Effect of Monetary Policy on Government Spending Multiplier*

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Abstract

This paper empirically examines the effect of monetary policy on the government spending multiplier when the nominal interest rate is not bound to zero. We estimate a time-varying coefficient vector autoregressive (TVC-VAR) model using 2000:Q1 to 2019:Q3 quarterly data of Korea, whose policy rate is distant from zero. We find a substantial degree of time variation in the medium-run government spending multipliers, which increase over time and become statistically different from zero throughout the 2010s. Yet the reverse pattern is observed in the policy rate responses to government spending shocks, decreasing gradually until 2008−09 and then stagnating for the subsequent period. Decompositions of the policy rate responses reveal that inflation is an important ingredient in determining the responses of the nominal interest rate to government spending shocks, thus has a critical impact on the size of the government spending multipliers. In particular, our finding underscores a substantial role of the monetary policy stance against inflation in shaping the government spending multipliers.

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

The effects of expansionary government spending on macroeconomic aggregates depend on a host of factors. Among them, the extent to which monetary policy responds to inflation in times of fiscal expansions has been given much research attention. Theory predicts that an increase in government spending raises the price level, as well as the expected path of inflation when prices are sticky. Monetary policy actively targeting inflation raises the nominal interest rate more than the increase in inflation. Real interest rates then rise, suppressing private spending, offsetting some of the increase in goods demand, and finally *ceteris paribus* producing smaller multipliers.[1] By the same reasoning, the macroeconomic consequences of a government spending expansion coupled with monetary policy targeting inflation less actively are shaped primarily by a fall in real interest rates, mapped into larger multipliers.

The channel through which monetary policy affects the size of government spending multipliers is extensively studied in an environment where the zero lower bound (ZLB) constrains nominal interest rates. In counteracting the global financial crisis (GFC) of 2008, fiscal authorities in many countries adopted numerous stimulus packages while their central banks kept short-term nominal interest rates close to zero. This has provided a real-life case for many researchers to investigate the relationship between monetary policy and spending multipliers. A plethora of previous studies on this issue have been carried out on the basis of either a theoretical perspective [Eggertsson (2008), Christiano et al. (2011), and Davig and Leeper (2011)] or an empirical framework [Ramey (2011), Crafts and Mills (2013), and Miyamoto et al. (2018)].

Nevertheless, the ZLB is regarded as a special case in which central banks' concerns shift away from their central objective—inflation targeting (IT)—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)]. The discussion is generalizable to broader environments in which monetary policy obeys a typical Taylor-type rule. In this vein, Christiano et al. (2011) establish a systematic relationship between the degree of the monetary authority's anti-inflationary stance and the size of government spending multipliers. Based on a new Keynesian model, they demonstrate that government spending multipliers decline as monetary policy reacts more actively to inflation. Empirical analyses march alongside theory. For instance, Rossi and Zubairy (2011) and Dupor and Li (2015) use a structural vector autoregression (VAR) model and compare government spending multipliers for the pre- and post-Volcker periods, in order to examine if the aggressive anti-inflationary stance since the appointment of Volcker influences the effects of fiscal stimulus.

[1] The effect is often referred to as the "inter-temporal effect" [Davig and Leeper (2011)] or the "expected inflation channel" [Dupor and Li (2015)] of government spending.

This paper explores empirically whether monetary policy matters in shaping government spending multipliers under a non-ZLB environment. We particularly focus on the Korean economy as a laboratory for the following reasons. First, mainly because Korea potentially has a positive effective lower bound as a small open economy, the policy interest rate in Korea has never been bound to zero during the past two decades, as reported in Figure 1. Second, the growth rate of output has declined substantially for the post-GFC period compared to the pre-crisis one, and Korea's fiscal authority has made constant efforts to stimulate the economy through government spending expansions. Lastly, and most importantly, a historical narrative of monetary policy in the country reveals that the central bank's anti-inflationary stance has changed many times since its policy shift from the money-aggregate-based approach to the IT system in the late 1990s. As a primary action plan to support the policy shift, the Bank of Korea (BOK) launched a medium-term inflation targeting (MTIT) system in 2004. The crux of MTIT was to set the target inflation rate as well as its range for the upcoming three years, which was then revised at the end of the 3-year term [Bank of Korea (2004, 2006, 2009, 2012, 2015, 2019)].

In this article, we take up the issue by employing a time-varying coefficient VAR (hereafter, TVC-VAR) method developed by Primiceri (2005) and Galí and Gambetti (2015). The choice of the TVC-VAR model for empirical analyses is guided by the dearth of evidence on how the extent to which Korea's monetary policy reacts to inflation has evolved over time. This contrasts markedly with the case of advanced countries. For the US, for instance, there seems to be a solid consensus among researchers and policymakers that the Federal Reserve's stance toward inflation changed dramatically with the appointment of Volcker [e.g., Clarida et al. (2000), Lubik and Schorfheide (2004) and Bianchi (2013), among many others]. Accordingly, the analogous literature for advanced economies attempts to calculate fiscal multipliers for different monetary policy regimes, simply by splitting the sample period corresponding to each monetary policy regime. In contrast, this line of research is lacking for Korea, and thus our empirical strategy is to let the TVC-VAR specification become an agnostic but unified framework in identifying the time-varying monetary policy stance and resulting government spending multiplier estimates.

Our empirical results based on the TVC-VAR model estimated with Korean time series from 2000:Q1 to 2019:Q3 are as follows. First, we find that the government spending multiplier estimates display a significant time variation, particularly standing out in the medium-run horizon. Regardless of the horizon, the present value multiplier estimates display an increasing tendency over time. The size and significance of the multipliers, however, are quite different for the 4-quarter horizon and beyond such that the multipliers become larger in size, a tendency that becomes more pronounced for the post-GFC period. As a result, the present-value multipliers for the 4-quarter horizon and beyond become statistically different from zero throughout the 2010s.

Second, the impulse responses of the nominal interest rate to positive government spending shocks in the short run display a mild degree of time variation, decreasing gradually until 2008−09 and then stagnating for the subsequent period. Combining the time-varying patterns of the medium-run present-value multipliers and short-run interest rate responses, our results suggest a negative relationship between these two objectives. It is well-established in the existing literature that the size of government spending multipliers depends substantially on how monetary policy behaves in times of a fiscal expansion [Eggertsson (2008), Christiano et al. (2011), and Erceg and Lindé (2014), among many others]. Our finding of the negative relationship in this regard deserves careful scrutiny in assessing a potential role of monetary policy as a determinant of government spending multipliers.

The primary contribution of this paper is to examine the behavior of inflation and monetary policy responses to it as the source of the time-varying pattern of the nominal interest rate responses to government spending shocks. From a theoretical perspective, a conventional Taylor-type rule posits that fluctuations in inflation can change the nominal interest rate through two channels: (i) the degree of policy responsiveness to a unit change in inflation; and (ii) the magnitude of the inflation fluctuations. Guided by the theory, we assess the role of inflation in determining the time-varying pattern of the interest rate in response to exogenous changes in government spending. Theory-consistent decompositions of the interest rate responses reveal a substantial degree of time variation both in the monetary authority's anti-inflationary stance and inflation volatility. More importantly, our finding from the decomposition indicates that inflation is an important ingredient in determining the responses of the nominal interest rate to government spending shocks. The inflation-driven component of the interest rate responses dominates the other variables in terms of magnitude, and shows a similar time variation with the responses themselves.

In order to complete the analysis, we finally examine the importance of monetary policy in shaping the government spending multiplier. Two experiments are conducted for this purpose. The first experiment is designed to evaluate the role of monetary policy *as a whole* by estimating the TVC-VAR model without the nominal interest rate. By taking the policy rate out of the model, we completely shut down the channel through which the nominal interest rate, and thus monetary policy, affects the spending multiplier. We then move to the second exercise, which focuses specifically on the inflation-targeting dimension of monetary policy as a determinant of government spending multipliers. To this end, we keep all the model variables, but restrict the model's parameters governing the inflation-driven component of the interest rate responses to be time invariant. This experiment is likely to reveal the prominent factor characterizing the time variation in the government spending multiplier, related to monetary policy behavior and inflation dynamics.

The results from the two experiments indicate that changes in the nominal interest rate produced by inflation fluctuations are important for the size of the government spending multiplier. The difference in the multipliers between the specifications with and without the nominal interest rate displays a correlation near unity with the inflation-driven component of the interest rate responses. This finding ascribes a critical role in the recent surge in government spending multipliers to shifts in the policy stance toward inflation and in inflation volatility. Among these two factors, we find that changes in the anti-inflationary stance are a more crucial determinant of the time-varying pattern in the present-value multipliers than those in the size of shocks governing inflation dynamics. Our finding in this regard echoes those in the existing literature highlighting the importance of the central bank's anti-inflationary stance to the size of government spending multipliers, including Kim (2003), Christiano et al. (2011), Davig and Leeper (2011) and Dupor and Li (2015), among many others.

2 ECONOMETRIC SPECIFICATION

To empirically analyze the evolution of the government spending multiplier with changes in monetary policy behavior over time, we utilize a TVC-VAR model as in Primiceri (2005) and Galí and Gambetti (2015). Both studies assess how monetary policy changes affect macroeconomic variables over time. We extend these models to incorporate government spending shocks to examine the interaction between fiscal and monetary policy. In this section, we illustrate the VAR model specification and the data construction employed in this paper.

2.1 VAR WITH TIME-VARYING COEFFICIENTS

Consider the reduced-form VAR model given as

$$z_t = \mu_0 + \mu_1 t + \mu_2 t^2 + Dx_t + B_{1,t} z_{t-1} + \ldots + B_{\ell,t} z_{t-\ell} + u_t, \quad t = 1, \ldots, T, \tag{1}$$

where μ_0 is a constant term, and t and t^2 denote linear and quadratic time trends, respectively. x_t is an $m \times 1$ vector of exogenous variables with the time-invariant coefficient matrix D. z_t is an $n \times 1$ vector of endogenous variables and $B_{i,t}$'s with $i = 1, \ldots, \ell$ are $n \times n$ matrices of time-varying coefficients associated with the endogenous variables where ℓ denotes the lag length of the VAR model. u_t is a heteroskedastic reduced-form error with $E(u_t) = 0$, $E(u_t u_t') = \Sigma_{u,t}$ and $E(u_t u_s') = 0$ for $s \neq t$. Three lags ($\ell = 3$) are assumed based on the information criteria such as AIC and BIC.

We augment the exogenous variables x_t in order to factor in external factors affecting economic fluctuations in Korea. Four variables are included as exogenous variables in the baseline model: (i) the US federal funds rate (FFR); (ii) the real exchange rate (RER) of the Korean won against the US dollar; (iii) the growth rate of oil prices; and (iv) US output. The FFR is considered to control for US monetary policy, which is likely to affect the Korean central bank's policy decisions. In a similar vein, we include the RER as a potential determinant of monetary policy in Korea. Oil prices are taken into account given their importance in shaping business cycles in Korea, the seventh largest oil consumer in the world. Having no oil reserves in the country, Korea relies solely on oil imports and has naturally become one of the largest oil importers worldwide. Lastly, US output is included as a proxy variable for the world business cycle. Notice that these variables are assumed to be exogenous since, as a small open economy, Korea's domestic variables are likely to be affected by global variables, but not vice versa.

Since coefficients are allowed to vary over time, TVC-VAR models are often plagued by the curse of dimensionality—the number of parameters to be estimated increases rapidly with the number of endogenous variables. We accordingly limit endogenous variables to the following four: (i) government spending, g_t; (ii) output, y_t; (iii) the CPI inflation rate, π_t; and (iv) the policy nominal interest rate, r_t. g_t and y_t are essential in measuring the expansionary effects of government spending, i.e. government spending multipliers.[2] The inclusion of inflation and the nominal interest rate is to complete the 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 minimum statistics sufficient to summarize central banks' policy decisions, which in Korea as well are conditioned on output and inflation [see Primiceri (2005) and Coibion (2012), among many others, for US applications].

As the reduced-form errors are in general correlated, it is necessary to transform them into structural innovations e_t as follows:

$$A_t u_t = e_t, \tag{2}$$

where A_t is the lower-triangular Cholesky decomposition of the covariance matrix $\Sigma_{u,t}$ at time t. The structural innovations have the covariance matrix $E(e_t e_t') = \Sigma_{e,t}$ so that $A_t \Sigma_{u,t} A_t' = \Sigma_{e,t}\Sigma_{e,t}'$. By construction, the structural innovations e_t are uncorrelated with each other, i.e., the variance-covariance matrix of the structural disturbances $\Sigma_{e,t}$ is diagonal for all $t = 1, \ldots, T$.

The matrix A_t describes the contemporaneous relationship among the variables collected in the vector z_t, which captures a causal ordering between them. 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

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

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. Ordering output and inflation before the nominal interest rate can be justified by the implementation of monetary policy in reality, in that the monetary authority adjusts the policy interest rate after observing current output and inflation.[3]

Lastly, we provide the state-space representation of the VAR specification to close the model. The reduced-form VAR in (1) has a state-space representation, which can be written as:

$$\text{[Observation equation]} \quad z_t = Dx_t + Z_t' B_t + u_t, \qquad Z_t' = I_n \otimes [1, z_{t-1}', \ldots, z_{t-\ell}'], \tag{3}$$

$$\text{[State equation]} \quad B_t = B_{t-1} + \nu_t, \tag{4}$$

where the symbol $\otimes$ denotes the Kronecker product. As aforementioned, the TVC-VAR specification is subject to a sizable number of parameters changing over time. An estimation of the model's parameters that relies solely on a relatively limited number of observations may suffer from potential identification problems. To address this issue, we follow Primiceri (2005) and Galí and Gambetti (2015) by assuming a particular law of motion for the time-varying coefficients. We impose two structures on them in particular: (i) the elements of the matrices A_t and $\Sigma_{u,t}$ follow a random walk, i.e., a unit root AR(1) process; and (ii) all the innovations in the model follow multivariate normal distributions. Accordingly, the dynamics for the model's time-varying coefficients can be summarized as follows:

$$\alpha_t = \alpha_{t-1} + \zeta_t, \qquad \log \sigma_t = \log \sigma_{t-1} + \eta_t,$$

$$V = Var\left(\begin{bmatrix} u_t \\ \nu_t \\ \zeta_t \\ \eta_t \end{bmatrix}\right) = \begin{bmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{bmatrix},$$

[3] Given the recursive ordering scheme used to identify government spending shocks in this paper, it may be the case that the response of the interest rate to inflation can be different for alternative orderings, especially between output and inflation. Accordingly, we check whether the results are robust when an alternative ordering between output and inflation is considered. To this end, we estimate a model with inflation ordered ahead of output such that the entire ordering structure of the alternative specification is given as follows: government spending first, inflation second, output third, and the nominal interest rate last. As can be seen in the companion appendix, our main empirical results are altered very little when the alternative ordering is used instead.

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.

For the estimation procedure of the TVC-VAR model, we follow Primiceri (2005) and Galí and Gambetti (2015). Independent inverse-Wishart prior distributions are assumed for the hyper-parameters Q, W, and S. We employ normal distributions for the priors of the initial values for B_0, α_0, and $\log \sigma_0$. By combining these two assumptions, we induce that the entire sequences of B, α, and $\log \sigma$ are normally distributed conditioning on Q, W, and S. We use Gibbs sampling to simulate draws from the posterior distributions of the model's parameters. More specifically, we simulate 22,000 posterior draws, with the first 20,000 used as a burn-in period and every second thinned, leaving the final sample size of 1,000.[4]

2.2 DATA We employ Korean quarterly data from 1994:Q1 to 2019:Q3 for the estimation of the TVC-VAR model as above. We use the first 6-year sample, between 1994:Q1 and 1999:Q4, to initiate the prior distributions for the TVC-VAR model. Hence, the actual sample period for empirical analysis starts from 2000:Q1, when the BOK switched its monetary policy tool from the money-aggregate-based approach to interest-rate-based policy.

In the benchmark model, we have four endogenous variables: government spending, real GDP, the inflation rate, and the nominal interest rate. Government spending is seasonally adjusted using X-12-ARIMA and deflated by domestic CPI. The variables are then converted into per capita terms by dividing by the country's population. We compute the inflation rate by referencing CPI changes and use the domestic overnight call rate for the nominal interest rate. Our VAR specification also includes four exogenous variables that use quarterly data for the growth rate of oil prices, the federal funds rate, US real GDP per capita, and the real exchange rate against the dollar. We take logged values for all variables except for Korean and US nominal interest rates and real exchange rates. Appendix A provides details about data sources for all variables.

3 EMPIRICAL RESULTS FROM THE TVC-VAR MODEL

This section presents the empirical results from the TVC-VAR specification. Prior to the discussion of the TVC-VAR estimates, we first provide results from a constant-coefficient VAR model to get a sense how the inflation rate and interest rate respond to government spending shocks over the sample period. We then present our main empirical results from the TVC-VAR model and discuss the relationship between the evolution of government spending multipliers and changes in monetary policy captured by the interest rate responses.

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

3.1 ESTIMATES FROM A CONSTANT-COEFFICIENT VAR MODEL The response of inflation to government spending shocks is crucial for characterizing the channel through which monetary policy affects the size of government spending multipliers. If the price level or the expected path of inflation do not respond to government spending increases, an inflation-targeting central bank is not likely to intervene by raising the nominal interest rate. As a result, the government spending multiplier is unlikely to be affected by monetary policy. In this regard, to understand the dynamics of inflation and interest rates after a government spending shock, we hereafter present the estimation results from a constant coefficient VAR specification to provide the inflation and interest rate responses from government spending shocks.

Figure 2 displays the impulse responses to a 1% increase in government spending with constant coefficients. At impact, output increases significantly, but the inflation rate response is estimated to be around zero and not statistically significant. Non-inflationary responses to a positive government spending shock are not unique to Korea. Dupor and Li (2015) document a similar inflation response based on US data. Due to the insignificant inflation response, the inflation-targeting monetary authority does not need to raise the nominal interest rate in response to the government spending expansion. In our empirical results, however, the nominal interest rate plunges at impact. The responses of the nominal interest rate are initially negative and statistically different from zero and then converge to zero in a gradual manner. Although the negative response at impact seems a bit at odds with the monetary authority's inflation-targeting behavior, US studies such as Mountford and Uhlig (2009) and Ramey (2011) also report a fall in the interest rate following a positive government spending shock.

3.2 ESTIMATES FROM THE TVC-VAR MODEL We now inspect the macroeconomic consequences of government spending shocks utilizing 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:

$$\text{Present-Value Multiplier}(Q) = \frac{\sum_{q=0}^{Q}(1+\bar{r})^q y_q}{\sum_{q=0}^{Q}(1+\bar{r})^q g_q}\frac{1}{\overline{Y}/\overline{G}}, \tag{5}$$

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 3 shows how the median estimates of present-value multipliers vary over time and horizons. The figure makes clear that the effects of increases in government spending on output display a substantial degree of time variability, which is more pronounced in the longer horizons. In particular, the longer-run multipliers tend to spike after the GFC. 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.[5]

For full statistical analyses of the results, Figures 4 through 6 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 1, 4, 8 and 12 quarters after government spending shocks for the present-value multipliers, and up to 3 quarters after the shocks for the other variables. First of all, the detailed present-value multiplier estimates are reported in Figure 4. Although neither substantial in size nor statistically different from zero, it turns out that the multipliers at the 1-quarter horizon keep increasing over time. This time-varying pattern is maintained for the remaining horizons, but the size and significance of the multipliers are quite different for the 4-quarter horizon and beyond. From the 4-quarter horizon, the figure makes clear that the multipliers become larger in size, a tendency that becomes more pronounced for the post-GFC period. As a result, the present-value multipliers for the 4-quarter horizon and beyond become statistically different from zero throughout the 2010s. Rossi and Zubairy (2011) document that fiscal policy shocks are important for explaining the medium cycle fluctuation of output. Our estimates in this regard are consistent with their finding, particularly for the period after the GFC. Consequently, all these findings indicate that government spending shocks tend to have bigger and more persistent effects on output in the recent period than in the pre-GFC one.[6]

Figure 5 provides the median and 68% band estimates of inflation impulse responses to positive government spending shocks for selected horizons. Focusing on the responses at impact, the fiscal expansions tend to be inflationary over the entire sample period in term of the median estimates, but the effect attenuates over time. A similar tendency is observed for the 1- and 3-quarter horizon inflation responses. Nevertheless, the effect of government spending shocks on inflation is likely

[5] As shown in Rossi and Zubairy (2011) and Ramey (2013), the behavior of the tax response to a government spending shock may have a crucial implication for the size of government spending multipliers. Guided by these studies, we estimate a TVC-VAR model augmented with taxes and obtain empirical results from the model. As presented in the companion appendix, we find that the results are unlikely to be sensitive to the inclusion of taxes in the model.

[6] A potential source of the difference in the size of the multipliers is the persistence of government spending shocks. For instance, Aiyagari et al. (1992) and Baxter and King (1993) establish a theoretical argument that the response of investment to a government spending shock hinges critically upon the persistence of the shock—a more persistent increase in government spending tends to crowd in investment, which is then, *ceteris paribus*, mapped into larger output multipliers. We accordingly compare the persistence of the identified government spending shocks across time and find that it is unlikely to vary significantly over different dates. The results are provided in the companion appendix.

to be insignificant as the 68% bands include zero for all the periods and horizons considered.

Lastly, the impulse responses of the nominal interest rate to positive government spending shocks are plotted in Figure 6, characterizing how monetary policy has been conducted in times of government spending expansions. In line with the constant-coefficient VAR estimates, the responses at impact are negative and statistically different from zero over the whole sample span. Aside from the significant plunge at impact, the interest rate responses display a mild degree of time variation, decreasing gradually until 2008−09 and then stagnating for the subsequent period. Similar patterns are observed in the interest rate responses beyond the impact horizon. For the responses at the 1- and 2-quarter horizons, for instance, the responses of the nominal interest rate are insignificantly different from zero in the early 2000s, whereas they become significantly negative from the mid-2000s and onward. The sizable response of the nominal interest rate, however, is short-lived and vanishes as the horizon increases. For the entire sample span, the responses of the interest rate to government spending shocks in the 3-quarter horizon and beyond become smaller in size and are statistically indifferent from zero.

In sum, the TVC-VAR results indicate that, regardless of the horizon, the present-value multipliers increase gradually over time. This tendency is more pronounced for the medium-run horizon, and the multipliers in the 4-quarter horizon and beyond become statistically different from zero for the post-GFC period. Meanwhile, the short-run responses of the nominal interest rate to government spending expansions turn out to be negative for the entire sample span, standing out more for the recent sample after the GFC. Combining the time-varying patterns of the medium-run present-value multipliers and short-run interest rate responses, our results suggest a negative relationship between these two objectives. It is well-established in the existing literature that the size of government spending multipliers depends substantially on how monetary policy behaves in times of a fiscal expansion [Eggertsson (2008), Christiano et al. (2011), and Erceg and Lindé (2014), among many others]. In our VAR framework, the information concerning monetary policy behavior is condensed in the nominal interest rate. Thus the negative relationship deserves careful scrutiny in assessing a potential role of monetary policy as a determinant of government spending multipliers.

4 DECOMPOSITION OF THE NOMINAL INTEREST RATE RESPONSES TO GOVERNMENT SPENDING SHOCKS

Given the negative relationship found in Section 3.2, this section attempts to unveil the source of the time-varying pattern of the nominal interest rate responses to government spending shocks. From a theoretical perspective, Christiano et al. (2011) establish a systematic relationship between the degree of the monetary authority's anti-inflationary stance and the size of government spending multipliers. The underlying mechanism is that when monetary policy actively targets inflation, the increase in the nominal interest rate is greater than the rise in inflation. Real interest rates then rise, suppressing private spending, offsetting some of the increase in goods demand, and finally *ceteris paribus* producing smaller multipliers. Thus a potentially important channel in understanding the time-varying pattern of the nominal interest rate responses to government spending shocks may revolve around the behavior of inflation and monetary policy responses to it.

4.1 DECOMPOSING THE INTEREST RESPONSE INTO MONETARY POLICY STANCE AND INFLATION VOLATILITY

Conventional theoretical models posit that, after log-linearization, the nominal interest rate is determined by a Taylor-type rule as follows:

$$\hat{r}_t = \rho_r \hat{r}_{t-1} + (1 - \rho_r)\left(\phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t\right) + \sigma_r \epsilon_t^r, \tag{6}$$

where a hat ($\hat{}$) denotes percentage deviations of a variable from its steady state and ϵ_t^r is the monetary policy disturbance capturing discretionary changes in the interest rate. r_t, π_t and y_t denote the nominal interest rate, inflation rate and output, respectively. The degree of the monetary authority's anti-inflationary stance in (6) is captured by the coefficient ϕ_π, measuring changes in the nominal interest rate in response to a unit change in inflation.

Notice that our VAR specification yields a monetary policy rule analogous to (6). For this purpose, after abstracting from the deterministic components such as the time trends and exogenous variables, the reduced-form TVC-VAR model in (1) can be written as follows:

$$\begin{bmatrix} g_t \\ y_t \\ \pi_t \\ r_t \end{bmatrix} = \sum_{j=1}^{\ell} \begin{bmatrix} & \cdots & & \\ & \cdots & & \\ & \cdots & & \\ b_{j,t}^{4,1} & b_{j,t}^{4,2} & b_{j,t}^{4,3} & b_{j,t}^{4,4} \end{bmatrix} \begin{bmatrix} g_{t-j} \\ y_{t-j} \\ \pi_{t-j} \\ r_{t-j} \end{bmatrix} + \begin{bmatrix} u_t^1 \\ u_t^2 \\ u_t^3 \\ u_t^4 \end{bmatrix}, \tag{7}$$

where $b_{j,t}^{n,m}$ denotes the j-th lagged coefficient of the m-th variable in the equation of the n-th variable, allowed to vary over time. In particular, the last equation in (7), which characterizes the behavior of the nominal interest rate, can be written as

$$r_t = \sum_{j=1}^{\ell} b_{j,t}^{4,1} g_{t-j} + \sum_{j=1}^{\ell} b_{j,t}^{4,2} y_{t-j} + \sum_{j=1}^{\ell} b_{j,t}^{4,3} \pi_{t-j} + \sum_{j=1}^{\ell} b_{j,t}^{4,4} r_{t-j} + u_t^4. \tag{8}$$

Compared to (6), equation (8) has two distinctive features: (i) the nominal interest rate responds not only to output and inflation but also to government spending; and (ii) it responds to lagged output, inflation and government spending, instead of to the contemporaneous values of these variables. Nevertheless, it is notable that the VAR-based parameter governing the degree of the monetary authority's anti-inflationary stance, analogous to the parameter ϕ_π in (6), can be recovered from (8). We denote the parameter by $\phi'_{\pi,t}$, which can be obtained by matching coefficients in equations (6) and (8) as follows:

$$\phi'_{\pi,t} \equiv \sum_{j=1}^{\ell} \left(\frac{b_{j,t}^{4,3}}{1 - b_{j,t}^{4,4}} \right). \tag{9}$$

Notice that unlike the theoretical parameter ϕ_π, the VAR estimates of $\phi'_{\pi,t}$ are allowed to vary over time due to the time-varying coefficients in the model. Accordingly, the TVC-VAR framework is suitable in identifying any time variation in the monetary authority's anti-inflationary stance.

The estimates for the converted monetary policy parameter to inflation, $\phi'_{\pi,t}$, are provided in Figure 7. As shown in the upper panel of the figure, the 68% band estimates always contain zero, indicating that the parameter is unlikely to be statistically different from zero mainly because of the wide error band. Nevertheless, the median estimates for $\phi'_{\pi,t}$ display a clear time-varying pattern as shown in the lower panel of the figure. They increase gradually from the early 2000s to 2008−09 and then decrease for the subsequent period.

But this is not the only way that inflation affects the nominal interest rate. The monetary policy rule in (6) makes clear that fluctuations in inflation can change the nominal interest rate through two channels: (i) the degree of policy responsiveness to a unit change in inflation, captured by ϕ_π; and (ii) the magnitude of the inflation fluctuations, reflected in $\hat{\pi}_t$. In this regard, the evolution of inflation volatility can also influence nominal interest rate dynamics. Accordingly, we investigate the second channel in order to complete the analysis on the role of inflation in characterizing the interest rate responses to government spending shocks, as displayed in Figure 6.

Figure 8 plots the posterior estimates for standard deviations of reduced-form residuals in the inflation equation (u_t^3), denoted by σ_t^3. The standard deviation estimates display a clear decreasing trend with an exception of the period around the GFC. The beginning of the sample period is right after the Asian Currency Crisis of 1997−98, recognized as the most adverse economic event in modern Korean history. The high estimates of inflation volatility in the early 2000s may reflect the economic instability that the episode created. Similarly, the spike in volatility in the late-2000s is associated with the economic turmoil produced by the GFC.

4.2 INFLATION AS A DETERMINANT OF THE INTEREST RATE RESPONSE

Given the two channels through which changes in inflation affect nominal interest rate dynamics, this section focuses on assessing the role of inflation in determining the time-varying pattern of the interest rate in response to exogenous changes in government spending, summarized in Figure 6.

We begin with the fact that the impulse responses of the nominal interest rate are a function of the $b_{j,t}^{n,m}$ estimates in (7) and the Cholesky factors in (2) written as

$$\begin{bmatrix} a_t^{1,1} & 0 & 0 & 0 \\ a_t^{2,1} & & 0 & 0 \\ a_t^{3,1} & \vdots & & 0 \\ a_t^{4,1} & & \vdots & \vdots \end{bmatrix}, \tag{10}$$

where $a_t^{n,m}$ is the n-th row and m-th column element of the lower-triangular Cholesky factor of $\Sigma_{u,t}$, which is also time varying.[7] For instance, the responses of the nominal interest rate to a government spending shock at impact and at the 1-quarter horizon, evaluated at a specific time period t, are given as

$$\begin{aligned} \text{Impact:} \quad & a_t^{4,1}, \\ \text{1 quarter:} \quad & \textstyle\sum_{k=1}^{4} b_{1,t}^{4,k} a_t^{k,1} = \underbrace{b_{1,t}^{4,1} a_t^{1,1}}_{\equiv \psi_t^{4,1}} + \underbrace{b_{1,t}^{4,2} a_t^{2,1}}_{\equiv \psi_t^{4,2}} + \underbrace{b_{1,t}^{4,3} a_t^{3,1}}_{\equiv \psi_t^{4,3}} + \underbrace{b_{1,t}^{4,4} a_t^{4,1}}_{\equiv \psi_t^{4,4}}, \end{aligned}$$

where $\psi_t^{4,m}$ represents the response of the fourth variable (the nominal interest rate) created by the m-th variable. Given that our reduced-VAR model has a lag length of three (i.e., $\ell = 3$), we analogously redefine $\psi_t^{4,m}$ as follows:

$$\psi_t^{4,m} \equiv \left(\sum_{j=1}^{\ell} b_{j,t}^{4,m} \right) a_t^{m,1}, \tag{11}$$

which is the sum of the reduced-form VAR coefficients adjusted by the corresponding Cholesky factor, proxying the role of the m-th variable in characterizing the nominal interest rate responses to government spending shocks.

Figure 9 plots the decomposition results. The figure makes it clear that, besides the interest rate itself, inflation is the most important ingredient in determining the responses of the interest rate to government spending shocks. The adjusted sums associated with the interest rate dominate the others in terms of magnitude. Turning to their time-varying pattern, the adjusted sums decrease from the beginning of the sample span until the early 2010s, and then stagnate for the subsequent period. This finding can be accounted for by the aforementioned decomposition of inflation using

[7] It is worth noting that $a_t^{n,m}$'s are functions of the elements in the variance-covariance matrix of the reduced-form VAR, $\Sigma_{u,t}$. More specifically, $a_t^{n,1}$'s can be expressed with the standard deviation and correlation coefficients of the variables as follows: $a_t^{1,1} = \sigma_t^1$, $a_t^{2,1} = \sigma_t^2 \rho_t^{1,2}$, $a_t^{3,1} = \sigma_t^3 \rho_t^{1,3}$ and $a_t^{4,1} = \sigma_t^4 \rho_t^{4,3}$, where $\rho_t^{i,j}$ denotes the correlation coefficient between the i-th and j-th variables at time t. Hence, these expressions show how the σ_t^3 estimates discussed in Section 4.1 affect the response of the nominal interest rate to government spending shocks.

our estimates. The upward pressure of inflation on the nominal interest rate responses to government spending shocks for the pre-GFC period may stem jointly from its high volatility and the elevated responsiveness of monetary policy to it. For the post-GFC sample, however, both the variations of inflation and degree of the anti-inflationary stance decrease, which helps rationalize the limited effect of inflation on the interest rate responses during that time.

It is notable that the time-varying pattern of $\psi_t^{4,3}$ is broadly consistent with that of the nominal interest rate following government spending expansions reported in Figure 6. Together with the negative relationship between the size of government spending multipliers and nominal interest rate responses to government spending shocks discussed in Section 3.2, this finding suggests a potential importance of the time variation in $\psi_t^{4,3}$ in determining the effect of government spending on output.

5 ROLE OF MONETARY POLICY ON GOVERNMENT SPENDING MULTIPLIERS

This section examines the importance of monetary policy in shaping the government spending multiplier. We conduct two experiments for this purpose. The first experiment is designed to evaluate the role of monetary policy *as a whole* on the size of the government spending multiplier. This task is achieved by estimating the TVC-VAR model without the nominal interest rate (a 3-variable TVC-VAR model) but otherwise in a way that is identical to the baseline 4-variable specification. By taking the policy rate out of the model, we completely shut down the channel through which the nominal interest rate, and thus monetary policy, affects the spending multiplier. We then move to the second exercise, which focuses specifically on the inflation-targeting dimension of monetary policy as a determinant of government spending multipliers. To this end, we keep the 4-variable framework, but restrict the parameters appearing in the adjusted sum of the inflation coefficients ($\psi_t^{4,3}$) in Section 4.2 to be fixed at their sample median estimates. This experiment is likely to reveal the prominent factor characterizing the time variation in the government spending multiplier, related to monetary policy behavior and inflation dynamics.

5.1 COMPARISON TO THE 3-VARIABLE MODEL WITHOUT THE NOMINAL INTEREST RATE

The estimates from our baseline specification suggest a negative relationship between the size of the present-value multipliers and magnitude of the nominal interest rate responses to government spending shocks. This finding underscores a potential role of monetary policy with respect to the government spending multiplier. To examine this role in a formal manner, we begin by estimating a 3-variable TVC-VAR model without the nominal interest rate.

Figure 10 makes a comparison between the baseline and 3-variable present-value multipliers for selected horizons. A notable observation is that the overall level of the 4-, 8-, and 12-quarter multipliers are similar across the two specifications, while their relative size varies considerably over time. Focusing first on the 4-quarter horizon estimates, the difference in the multipliers across the two specifications is observed only for the 2000s as the 3-variable estimates are systemically higher than those of the baseline model.

The relative size of the multipliers across the two specifications, however, changes dramatically for longer horizons. In order to highlight this feature, the upper panels of Figure 11 depict the median and 68% error bands for the gap between the baseline and 3-variable multiplier estimates associated with the 8- and 12-quarter horizons. In each figure, the gap is calculated by subtracting the baseline multiplier estimates from the 3-variable ones. Although not statistically different from zero, the median gap estimates show a mild U-shape with the sign flipped in the late 2000s around the GFC episode. Notice that the time-varying pattern of the present-value multiplier gap estimates are quite similar to that of the sum of the inflation coefficients in the nominal interest rate equation multiplied by the corresponding Cholesky factors, $\psi_t^{4,3}$, emerging from the baseline 4-variable TVC-VAR model as defined in Section 4.2. As made explicit in the middle panels of the figure, these two objectives fluctuate around zero and display a similar pattern of time variation. This finding suggests a crucial role of the nominal interest rate fluctuations concerning inflation in accounting for the present-value multiplier gap.

As a formal characterization of this conjecture, the lower panels of Figure 11 plot the median differences between the baseline and 3-variable present-value multipliers against the median $\psi_t^{4,3}$ estimates. The figures reveal a strong positive relationship between these objectives with correlation coefficients of 0.95 (8-quarter) and 0.94 (12-quarter), respectively. Since the only difference in the two specifications is the presence of the nominal interest rate in the model, the gap between their multipliers is likely to capture the role of monetary policy *as a whole* in shaping the government spending multiplier. Given the high correlations between the multiplier gap estimates and $\psi_t^{4,3}$ estimates, our finding indicates that changes in the nominal interest rate produced by inflation fluctuations can be an important source of determining the size of the government spending multiplier.

5.2 Comparison to the 4-variable Model Estimates under Counterfactual Scenarios

In the first experiment, we completely shut down the monetary policy channel by eliminating the nominal interest rate in the TVC-VAR model. Since this experiment is an extreme case, we conduct a second experiment, which features a 4-variable TVC-VAR model like the baseline but without the time variability of the nominal interest rate response to inflation changes.

Section 4.2 makes explicit that changes in the nominal interest rate created by inflation fluctuations, $\psi_t^{4,3}$, can be decomposed into two elements: (i) the lagged inflation coefficients in the nominal interest rate equation of the model, $b_{j,t}^{4,3}$'s for $j = 1, 2, 3$; and (ii) the Cholesky factor for inflation, $a_t^{3,1}$. Accordingly, the time variation in $\psi_t^{4,3}$ stems from the time variation in both estimates. The decomposition may be significant since, as aforementioned, changes in each of these two objectives have distinct interpretations. Fluctuations in the lagged inflation coefficients are likely to reflect changes in the policy stance toward inflation, while those in the Cholesky factor for inflation tend to capture the size of shocks governing inflation dynamics.

To investigate the impact of monetary policy on the government spending multipliers, we begin by assessing the role of the lagged inflation coefficients, representing changes in the policy stance toward inflation. The exercise is implemented by fixing the lagged inflation coefficients at their sample median estimate to eliminate the time variability in the monetary policy stance, but the other coefficients use the actual estimates.

The results associated with this counterfactual are provided in Figure 12. Restricting the lagged inflation coefficients to be time-invariant alters the present-value multiplier estimates. The 8- and 12-quarter present-value multipliers differ substantially from the actual estimates, and the differences remain throughout the sample period. More important, the time-varying pattern of the 8- and 12-quarter horizon counterfactual multipliers is similar to that of the 3-variable model without the nominal interest rate presented in Figure 10. This finding is notable since controlling for the monetary stance toward inflation alone can produce an effect similar to that created by the absence of the policy variable.

A distinct pattern of time variability in the multiplier estimates, however, emerges when controlling for the size of shocks governing inflation dynamics. Figure 13 depicts the present-value multipliers under a counterfactual scenario in which the Cholesky factor for inflation is fixed at its sample median estimate, while using the actual time-varying VAR estimates for the rest of the coefficients including the lagged inflation ones. As shown in the figure, the gap between the actual and counterfactual multipliers is very restricted compared to the previous exercise. Consequently, the counterfactual multipliers exhibit quite a different time variation from that of the 3-variable model estimates.

In a nutshell, the results from the two counterfactuals indicate that changes in the policy stance toward inflation are a more crucial determinant of the time-varying pattern in the present-value multipliers than those in the size of shocks governing inflation dynamics. Our finding in this regard echoes those in the existing literature highlighting the importance of the central bank's anti-inflationary stance to the size of government spending multipliers, including Kim (2003), Christiano et al. (2011), Davig and Leeper (2011) and Dupor and Li (2015), among many others.

6 CONCLUSION

This paper empirically examines whether monetary policy is an important determinant of the size of government spending multipliers. Most of the previous studies probe a similar question under the ZLB environment when monetary policy does not respond to inflation. In contrast, our analysis aims to measure the effect of monetary policy on the multiplier under a non-ZLB environment; hence, we select the Korean economy as a laboratory, whose nominal interest rate has never been close to zero.

To estimate the evolutionary effect of monetary policy on the government spending multiplier, we apply a TVC-VAR model to the Korean time series from 2000:Q1 to 2019:Q3. A substantial degree of time variation is identified in the medium-run government spending multiplier, yet the shape is the reverse of that of the policy rate responses to government spending expansions. Based on this finding, we explore the source of the negative relationship between the policy rate responses and the spending multiplier.

Our empirical results indicate that the monetary policy response to inflation in times of government spending expansions is crucial for the size of the government spending multiplier. Further decompositions of the nominal interest rate responses reveal that changes in the monetary policy stance against inflation play a more significant role in governing the time-varying pattern in the government spending multipliers than those in inflation variability. In this regard, our finding confirms Christiano et al. (2011)'s theoretical results such that, in a simple analytical model, a negative relationship is established between the Taylor-rule coefficient on inflation and the government spending multiplier in the long run.

A DATA

We employ Korean data from 1990:Q1 to 2019:Q3 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 prices, the federal funds rate, US real GDP per capita, and the real exchange rate against the dollar. Detailed data descriptions are as follows:

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

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 Real Consumption: Real gross private consumption expenditure, seasonally adjusted / Source: BOK-ECOS
- Domestic Real Investment: Real gross fixed capital formation, seasonally adjusted / Source: 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 barrel, 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 FIGURES

Figure 1: Time series for the quarterly CPI inflation rate (solid line) and nominal interest rate (overnight call rate, dotted line) of Korea, from 2000:Q1 to 2019:Q3. The y-axis is in percentage.

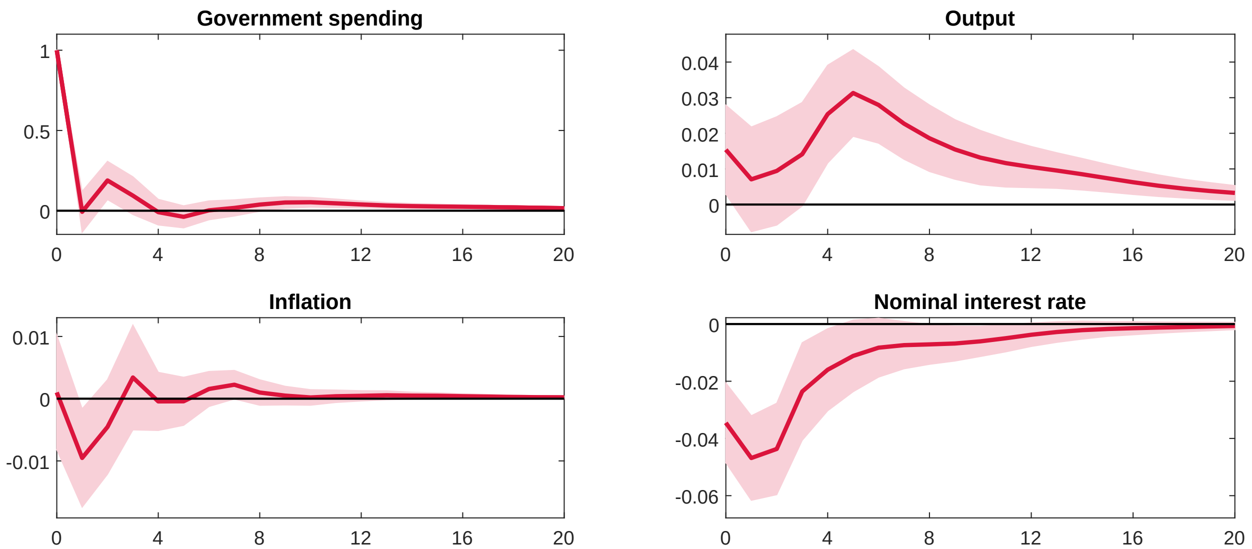

Figure 2: Impulse responses to a 1% increase in government spending with constant coefficients. In each panel, point estimate (solid) and 68% confidence interval estimates (shaded area) are reported. The x-axis measures quarters and the y-axis is in percentage.

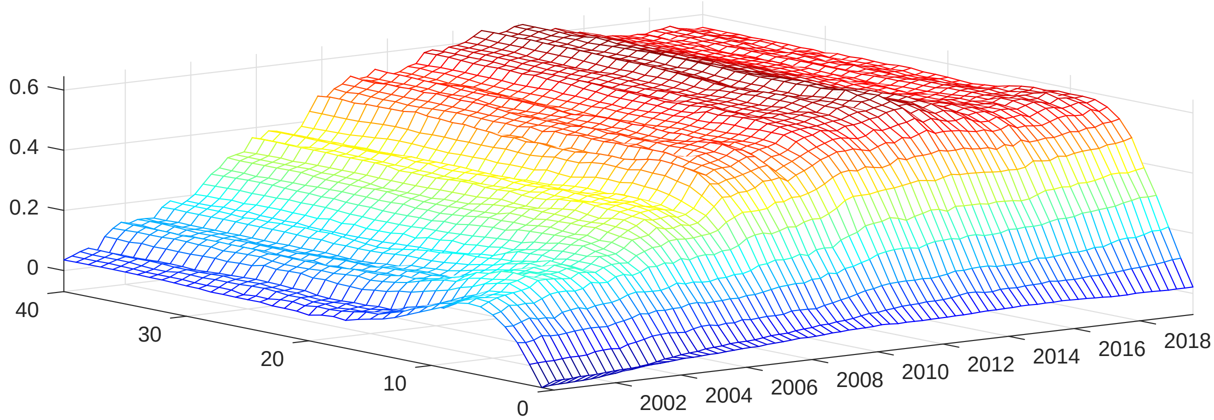

Figure 3: Time-varying present-value multipliers associated with the baseline 4-variable TVC-VAR model. Median estimates are reported. This figure presents the present-value multiplier estimates in Korean won produced by a 1-won increase in government spending.

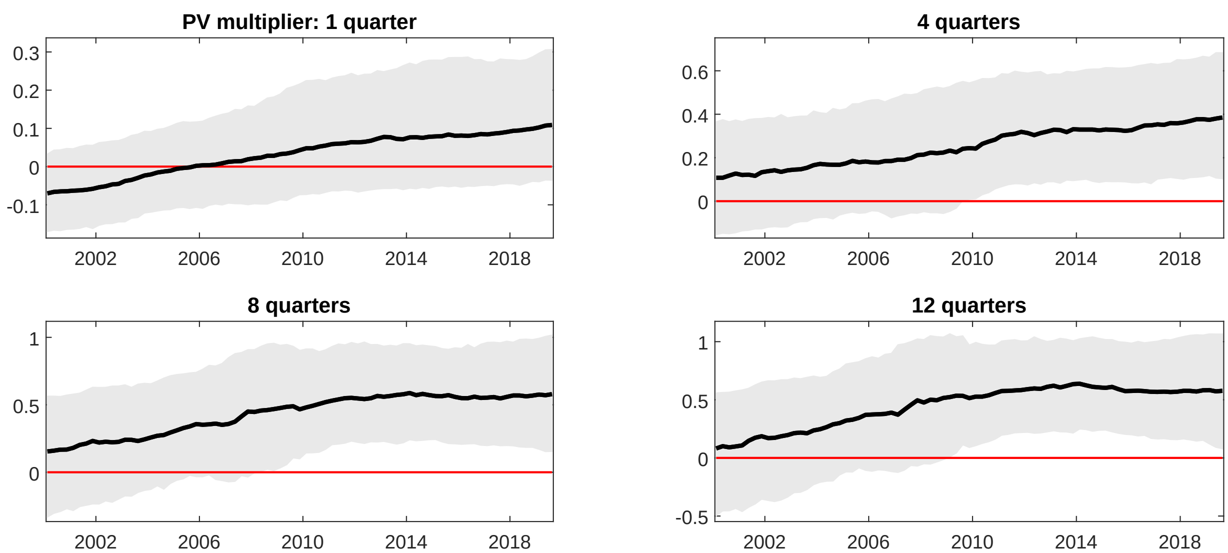

Figure 4: Time-varying present-value multipliers for selected horizons associated with the baseline 4-variable TVC-VAR model. In each panel, median (solid line) and 68% band (shaded area) estimates are reported. The y-axis is in Korean won.

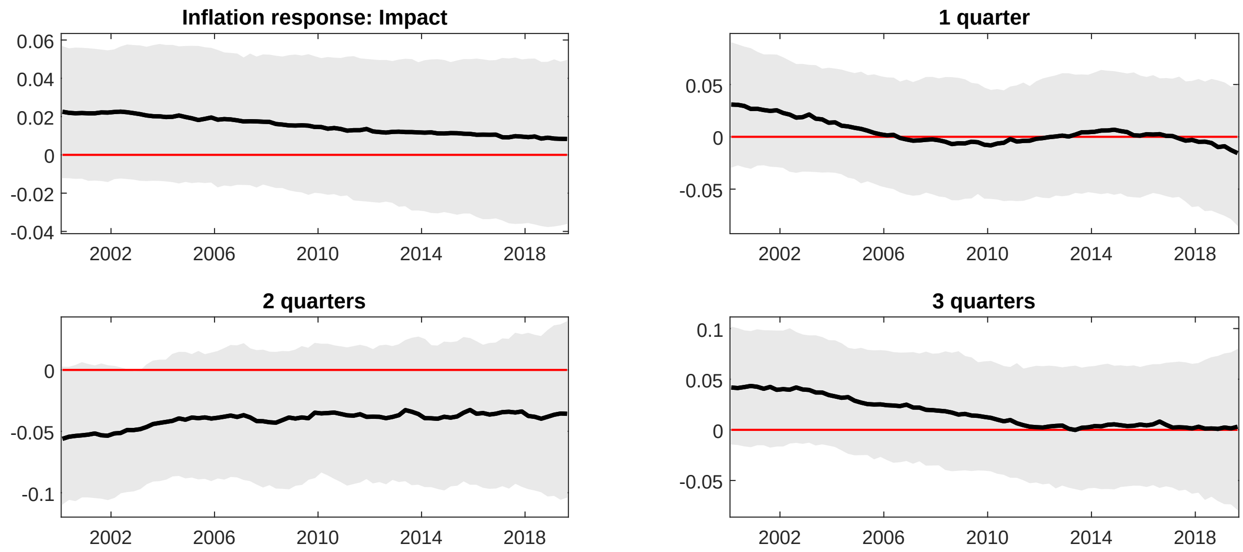

Figure 5: Time-varying impulse responses of inflation to 1% increases in government spending for selected horizons associated with the baseline 4-variable TVC-VAR model. In each panel, median (solid line) and 68% band (shaded area) estimates are reported. The y-axis is in percentage.

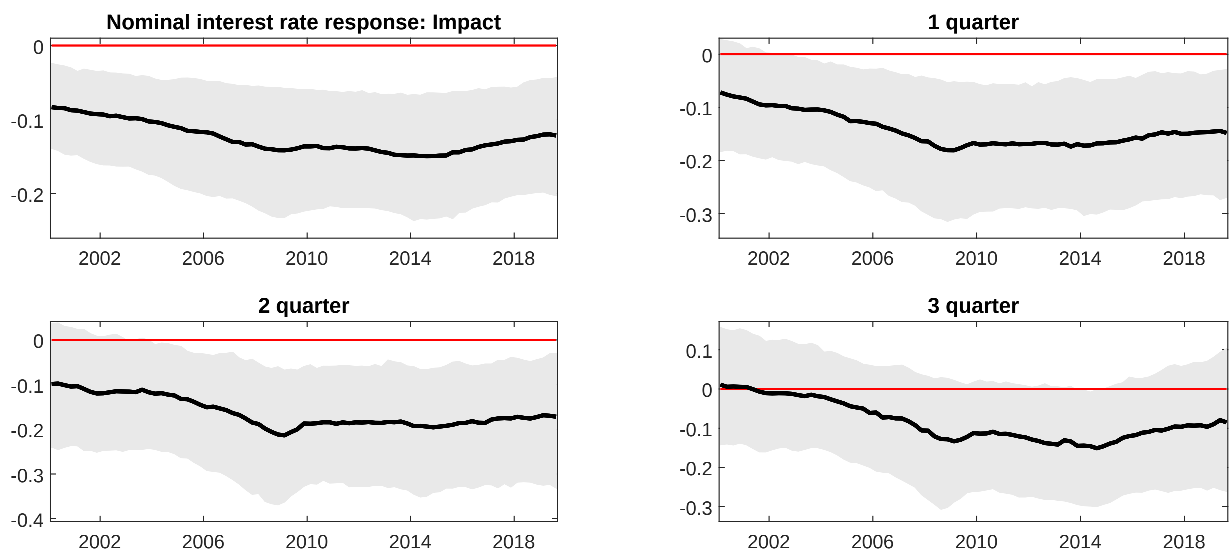

Figure 6: Time-varying impulse responses of the interest rate to 1% increases in government spending for selected horizons associated with the baseline 4-variable TVC-VAR model. In each panel, median (solid line) and 68% band (shaded area) estimates are reported. The y-axis is in percentage.

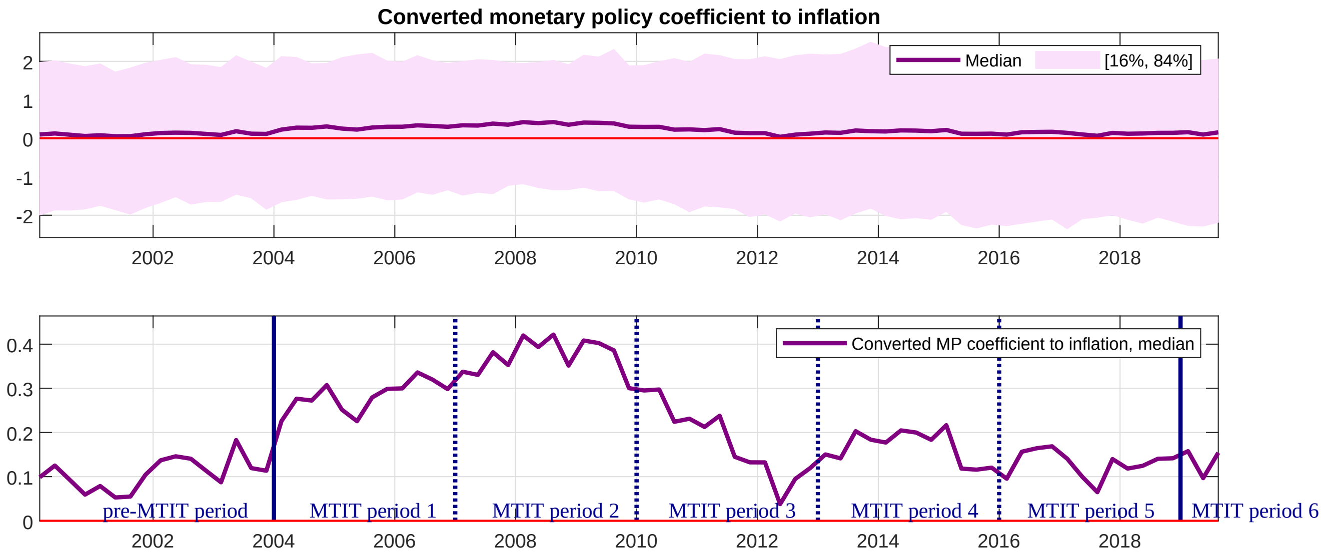

Figure 7: **[Upper panel]** Converted monetary policy responses to lagged inflation associated with the baseline 4-variable TVC-VAR model. Median (solid line) and 68% band (shaded area) estimates are reported. **[Lower panel]** Median converted monetary policy responses to lagged inflation associated with the baseline 4-variable TVC-VAR model. The vertical lines indicate the medium-term inflation targeting (MTIT) periods, with the target revised every three years since 2004.

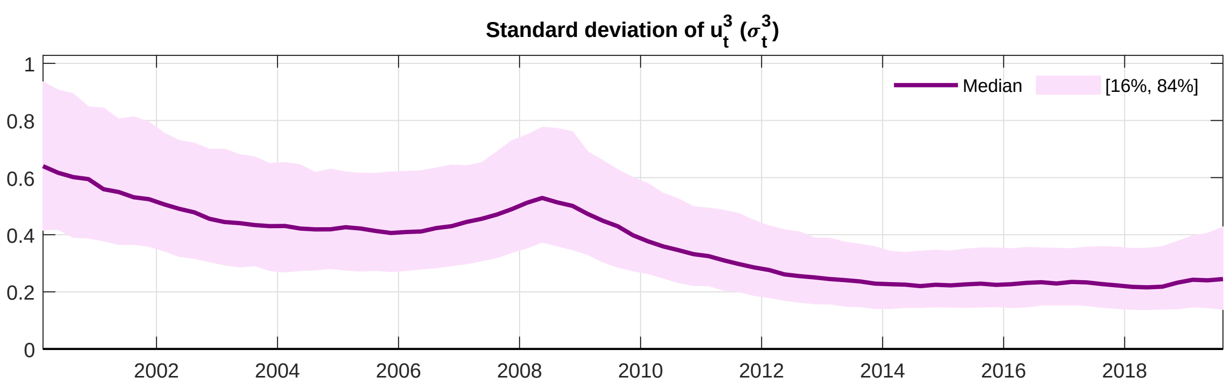

Figure 8: Time-varying standard deviations of the reduced-form residuals for inflation (u_t^3), associated baseline 4-variable TVC-VAR model. Median (solid line) and 68% band (shaded area) estimates are reported.

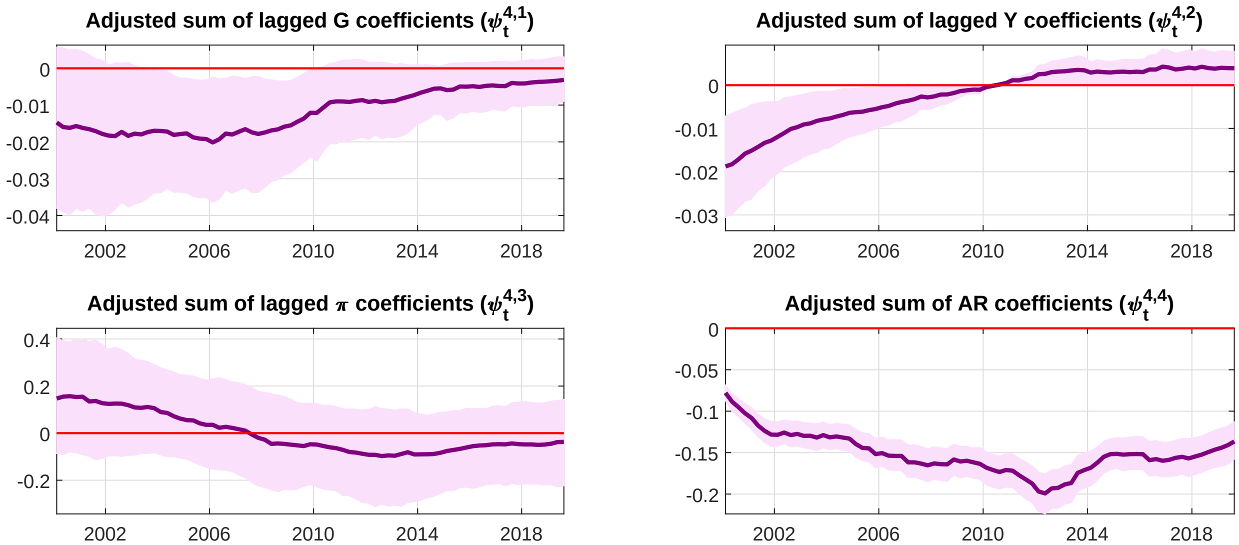

Figure 9: Sums of each reduced-form VAR coefficients in the nominal interest rate equation multiplied by the corresponding Cholesky factors, associated with the baseline 4-variable TVC-VAR model. In each panel, median and 68% band estimates are reported.

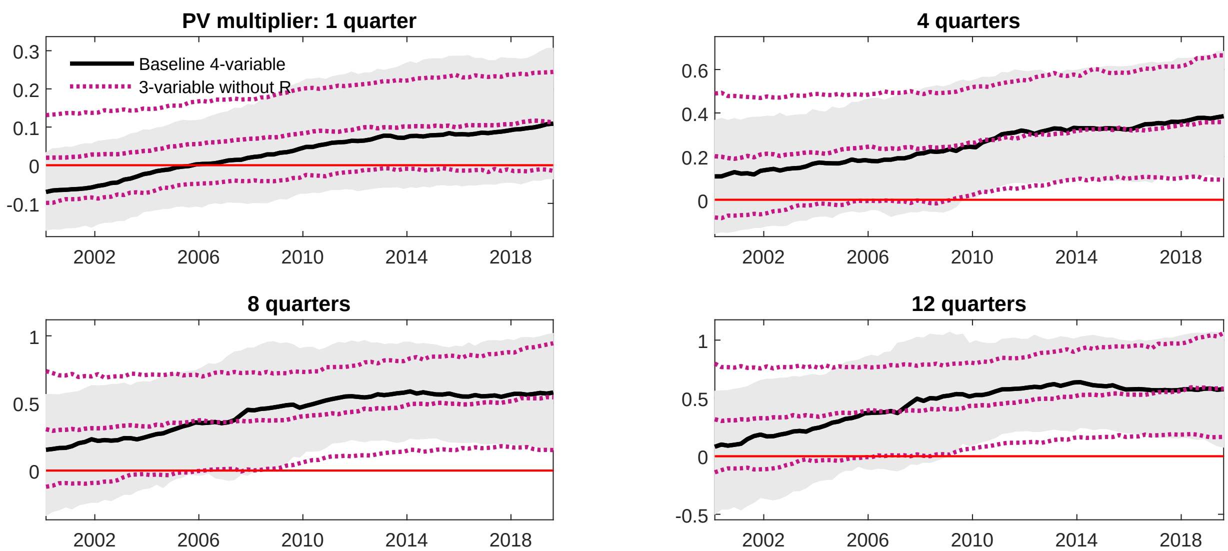

Figure 10: Time-varying present-value multipliers for selected horizons, associated with the baseline 4-variable TVC-VAR model (solid line with shaded area) and with the 3-variable TVC-VAR model without the nominal interest rate (dotted lines). In each panel, median and 68% band estimates are reported. The y-axis is in Korean won.

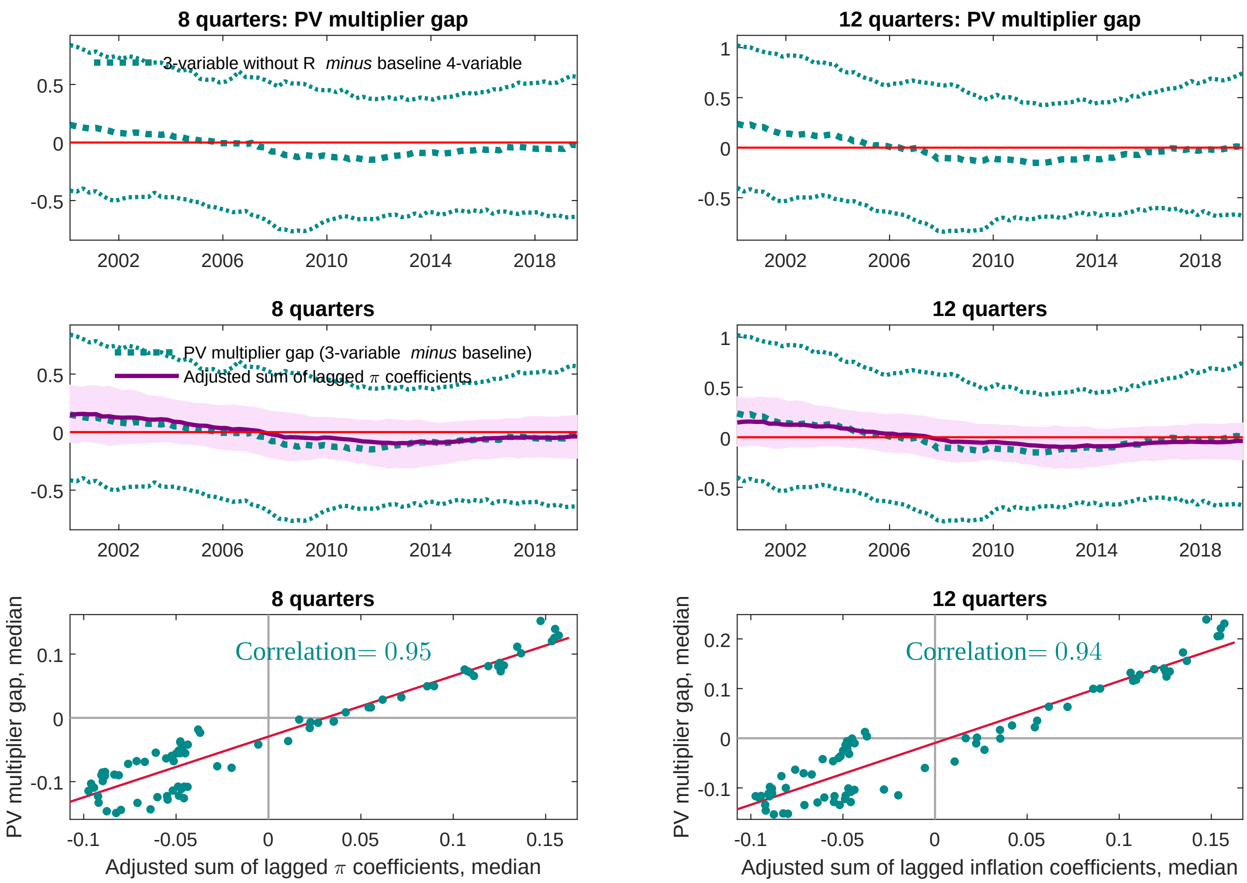

Figure 11: **[Upper panels]** Differences between the time-varying present-value multipliers for selected horizons associated with the 3-variable TVC-VAR model without the nominal interest rate and baseline 4-variable TVC-VAR model. In each panel, median and 68% band estimates are reported. The y-axis is in Korean won. **[Middle panels]** Differences between the time-varying present-value multipliers for selected horizons associated with the 3-variable TVC-VAR model without the nominal interest rate and baseline 4-variable TVC-VAR model, along with the sum of the inflation coefficients in the nominal interest rate equation multiplied by the corresponding Cholesky factors associated with the baseline 4-variable TVC-VAR model. In each panel, median and 68% band estimates are reported. **[Lower panels]** Scatter plots for the median sums of the inflation coefficients in the nominal interest rate equation multiplied by the corresponding Cholesky factors (x-axis) and median differences between the time-varying present-value multipliers (y-axis). In each panel, the solid line indicates the fitted values of the linear OLS regression.

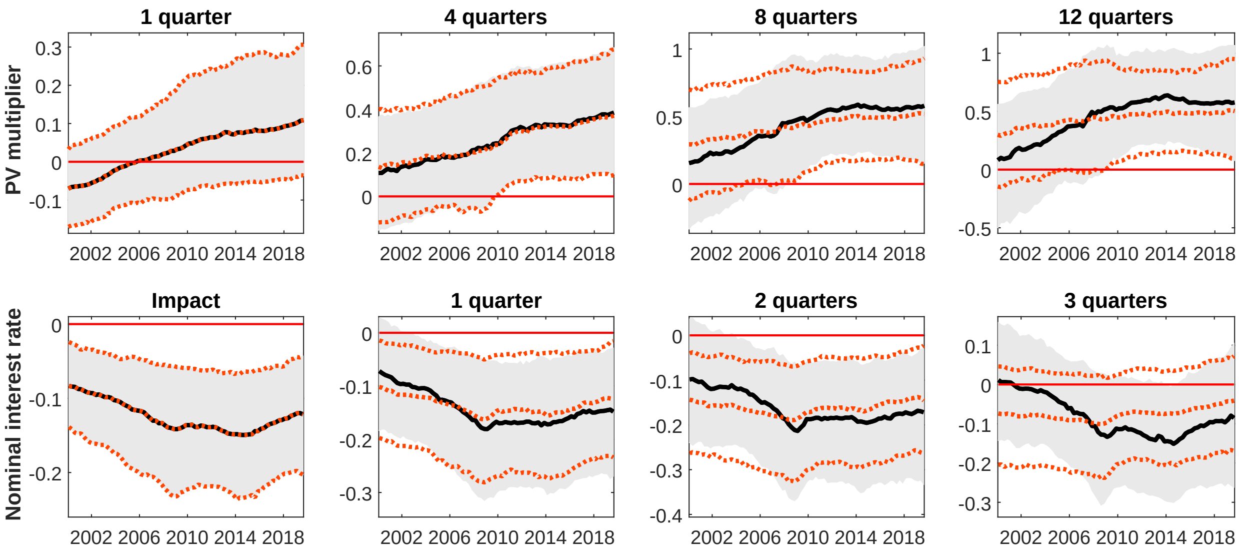

Figure 12: Actual (solid line with shaded area) and counterfactual (dashed lines) time-varying present-value multipliers (upper panels) and nominal interest rate (lower panels) responses to government spending shocks for selected horizons, associated with the baseline 4-variable TVC-VAR model. The counterfactual scenario assumes that the lagged inflation coefficients in the nominal interest rate equation of the reduce-form VAR model are fixed at their sample median estimates.

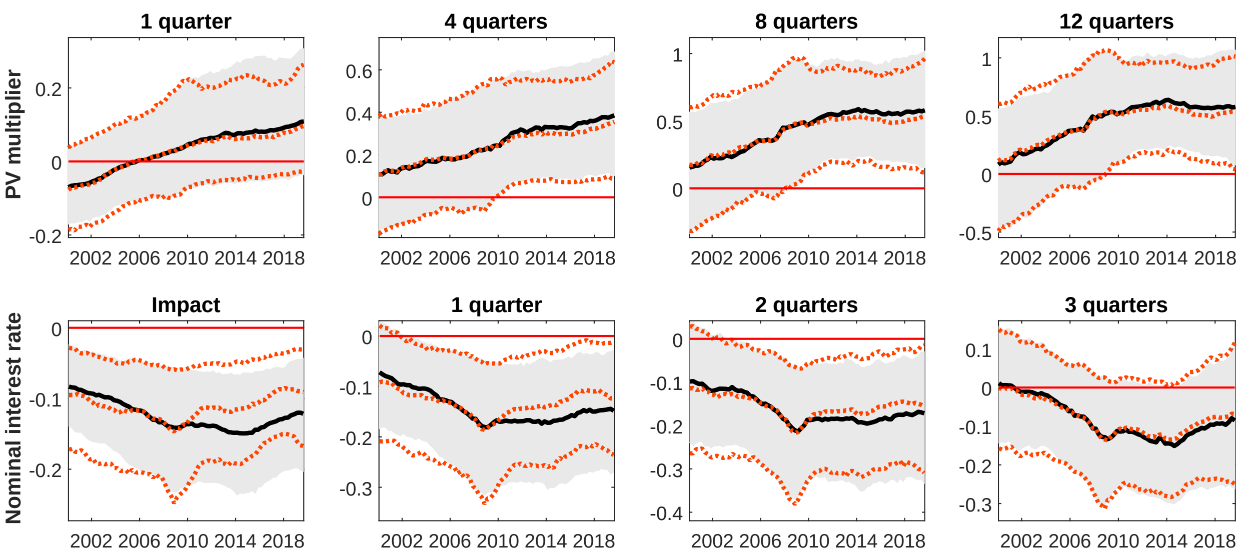

Figure 13: Actual (solid line with shaded area) and counterfactual (dashed lines) time-varying present-value multipliers (upper panels) and nominal interest rate (lower panels) responses to government spending shocks for selected horizons, associated with the baseline 4-variable TVC-VAR model. The counterfactual scenario assumes that the Cholesky factor for inflation is fixed at its sample median estimate.

C ADDITIONAL RESULTS (NOT FOR PUBLICATION)

This appendix provides additional results not included in the paper.

C.1 ROBUSTNESS: CONTROLLING FOR TAXES This section provides a robustness check by augmenting the model with taxes. The first subsection discusses the effect of government shocks on macroeconomic variables, whereas the second subsection conducts the counterfactual experiments in Section 5 with taxes.

C.1.1 EFFECT OF GOVERNMENT SPENDING SHOCKS WITH TAXES 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 one employed in Perotti (2005) and Caldara and Kamps (2008) for evaluating the efficacy of government spending in stimulating output. 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 by the fact 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 A1. First, the impulse responses of taxes are not statistically different from zero for most of the periods and horizons considered. Second, although not statistically significant, tax responses exhibit a slight upward tendency over time in terms of the median estimates. This finding is universal to all the

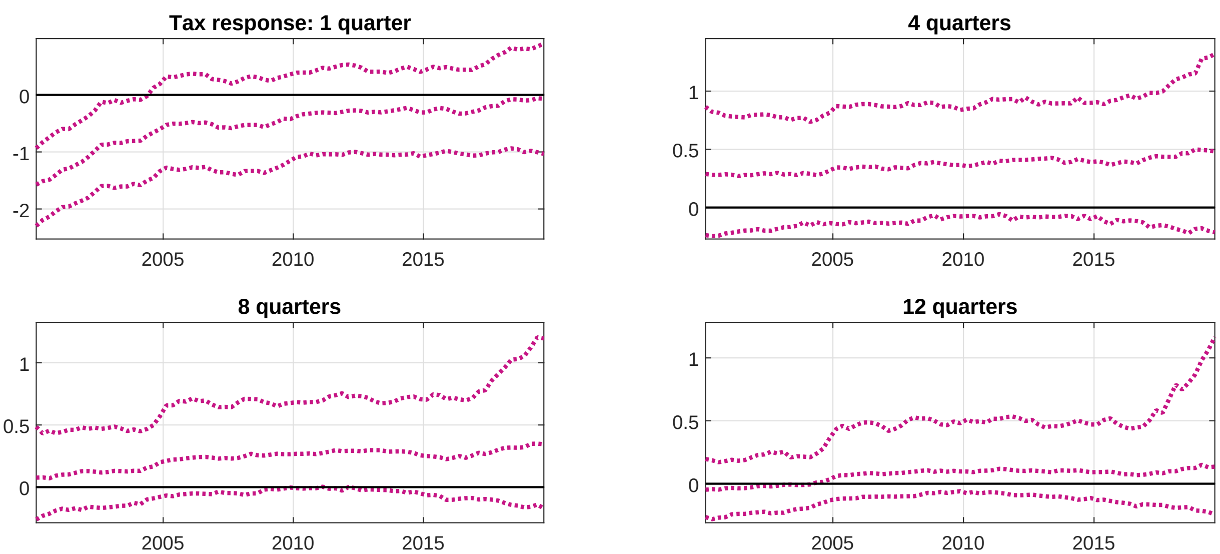

Figure A1: Time-varying impulse responses of taxes to 1% increases in government spending for selected horizons associated with the 5-variable TVC-VAR model augmented with taxes. In each panel, median and 68% band estimates are reported. The y-axis is in percentage.

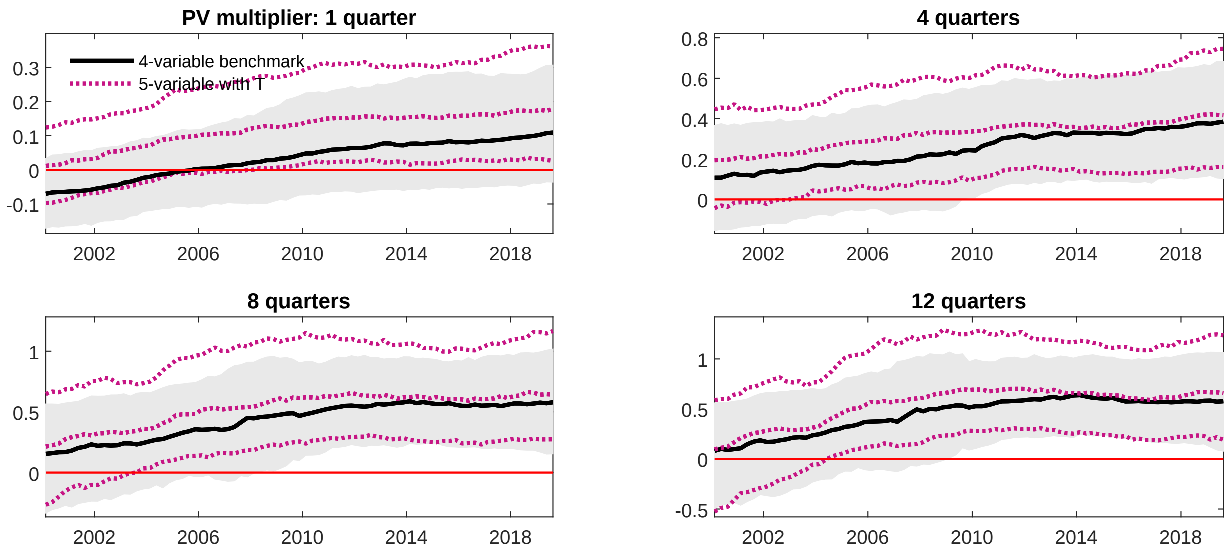

Figure A2: Time-varying present-value multipliers for selected horizons, associated with the 4-variable baseline TVC-VAR model (solid line with shaded area) and with the 5-variable TVC-VAR model augmented with taxes (dotted lines). In each panel, median and 68% band estimates are reported. The y-axis is in Korean won.

considered horizons.

Figure A2 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. Overall, the impulse responses from the 5-variable model display slightly wider band estimates than those from the baseline 4-variable VARs, which is observed more clearly for longer horizons. This tendency may be attributable to the "curse of dimensionality" problem typically associated with TVC-VAR models in which the number of parameters to be estimated increases rapidly with additional model variables. The longer-run multipliers tend to become slightly bigger under the 5-variable system, and the difference stands out more for the beginning of the sample period. It is nonetheless worth noting that controlling for taxes does not alter substantially the time-varying pattern of the government spending multiplier estimates.

C.1.2 Comparison to the 4-variable Model without the Nominal Interest Rate

For a robustness check, we estimate a model with taxes, but without the nominal interest rate, and compare the results to those of the baseline 4-variable specification. The results, which are the 5-variable VAR model counterparts of Figure 10, are depicted in Figure A3. In addition, Figure A4 reports the 5-variable model results analogous to Figure 11. These figures show that the main findings of the paper are unlikely to be altered by adding taxes to the model.

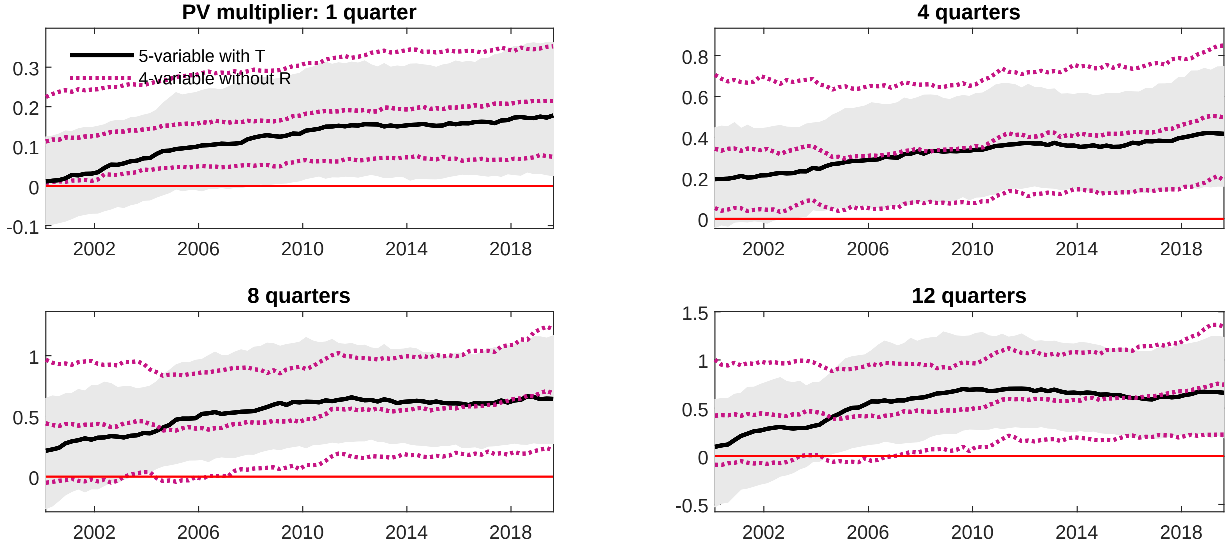

Figure A3: Time-varying present-value multipliers for selected horizons, associated with the 5-variable TVC-VAR model augmented with taxes (solid line with shaded area) and with the 4-variable TVC-VAR model without the nominal interest rate (dotted lines). In each panel, median and 68% band estimates are reported. The y-axis is in Korean won.

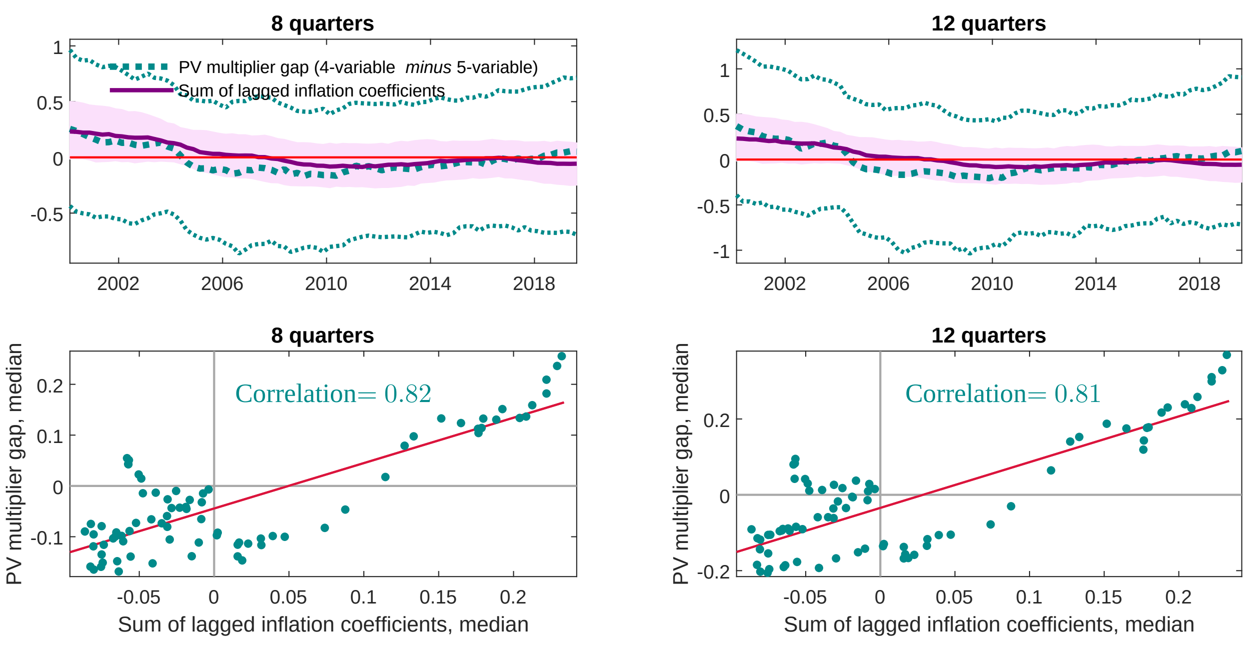

Figure A4: **[Upper panels]** Differences between the time-varying present-value multipliers for selected horizons associated with the 4-variable TVC-VAR model without the nominal interest rate and 5-variable TVC-VAR model augmented with taxes, along with the sum of the inflation coefficients in the nominal interest rate equation multiplied by the corresponding Cholesky factors associated with the 5-variable TVC-VAR model augmented with taxes. In each panel, median and 68% band estimates are reported. **[Lower panels]** Scatter plots for the median sums of the inflation coefficients in the nominal interest rate equation multiplied by the corresponding Cholesky factors (x-axis) and median differences between the time-varying present-value multipliers (y-axis). In each panel, the solid line indicates the fitted values of the linear OLS regression.

C.2 GOVERNMENT SPENDING IMPULSE RESPONSES FOR SELECTED DATES Figure A5 plots the impulse responses of government spending to 1% initial increases in government spending for selected dates.

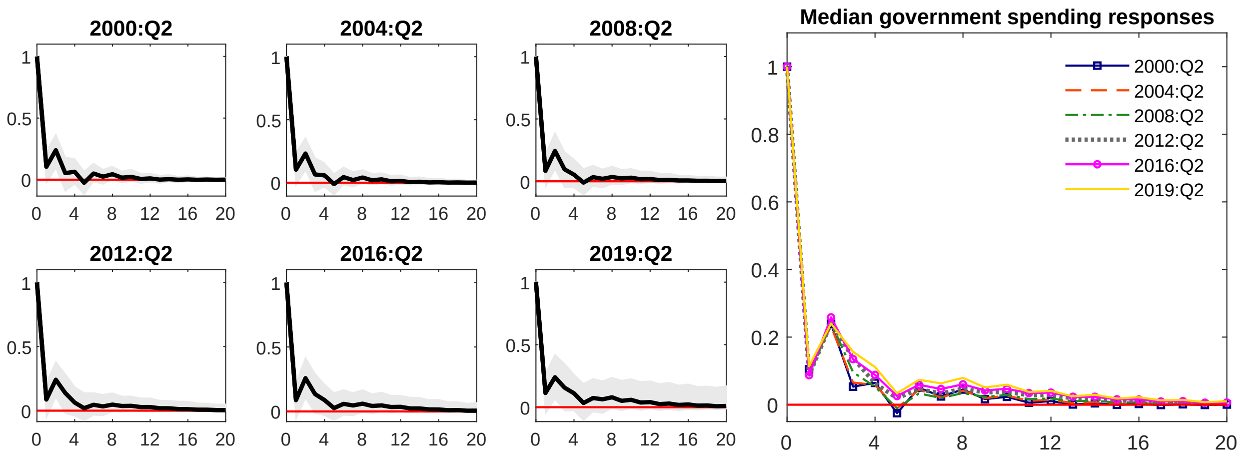

Figure A5: Impulse responses of government spending to 1% initial increases in government spending for selected dates associated with the TVC-VAR model. In the left 6 panels, median (solid line) and 68% band (shaded area) estimates are reported, while median estimates across various dates are plotted in the right panel. The y-axis is in percentage.

C.3 ALTERNATIVE ORDERING OF THE VARIABLES Given the recursive ordering scheme used to identify government spending shocks in this paper, it may be the case that the response of the interest rate to inflation can be different for alternative orderings, especially between output and the inflation rate. Accordingly, we check whether the results are robust when an alternative ordering between output and inflation is considered. To this end, we estimate a model with inflation ordered ahead of output such that the entire ordering structure of the alternative specification is given as follows: government spending first, inflation second, output third, and the nominal interest rate last.

Figure A6 plots the present-value multiplier estimates that emerge from the model with the alternative ordering, together with those from the baseline specification. Figures A7 and A8 show how the impulse responses of inflation and the nominal interest rate vary depending upon the alternative ordering. All these figures indicate that the results change very little when the alternative ordering is used instead. The impulse responses associated with both orderings look quite alike, as they show a similar pattern of time variation.

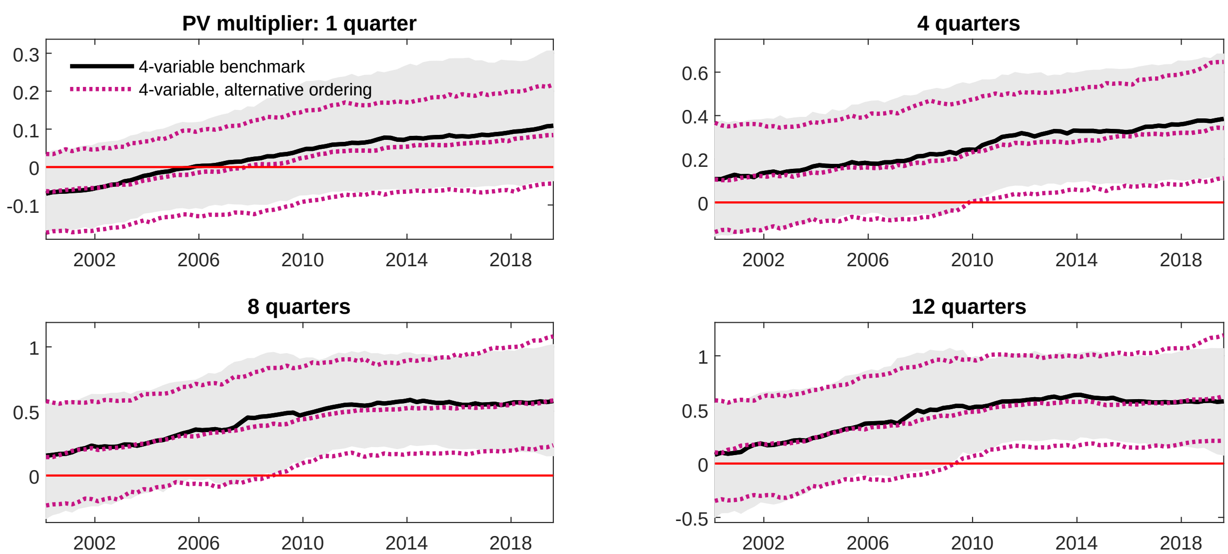

Figure A6: Time-varying present-value multipliers for selected horizons, associated with the baseline 4-variable TVC-VAR model (solid line with shaded area) and with the 4-variable TVC-VAR model with the alternative ordering of output and inflation (dotted lines). In each panel, median and 68% band estimates are reported. The y-axis is in Korean won.

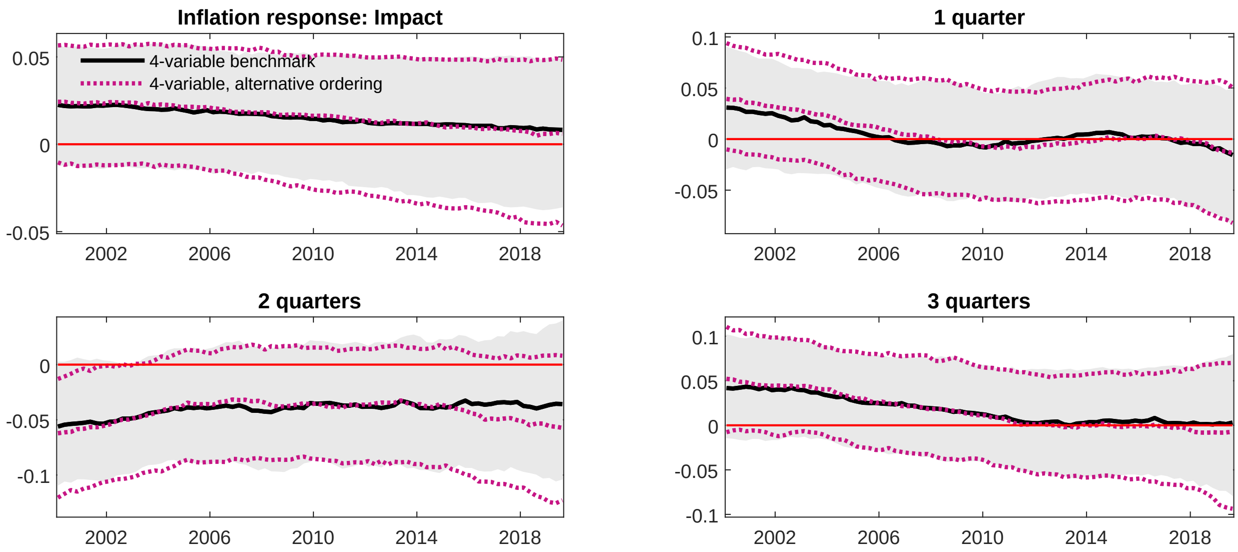

Figure A7: Time-varying impulse responses of inflation to 1% increases in government spending for selected horizons associated with the baseline 4-variable TVC-VAR model. In each panel, median (solid line) and 68% band (shaded area) estimates are reported. The y-axis is in percentage.

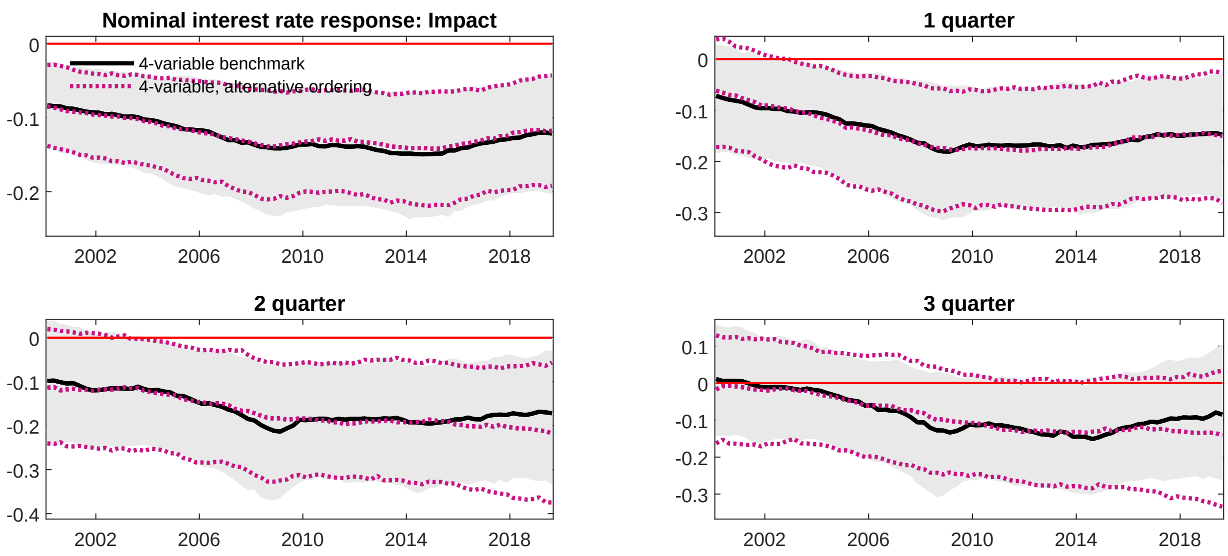

Figure A8: Time-varying impulse responses of the interest rate to 1% increases in government spending for selected horizons associated with the baseline 4-variable TVC-VAR model. In each panel, median (solid line) and 68% band (shaded area) estimates are reported. The y-axis is in percentage.

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