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THE IMPACT OF TAX POLICY ON ECONOMIC GROWTH FROM AGGREGATE AND STRUCTURAL TAX PERSPECTIVE IN CHINA: A LT-TVP-FAVAR APPROACH

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The Impact of Tax Policy on Economic Growth from Aggregate and Structural Tax Perspective in China: A LT-TVP-FAVAR Approach

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Abstract

This study proposes a new latent threshold time-varying parameters factor-augmented vector autoregressive (LT-TVP-FAVAR) model and then explore the dynamic impact of Chinese tax policy on economic growth from the dual perspective of total tax revenue and tax structure. The proposed LT-TVP-FAVAR model can both model parameter changes and avoid overparameterization such that it can capture economic dynamics better. We propose a two-step estimation method (including a Markov chain Monte Carlo algorithm) to estimate the LT-TVP-FAVAR model. Extensive point forecasts present evidence for the LT-TVP-FAVAR model's strength. The main empirical conclusions are: (1) increasing total tax revenue has a negative impact on economic growth, but this has weakened since China entered the economic new normal period; (2) From the perspective of tax structure, increases in both commodity tax and income tax primarily exert a positive effect on economic growth, while increases in the other tax have a negative effect on economic growth. Additionally, the positive effect of increasing commodity taxes on economic growth has obviously weakened since China entered the economic new normal period, whereas the positive effect of income tax on economic growth sharply increased after the outbreak of the COVID-19 pandemic. The inhibitory effect of increases in the other tax on economic growth during the economic new normal and COVID-19 pandemic periods is stronger than during the financial crisis and economic recovery periods.

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1 Introduction

As an important means for the government to conduct macroeconomic regulation, tax policy plays

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an important role in a country's economic development. For instance, targeted tax policy tools and a rationalized tax structure can effectively balance the speed and quality of economic growth. In China, the Central Economic Work Conference in 2019 pointed out that active fiscal policies should be strengthened and made more effective, and larger-scale tax and fee cuts should be implemented. Subsequently, the 20th Chinese Communist Party National Congress in its 2022 report emphasized the need to improve the modern budget system, optimize the tax structure, and improve the fiscal transfer payment system. This is a major deployment made by the Chinese government to accelerate the establishment of a modern fiscal and taxation system, and the focus on further improving the modern taxation system is to optimize tax structure. Most recently, the 2024 Chinese Government Work Report emphasized the need to implement structural tax and fee reduction policies.

Together, these developments show the importance given to tax policy in China's economic development. Further, as the world's second largest economy, China plays an important role in global economic development. The impact of the three-year COVID-19 pandemic has brought many challenges to Chinese economy development; in addition, with the sluggish recovery of the world economy, intensified geopolitical conflicts, and the rise of protectionism and unilateralism, China's economic development continues to be increasingly affected by the adverse external environment. Hence, it is imperative to systematically explore the impact of Chinese tax policy on economic growth, which will offer policymakers new insights into how to better formulate policy to promote China's economic growth.

Many studies explore the relationship between tax policy and economic growth. Some address the relationship between tax structure and economic growth (e.g., Lee and Gordon, 2005; Stoilova, 2017; McNabb, 2018; Neog and Gaur, 2020; Balasoiu et al., 2023), while several consider the effect of total tax revenue on economic growth (e.g., Myles, 2000; Biswas et al., 2017; Arvin et al., 2021; Gurdal et al., 2021). Additionally, some studies focus on the particular impact of income taxes (e.g., Shin, 2012; Gale and Samwick, 2017), direct and indirect taxes (e.g., Nguyen, 2019), energy taxes (e.g., Ojha et al., 2020; Hassan et al., 2022), environmental taxes (e.g., Hassan et al., 2020), and others on economic growth.

However, among these studies, few explore the impact of Chinese tax policy on economic growth. Even when they do, they merely focus on a single tax such as the housing property tax (e.g., Li and Lin, 2023), value-added tax (Li and Shen, 2023), carbon tax (e.g., Fang et al., 2013; He et al., 2021; Chang et al., 2023), or agricultural tax (e.g., Shi and Ye, 2018). Further, some studies consider total tax revenue (e.g., Zeng and Li, 2013; Yang, 2016), but they only use econometric or statistical models with constant parameters to carry out empirical analysis, which unfortunately cannot fully capture the time-varying characteristics of the effect of tax policy on economic growth.

To address these issues, we propose a new latent threshold time-varying parameters factor-augmented vector autoregressive (LT-TVP-FAVAR) model to explore the dynamic impact of Chinese tax policy on economic growth from the perspective of total tax revenue and tax structure. The contributions of the study are threefold.

First, we explore the dynamic impact of Chinese tax policy on economic growth from the perspective of total tax revenue and tax structure, which provides policymakers with deeper insights into effective tax policy suggestions to promote China's economic growth. Additionally, we address the gap resulting from a lack of research concerning the time-varying effects of Chinese tax policy on economic growth from the perspective of total tax revenue and tax structure. Note that, as commodity and income taxes account for a large proportion of China's total tax revenues, we divide total tax revenue into commodity tax, income tax, and the other tax to measure tax structure.

Second, we propose the LT-TVP-FAVAR model, which is capable of both capturing economic dynamics and avoiding overparameterization, by introducing the latent threshold technology developed by Nakajima and West (2013) into the traditional TVP-FAVAR model proposed by Korobilis (2013). The TVP-FAVAR model have enjoyed great popularity in recent years as a way of modeling the parameter change that occurs in many macroeconomic and financial time series variables. However, the TVP-FAVAR model's flexibility, arising from its time-varying characteristics, comes at the cost of overparameterization, which can lead to perfect in-sample fit but poor out-of-sample forecast performance. We employ the latent threshold method, which can shrink a time-varying parameter's value to zero when it falls below a threshold, to address this challenge. The new proposed LT-TVP-FAVAR model is a general model, which indicates that one can straightforwardly use it to carry out empirical analysis (such as monetary policy analysis and economic forecasting) in economics and finance. Nonetheless, it is worthwhile mentioning that while some existing studies have developed latent threshold factor models with time-varying parameters, they differ from our model. For instance, Nakajima and West (2012) considered a latent threshold approach to a dynamic factor model, but where the variance and covariance matrix of the error term in the vector autoregressive (VAR) equation was diagonal. Zhou et al. (2014) likewise proposed a latent threshold dynamic factor model, but that model did not include observed explanatory variables. Hacioglu and Tuzcuoglu (2016) proposed a threshold factor-augmented vector autoregression model, but the parameters in the VAR equation of their model remain constant. Nakajima and West (2017) introduced a latent threshold to a dynamic factor model, but the variance and covariance matrix of the error term in the VAR equation is diagonal. Zhao and Liu (2021) proposed a new time-varying parameter factor model with shrinkage and sparsification, but they only focused on the pure factor structure and did not include the observed regressors in the VAR equation. Alves et al. (2024) developed a time-varying factor model with the least absolute shrinkage, but did not include a VAR equation in their model.

Lastly, following Korobilis (2013), we propose a simple two-step estimation strategy for the proposed LT-TVP-FAVAR model. The LT-TVP-FAVAR model comprises two equations: namely, a VAR equation with time-varying parameters and a factor analysis regression equation. We use standard principal components technology to approximate the unobserved common factors in the factor analysis regression in the first step and then estimate the remaining parameters in the VAR equation with time-varying parameters conditional on these estimates of the factors using a Markov Chain Monte Carlo (MCMC) algorithm.

The remainder of the paper is organized as follows. Section 2 provides our research background. Section 3 describes in detail the LT-TVP-FAVAR model, providing the identification of factors, the parameter estimation, the identification of tax policy shocks, the determination of the numbers of factors and lags, the data description, and the point forecasts obtained. Section 4 presents the empirical results from the proposed LT-TVP-FAVAR model and Section 5 concludes. The appendix provides the MCMC algorithm and other empirical results.

2 Background

2.1 Taxation and economic growth theory

The economic growth effect of tax policies has always been of great concern to scholars, and different schools of economics have dissimilar viewpoints about the effect of taxation on economic growth. The classical school proposed that tax can reduce personal disposable income, and lower capital accumulation by affecting investors' expected return rate on investment, thereby suppressing economic growth (e.g., Smith, 1981). The neoclassical school believed that economic growth depends on capital stock and labor force, and macroeconomic policy can not affect long-run economic growth rate as an exogenous variable (e.g., Solow, 1956). The Keynesian school maintained that a reduction in tax can increase the propensity to consume, thereby promoting economic growth (e.g., Keynes, 1997). The endogenous growth theory believed that tax affects long-run economic growth rate by changing the cost and benefit of the the marginal condition governing the learning decision (e.g., Lucas, 1990). Most scholars agree that a reduction in tax can promote economic growth (e.g., Romer and Romer, 2010; Arvin et al., 2021; Dabla-Norris and Lima, 2023). Moreover, there still exist debate as to the impact of specific tax categories on economic growth (e.g., Nguyen et al., 2021; Gechert and Heimberger, 2022; Zhang et al., 2024). Hence, it is necessary for us to carry out specific empirical analysis to obtain clear results about the effect of Chinese tax policy on economic growth.

2.2 Economic situation and policies

Looking back through history, we can find an obvious correlation between the changes in China's taxation and economic growth. According to changes in economic development needs, China is also constantly adjusting its tax policies. For example, during the planned economic system, China's economic inefficiency and development lag were caused by the loss of vitality of microeconomic entities. For this reason, the Chinese government implemented the policy of tax reduction to reduce the burden of microeconomic entities and improve the development environment of local enterprises. This promoted rapid economic growth in the early stage of reform and opening up. However, the decentralization in the early stage of reform also caused the proportion of national fiscal revenue to GDP to decline rapidly, weakening the ability of fiscal policy to regulate the macroeconomy. Against the background of rapid economic growth, and of weakening fiscal policy effects caused by reduced national fiscal revenue, the Chinese government proposed the tax-sharing reform at the Third Plenary Session of the 14th Central Committee. Moreover, the Chinese government introduced the value-added tax, which was stipulated to be shared between the central and local governments, thereby promoting industrial division and factor flow under market economy conditions.

After the reform and opening up, China was in an extensive high-speed economic growth mode. After the subprime mortgage crisis in America, the Chinese government introduced a 4 trillion stimulus policy in 2008, which aggravated the overcapacity and excessive expansion in infrastructure and real estate industry. As China's infrastructure level continues to improve, the effectiveness of traditional policies to drive the economy, which are achieved by investing in industries such as infrastructure, has gradually weakened. At the same time, China's trade frictions with other countries have gradually intensified compared to the beginning of joining the World

Trade Organization (WTO), resulting in increased pressure on China's foreign trade. Therefore, China strives to transform its economy, trying to shift from the original extensive high-speed economic growth to a high-quality economic growth mode that has higher production efficiency and competitiveness, with tax policies also being adjusted to meet the needs of economic development. Specifically, in 2015, China proposed a policy of "three cuts, one reduction, and one supplement" based on the supply-side structural reform[1]. As for the aspect of taxation, it requires reducing the tax burden on enterprises to stimulate economic growth, especially for lowering the value-added tax rate of the manufacturing industry to guide the industry to accelerate industrial transformation and upgrading.

In the post-crisis era of the COVID-19 pandemic, the further intensification of economic downward pressure and trade frictions has made China more urgent in achieving industrial upgrading and economic transformation. Tax measures such as adjusting the tax structure are essential for the government to accelerate China's economic transformation. Moreover, the downward pressure on housing prices in recent years has increased the pressure on the government fiscal revenue. The downward pressure on the economy and weak domestic demand have worsened the survival environment of enterprises and weakened consumer confidence. These have put forward more stringent requirements on the accuracy of the design of tax policies.

Given that commodity and income taxes account for a large proportion of total tax revenue in China, we divide total tax revenue into commodity tax, income tax, and the other tax to reflect tax structure. Commodity tax is a tax levied on commodities and services, including value-added tax and consumption tax. These account for the largest proportion of Chinese tax revenue and conduce to ensuring the stability of tax revenue. As a form of indirect taxation, commodity taxes are often passed on to consumers as taxpayers by adjusting commodity prices. The government can guide the optimization of industrial structure and the transformation and upgrading of industry by implementing different commodity tax rates on different industries.

Income tax primarily comprises personal income tax and corporate income tax, which are not readily passed on and can directly affect the wealth allocation of individuals and enterprises. Implementing higher income tax rates on large incomes can change wealth distribution and reduce the disparities in wealth and income (Keynes, 1997). Moreover, the tax shifting of commodity taxes

[1] The "three cuts, one reduction, and one supplement" refers to the five tasks of cutting overcapacity, cutting inventory, cutting leverage, reducing costs, and making up for shortcomings. General Secretary Xi Jinping proposed it at the 2015 Central Economic Work Conference of China in response to the supply-side structural reform.

from taxpayers to consumers and the reduction of income caused by income taxes not only prompt consumers to adjust their consumption structure so that enterprises can better make production decisions that are compatible with consumption in quantity and structure, but also conduce to eliminating uncompetitive enterprises such as zombie companies by increasing pressure on enterprises, thereby accelerating the optimization of economic structure and the transformation and upgrading of economy.

The other tax includes all of house property tax, land value-added tax, farmland occupation tax, urban land use tax, vehicle purchase tax, and deed tax. Nonetheless, the other tax category accounts for the smallest proportion of total tax revenue. The government can guide the economic focus to shift from industries such as real estate to industries such as emerging industries by increasing the proportion of the other tax and decreasing the tax rate of industries such as emerging industries, thereby accelerating the optimization of economic structure and the transformation and upgrading of industry.

Given the argument above, we can see that taxation is an important means of regulating economic growth, whether from the existing theoretical studies or from the actual intervention and regulation of Chinese government. The government can improve the development environment of enterprises through large-scale tax cuts and thereby promotes economic growth. Furthermore, by adjusting tax structure, the government can enhance the adaptability of production to consumption in quantity and structure, guide the economic focus to shift from industries such as real estate to industries such as emerging high-technology industries, promote a more equal distribution of v d3rincomes, and accelerate industrial transformation and upgrading, thereby improving the quality of economic development. Therefore, in the current stage of China's economy being under downward pressure and the process of China's economic transformation and upgrading, it is essential to explore the impact of total tax revenue and tax structure on economic growth and provide appropriate policy responses.

3 Model and data

3.1 Model

In this study, we construct the LT-TVP-FAVAR model as follows:

$$y_t = \beta_{1t} y_{t-1} + \cdots + \beta_{pt} y_{t-p} + v_t \equiv X_t b_t + v_t, \tag{1}$$

$$x_t = \lambda^f f_t + \lambda^z z_t + u_t, \tag{2}$$

with

$$b_{it} = \bar{b}_{it} \cdot I(|\bar{b}_{it}| \geq d_i^b), \quad i = 1, \cdots, pm^2, \tag{3}$$

$$a_{jt} = \bar{a}_{jt} \cdot I(|\bar{a}_{jt}| \geq d_j^a), \quad j = 1, \cdots, m(m-1)/2, \tag{4}$$

where $y_t = (f_t', z_t')'$ for $t = 1, \cdots, T$, f_t is a $k \times 1$ vector of unobserved common factors, z_t are a $l \times 1$ vector of observed economic variables; β_{jt} is an $m \times m$ matrix of time-varying coefficients at lag j, $j = 1, \cdots, p$, $m = k + l$; v_t is an $m \times 1$ vector of error term following $N(0, \Omega_t)$, where Ω_t is a positive definite matrix and can be factorized with Cholesky decomposition as $\Omega_t = A_t^{-1} \Sigma_t \Sigma_t' A_t^{-1\prime}$,

$$A_t = \begin{pmatrix} 1 & & & \\ a_{21,t} & 1 & & \\ \vdots & \ddots & \ddots & \\ a_{m1,t} & \cdots & a_{mm-1,t} & 1 \end{pmatrix}, \quad \Sigma_t = \begin{pmatrix} \sigma_{1t} & & & \\ & \sigma_{2t} & & \\ & & \ddots & \\ & & & \sigma_{mt} \end{pmatrix};$$

$X_t = I_m \otimes (y_{t-1}', \cdots, y_{t-p}')$ (where I_m is an m-dimensional identity matrix and $\otimes$ denotes the Kronecker product) and b_t is a $pm^2 \times 1$ vector by stacking the set of β_{jt} by rows and by order, $j = 1, \cdots, p$; x_t is an $n \times 1$ vector consisting of hundreds of additional observed economic variables, which is linked to f_t and z_t through a factor analysis regression; λ^f and λ^z are constant coefficient matrices of dimensions $n \times k$ and $n \times l$, respectively; u_t is an $n \times 1$ vector of idiosyncratic term (i.e., error term); b_{it} denotes the i-th element in b_t, d_i^b is a latent threshold with $d_i^b \geq 0$, and b_{it} are governed by the underlying latent time-varying parameters $\bar{b}_{it}$ and the indicator function $I(\cdot)$, which implies that one explanatory variable has a time-varying coefficient whose value is shrunk to zero when it falls below a threshold. Let a_t be the vector of the nonzero and non-one elements of A_t (stacked by rows) and a_{jt} refers to the j-th element in a_t. Similar to b_{it}, a_{jt} also has a latent threshold $d_j^a \geq 0$ and the underlying latent time-varying parameters $\bar{a}_{jt}$.

Let $\bar{b}_t = (\bar{b}_{1t}, \cdots, \bar{b}_{pm^2 t})'$, $\bar{a}_t = (\bar{a}_{1t}, \cdots, \bar{a}_{m(m-1)/2t})'$, and $\sigma_t^2 = (\sigma_{1t}^2, \cdots, \sigma_{mt}^2)'$. The dynamics of the time-varying parameters are specified as follows:

$$\bar{b}_t = \mu_b + \Phi_b(\bar{b}_{t-1} - \mu_b) + \eta_{bt}, \qquad \eta_{bt} \sim N(0, V_b) \tag{5}$$

$$\bar{a}_t = \mu_a + \Phi_a(\bar{a}_{t-1} - \mu_a) + \eta_{at}, \qquad \eta_{at} \sim N(0, V_a) \tag{6}$$

$$\log(\sigma_t^2) = \mu_\sigma + \Phi_\sigma[\log(\sigma_{t-1}^2) - \mu_\sigma] + \eta_{\sigma t}, \qquad \eta_{\sigma t} \sim N(0, V_\sigma) \tag{7}$$

where μ_b, μ_a, and μ_σ are intercept vectors of dimensions $pm^2 \times 1$, $m(m-1)/2 \times 1$, and $m \times 1$, respectively; Φ_b, Φ_a, and Φ_σ denote diagonal coefficient matrices of dimensions $pm^2 \times pm^2$, $m(m-1)/2 \times m(m-1)/2$, and $m \times m$, respectively; η_{bt}, η_{at}, and $\eta_{\sigma t}$ are pm^2-, $m(m-1)/2$-, and m-dimensional error vectors, respectively; and V_b, V_a, and V_σ are all diagonal variance matrices.

Identification of factors and parameter estimation The identification of common factors addresses two aspects. First, we need to separate the common component f_t from the idiosyncratic component (i.e., the error term) v_t and u_t. Second, we cannot identify the loadings and factors without restrictions because, for instance, there exists an arbitrary invertible matrix Q such that $\lambda^f QQ^{-1} f_t$. Additionally, specific identification conditions also depend on specific estimation methods. For instance, if we estimate the latent factors (treated as unobserved parameters) along with the other parameters in a single step using a MCMC algorithm, then we need at least $k^2 + kl$ restrictions to identify f_t because there are $k^2 + kl$ free elements in $Q_{k\times k}$ and $\tilde{Q}_{k\times l}$, where $\tilde{Q}$ denote coefficient matrices stemming from a linear combination of f_t and z_t (i.e., $Qf_t + \tilde{Q}z_t$). This linear combination is considered because f_t and x_t both depend on z_t according to equations (1) and (2), which indicates that the factors need to avoid rotations of this linear combination form in case there exists a factor $\tilde{f}_t = Qf_t + \tilde{Q}z_t$ such that $\lambda^f f_t + \lambda^z z_t = (\lambda^f Q^{-1})\tilde{f}_t + (\lambda^z - \lambda^f Q^{-1}\tilde{Q})z_t$ by substituting for $f_t = Q^{-1}(\tilde{f}_t - \tilde{Q}z_t)$ in equation (2). Hence, there needs k^2 restrictions for Q and additional kl restrictions for $\tilde{Q}$. However, while this identification scheme for the factors is feasible, it can impair the economic meaning of the factors. For example, Bernanke et al. (2005) used a triangular identification restriction in the upper $k \times k$ block of the loadings matrix and argued that Bayesian estimation produces factors that do not capture information about real activity and prices.

Hence, following Korobilis (2013), we apply a conceptually and computationally simple two-step estimation method, which allows us to directly apply the idea of the standard identification scheme for the factors in the LT-TVP-FAVAR model. Specifically, the factors are estimated using standard principal components for equation (2) in the first step and then, following Nakajima and West (2013), we estimate the remaining parameters conditional on these estimates of the factors using the MCMC algorithm. We describe in detail the estimation of f_t in the first step in Section 3.2, with the MCMC algorithm, including the parameter priors and five-step Gibbs sampling in Appendix A. Given the estimation of f_t is directly based on equation (2), we only need to impose identification restrictions on equation (2). Specifically, the identification conditions for the common factors in the LT-TVP-FAVAR model are as follows:

Assumption 1. *Let* $\gamma_f^{(n)}$ *denote the minimum eigenvalue of* $\sum_{i=1}^{n}\sum_{j=1}^{n}\text{cov}(\lambda_i^f f_t, \lambda_j^f f_t)$ *, where* λ_i^f *is the* i *-th row of* λ^f *.* $\gamma_f^{(n)}$ *diverges as* $n \to \infty$ *, that is,* $\lim_{n\to\infty}\gamma_f^{(n)} = \infty$ *.*

Assumption 2. *Let* $\gamma_u^{(n)}$ *denote the maximum eigenvalue of* $\sum_{i=1}^{n}\sum_{j=1}^{n}\text{cov}(u_{it}, u_{jt})$ *, where* u_{it} *is the* i *-th element of* u_t *. There exists an* M *independent of* n *such that* $\gamma_u^{(n)} \le M < \infty$ *.*

Assumption 3. *Let* $f_t^* = f_t + \phi z_t$ *(where* ϕ *is a given* $k \times l$ *parameter matrix) denote a rotation of* f_t and satisfy $x_t = \lambda^{f^*} f_t^* + \lambda^z z_t + u_t$. $\lambda^{f^*\prime}\lambda^{f^*}/n$ *is a diagonal matrix and* $F_t F_t' / T = I_f$ *where* $F_t = (f_1^*, \cdots, f_T^*)_{k\times T}$ *and* I_f *is a* $k \times k$ *identity matrix.*

Assumptions 1 and 2 are standard to ensure that the common component $\lambda^f f_t$ can be separated from the idiosyncratic component u_t as $n \to \infty$, while λ^f and f_t are fixed by Assumption 3 because $F_t F_t' / T = I_f$ provides $k(k-1)/2$ restrictions and diagonal $\lambda^{f^*\prime}\lambda^{f^*}/n$ provides $k(k+1)/2$ restrictions. We will elucidate Assumption 3 further in Section 3.2.

3.2 Identification of tax policy shocks

In this study, we include a tax policy variable and an economic growth variable in z_t to analyze the impact of tax policy on economic growth. As there remains the ordering of variables in y_t due to the Cholesky decomposition of Ω_t, we need to carefully consider the position of the tax policy variable (in other words, the identification of tax policy shocks). Specifically, the tax policy variable is sorted last in y_t, and the economic growth variable is placed before the tax policy variable but after the unobserved factors f_t, which indicates that tax policy is identified in a recursive manner. Note that the idea of this kind of recursive manner for identifying tax policy shocks to economic growth has been also applied in recent studies (e.g., Berg, 2015; Glocker et al., 2019; Jiménez et al., 2023). Let us explain this recursive manner further. Equation (1) can be rewritten as

$$y_t = \beta_{1t} y_{t-1} + \cdots + \beta_{pt} y_{t-p} + A_t^{-1}\Sigma_t e_t, \qquad e_t \sim N(0, I_\varepsilon)$$

where I_ε is an $m \times m$ identity matrix. Note that $y_t - \beta_{1t} y_{t-1} - \cdots - \beta_{pt} y_{t-p} = v_t = A_t^{-1}\Sigma_t e_t$, which means that, for $m = 3$ (for simplicity),

$$v_{1t} = \sigma_{1t} e_{1t}, \tag{8}$$

$$v_{2t} = \sigma_{2t} e_{2t} - a_{21,t} v_{1t}, \tag{9}$$

$$v_{3t} = \sigma_{3t} e_{3t} - a_{31,t} v_{1t} - a_{32,t} v_{2t}, \tag{10}$$

where e_{jt} and v_{jt} denote the j-th elements of e_t and v_t, respectively, $j = 1, \cdots, 3$. Obviously, if v_{1t} increases one unit at t (then, y_{1t} will increase one unit), v_{1t} will have a contemporaneous effect on v_{2t} and v_{3t} (thus, y_{2t} and y_{3t} will be affected) according to equations (9) and (10). However, if v_{2t} increases one unit at t, then it will only have a contemporaneous effect on v_{3t} but not a contemporaneous effect on v_{1t}, according to (8) and (10). Similarly, for v_{3t}, it cannot have a contemporaneous effect on v_{1t} and v_{2t}. In other words, y_{1t} can contemporaneously affect y_{2t} and y_{3t} but not vice versa; additionally, y_{2t} can contemporaneously affect y_{3t} but not vice versa. Hence, according to this kind of recursive structure, the identification of tax policy shocks is achieved by a specific ordering of all variables in y_t, that is, $y_t = (f_t', z_{1t}, z_{2t})'$ where z_{1t} and z_{2t} denote the economic growth variable and the tax policy variable, respectively. For the ordering of the elements in f_t, following the notion in Belviso and Milani (2006), we sort the factor capturing real activity in the first position, which is sequentially followed by the factors representing credit and finance (see Section 3.4 for details).

Given the latent factors are obtained from additional macroeconomic variables, they could contain some information or components that can be affected contemporaneously by the tax policy and economic growth variables. Hence, for the factors sorted before the tax policy and economic growth variables, we need to separate out that component contemporaneously affected by the tax policy and economic growth variables. We follow the idea of Bernanke et al. (2005) to address this issue. First, f_t^* is estimated by standard principal components for the equation $x_t = \lambda^{f^*} f_t^* + \lambda^z z_t + u_t$ in Assumption 3 and let $\hat{f}_t^*$ denote the estimate of f_t^*; then, we estimate the regression $\hat{f}_t^* = \phi z_t + \xi_t$ (whose purpose is to separate the component affected by z_t) and let $\hat{\phi}$ denote the estimate of ϕ; lastly, the estimate of f_t, $\hat{f}_t$, is obtained by $\hat{f}_t = \hat{f}_t^* - \hat{\phi} z_t$. This is why we introduce the rotation of f_t (i.e., $f_t^* = f_t + \phi z_t$) in Assumption 3.

3.3 Data

The observable variables in the LT-TVP-FAVAR model consist of z_t and x_t. To measure the economic growth variable (i.e., z_{1t}), we use the log-difference of GDP. For the tax policy variable (i.e., z_{2t}), given we consider the dynamic impact of Chinese tax policy on economic growth from the perspective of both total tax revenue and tax structure, we measure them separately. Specifically, for total tax revenue, we use the ratio of total tax revenue to GDP (denoted z_{2t}^{total}); for tax structure, we divide total tax revenue into three parts (i.e., commodity tax, income tax, and the other tax) and use the proportions of these three taxes to total tax revenue (denoted $z_{2t}^{commodity}$, z_{2t}^{income}, and z_{2t}^{other}, respectively) to measure tax policy. Note that commodity tax includes value-added and consumption taxes; income tax is the sum of personal income and corporate income taxes; and the other tax comprises property, land value-added, farmland occupation, urban land use, vehicle purchase, deed, and other taxes. As for x_t, we select 344 macroeconomic variables (including various types of output, employment, consumption, imports and exports, various price indices, long- and short-term interest rates, etc.) as x_t in order to obtain common factors. We specify quarterly data for all economic variables and the sample period spans the first quarter of 2007 (Q1-2007) to the fourth quarter of 2023 (Q4-2023) considering data availability. The source of our data is the China Economic Information Network Statistics Database[1]. All variables are standardized and transformed to be stationary.

3.4 Numbers of factors and lags

For the number of latent common factors, following Korobilis (2013), we set $k = 3$ (i.e., three common factors) to represent real activity, credit, and finance (see Figure 1). Note that we use z_{2t}^{total} (along with x_t and z_{1t}) to estimate three factors instead of $z_{2t}^{commodity}$ or z_{2t}^{income} or z_{2t}^{other} because z_{2t}^{total} contains all information that is used to construct $z_{2t}^{commodity}$, z_{2t}^{income}, and z_{2t}^{other}.

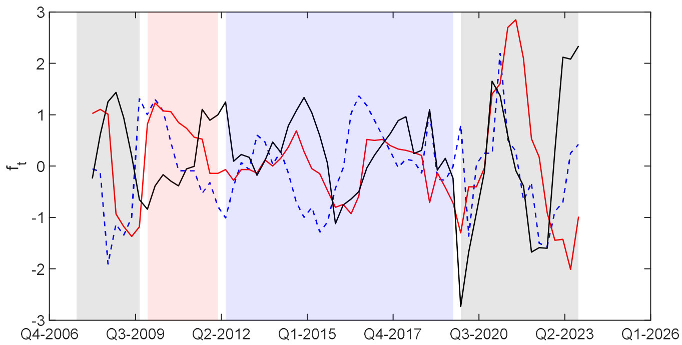

Figure 1: Three common factors $\hat{f}_t$

It is evident that the temporal evolution of the three common factors all fluctuated significantly around 2008 and 2020, which precisely corresponds to two typical economic facts: the global financial crisis after 2007 and the COVID-19 pandemic after 2020. To better describe the empirical results in Section 4, we divide the full sample period (i.e., from Q1-2007 to Q4-2023) into four sub-periods: a financial crisis period (Q1-2007 ~ Q4-2009), an economic recovery period (Q1-2010 ~

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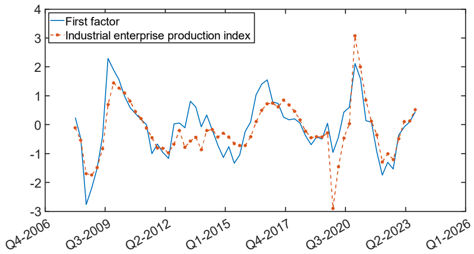
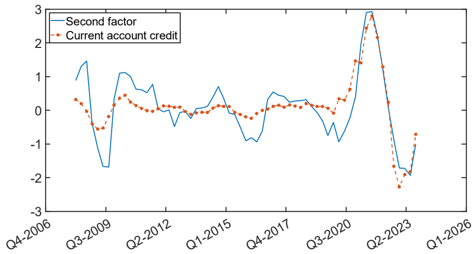
[1] See https://db.cei.cn/.

Q2-2012), an economic new normal period[1] (Q3-2012 ~ Q4-2019), and a COVID-19 pandemic period (Q1-2020 ~ Q4-2023). Lastly, following some literature relevant to the TVP-VAR model and TVP-FAVAR model (see Primiceri, 2005; Koop et al., 2009; Korobilis 2013), we set the number of the lags in equation (1) to be $p = 2$.

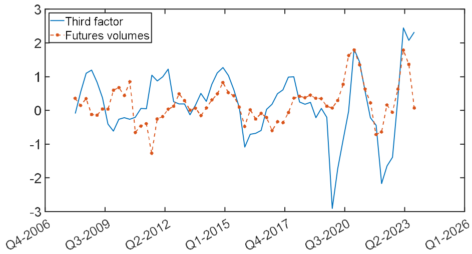
To understand these three factors better, we use $\hat{f}_t^*$ to describe them further because $\hat{f}_t$ is a rotation of $\hat{f}_t^*$. Figure 2 plots each of the factors $\hat{f}_t^*$ against a single economic variable, which closely approximates (graphically) the factor, selected from the 344 macroeconomic variables included in our analysis. The temporal evolution of the first factor in Figure 2(a) is similar to that of the industrial business production, which indicates that the first factor well captures real activity. Figure 2(b) presents the second and third factors whose movements are close to the current account credit and futures volumes, respectively. Note that there is no need to test how close each factor is to a specific economic variable; instead, our purpose is to provide some economic interpretation for each factor.



(a)



(b)



(c)

Figure 2: Three common factors $\hat{f}_t^*$ and selected macroeconomic variables

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1 The term "new normal" was first proposed by Chinese President Xi Jinping during his visit to Henan in May 2014. At the time, he said: "China's development is still in an important strategic opportunity period. We must strengthen our confidence, proceed from the current stage characteristics of China's economic development, adapt to the new normal, and maintain a strategic normal mentality." Because China's GDP growth rate began to decline in 2012 (growth in 2012, 2013, and the first half of 2014 was 7.7%, 7.7%, and 7.4%, respectively), the new normal period marked the end of the high average growth of about 10% that had prevailed over the previous three decades.

3.5 Point forecasts

In this section, we present evidence regarding the performance of the LT-TVP-FAVAR model based on the point forecasts to justify its use. Specifically, we consider h-step-ahead point forecasts ($h=1,2,3$) and adopt the following rolling window scheme to carry out point forecasts. For $h=1$, as the starting point of the rolling window, we use the first 50 observations from the sample period, Q2-2008 ~ Q3-2020, to estimate the models, which are then used to predict the outcomes for Q4-2020. Then, we move the rolling window one step ahead (i.e., the sample period is from Q3-2008 to Q4-2020) and use the resulting estimates to predict the outcomes for Q1-2021. We proceed recursively in this fashion until Q1-2023 and obtain a sequence of forecasts from Q4-2020 to Q2-2023. Similarly, for $h=2$ and 3. We measure the precision of the h-step-ahead point forecasts using the mean-squared error (MSE):

$$\text{MSE}_h = \frac{1}{\rho}\sum_{t=50+h}^{50+h+\rho}\left(y_t - \hat{y}_t\right)'\left(y_t - \hat{y}_t\right)/m,$$

where ρ denotes the number of rolling windows and $\hat{y}_t$ refers to the predicted values of y_t. To measure the predictive accuracy of y_t on the time dimension, we use the cumulative sum of forecasting errors:

$$\text{CSE}_\tau^h = \sum_{t=50+h}^{\tau}\left(y_t - \hat{y}_t\right)'\left(y_t - \hat{y}_t\right)/m,$$

for $\tau = 50+h,\cdots,50+h+\rho$.

As we consider the impact of tax policy on economic growth from the perspective of total tax revenue and tax structure, there are four cases for y_t (i.e., the tax policy variable z_{2t} in y_t is measured by z_{2t}^{total}, $z_{2t}^{commodity}$, z_{2t}^{income}, and z_{2t}^{other}, respectively). Table 1 reports the results of h-step-ahead point forecasts of the FAVAR, TVP-FAVAR, and LT-TVP-FAVAR models for these four cases[1]. The predictive performance of the LT-TVP-FAVAR over different forecast horizons is clearly better than that of its competitors in all cases, which indicates that it can better analyze the dynamic impact of the tax policy on economic growth and obtain more reliable results.

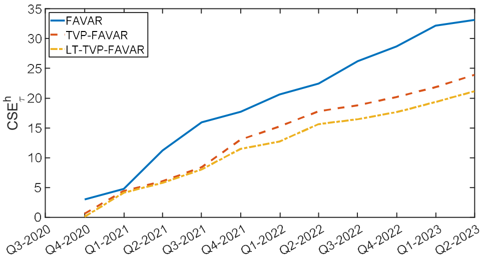
Figures 3–5 plot the CSE_τ^h of the h-step-ahead point forecasts of the three models, which illustrate the increasing path of the predictive error. For $h=1$, the LT-TVP-FAVAR model consistently beats the FAVAR and TVP-FAVAR models for all cases. For $h=2$, the performance

[1] To convince readers better, we also present the results of h-step-ahead point forecasts of three models for the number of factors $k=1$ and 2, respectively, in Appendix B. The results show that the LT-TVP-FAVAR model greatly outperform its competitors in almost all settings.

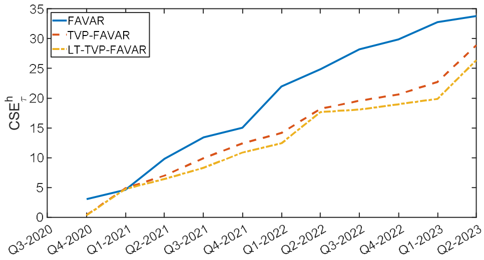
of the LT-TVP-FAVAR model is similar to that of the TVP-FAVAR model in Case 1, whereas the LT-TVP-FAVAR model exhibits much smaller increases in predictive error relative to the FAVAR and TVP-FAVAR models after the initial periods of the COVID-19 pandemic for the other cases. For $h=3$, the LT-TVP-FAVAR model consistently outperforms the FAVAR and TVP-FAVAR models in Cases 2 and 4, while the performance of the LT-TVP-FAVAR model is better than its competitors after Q2-2021 in Cases 1 and 3. These results suggest the LT-TVP-FAVAR model can better capture the economic dynamics during the COVID-19 pandemic than either the FAVAR or TVP-FAVAR models.

Table 1: MSE_h **of the** h **-step-ahead point forecasts of the three different models for the four cases**

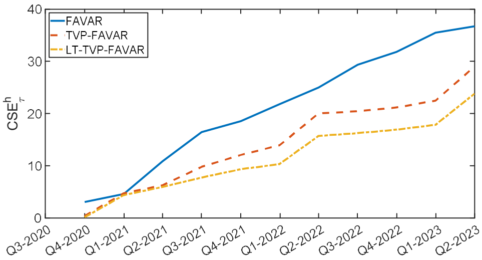
		FAVAR	TVP-FAVAR	LT-TVP-FAVAR
Case 1: $y_t=(f_t',z_{1t},z_{2t}^{total})'$				
	$h=1$	3.01434	2.17521	1.92430
	$h=2$	2.77035	2.03193	2.00936
	$h=3$	2.70593	1.91663	1.67456
Case 2: $y_t=(f_t',z_{1t},z_{2t}^{commodity})'$				
	$h=1$	3.07078	2.62639	2.39809
	$h=2$	2.90686	2.99115	2.65622
	$h=3$	2.57211	2.41037	2.15287
Case 3: $y_t=(f_t',z_{1t},z_{2t}^{income})'$				
	$h=1$	3.33534	2.63594	2.16463
	$h=2$	3.30441	3.28791	2.76160
	$h=3$	3.12716	2.61799	2.40204
Case 4: $y_t=(f_t',z_{1t},z_{2t}^{other})'$				
	$h=1$	2.84017	2.30274	1.95585
	$h=2$	2.36635	2.77777	2.17676
	$h=3$	2.26155	2.02626	1.64786



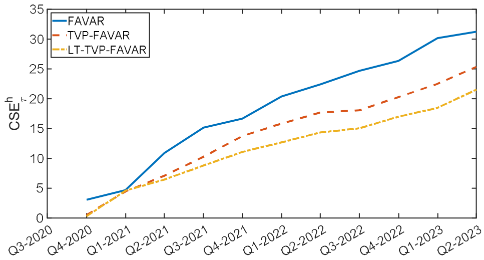
(a) Case 1



(b) Case 2

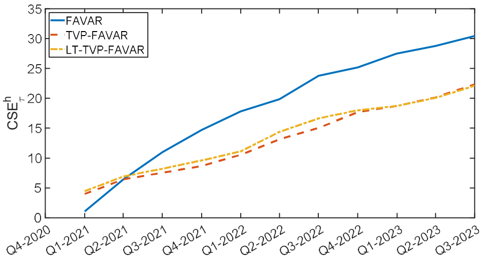


(c) Case 3

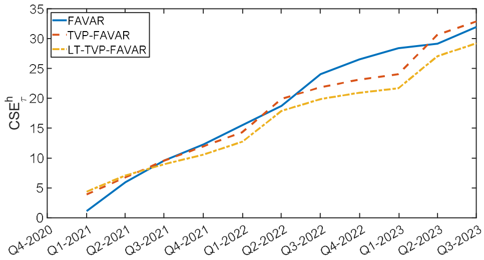


(d) Case 4

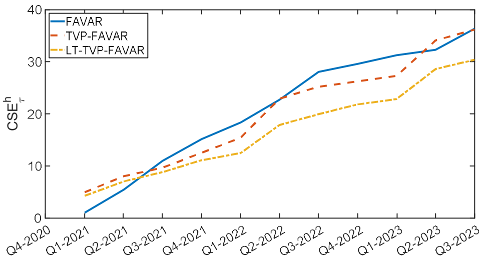
Figure 3: CSE_{τ}^{h} of h-step-ahead point forecasts of the three models with $h=1$ for the four cases



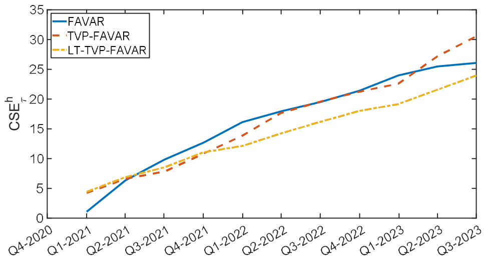
(a) Case 1



(b) Case 2

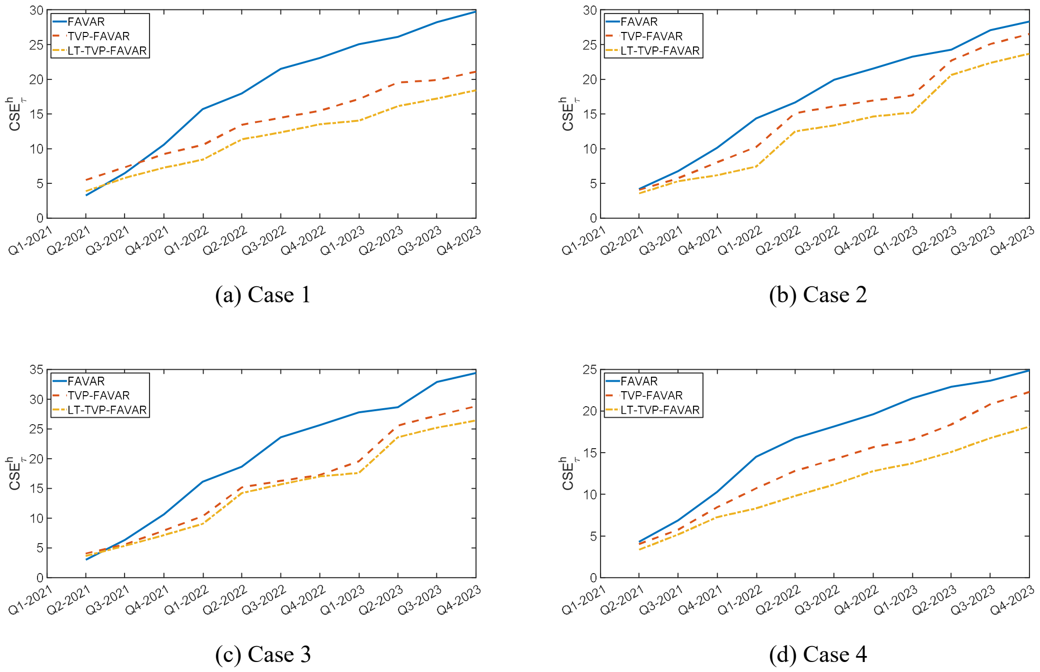


(c) Case 3



(d) Case 4

Figure 4: CSE_{τ}^{h} of h-step-ahead point forecasts of the three models with $h=2$ for the four cases



(a) Case 1 (b) Case 2

(c) Case 3 (d) Case 4

Figure 5: CSE_τ^h **of** h **-step-ahead point forecasts of the three models with** $h=3$ **for the four cases**

4 Impact of tax policy on economic growth

In this section, we present the main results of the dynamic impact of the tax policies on economic growth from the perspective of total tax revenue and then tax structure[1].

4.1 Total tax revenue

This section explores the time-varying impact of total tax revenue on economic growth. First, we depict the temporal evolution of the ratio of total tax revenue to GDP from Q1-2007 to Q4-2023 in Figure 6. We then illustrate the impulse response of economic growth to the shock of total tax revenue in Figure 7.

As shown in Figure 6, the ratio of total tax revenue to GDP fluctuates strongly from Q1-2007 to Q4-2023, initially exhibiting a downward trend during the global financial crisis. There is no doubt that after the outbreak of the global financial crisis, China's economy was in a depressed state due to the impact of the global economy, and effective demand declined significantly. During this period, a large-scale reduction in total tax revenue could effectively promote consumption and investment to alleviate the downturn of the economy and achieve economic recovery as soon as possible. Then, the trend in the ratio of total tax revenue to GDP turned upward and then maintained stable

[1] To validate our baseline results, following Jiménez et al. (2023) we present a robustness exercise using GDP growth rate to replace GDP as the economic growth variable in our model in Appendix C. The results are consistent with our baseline model's main results described in Section 5 (i.e., Conclusion).

fluctuations until 2016 when it again began to decline. China's economy entered a recovery stage after the global financial crisis, which is responsible for the upward trend in total tax revenue. Subsequently, China's economy entered the economic new normal period with total tax revenue remaining stable at first and then exhibiting a descending trend. During this period, the expansionary fiscal policy of a structural tax reduction was the key to achieving stable economic growth in China. Lastly, there is an obvious fluctuation of the ratio of total tax revenue to GDP during the COVID-19 pandemic period. It is undeniable that the unexpected disaster of the COVID-19 pandemic caused profound socioeconomic disruption in China, and is responsible for the fluctuations in total tax revenue.

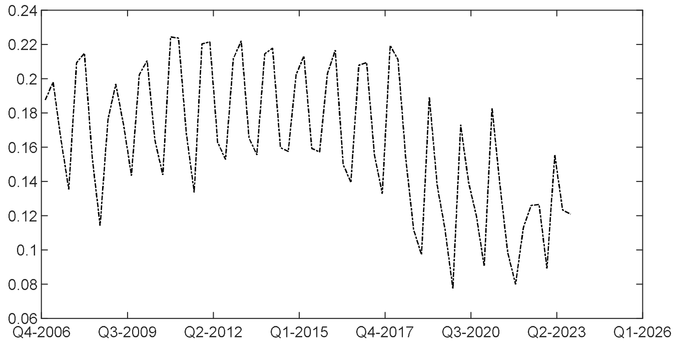
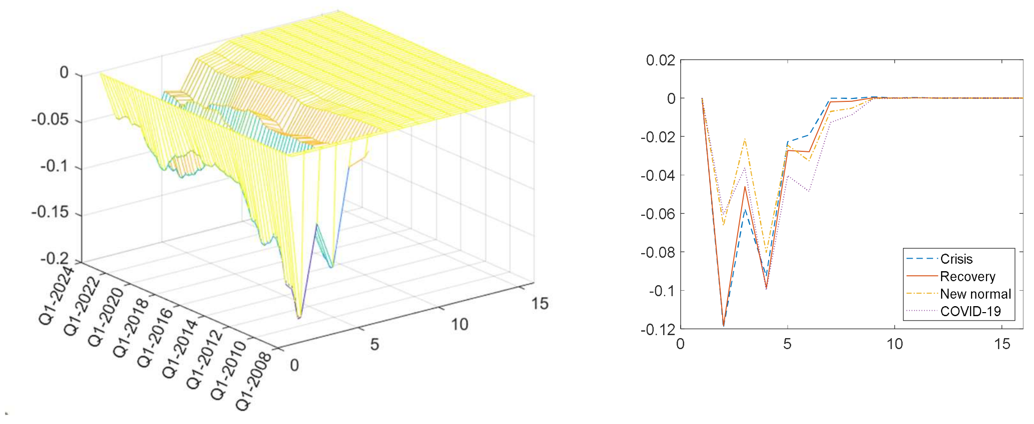


Figure 6: Temporal evolution of the ratio of total tax revenue to GDP (raw data)

Figure 7(a) depicts the impulse response of economic growth to a one-unit positive shock in total tax revenue at different time points. In the three-dimensional graph, the x-axis represents the duration of the impulse response, the y-axis the different time points at which the shock of total tax revenue takes place, and the z-axis is the numerical value of the impulse response function. As shown, the positive shock of total tax revenue from Q2-2008 to Q4-2023 resulted in a negative impulse response of economic growth, which then returns to zero in the ninth quarter after the shock, indicating that the increase in total tax revenue has a negative effect on economic growth sustained over nine quarters.

To better illustrate the impulse responses over different periods, Figure 7(b) plots the cross-time means of the impulse response function values of economic growth to the shock of total tax revenue during the financial crisis, economic recovery, economic new normal, and COVID-19 pandemic periods. As shown, the impact of increasing total tax revenue on economic growth is significantly different before and after the new normal period. Specifically, the economic growth-inhibiting effect of increasing total tax revenue during the financial crisis and economic recovery periods is stronger than those during the economic new normal and COVID-19 pandemic periods. A possible reason is that after the financial crisis, the Chinese government increased investment in some industries, such as heavy industry and infrastructure, in response to the economic downturn, whereas investment in technological research and development (R&D) and elsewhere to improve productivity has decreased, thereby leading to a decline in the rate of economic growth. After China entered the economic new normal period, the Chinese government adopted stable and healthy development and high-quality growth as its goals for economic development, continued to optimize economic structure, and increased its support for emerging high technology industries to improve productivity. These measures made economic growth more resilient, and so the negative impact of increasing total tax revenue on economic growth weakened.



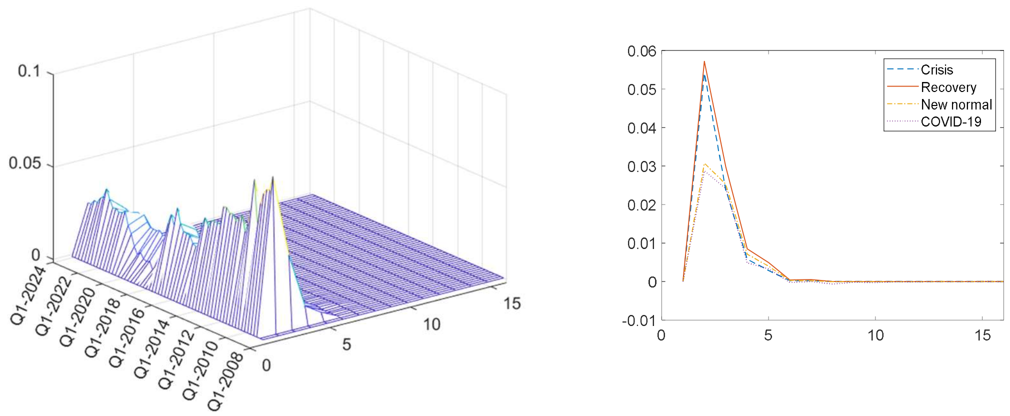
(a) (b)

Figure 7: Impulse response of economic growth to total tax revenue

Overall, from the perspective of total tax revenue, China's tax policy has a dynamic impact on economic growth. During the four periods (i.e., the financial crisis, the economic recovery, the economic new normal, and the COVID-19 pandemic periods), increasing total tax revenue has an inhibiting effect on economic growth, which means that the implementation of proactive fiscal policy (including preferential tax policy and reducing total tax revenue) can promote economic growth effectively by reducing the tax burden of various market economic entities. However, the impact of taxation on economic growth depends not only on total tax revenue, but also on tax structure in that a reasonable tax structure and adaptive structural tax policies are crucial to economic growth. We now explore the dynamic impact of tax policy on economic growth from the perspective of tax structure.

4.2 Tax structure

In this section, we analyze the dynamic impact of tax structure on economic growth, as illustrated in Figures 8, 10, and 11.



(a) (b)

Figure 8: Impulse response of economic growth to commodity tax

Figure 8(a) presents the impulse response of economic growth to a one-unit positive shock of commodity tax at different time points. As shown, the positive shock of commodity tax from Q2-2008 to Q4-2023 causes a positive impulse response of economic growth, which indicates that increasing commodity tax can promote economic growth. A possible reason is that from the perspective of fiscal revenue, commodity tax is the main component of Chinese tax revenue, which helps to ensure the stability of fiscal revenue and then provides financial support for economic development and construction, thereby promoting the production and the operation of enterprises and improving their external environment. In addition, with the continuous improvements in the level of enterprise development and the living standards of residents, increasing commodity tax will prompt consumers to adjust their consumption demands and preferences, and enable enterprises to adjust production decisions and supply structures according to the changes in consumer purchasing decisions. This is conducive to optimizing resource allocation and industrial structure adjustment, and thus promoting economic growth.

Figure 8(b) plots the cross-time means of the impulse response function values of economic growth to the shock of commodity tax during the financial crisis, economic recovery, new normal, and COVID-19 pandemic periods. The impulse response function values of economic growth in the different periods all peak in the second quarter after the commodity tax shock. This indicates that the positive effect of commodity tax on economic growth reaches its maximum in the second quarter after the commodity tax shock. In addition, there is a significant difference in the impact of increasing commodity taxes on economic growth before and after the economic new normal period.

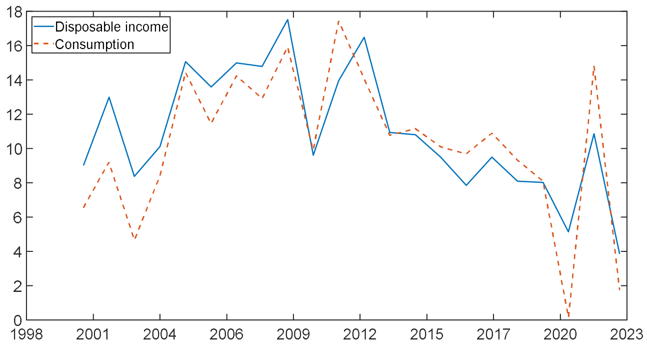
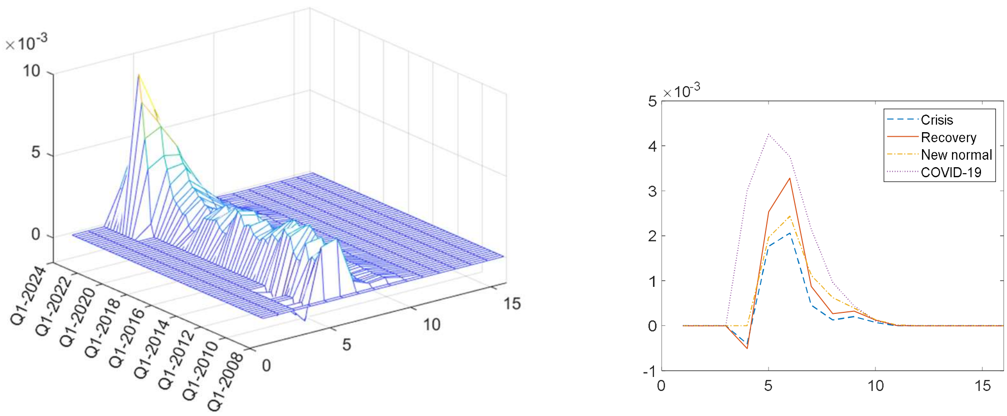


Figure 9: Growth rates of per capita disposable income and consumption in China



(a) (b)

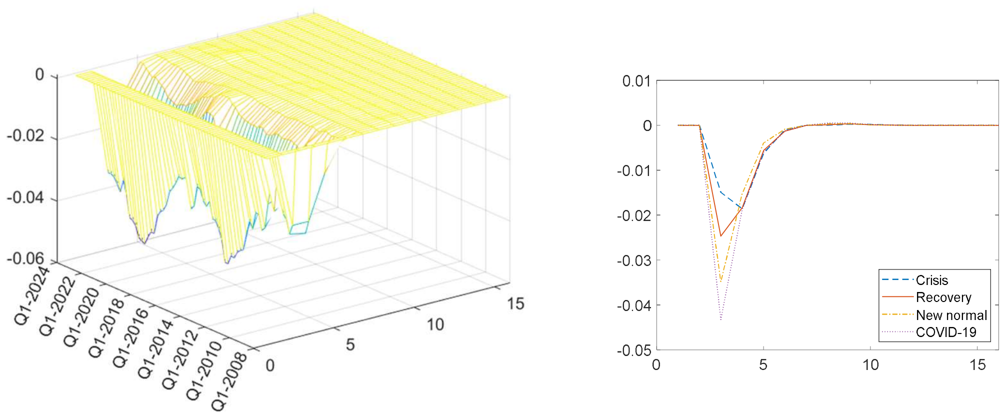
Figure 10: Impulse response of economic growth to income tax

To be specific, an increasing commodity tax has the strongest positive effect on economic growth during the financial crisis and economic recovery periods, and the peaks of the impulse response functions during the financial crisis and economic recovery periods are about double those during the new normal and the COVID-19 pandemic periods. This may be due to the fact that during the financial crisis and economic recovery periods, China's economic development was in a pattern of extensive and rapid growth with household income and consumption on an upward trend as shown in Figure 9, while household income and consumption were on a downward trend after entering the new normal period, with consumer demand then suppressed. Therefore, the positive effect of increasing commodity tax on economic growth by triggering corporate survival decisions and optimizing supply structure adjustments weakens after entering the economic new normal period.

Figure 10(a) presents the impulse response of economic growth to a one-unit positive shock of income tax at different time points. As shown, the positive shock of income tax at each time point causes a positive impulse response of economic growth, and only at some time points does economic growth generate a weak negative response in the early stages after the income tax shock. This means that increasing income tax has a positive effect on economic growth. One possible reason is that income tax, which is levied directly on individuals and enterprises, directly affects the wealth allocation of individuals and enterprises. As for the positive effect, on the one hand, the levying of personal income tax reduces the disposable income of individuals, weakens their real purchasing power and effective demand, and thus encourages them to adjust their consumption structure. This then enables manufacturers to adjust the supply structure according to the changes in consumer demand in the market, promoting the reasonable allocation of social resources and the optimization and upgrading of industrial structure. In addition, personal income tax in China is progressive, which means that the higher the income, the greater the tax burden borne by individuals. This is conducive to adjusting the distribution of income and narrowing the gap between the rich and poor, thereby promoting the healthy development of the economy. On the other hand, the levying of corporate income tax reduces the disposable funds of enterprises, thereby encouraging enterprises to enhance their own competitiveness to increase corporate profits and make up for the capital constraints resulting from higher taxation. Under the dual pressure of tightened corporate capital constraints and the decline in consumer demand, the market can accelerate the elimination of companies that are not sufficiently competitive, such as zombie companies, and the market environment will then improve, leading to the acceleration of the transformation and upgrading of the economic structure, thereby promoting economic growth. A possible reason for the generation of a negative impulse response in the early stages after the income tax shock is that the levying of personal income tax reduces disposable income, which can weaken real purchasing power and effective demand, and thereby manufacturer production incentives, thus suppressing economic growth.

Figure 10(b) depicts the cross-time values of the impulse response function values of economic growth to the shock of income tax shock during the financial crisis, economic recovery, new normal, and COVID-19 pandemic periods. As shown, the positive effect of increasing income tax on economic growth during the COVID-19 pandemic period is obviously stronger than during the other three periods. One possible reason is that the economic pressure faced by China during the COVID-19 pandemic period was more severe. The reason could be that friction and competition in foreign trade between China and other countries intensified during the COVID-19 pandemic period. For example, the United States “decoupled and cut off the supply chains” from China, conducted a “reindustrialization” strategy and implemented the “alternative Asian supply chain” plan. These trade frictions between the US and China enhanced the competitiveness of countries such as Vietnam against China in low-end manufacturing. In addition, China’s high-end manufacturing was also restricted by the United States, which limited the export of high-tech components such as chips to China, resulting in a decline in the competitiveness of Chinese exports.

As for the domestic market, the cumulative year-on-year growth rate of per capita consumer expenditure in China dropped sharply from 17.6% in March 2021 to −0.2% in December 2022. The long-term decline in domestic consumer demand and the intensification of trade friction and competition in foreign trade made the development environment faced by Chinese companies particularly severe during the COVID-19 pandemic period. Therefore, the intensity of the elimination of uncompetitive enterprises caused by increasing income tax during the COVID-19 pandemic period was stronger than during the other three periods. As a result, the positive effect of increasing income tax on economic growth by accelerating the optimization and the upgrading of the industrial structure is also stronger than during the other three periods.



(a) (b)

Figure 11: Impulse response of economic growth to the other tax

Figure 11(a) presents the impulse response of economic growth to a one-unit positive shock of the other tax at different time points. As shown, the other tax at each time point causes a negative impulse response of economic growth, which means that increasing the other tax has an obvious inhibiting effect on economic growth. This is because the other tax includes all of house property, land value-added, vehicle purchase, and other taxes. Therefore, increasing the other tax weakens investors' enthusiasm for investment in physical assets such as real estate and related industries, thereby limiting the development of physical asset markets and then inhibiting economic growth. Conversely, the reduction in the proportion of the other tax is conducive to promoting investment in physical assets such as real estate and other related industries, thereby promoting economic growth.

Figure 11(b) presents the cross-time values of the impulse response function values of economic growth to the other tax shock during the financial crisis, economic recovery, economic new normal, and COVID-19 pandemic periods. The result shows that the negative effect of the other tax shock on economic growth during the economic new normal and COVID-19 pandemic periods is stronger than during the financial crisis and economic recovery periods. A possible reason is that since 2007, the proportion of added value of the real estate industry to GDP in China has gradually increased, and the uptrend of this ratio is especially rapid after China entered the economic new normal period. This indicates that the contribution of the real estate industry to economic growth obviously enhanced after the economic new normal period. Therefore, by inhibiting the development of real estate industry, the inhibitory effect of increasing the other tax on economic growth during the economic new normal and COVID-19 pandemic periods is stronger than during the financial crisis and economic recovery periods.

Overall, commodity, income, and the other tax during different periods have a dynamic impact on economic growth. Increasing commodity and income taxes has a positive effect on economic growth, whereas increasing the other tax has a negative effect on economic growth.

5 Conclusion

This study proposed the LT-TVP-FAVAR model by introducing the latent threshold technology into the TVP-FAVAR model such that it can capture economic dynamics better. We developed an effective two-step method to estimate the LT-TVP-FAVAR model. Extensive point forecasts with different forecasting horizons provide evidence for the strength of the LT-TVP-FAVAR model relative to the FAVAR and TVP-FAVAR models, which indicates that the LT-TVP-FAVAR can capture real economic dynamics better and provide more reliable results for empirical analysis.

Then, we explore the effect of Chinese tax policy on economic growth from the dual perspective of total tax revenue and tax structure. The main empirical conclusions are as follows. First, we find that increasing total tax revenue has a negative effect on economic growth. Moreover, the empirical results also show that as for time variation, this negative effect during the economic new normal and COVID-19 pandemic periods is weaker than during the financial crisis and the economic recovery periods. Second, from the perspective of tax structure, it is found that increasing commodity or income tax has a positive effect on economic growth, while the effect of increasing the other tax is converse. As for time variation, the empirical results show that the positive effect of increasing commodity tax on economic growth during the economic new normal and the COVID-19 pandemic periods is obviously weaker than during the financial crisis and economic recovery periods. The positive effect of increasing income tax on economic growth during the COVID-19 pandemic period is obviously stronger than during other periods. Additionally, the negative impact of increasing the other tax on economic growth during the economic new normal and COVID-19 pandemic periods is obviously stronger than during the financial crisis and economic recovery periods.

These results have implications as follows. First, it is crucial to divide total tax revenue into different categories of tax components for analyzing the impact of tax policy on economic growth. If we focus exclusively on total tax revenue shock, it is evident that increasing total tax revenue would only inhibit economic growth; however, the empirical results of the structural tax shocks suggest that only the other tax shock (instead of commodity tax and income tax shocks) mainly has this inhibitory effect. This indicates that the inhibitory effect of total tax revenue shock on economic growth mainly comes from the other tax rather than from commodity tax or income tax. Hence, only focusing on total tax revenue shock would lead us to miss these insights. For this reason, this study considers the total tax revenue and structural tax shocks, contributing to making up for the vacancy of the literature exploring and contrasting the time-varying effect of China's total tax revenue and tax structure on economic growth. Second, total tax revenue and structural tax shocks both mainly have a positive impact on economic growth in the dimension of time, but these positive effects vary over time. This suggests that it is necessary to keep watch on the changes in the effect of tax policy on economic growth over time so that China's government can make tax policy adapting to the changes in the tax policy effect better in a timely manner.

Since China entered the economic new normal period, China's economic growth has been slowing down gradually. Additionally, the recent COVID-19 pandemic has caused a negative impact on China's economic growth. According to the empirical results above, we also present some policy suggestions below so that China's government can regulate economic growth better using tax policy.

To promote economic growth, China's government should moderately increase the share of commodity and income taxes and strengthen the supervision and taxation of individuals and enterprises. For R&D enterprises, especially innovative small and medium-sized and micro enterprises, appropriate preferential policies such as tax reductions and exemptions can be implemented for R&D to encourage enterprises to improve their innovation capabilities and thus enhance market vitality. Additionally, the share of the other tax should be reduced moderately to promote China's economic growth. This could be achieved, for example, by reducing the proportions of property and vehicle purchase taxes and alleviating the tax burdens on residents for purchasing real estate and vehicles, thereby encouraging households to increase their investment in physical assets such as real estate, which will help promote economic growth.

There are several directions for future research. First, it would be interesting to extend our study by exploring the transmission mechanism of different tax components shock on economic growth. Second, the proposed LT-TVP-FAVAR model in this study is a general model, which can be straightforwardly applied in other contexts in economics and finance, such as monetary policy analysis and financial or economic indices forecasting.

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Appendix A

In this section, we describe the MCMC algorithm in the second step of the two-step estimation method for the LT-TVP-FAVAR model. To describe the MCMC algorithm better, we first introduce some additional notations and undertake some equation transformations. Let $d^b = (d_1^b, \cdots, d_{pm^2}^b)'$, $d_{-i}^b = d^b \setminus d_i^b$, $d^a = (d_1^a, \cdots, d_{m(m-1)/2}^a)'$, $s_t^b = (s_{1t}^b, \cdots, s_{pm^2 t}^b)'$ where $s_{it}^b = I(|\bar{b}_{it}| \geq d_i^b)$ for $i = 1, \cdots, pm^2$, $\bar{b}^T = (\bar{b}_1, \cdots, \bar{b}_T)$, $\bar{b}_{-t}^T = \bar{b}^T \setminus \bar{b}_t$, $\bar{a}^T = (\bar{a}_1, \cdots, \bar{a}_T)$, $\sigma^{2,T} = (\sigma_1^2, \cdots, \sigma_T^2)$, $y^T = (y_1, \cdots, y_T)$, $\Theta_b = (\mu_b, \Phi_b, V_b)$, $\Theta_a = (\mu_a, \Phi_a, V_a)$, and $\Theta_\sigma = (\mu_\sigma, \Phi_\sigma, V_\sigma)$.

Given $A_t v_t = \Sigma_t e_t$, it then follows that

$$\begin{aligned}
\sigma_{1t} e_{1t} &= v_{1t} \\
\sigma_{2t} e_{2t} &= a_{21,t} v_{1t} + v_{2t} \\
\sigma_{3t} e_{3t} &= a_{31,t} v_{1t} + a_{32,t} v_{2t} + v_{3t} \\
&\vdots \\
\sigma_{mt} e_{mt} &= a_{m1,t} v_{1t} + a_{m2,t} v_{2t} + \cdots + a_{mm-1,t} v_{m-1t} + v_{mt}
\end{aligned},$$

which means that for $i = 2, \cdots, m$,

$$\frac{v_{it}}{\sigma_{it}} = -\frac{1}{\sigma_{it}} v^{i-1t'} a_{it} + e_{it}, \tag{A.1}$$

where $v^{i-1t} = (v_{1t} / \sigma_{it}, \cdots, v_{i-1t} / \sigma_{it})'$ and $a_{it} = (a_{i1,t}, \cdots, a_{ii-1,t})'$. Let $m_t = A_t v_t$; then, from $A_t v_t = \Sigma_t e_t$, we have $m_{it} = \sigma_{it} e_{it}$ for $i = 1, \cdots, m$, which means that

$$\log(m_{it}^2) = \log(\sigma_{it}^2) + \log(e_{it}^2). \tag{A.2}$$

Priors $\mu_{b,i} \sim N(\mu_{b0}, w_{b0}^2)$, $\mu_{a,i} \sim N(\mu_{a0}, w_{a0}^2)$, and $\exp(-\mu_{\sigma,i}) \sim G(\mu_{\sigma 0}, w_{\sigma 0})$, where $G(\cdot)$ denotes the gamma distribution, and $\mu_{b,i}$, $\mu_{a,i}$, and $\mu_{\sigma,i}$ denote the i-th elements of μ_b, μ_a, and μ_σ, respectively. $(\Phi_{b,i} + 1)/2 \sim B(\varphi_{b0}, \pi_{b0})$, $(\Phi_{a,i} + 1)/2 \sim B(\varphi_{a0}, \pi_{a0})$, and $(\Phi_{\sigma,i} + 1)/2 \sim B(\varphi_{\sigma 0}, \pi_{\sigma 0})$, where $B(\cdot)$ denotes the beta distribution, and $\Phi_{b,i}$, $\Phi_{a,i}$, and $\Phi_{\sigma,i}$ denote the i-th diagonal elements of Φ_b, Φ_a, and Φ_σ, respectively. $V_{b,i}^{-2} \sim G(\alpha_{b0}/2, S_{b0}/2)$, $V_{a,i}^{-2} \sim G(\alpha_{a0}/2, S_{a0}/2)$, and $V_{\sigma,i}^{-2} \sim G(\alpha_{\sigma 0}/2, S_{\sigma 0}/2)$, where $V_{b,i}$, $V_{a,i}$, and $V_{\sigma,i}$ denote the i-th diagonal elements of V_b, V_a, and V_σ, respectively. $\bar{b}_{i1} | \Theta_b \sim N(\mu_{b,i}, v_{b,i}^2)$ and $\bar{a}_{i1} | \Theta_a \sim N(\mu_{a,i}, v_{a,i}^2)$, where $v_{b,i}^2 = V_{b,i} / (1 - \Phi_{b,i}^2)$ and $v_{a,i}^2 = V_{a,i} / (1 - \Phi_{a,i}^2)$. Additionally, $d_i^b | \mu_{b,i}, \Phi_{b,i}, V_{b,i} \sim U(0, |\mu_{b,i}| + K v_{b,i})$ and $d_j^a | \mu_{a,j}, \Phi_{a,j}, V_{a,j} \sim U(0, |\mu_{a,j}| + K v_{a,j})$, where $U(\cdot)$ denotes the uniform distribution. Following Nakajima and West (2013), we set $\mu_{b0} = \mu_{a0} = 0$, $w_{b0}^2 = w_{a0}^2 = 1$, $\mu_{\sigma 0} = 3$, $w_{\sigma 0} = 0.03$, $\varphi_{b0} = \varphi_{a0} = \varphi_{\sigma 0} = 20$, $\pi_{b0} = \pi_{a0} = \pi_{\sigma 0} = 1.5$, $\alpha_{b0} = 40$, $\alpha_{a0} = \alpha_{\sigma 0} = 4$, $S_{b0} = S_{a0} = S_{\sigma 0} = 0.02$, and $K = 3$.

Step 1: drawing $\bar{b}_t$

Conditional on $(\Theta_b, d^b, \bar{a}^T, \sigma^{2,T}, y^T)$, we draw the conditional posterior $p(\bar{b}_t \mid \bar{b}_{-t}^T)$ sequentially for $t = 1, \cdots, T$ using a Metropolis–Hastings (MH) sampler. The MH proposals come from a non-threshold version of the LT-TVP-FAVAR model at each time $t = 1, \cdots, T$. Specifically, for $t = 2, \cdots, T-1$, we fix $s_{t,i}^b = 1$ (where $s_{t,i}^b$ denotes the i-th element in s_t^b) and take a proposal distribution $N(\bar{b}_t \mid \varpi_t, M_t)$ where

$$
\begin{aligned}
M_t^{-1} &= X_t' \Omega_t^{-1} X_t + V_b^{-1}(I + \Phi_b' \Phi_b), \\
\varpi_t &= M_t \left\{ X_t' \Omega_t^{-1} y_t + V_b^{-1} \left[\Phi_b (\bar{b}_{t-1} + \bar{b}_{t+1}) + (I - 2\Phi_b + \Phi_b' \Phi_b) \mu_b \right] \right\}.
\end{aligned}
$$

For $t = 1$ and $t = T$, we take proposal distributions $N(\bar{b}_1 \mid \varpi_1, M_1)$ and $N(\bar{b}_T \mid \varpi_T, M_T)$, where

$$
\begin{aligned}
M_1^{-1} &= X_1' \Omega_1^{-1} X_1 + V_{b0}^{-1} + V_b^{-1} \Phi_b' \Phi_b, \\
\varpi_1 &= M_1 \left\{ X_1' \Omega_1^{-1} y_1 + V_{b0}^{-1} \mu_b + V_b^{-1} \Phi_b \left[\bar{b}_2 - (I - \Phi_b) \mu_b \right] \right\},
\end{aligned}
$$

and

$$
\begin{aligned}
M_T^{-1} &= X_T' \Omega_T^{-1} X_T + V_b^{-1}, \\
\varpi_T &= M_T \left\{ X_T' \Omega_T^{-1} y_T + V_b^{-1} \left[\Phi_b \bar{b}_{T-1} + (I - \Phi_b) \mu_b \right] \right\},
\end{aligned}
$$

where $V_{b0} = \mathrm{diag}(v_{b,1}^2, \cdots, v_{b,pm^2}^2)$. The candidate is accepted with probability

$$
\alpha(\bar{b}_t, \bar{b}_t^*) = \min \left\{ 1, \frac{N(y_t \mid X_t b_t^*, \Omega_t) N(\bar{b}_t \mid \varpi_t, M_t)}{N(y_t \mid X_t b_t, \Omega_t) N(\bar{b}_t^* \mid \varpi_t, M_t)} \right\},
$$

where $b_t^* = (b_{1t}^*, \cdots, b_{pm^2 t}^*)$ with $b_{it}^* = \bar{b}_{it}^* \cdot I(|\bar{b}_{it}^*| \geq d_i^b)$ for $i = 1, \cdots, pm^2$.

Step 2: drawing $\bar{a}_t$

Conditional on $(\Theta_a, d^a, \bar{b}^T, \sigma^{2,T}, y^T)$, we draw $\bar{a}_t$ using the same MH algorithm as $\bar{b}_t$ based on the equations (4), (6), and (A.1).

Step 3: drawing σ_t^2

Conditional on $(\Theta_\sigma, \bar{b}^T, \bar{a}^T, y^T)$, we draw σ_t^2 using the standard forward-filtering and backward-sampling algorithm (e.g., Primiceri, 2005; Zhao and Liu, 2021) for equations (7) and (A.2).

Step 4: drawing Θ_b***,*** Θ_a***, and*** Θ_σ

For Θ_b, conditional on $(\bar{b}^T, d^b, y^T)$, drawing of the parameters Θ_b reduces to generation from conditionally independent posterior $p(\mu_{b,i}, \Phi_{b,i}, V_{b,i}, \mid \bar{b}^T, d_i^b)$ for $i = 1, \cdots, pm^2$. First, the conditional posterior density of $\mu_{b,i}$ is

$$p(\mu_{b,i} \mid \Phi_{b,i}, V_{b,i}, \beta^T, d_i^b) \propto TN(\mu_{b,i} \mid \hat{\mu}_{b,i}, \hat{w}_{b,i}^2)(|\mu_{b,i}| + Kv_{b,i})^{-1},$$

where TN denotes the density of a truncated normal for $\mu_{b,i}$ on $\{\mu_{b,i} : d_i^b < |\mu_{b,i}| + Kv_{b,i}\}$ and

$$\hat{w}_{b,i}^2 = \left[\frac{1}{w_{b0}^2} + \frac{(1-\Phi_{b,i}^2) + (T-1)(1-\Phi_{b,i})^2}{V_{b,i}} \right]^{-1},$$

$$\hat{\mu}_{b,i} = \hat{w}_{b,i}^2 \left[\frac{\mu_{b0}}{w_{b0}^2} + \frac{(1-\Phi_{b,i}^2)\bar{b}_{i1} + (1-\Phi_{b,i})\sum_{t=1}^{T-1}(\bar{b}_{it+1} - \Phi_{b,i}\bar{b}_{it})}{V_{b,i}} \right].$$

A MH step draws a candidate $\mu_{b,i}^*$ from this truncated normal distribution, accepting the draw with probability

$$\min\left\{1, \frac{|\mu_{b,i}| + Kv_{b,i}}{|\mu_{b,i}^*| + Kv_{b,i}}\right\}.$$

Second, the conditional posterior density of $\Phi_{b,i}$ is

$$p(\Phi_{b,i} \mid \mu_{b,i}, V_{b,i}, \beta^T, d_i^b)$$
$$\propto B(\varphi_{b0}, \pi_{b0})(1-\Phi_{b,i}^2)^{1/2} TN_{(-1,1)\times E_i}(\mu_{b,i} \mid \hat{\Phi}_{b,i}, \sigma_{\Phi_{b,i}}^2)\left[|\mu_{b,i}| + KV_{b,i}^{1/2} / (1-\Phi_{b,i}^2)^{1/2} \right]^{-1},$$

where $\hat{\Phi}_{b,i} = \sum_{t=1}^{T-1} \tilde{b}_{it+1}\tilde{b}_{it} / \sum_{t=2}^{T-1} \tilde{b}_{it}^2$, $\sigma_{\Phi_{b,i}}^2 = V_{b,i} / \sum_{t=2}^{T-1} \tilde{b}_{it}^2$, $\tilde{b}_{it} = \bar{b}_{it} - \mu_{b,i}$, and E_i is the truncation region $E_i = \{\Phi_{b,i} : d_i^b < |\mu_{b,i}| + KV_{b,i}^{1/2} / (1-\Phi_{b,i}^2)^{1/2}\}$. A MH step draws a candidate $\Phi_{b,i}^*$ from this truncated normal, accepting the draw with probability

$$\min\left\{1, \frac{B(\Phi_{b,i}^* \mid \varphi_{b0}, \pi_{b0})(1-\Phi_{b,i}^{*2})^{1/2}\left[|\mu_{b,i}| + KV_{b,i}^{1/2} / (1-\Phi_{b,i}^2)^{1/2} \right]}{B(\Phi_{b,i} \mid \varphi_{b0}, \pi_{b0})(1-\Phi_{b,i}^2)^{1/2}\left[|\mu_{b,i}| + KV_{b,i}^{1/2} / (1-\Phi_{b,i}^{*2})^{1/2} \right]}\right\}.$$

Third, the conditional posterior density of $V_{b,i}^{-1}$ is

$$p(V_{b,i}^{-1} \mid \mu_{b,i}, \Phi_{b,i}, \beta^T, d_i^b)$$
$$\propto TG(V_{b,i}^{-1} \mid \hat{V}_{b,i}/2, \tilde{V}_{b,i}/2)\left[|\mu_{b,i}| + KV_{b,i}^{1/2} / (1-\Phi_{b,i}^2)^{1/2} \right]^{-1},$$

where TG is the density of the implied gamma distribution truncated to
$V_{b,i}^{-1}\left\{V_{b,i}^{-1} : d_i^b < |\mu_{b,i}| + KV_{b,i}^{1/2} / (1-\Phi_{b,i}^2)^{1/2}\right\}$, and

$$\hat{V}_{b,i} = \alpha_{b0} + T, \quad \tilde{V}_{b,i} = S_{b0} + (1-\Phi_{b,i}^2)\tilde{b}_{i1}^2 + \sum_{t=1}^{T-1}(\tilde{b}_{it+1} - \Phi_{b,i}\tilde{b}_{it})^2.$$

A MH step draws a candidate $1/V_{b,i}^*$ from this truncated gamma distribution, accepting the draw with probability

$$\min\left\{1, \frac{|\mu_{b,i}| + KV_{b,i}^{1/2} / (1-\Phi_{b,i}^2)^{1/2}}{|\mu_{b,i}| + KV_{b,i}^{*1/2} / (1-\Phi_{b,i}^2)^{1/2}}\right\}.$$

Lastly, for Θ_a, conditional on $(\bar{a}^T, d^a, y^T)$, we use the same algorithm as Θ_b to draw the parameter Θ_a. For Θ_σ, conditional on $(\sigma^{2,T}, y^T)$, we draw the parameter Θ_σ following the same drawing strategy as Θ_b, although this does not require the rejection step associated with the thresholds.

Step 5: drawing d^b **and** d^a

Conditional on the other parameters, we adopt a direct MH algorithm to draw the conditional posterior distribution of d^b and d^a. Specifically, for d^b, conditional on $(\Theta_b, \Theta_a, \Theta_\sigma, d_{-i}^b, d^a, \bar{b}^T, \bar{a}^T, \sigma^{2,T}, y^T)$, a candidate is drawn from the conditional prior, $d_i^{b*} \sim U(0, |\mu_{b,i}| + Kv_{b,i})$, and accepted with probability

$$\alpha(d_i^b, d_i^{b*}) = \min\left\{1, \prod_{t=1}^{T} \frac{N(y_t \mid X_t b_t^*, \Omega_t)}{N(y_t \mid X_t b_t, \Omega_t)}\right\},$$

where b_t is the state based on the current thresholds (d_{-i}^b, d_i^b) and b_t^* is the candidate based on (d_{-i}^b, d_i^{b*}). Similarly for drawing d^a.

Appendix B

In this section, Tables B.1 and B.2 present the results of h-step-ahead point forecasts of three models in four cases for the number of factors $k=1$ and 2, respectively. Obviously, the LT-TVP-FAVAR model greatly beat its competitors in almost all settings.

Appendix C

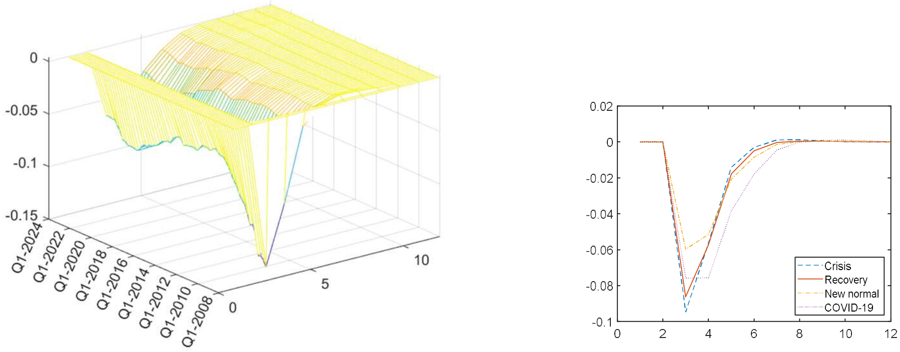
In this section, we provide a robustness exercise using GDP growth rate to replace GDP as the economic growth variable in our model to validate our baseline results. Figure C.1 presents impulse responses of economic growth to different tax categories, which are consistent with our baseline model's main results described in Section 5.

Table B.1: MSE_h **of the** h **-step-ahead point forecasts of the three models for** $k=1$

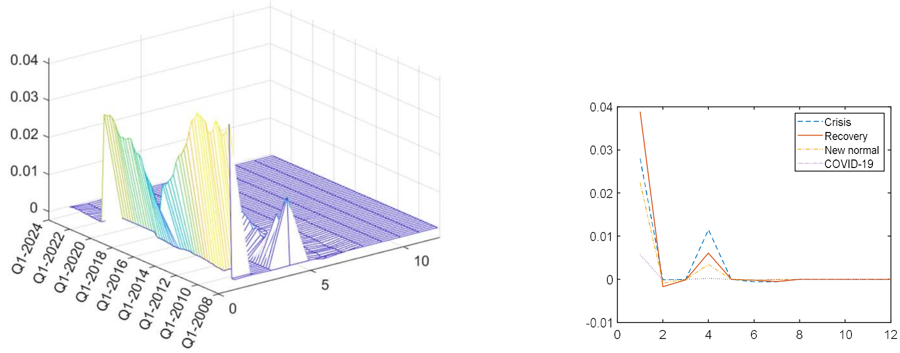
		FAVAR	TVP-FAVAR	LT-TVP-FAVAR
Case 1: $y_t=(f_t',z_{1t},z_{2t}^{total})'$				
	$h=1$	1.75243	1.57119	1.54745
	$h=2$	1.66875	1.63742	1.63706
	$h=3$	1.44861	1.16304	1.08313
Case 2: $y_t=(f_t',z_{1t},z_{2t}^{commodity})'$				
	$h=1$	2.44825	2.65160	2.19407
	$h=2$	2.54196	2.65734	2.27948
	$h=3$	2.01231	2.51549	1.95475
Case 3: $y_t=(f_t',z_{1t},z_{2t}^{income})'$				
	$h=1$	2.58501	3.28544	2.69477
	$h=2$	3.15748	3.43661	2.80326
	$h=3$	2.59728	3.04148	2.35254
Case 4: $y_t=(f_t',z_{1t},z_{2t}^{other})'$				
	$h=1$	1.93372	1.53218	1.41288
	$h=2$	1.58861	1.88940	1.54805
	$h=3$	1.20955	1.04554	1.04627

Table B.2: MSE_h **of the** h **-step-ahead point forecasts of the three models for** $k = 2$

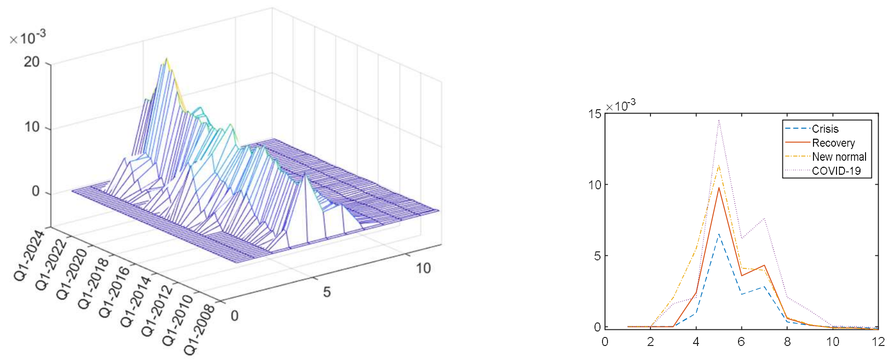
		FAVAR	TVP-FAVAR	LT-TVP-FAVAR
Case 1: $y_t = (f_t', z_{1t}, z_{2t}^{total})'$				
	$h = 1$	2.71946	2.00456	1.95171
	$h = 2$	2.87303	2.32734	2.05072
	$h = 3$	3.02303	1.28287	1.29865
Case 2: $y_t = (f_t', z_{1t}, z_{2t}^{commodity})'$				
	$h = 1$	3.12862	2.95477	2.39633
	$h = 2$	3.16231	3.14398	2.67616
	$h = 3$	3.03372	2.07328	1.73457
Case 3: $y_t = (f_t', z_{1t}, z_{2t}^{income})'$				
	$h = 1$	3.11200	2.78520	2.47288
	$h = 2$	3.56867	4.04203	3.11850
	$h = 3$	3.49837	2.58684	2.03723
Case 4: $y_t = (f_t', z_{1t}, z_{2t}^{other})'$				
	$h = 1$	2.79053	2.14128	1.91014
	$h = 2$	2.58820	2.17155	1.92750
	$h = 3$	2.57924	1.08065	1.16227



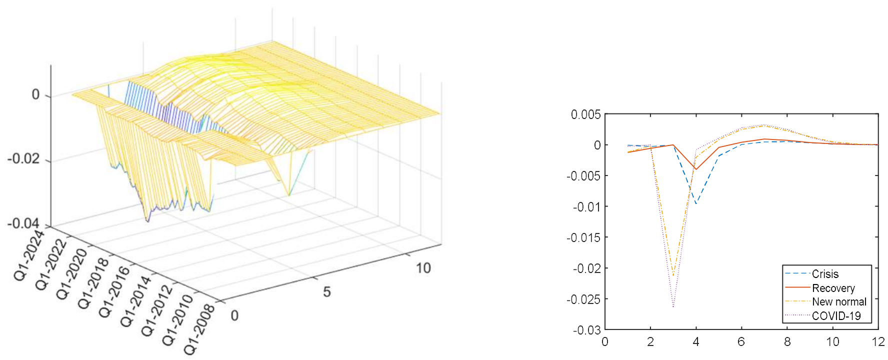
(a) Impulse response of economic growth to total tax revenue



(b) Impulse response of economic growth to commodity tax



(c) Impulse response of economic growth to income tax



(d) Impulse response of economic growth to the other tax

Figure C.1: Impulse responses of economic growth to different tax categories