across the two scenarios is the interest rate response to government spending shocks, so the disparity in results corresponds to the role created by monetary policy behavior in times of government spending expansions. Thus this finding suggests that the recent surge in government spending multipliers reported in Figure 5 is in part shaped by the accommodative stance of monetary policy.

Finally, Table 2 tabulates the median and 68% estimates of the gap between the actual and counterfactual present value multipliers for selected periods and horizons. Focusing on the 2012:Q3 estimates when the gap is most pronounced and significant, 33% and 40% additional expansionary effects of government spending on output are attributable to the particular monetary policy behavior in terms of the median values. Although not significant, this effect seems to prevail throughout the 2010s. These findings have implications that extend beyond the exercises performed here—in principle, the monetary policy stance can have major implications for fiscal impacts.

4 ROBUSTNESS CHECK

4.1 IDENTIFIED MONETARY POLICY STANCE In gauging the monetary policy stance toward its stabilizing objectives, a potential concern associated with the framework in this article is whether the results are contaminated by the inclusion of government spending as a model's endogenous variable. This is because conventional monetary policy analyses tend to be embedded only with variables relevant to monetary policy decisions, and government spending is unlikely to be one of them. In this regard, a robustness check may be necessary to inspect if our result in Figure 3 is confronted with this issue. Accordingly, we construct a 3-variable VAR system without government spending so that the model contains the policy rate as well as the dual mandate objectives—output and inflation.

Figure 10 plots the impulse responses of the nominal interest rate to 1% inflation shocks (dotted lines), together with their baseline 4-variable model counterpart (solid line with shaded area). The impulse responses from the 3-variable model display slightly tighter band estimates than those from the 4-variable VARs. This tendency may be attributable to the "curse of dimensionality" problem, typically associated with TVC-VARs of many additional parameters to be estimated as the number of variables increase. Nevertheless, it is worth noting that the overall pattern of the responses remains quite similar to that of the baseline specification. The response pattern in the 2000s remains almost identical when government spending is excluded. For the subsequent period, the responses across the two models are quantitatively different, but not qualitatively. The responses with the 3-variable system are constantly higher than those of the baseline specification. However, the fact that monetary policy becomes less hawkish in the 2010s than its peak response in the late 2000s is almost unaltered under the 3-variable model.

4.2 CONTROLLING FOR TAXES As demonstrated in Rossi and Zubairy (2011) and Ramey (2013), how taxes behave in response to a government spending shock may have a crucial implication for the size of government spending multipliers. Guided by the findings in the existing literature, our second robustness check is to augment the model with taxes.

To this end, we specify a 5-variable VAR system consisting of government spending, output, inflation, taxes and the nominal interest rate. Notice that this set of variables is the ones employed in Perotti (2005) and Caldara and Kamps (2008). Following Caldara and Kamps (2008), the identification of government spending shocks relies on the recursive ordering as listed above.

Ordering taxes after output and inflation can be rationalized that, given the tax rate, the tax base is contemporaneously affected by these two variables, and thus tax receipts change.

Focusing first on the impulse responses of taxes, two findings emerge from Figure 11. First, there is no clear time-varying pattern in the tax responses. Second, the impulse responses of taxes are statistically indifferent from zero for all the periods and horizons considered, with an exception of the impact responses in the early 2000s. It is, however, noticeable that the tax responses at impact provide a characterization of government spending shocks over the sample period. Taxes decrease at impact in response to increases in government spending, indicating that the identified government spending shocks are initially deficit financed.

Figure 12 plots the present value multiplier estimates for selected horizons, associated with the 5-variable (dotted lines) and baseline 4-variable (solid line with shaded area) VAR specifications. Despite the decreases in taxes at impact, the present value multipliers up to 4 quarters remain almost unaltered by augmenting the model with taxes. The longer run multipliers tend to become slightly smaller under the 5-variable system, but the differences are only marginal as its 68% bands mostly overlap with those of the 4-variable benchmark. Hence, we find that controlling for taxes does not alter substantially the quantitative estimates of government spending multipliers.

5 CONCLUSION

After the Global Financial Crisis, the growth rate in Korea has steadily declined despite the low output volatility. In order to boost up the economic growth, the expansionary fiscal policy has been conducted since 2010. At the same time, the monetary policy has been less hawkish during these active fiscal policy regimes. Under this situation, our paper empirically assesses the effects of expansionary government spending on output changes over time, and investigate the role of monetary policy stance on the multipliers. We tackle these problems with a time-varying coefficient VAR model recently developed.

We apply TVC-VAR model in Korea from 2000:Q1 to 2018:Q2 with 4 endogenous variables, government spending, output, inflation and nominal interest rates. In order to reflect the small open economy features in Korea, we exogenously control some variables such as US federal funds rate, oil prices changes, the real exchange rate of Korean Won against the US dollar, and US output as a proxy for the world business cycle. The present value spending multipliers display some interesting trend across different time horizons. The impact multipliers have steadily increased overtime but the 4-quarter multipliers display V-shaped with the turning points at 2008. The 8-quarter and 12-quarter multipliers, however, significantly increased after GFC. On the other hand, the monetary policy stance, measured with the response of nominal interest rate to 1% increases of inflation, were more active until the GFC but moved toward relative passive stance after 2010. In order to examine the effects of the monetary policy changes on the fiscal multipliers, we perform a counterfactual analysis by restricting the coefficients in the interest rate equation to be zero. When monetary policy does not react to the economic shocks, the fiscal multipliers are significantly dropped compared to the baseline results. Specially, the differences are pronounced in the 8-quarter and 12-quarter multipliers after the GFC.

Our results have some important implications. For Korean economy point of view, we find that the recent expansionary fiscal policy has positive impact on the output growth especially in the long run. The 8-quarter and 12-quarter fiscal multipliers are significantly improved after the GFC. Next, these improvement in the long-run multipliers are supported by the accommodative monetary policy. As discussed before, the monetary policy stance has an important consequence to an expansionary fiscal policy. This viewpoint is supported by various empirical results from US. Our results from Korea is in line with these researches, and supports that the accommodative monetary policy stance can amplify the fiscal multipliers and the amplification is stronger in the long-run.

A DATA

We employ Korean data from 1990:Q1 to 2018:Q2 for the endogenous variables of the VAR models. Our VAR specifications also include four exogenous variables which use quarterly data for the growth rate of oil price, federal funds rate, US real GDP per capita, and real exchange rate against dollar. Detailed data descriptions are as follows:

$$\begin{aligned}
\text{Government Spending} &= \log(\text{Domestic Real Per Capita Government Spending}), \\
\text{GDP} &= \log(\text{Domestic Real Per Capita GDP}), \\
\text{Inflation Rate} &= \log(\text{Domestic CPI/Domestic CPI}(-1)) \times 100, \\
\text{Taxes} &= \log(\text{Domestic Real Per Capita Taxes}), \\
\text{Nominal Interest Rate} &= \text{Domestic Overnight Call Rate}, \\
\text{Growth Rate of Oil Pirce} &= \log(\text{Oil Price/Oil Price}(-1)) \times 100, \\
\text{US Nominal Interest Rate} &= \text{US Federal Funds Rate}, \\
\text{US GDP} &= \log(\text{US Real Per Capita GDP}), \\
\text{Real Exchange Rate} &= \text{Nominal Exchange Rate (won/dollar)} \times \text{US CPI/Domestic CPI.}
\end{aligned}$$

For the construction of the real per capita variables, domestic and US real series are divided by the corresponding country's population, except for the Korean fiscal data. Only seasonally unadjusted nominal variables are available for the Korean fiscal variables—government spending and taxes. They are therefore deseasonalized by using the X-13-ARIMA procedure and converted into real variables based on the domestic CPI. US GDP uses the real series. The original data and their sources are given as follows:

- Domestic Nominal Government Spending: Total government spending expenditure, not seasonally adjusted / Source: Korean Statistical Information Service (KOSIS)
- Domestic Real GDP: Real gross domestic product, seasonally adjusted / Source: The Bank of Korea's Economic Statistics System Database (BOK-ECOS)
- Domestic CPI: Consumer price indexes, 2015=100, seasonally adjusted / Source: BOK-ECOS
- Domestic Nominal Taxes: Total tax revenue, not seasonally adjusted / Source: KOSIS
- Domestic Nominal Interest Rate: Overnight call rate, uncollateralized, percent per annum, averages of daily figures / Source: BOK-ECOS
- Domestic Population: Total population, annual / Source: KOSIS

- Oil price: Global price of Dubai Crude, US dollars per barrell, quarterly, not seasonally adjusted / Source: Federal Reserve Economic Data (FRED, St. Louis Fed), Series ID “POILDUBUSDM”
- US Federal Funds Rate: Averages of daily figures, percent / Source: Board of Governors of the Federal Reserve System
- US Real GDP: Real gross domestic product, chained dollars, billions of chained (2009) dollars, seasonally adjusted at annual rates / Source: NIPA Table 1.1.6, Line 1
- Nominal Exchange Rate: Won/dollar exchange rate / Source: BOK-ECOS
- US CPI: Consumer price index for all urban consumers, all items, index 1982−1984=100, quarterly, seasonally adjusted / Source: FRED, Series ID “CPIAUCSL”
- US Population: Civilian noninstitutional population, ages 16 years and over, seasonally adjusted / Source: US Department of Labor, Bureau of Labor Statistics

B TABLES

	2000:Q2	2004:Q2	2008:Q2	2012:Q2	2016:Q2	2018:Q2
Impact	0.02	0.03	0.04	0.05	0.05	0.05
4 quarters	0.43	0.33	0.39	0.39	0.43	0.42
8 quarters	0.52	0.49	0.29	0.70	0.75	0.67
12 quarters	0.44	0.50	0.15	0.78	0.82	0.75
Peak (QTR)	0.54 (7)	0.51 (11)	0.65 (39)	0.85 (39)	0.88 (30)	0.82 (31)

Table 1: Median estimates of the present value multipliers for selected periods and horizons. The numbers reported in this table represent GDP responses in Korean won to initial increases in government spending by one Korean won.

	2000:Q2	2004:Q2	2008:Q2	2012:Q2	2016:Q2	2018:Q2
4 quarters	0.08	**0.06**	0.07	0.07	0.06	0.07
	[−0.02, 0.20]	**[0.00, 0.19]**	[−0.02, 0.21]	[−0.01, 0.21]	[−0.03, 0.21]	[−0.03, 0.23]
8 quarters	0.13	0.18	0.28	**0.33**	0.30	0.24
	[−0.27, 0.48]	[−0.10, 0.57]	[−0.02, 0.75]	**[0.03, 0.80]**	[−0.03, 0.81]	[−0.09, 0.82]
12 quarters	0.03	0.16	0.36	**0.40**	0.37	0.30
	[−0.59, 0.52]	[−0.23, 0.69]	[−0.06, 1.00]	**[0.00, 1.02]**	[−0.09, 1.05]	[−0.17, 1.04]

Table 2: Gap between the actual and counterfactual present value multipliers for selected periods and horizons. Median and [16%, 84%] estimates are reported.

C FIGURES

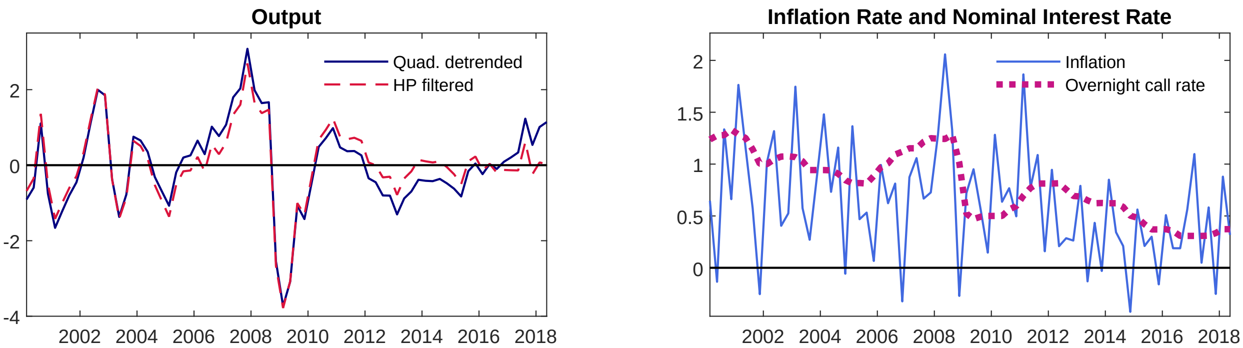

Figure 1: Time series for the macroeconomic aggregates in Korea, from 2000:Q1 to 2018:Q2. **[Left panel]** Real per capita output, quadratic detrended (solid line) and HP-filtered (dashed line). **[Right panel]** Quarterly inflation rate (solid line) and nominal interest rate (overnight call rate, dotted line).

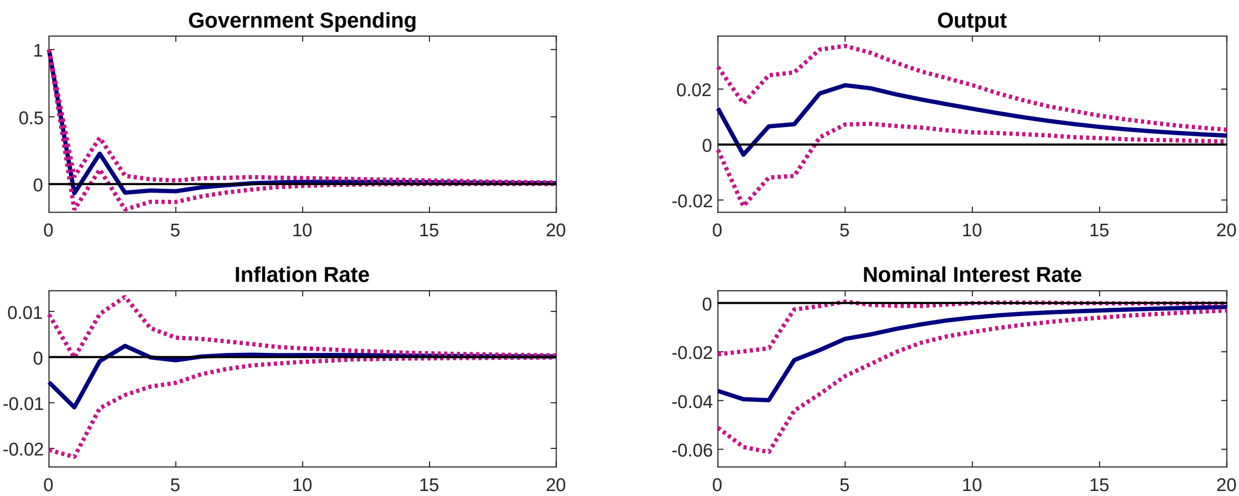

Figure 2: Impulse responses to a 1% increase in government spending, associated with the fixed coefficient VAR model. In each panel, point estimate (solid line) and 68% confidence interval estimates (dashed lines) are reported. The x-axis measures quarters.

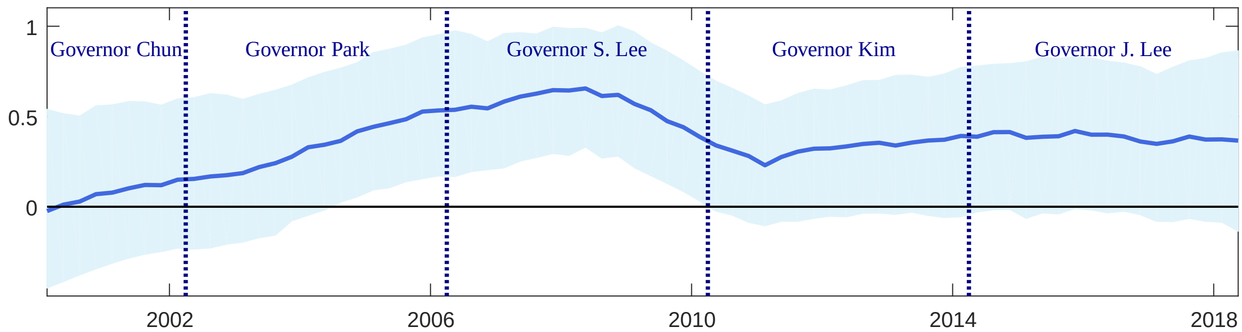

Figure 3: Time-varying impulse responses of the interest rate at impact to 1% increases in inflation, associated with the TVC-VAR model. Median (solid line) and 68% band (shaded area) estimates are reported. The vertical lines indicate the Bank of Korea governor terms.

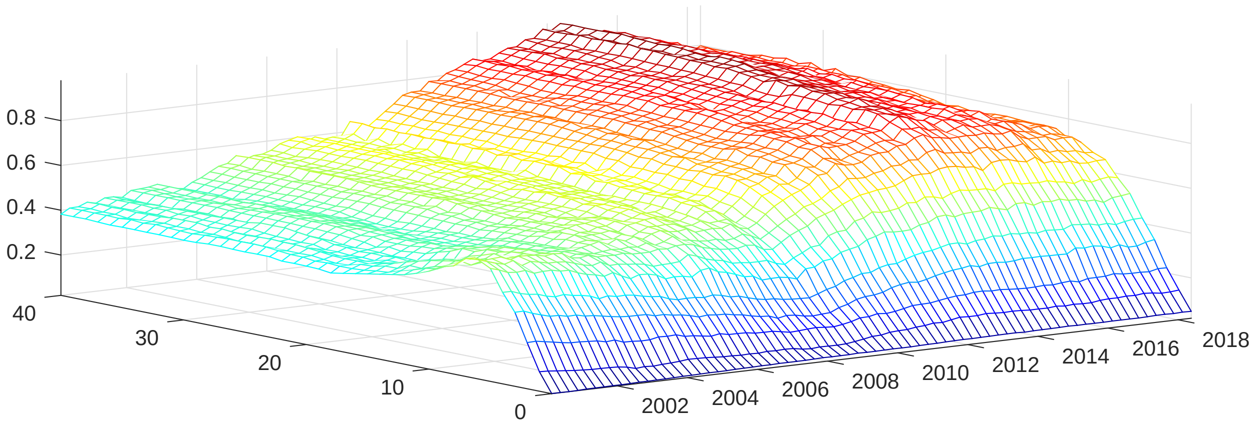

Figure 4: Time-varying present value multipliers, associated with the TVC-VAR model. Median estimates are reported.

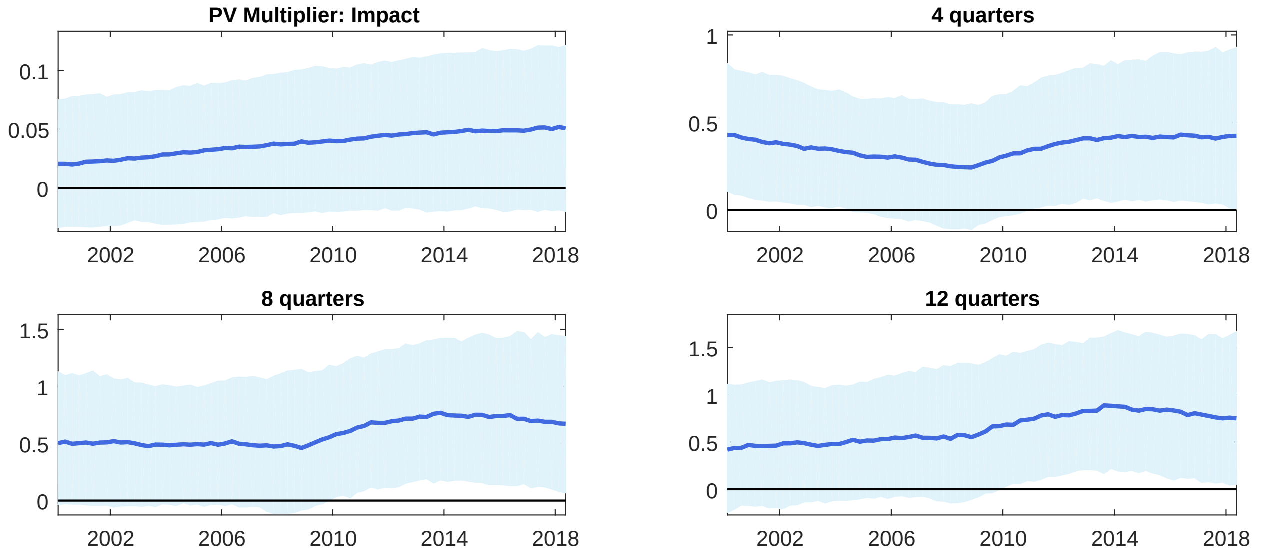

Figure 5: Time-varying present value multipliers for selected horizons, associated with the TVC-VAR model. In each panel, median (solid line) and 68% band (shaded area) estimates are reported.

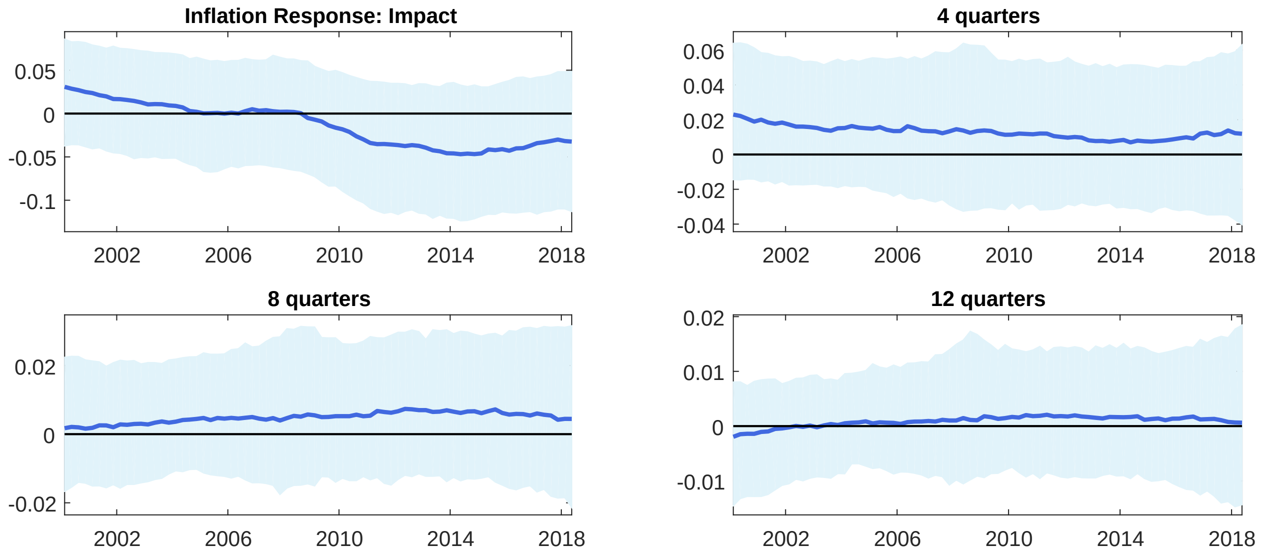

Figure 6: Time-varying impulse responses of inflation to 1% increases in government spending for selected horizons, associated with the TVC-VAR model. In each panel, median (solid line) and 68% band (shaded area) estimates are reported.

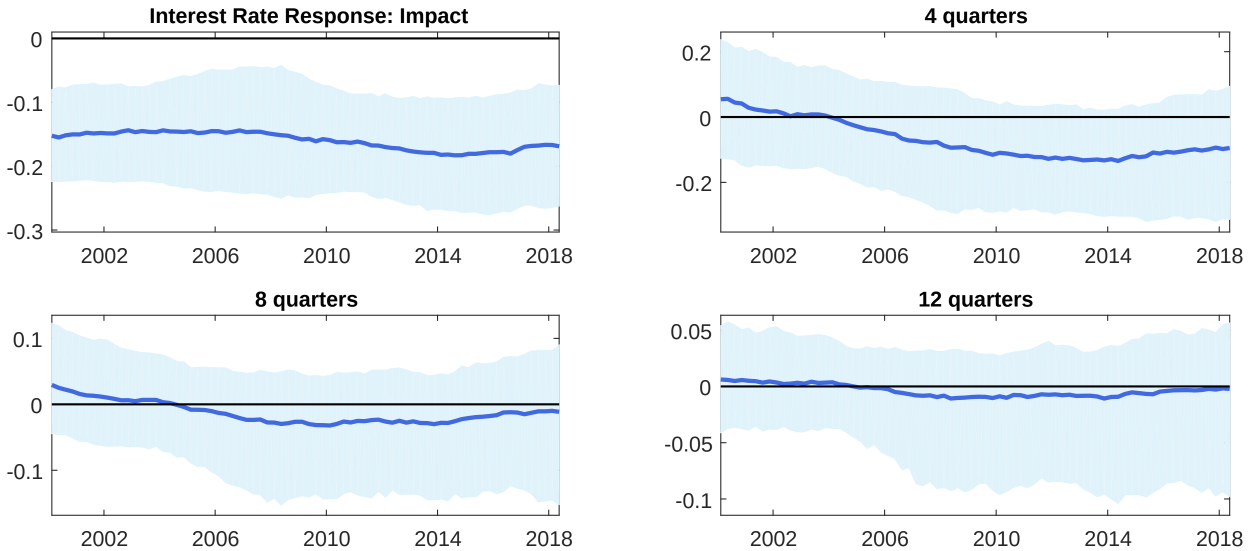

Figure 7: Time-varying impulse responses of the interest rate to 1% increases in government spending for selected horizons, associated with the TVC-VAR model. In each panel, median (solid line) and 68% band (shaded area) estimates are reported.

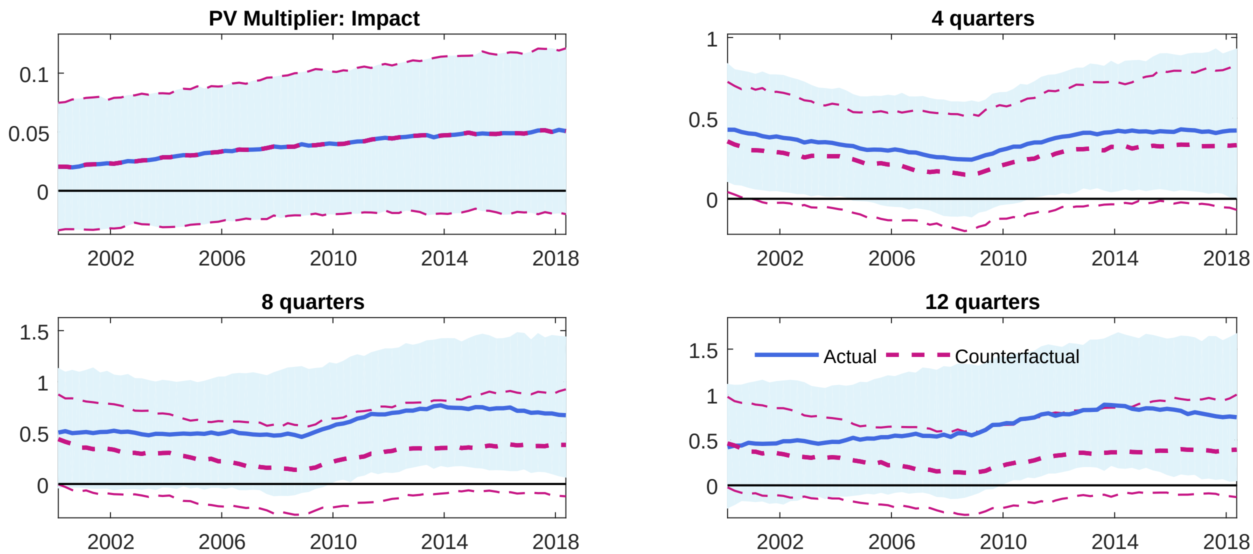

Figure 8: Actual (solid line with shaded area) and counterfactual (dashed lines) time-varying present value multipliers for selected horizons, associated with the TVC-VAR model. In each panel, median and 68% band estimates are reported. The counterfactual impulse responses are calculated under the assumption that the nominal interest rate did not change in response to government spending shocks.

Figure 9: The differences between actual and counterfactual time-varying present value multipliers for selected horizons, associated with the TVC-VAR model. In each panel, median (thick dash-dot line) and 68% band (thin dash-dot lines) estimates are reported. The counterfactual impulse responses are calculated under the assumption that the nominal interest rate did not change in response to government spending shocks.

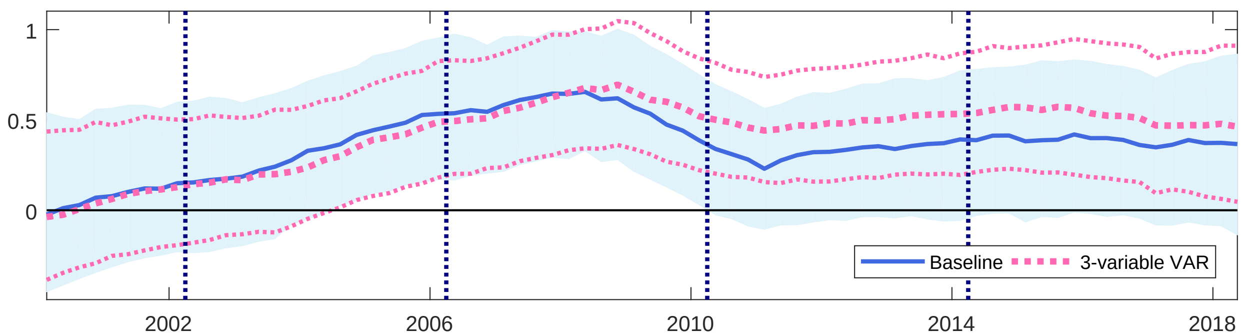

Figure 10: Time-varying impulse responses of the interest rate at impact to 1% increases in inflation, associated with the benchmark TVC-VAR model with 4 variables (solid line with shaded area) and the 3-variable TVC-VAR model without government spending (dotted lines), respectively. Median and 68% band estimates are reported. The vertical lines indicate the Bank of Korea governor terms.

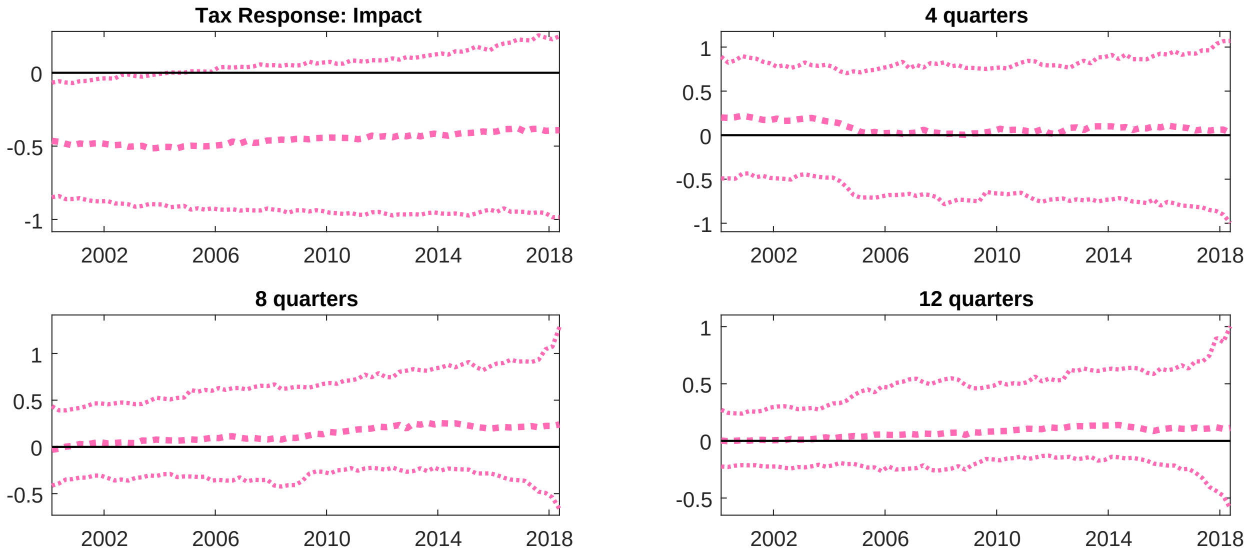

Figure 11: Time-varying impulse responses of taxes to 1% increases in government spending for selected horizons, associated with the 5-variable TVC-VAR model augmented with taxes. In each panel, median (thick dotted line) and 68% band (thin dotted lines) estimates are reported.

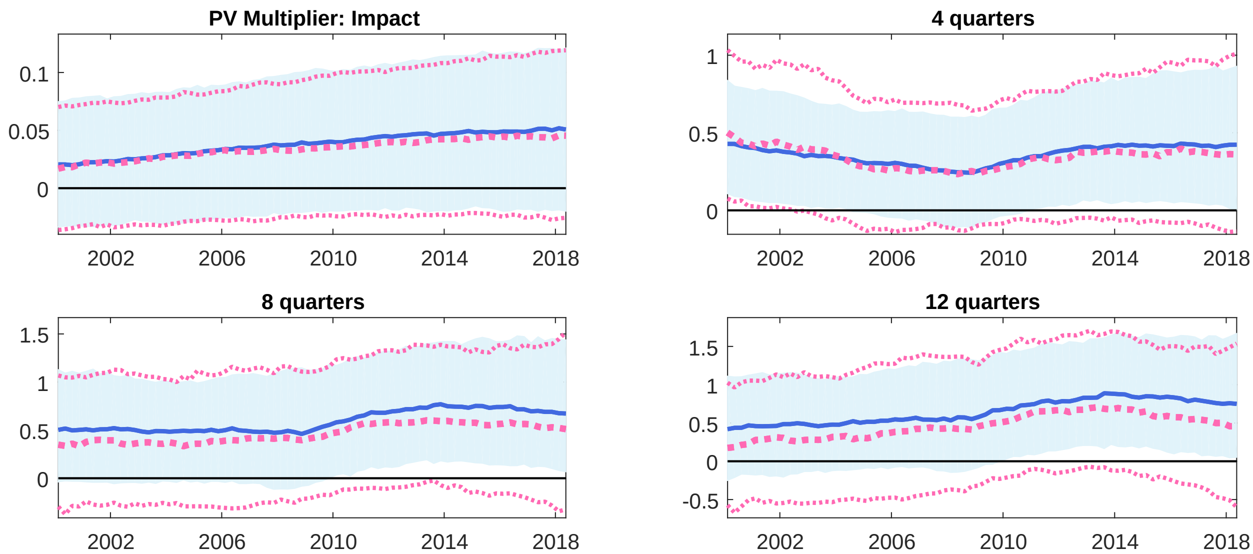

Figure 12: Time-varying present value multipliers for selected horizons, associated with the benchmark TVC-VAR model with 4 variables (solid line with shaded area) and the 5-variable TVC-VAR model augmented with taxes (dotted lines). In each panel, median and 68% band estimates are reported.

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