Fiscal Policy and the Government Debt Maturity Structure

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Abstract

This paper studies the attenuating effects of government debt maturity structure on the transmission of fiscal policy shocks. I use local projection methods with external instrumental variables to show that longer maturity or duration significantly dampens the output expansionary and inflationary effects of fiscal policy. A model of fiscal theory of price level is able to nicely rationalize my empirical findings. The main mechanism is that longer duration of the debt portfolio allows the government to exploit more capital gains against the private investors in face of a deficit shock, reducing the desire to inflate away existing debt.

1. Introduction

The US fiscal stimulus in response to the Covid pandemic has been swift and normous. According to the National Income and Product Account (NIPA), the US government current expenditures amount to 45% of GDP in the second quarter of 2020. This number is much larger than what we saw in the 2008 financial crisis, where the current expenditure-to-GDP ratio peaked at 25% in the first quarter of 2010. Throughout the pandemic, the Covid-related unprecedented fiscal relief packages included: the Coronavirus Preparedness and Response Supplemental Appropriations Act, the Families First Coronavirus Response Act (FFCRA), the Coronavirus Aid, Relief, and Economic Security Act (CARES), the Consolidated Appropriations Act (CAA), the American Rescue Plan Act, and a number of executive orders issued by President Trump and President Biden.

The massive fiscal response in face of the Covid crisis has renewed our interest in the effects of fiscal policy and the transmission of fiscal policy shocks. In this paper, I provide answers the following two questions: i) What are the macroeconomic effects of fiscal policy stimulus? ii) How does the maturity structure of the government debt affect the transmission

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of fiscal policy shocks? The first question has been studied for decades using structural vector auto-regressions (SVAR), but there is a lack of consensus in the effects of size of fiscal policy shocks (Ramey, 2019). This lack of consensus comes from different identification approaches such as Cholesky decomposition and sign restrictions. Althou SVAR has been the major empirical method in estimating causal effects and calculating impulse responses, this paper uses local projections with external instrumental variables (Jordà, 2005; Stock and Watson, 2018) for causal effects and impulse responses. Local projections are able to consider the local approximations for each horizon of impulse responses and are more robust to model misspecification. In this sense, it may be superior to the SVAR method. The second question, which looks into the interaction between the government debt maturity structure and the transmission of fiscal policy shocks, has not been analyzed much in the literature as far as I know. Both theoretical works and empirical works are almost non-existent on this topic. This paper tries to provide a first investigation into the impact of maturity composition on fiscal policy stimulus. This may prove significance in future fiscal policy designs and implementations.

In the empirical part of our paper, I first explore the macroeconomic effects of changes in government expenditures. Using local projections with external instruments, I show that a fiscal stimulus increases output and inflation. This is consistent with most existing works that government spending is expansionary and inflationary. Hence, the unprecedented massive fiscal stimulus may be the reason why we have been experiencing a recent surge in inflation after the pandemic (The reasons for excess inflation after the pandemic is not the focus of this paper). My empirical impulse responses reveal some new interesting facts. First, the primary surplus process exhibit the s-shaped property (Cochrane, 2019): current deficits will be followed by future surplus because government borrowing today requires promises of future surplus to repay the debt. Second, both short term and long term interest rates slightly decline in the short run and rise in the medium run. The slight decline of interest rates may be evidence of the coordination of fiscal policy and monetary policy in face of recessions. Eventually, interest rates go up in response to an expansionary fisca policy shock because the monetary authority raises rates according to the increase of output and inflation.

By exploiting the repealing of interest rate ceiling law (forbidding the Treasury to issue debt with interest rates above 4.25%) in 1988, I show that longer maturity of government debt attenuates the effects of fiscal policy. Due to this interest rate ceiling law, we can view the pre-1988 period and the post-1988 period as two maturity regimes. Maturity structure measured by short debt to long debt ratio[1], percentage share of short debt, market value

[1]Throughout the paper, short debt is defined as debt maturing less than a year, and long debt is defined as debt maturing over a year.

weighted average maturity level, and duration to GDP ratio (Andreolli, 2021) confirm the stylized fact that the government debt maturity and duration is significantly higher post 1988 than pre 1988. Using local projections with external instruments and interaction terms, I show that the effects of fiscal policy stimulus on output, inflation, interest rates, and market value debt/GDP are dampened when the debt maturity/duration is higher. This is the main novel result in this paper and it is subject to a number of robustness checks including different instrumental variables used in identification and different maturity measures.

The previous empirical results can be understood from the perspective of the fiscal theory of price level (FTPL). The foundation of FTPL is that the real market value of government liabilities is equal to the PV of future real primary surplus. Price level is determined by future fiscal variables such that this equality holds. This theory gives a central role to fiscal policy in price level determination. I present a simple linearized FTPL model (Cochrane, 2019; Cochrane, 2022) to rationalize my empirical results. In response to a deficit shock, the government will finance the deficit by both issuing new debt and devaluing existing debt with higher inflation. Increasing the price level and inflation is the tool for the fiscal authority to erode the real value of existing nominal liabilities. This devaluation of government debt makes it less attractive to investors. As a result, investors turn to buy more real assets, goods and services. This boosts aggregate demand so that output will increase. On one hand, since the monetary authority typically sets interest rates according to output gap and inflation, interest rates will increase following the increase of output and inflation. On the other hand, debt holders may demand higher yield anticipating higher future inflation. So far, I have shown that the model-implied impulse responses to deficit shocks match very well with empirical evidence. This can be interpreted as a test of the FTPL proving that the theory works well with the US data.

I estimate the model parameters by matching the model-implied and empirical impulse responses. Using the estimated model as a laboratory, I conduct counter-factual analysis to study the different maturity regime by varying the maturity structure coefficient. Again, this theoretical analysis speaks to my empirical results that fiscal policy effects are attenuated with higher government debt maturity/duration. Imagine that if there were only short debt maturing right next period, the beginning-of-period market value of the government debt portfolio would be fixed at the face value. Then all the impact of deficit shocks has to be fully absorbed by inflation in the current period such that the real market value of debt equals to the present value of surplus. When long term debt exists, expected future inflation reduces the price of long term debt and the government achieve a capital gain against the private sector. Hence, the market value of the government debt portfolio has already been eroded via the long debt channel, which buffers the need to increase inflation. As a result, the effects of deficit shocks on inflation will be smaller. The output expansionary effects will also be smaller because the inflationary effects are smaller.

Related literature and contributions. This paper mainly contributes to the empirical literature of fiscal policy transmission. SVAR has been the workhorse empirical specification for decades. Blanchard and Perotti (2002) identifies government spending shocks in an SVAR by ordering variables and using Cholesky decomposition. This identification approach requires a strict restriction on the impact matrix of SVAR. For example, their paper orders government spending first and assumes that spending is not responsive to other structural shocks within the quarter. They found that government spending shocks raise output, working hours, consumption, and real wages. Mountford and Uhlig (2009) identifies government spending shocks in an SVAR using sign restrictions and orthogonality conditions. They also find that spending shocks are expansionary. Ramey (2011) brings up the issue of fiscal foresight and argues that SVAR-identified shocks are anticipated in advance so that they are not unanticipated shocks. She attempts to solve this issue by including a military defense news series in the SVAR. The fiscal news shocks are identified by ordering the news first and Cholesky decomposition. Ramey and Zubairy (2018) is the first paper using the military news series as an instrument in a local projection approach to study the effects of government spending on output. They also ask whether the spending effects vary in different state of the economy. In specific, they find no evidence that the fiscal policy has different effects in periods of economic slack or when interest rates are near the zero lower bound (ZLB). Ramey (2016) and Ramey (2019) give thorough reviews of this line of literature.

My contribution to this line of literature is two fold. First, apart from the output effects that the literature has mainly focused on, I also show robust fiscal policy effects on inflation, interest rates, primary surplus, and government debt market value to GDP. Especially the s-shaped surplus response provides ample empirical support to the model specification in Cochrane's FTPL models. Second and most importantly, I explore the bigger question asked by Ramey and Zubairy (2018) that whether the effects of fiscal policy vary in different state of the economy. In specific, this paper is the first to find that fiscal policy effects depend on the maturity structure of government debt and that higher maturity attenuate the effects of fiscal policy.

The empirical evidence in this paper is shown to be consistent with the predictions of the fiscal theory of price level. This is a relatively new theory aiming to reconcile the fiscal side of the economy with the conventional New Keynesian theories. Influential works on FTPL include Leeper (1991), Sims (1994), Woodford (1994), Cochrane (2001), Sims (2013), Leeper and Leith (2016), Cochrane (2019), Cochrane (2022), etc. My slight contribution to this literature is on the empirical side: I provide empirical support to FTPL-type models.

This paper is also related to the following topics. Using surprise inflation to devalue existing government liabilities has been discussed by Giannitsarou et al. (2006), Hall and Sargent (2011), Krause and Moyen (2016), Hilscher et al. (2022), etc. Although I do not focus on the size and motivations of inflating away existing liabilities, I do provide empirical evidence to this idea. Optimal government debt maturity structure is also an important topic in the literature. Previous works focus on trading off the benefits and costs of long and short debt and discuss the optimal maturity structure of debt. Influential papers include Angeletos (2002), Buera and Nicolini (2004), Nosbusch (2008), Lustig et al. (2008), Greenwood et al. (2015), Bhandari et al. (2021), etc. Although this paper abstract from the optimal choice of maturity structure, my findings imply a different angle that may be important in the consideration of optimal maturity structure: different maturity regimes have different implications on the fiscal policy effects.

Paper structure. The remainder of the paper is structured as follows.Section 2 describes the empirical methodology and identification method. Section 3 presents the main empirical results regarding the effects of fiscal policy stimulus and the attenuation effects of longer maturity on fiscal policy transmission. Section 4 examines the economic mechanism behind my empirical results from the perspective of the fiscal theory of price level. Section 5 presents and estimates a FTPL model from Cochrane (2022). Section 6 connects the model-implied impulse responses to a deficit shock to my previous empirical impulse responses, and uses the model as a laboratory to conduct counter-factual analysis on the fiscal policy effects in different maturity regimes. Section 7 concludes and discuss future directions[2].

2. Empirical Methodology and Identification

A major goal of this paper is to empirical identify the macroeconomic effects of fiscal policy shocks and examine how the maturity structure impact the effects of fiscal policy shocks on the macro-economy. In section **??**, I discuss the main empirical specification: local projections. Section 2.2 describes the identification method via instrumental variables, choice of instruments, and the test for their relevance in the first stage. Section 2.3 compares local projections and SVAR and explains the reason why I choose the former as my main empirical design.

[2] Appendix A describes the data constructions and sources. Appendix B provides a detailed econometric discussion of identification via local projections with external instruments. Appendix C conducts robustness checks and sensitivity analysis on my empirical results. Appendix D shows the derivation of model equations. Appendix E provides a detailed discussion of the modeling technique of the s-shaped primary surplus process.

2.1. Empirical method: Local Projections

Local projections (Jordà (2005)) are used to estimate the effects of fiscal policy stimulus on macroeconomic outcomes. Because I am also interested in the differential effects of fiscal policy with different maturity structure, a naturla design is to interact a measure of maturity structure with the fiscal policy stimulus.

$$y_{t+h} = \beta_{0,h} + \beta_{1,h} \cdot \Delta g_t + \beta_{2,h} \cdot Controls_t + \varepsilon_{t+h} \tag{1}$$

$$y_{t+h} = \beta_{0,h} + \beta_{1,h} \cdot \Delta g_t + \beta_{2,h} \cdot \Delta g_t \cdot MaturityMeasure_{t-1} + \beta_{3,h} \cdot Controls_t + \varepsilon_{t+h} \tag{2}$$

Equation (1) estimates the effects of fiscal policy stimulus. y_{t+h} denotes the outcome variable h periods ahead, Δg_t denotes the changes in real government spending. Outcome variables include output gap, inflation, government debt portfolio return, privately held market value debt to GDP, 3-month short yield, 10-year long yield, and TFP changes. Control variables include 3 lags of the above variables. Data constructions and sources are discussed in Appendix A. The coefficient of interests is $\beta_{1,h}$, which I estimate for $h = 1, 2, ..., 20$ quarters.

Equation (2) explores the effects of government spending changes conditional on the maturity structure measure. The coefficients of interests are $\beta_{1,h}$ and $\beta_{2,h}$, which I estimate for $h = 1, 2, ..., 20$ quarters. First, I construct the following 4 maturity measures: i) short debt outstanding quantities to long debt ratio; ii) percentage share of short debt outstanding quantities; iii) market value weighted average maturity level; iv) duration to GDP ratio. Fig 1 shows the above 4 maturity measures from 1969Q1 to 2022Q2. Among the 4 measures, duration/GDP may be the most important metric for the fiscal authority as it measures the amount of interest rate exposure over GDP. This metric is constructed by Andreolli (2021) and used in his paper to study the impact of government debt maturity structure on monetary policy shocks.

However, I argue that directly using these maturity measures in the interaction term in equation (2) would be confusing and misleading. This is because according to the regression design with the previous maturity measure in the interaction term, we are implicitly assuming that a change in the maturity would have a immediate linear effects on the policy transmission. This implicit assumption is hardly true. In this paper, I try two different ways to alleviate this problem. Firstly, instead of directly using the previous period maturity measure, I compute the average value of previous 8 quarters for duration/GDP and use this average value in the interaction term. This specification is more intuitive because the previous 2-year average value can be a better measure of duration-related state of the economy. Secondly, I exploit the fact that pre-1988 and post-1988 are naturally two different maturity regimes by US legislations. A law was instituted in 1918 (Friedman and Schwartz, 2008) forbidding the US Treasury to issue government debt with interest rates above 4.25%. Before 1960s, this law was not restrictive since the interest rates were low. Entering the 60s, Friedman and Schwartz (2008) argued that this interest rate ceiling law started to bind as interest rates in the US kept going up, driving the US Treasury to lower the maturity. This historical description corresponds to the shortening of maturity structure from 1960s to mid 1970s in Fig 1 for all measures. Starting from the 70s, the Congress approved several small rounds of debt issuance allowing the bond yield to go beyond 4.25%. These allowances were interpreted as gradual steps to repeal the law. Finally in 1988, the law was completely repealed. This pattern corresponds to the gradual rise in maturity from mid 1970s to late 1980s in Fig 1. It is also clear in Fig 1 that the average maturity and/or duration is lower pre 1988 than post 1988. Both the history record and empirical data imply that 1988 could be a nice threshold between two maturity regimes: lower maturity pre 1988 and higher maturity post 1988. Therefore, I construct a dummy variable that equals 1 post 1988 as a maturity measure used in the interaction term in equation (2). I would argue that although this is a simple dummy measure of maturity regimes, it could be more appropriate in my linear local projection specifications.

2.2. Identification: Instrument Variables

Equation (1) and (2) cannot be directly estimated by OLS because fiscal policy changes themselves are endogenous to the macroeconomic responses. In econometric terms, government spending changes are correlated with the error terms. Using external instrumental variables is a nice identification method as they exploit the exogenous variations in the fiscal policy variables to identify the causal effects. Local projections with external instruments are comprehensively studied in Stock and Watson (2018). I also provide a detailed econometric discussion of identification with this approach in Appendix B.

The issue with the IV approach is that finding good instruments is a tough task. In this paper, I use three external instruments together and show that they have strong relevance to the fiscal policy changes in the first stage. The first two instruments are the SVAR-identified fiscal policy shock (Blanchard and Perotti, 2002) and the military defense news series (Ramey and Shapiro, 1998; Ramey, 2011; Ramey and Zubairy, 2018). The third instrument is new to the literature. I also use the SPF forecast error of real government expenditure growth to construct an additional instrumental variable. Since more and more recent studies have shown that forecast errors are predictable, I regress the forecast errors on

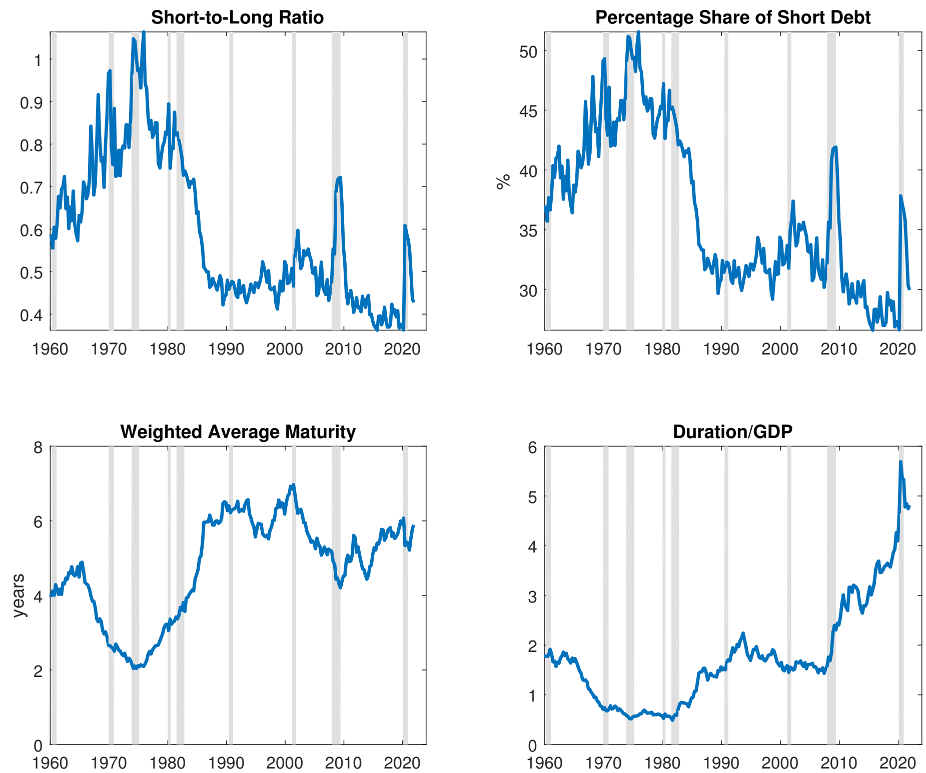

Fig. 1. Four Maturity Measures

lagged macroeconomic control variables and other forecast errors and use the residual as my instrumental variable. Fig 2 displays the 3 external instruments I use in the local projection regressions.

Following Stock and Watson (2018), to correctly identify $\beta_{1,h}$ in equation (1) and $\beta_{1,h}, \beta_{2,h}$ in equation (2), I need to make sure the following assumptions are satisfied. i) *Relevance*. The instrument z_t and the government spending shock $Shock_{g,t}$ must be correlated conditional on the controls. $z_t \cdot MaturityMeasure_{t-1}$ must be correlated with $Shock_{g,t} \cdot MaturityMeasure_{t-1}$ conditional on the controls. Table 1 presents the relevance test of instruments in the first stage. The the Blanchard-Perotti shock series is the most relevant individual instrument, followed by the residual forecast error, and then followed by the Ramey military defense news series. When all three instruments are used together, the first-stage adjusted R^2 rises to 58.41%. ii) *Contemporaneous exogeneity*. The instrument z_t and the interaction term $z_t \cdot MaturityMeasure_{t-1}$ must be uncorrelated with the contemporaneous error term ε_t. This should intuitively hold for all three instruments. The Blanchard-Perotti shock is an SVAR-identified structural shock, which by design should be

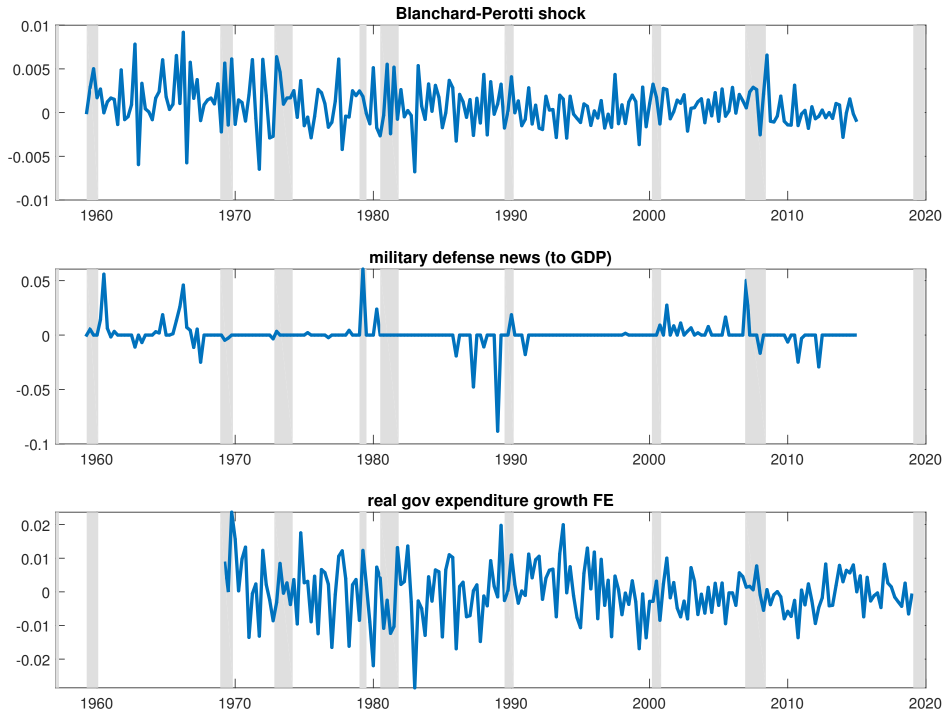

Fig. 2. Fiscal Policy Instrumental Variables

uncorrelated with other structural shocks. The Ramey military defense news series is built using narrative method by reading newspapers and journals such as *Business Week*. It comes from political events that are isolated to the current state of the economy. Thus, it is also exogenous by design. The residual real government spending growth forecast errors comes from regressing the forecast errors against other potential predictors of the forecast errors. Thus, it is reasonable to believe that the residual part of the forecast errors is only diven by fiscal policy shocks and is exogenous to other unobserved shocks. III) *lead/lag exogeneity*. The instrument z_t must be uncorrelated with all past and future shocks $Shock_{g,t+j}$ for $j \neq 0$. The lead exogeneity is not restrictive since shocks are defined to be unanticipated so that future shocks are uncorrelated with z_t realized at time t. The lag exogeneity is somewhat restrictive. But it is also reasonable to assume that the instrument is unpredictable by past fiscal shocks. iv) *Maturity structure exogeneity*. For $\beta_{2,h}$ in equation (2) to be properly identified, we also need to assume that the maturity structure of government debt is uncorrelated with other factors that influence the effectiveness of fiscal policy. According to Ramey (2019), some determinants of the effectiveness of fiscal policy include how the spending is distributed among heterogeneous agents, level of developments, exchange rate regimes, capital openness, etc. Because the maturity choice of the Treasury debt management team largely follows some stable pre-scheduled schemes and is slow moving, we can reasonably believe that this last assumption is true even if it is very difficult to test it.

Table 1: Testing Instrument Relevance in the First Stage

Instruments	First-Stage t-statistic	First-Stage adj. R^2
defense/GDP	2.6499	0.1776
Blanchard-Perotti shocks	12.6494	0.5339
forecast errors	8.6582	0.3849
together		0.5841

2.3. *Local Projection v.s. SVAR*

Local projection and SVAR are alternative empirical methods in estimating causal effects and calculating impulse responses. SVAR has been the workhorse empirical model for decades, but it subjects to the following weaknesses. i) There is typically no good reasons to believe that the true data generating process (DGP) follows a VAR. In contrast, local projection does not require a model specification of the underlying dynamic system, and thus is robust to mis-specifications of the true DGP. ii) VAR, by design, is a linear approximation of the true DGP, and it produces optimal global linear one-step ahead forecasts. However, we are often interested in multiple-horizon impulse responses. Calculating multiple-horizon impulses responses via VAR accumulates mis-specification errors when taking higher powers of the impact matrix. This is not an issue with local projection because it estimates local approximations of impulse responses for each horizon separately. iii) Standard error calculations in VAR are complicated because they are highly nonlinear functions of estimated parameters. As a result, inference in VAR is usually misleading. In contrast, local projection standard errors can be estimated straightforward in the simple regressions with standard statistical packages. Based on the above arguments, I choose to use local projection as my empirical specification.

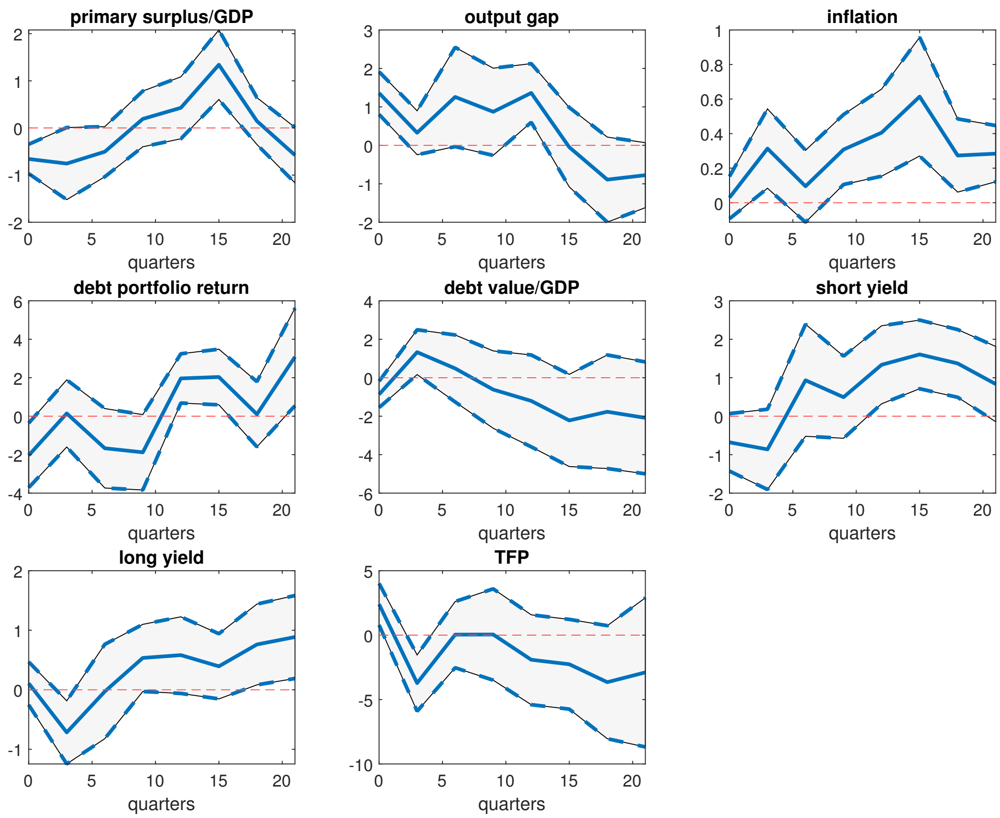

Fig. 3. Impulse Responses to Government Spending Shocks

3. Empirical Results

3.1. Macroeconomic Effects of Government Spending

Fig 3 shows the $\beta_{1,h}$ estimates for horizons $h = 0, 3, 6, ..., 21$ in equation (1) using all three instrumental variables. Results with separate instruments are shown in Appendix C. Heteroskedasticity and autocorrelation robust (HAR) standard errors are calculated and the 90 percentile confidence intervals are shown. The coefficients over time represent the impulses responses to government spending shocks over time. Notice that the coefficients are scaled such that the maximum negative response of primary surplus subsequent to a spending shock is around a unit. This scaling is appropriate because the scale of fiscal shock is undetermined and it aims to facilitate reading of the figures. The coefficients over time represent the impulses responses to government spending shocks over time. From the first panel, for example, we can interpret the fiscal policy shock as a certain fiscal spending shock that first reduces primary surplus by almost 1% during the first year. It also shows that the spending shock will eventually raise primary surplus by slightly more than 1% in approximately 4 years. The second panel shows that such fiscal shock raises output gap by slightly more than 1%. This output expansionary effect will persist for almost 4 years. The third panel shows that such fiscal shock is inflationary and the effect is more persistent than that on output. The fourth panel shows that the government debt portfolio return first declines and the rises. The fifth panel shows that the market value debt/GDP first rises a little and then declines, although the effects are not statistically significant. The sixth and seventh panels show that both short-term and long term interest rates first declines a little and then rises significantly.

These empirical results confirm the expansionary and inflationary effects of government spending shocks that are well-acknowledged in the literature. In addition, I supplement this literature by looking at the responses of debt portfolio return, market value debt/GDP, and interest rates. The interest rates responses are worth noticing as they are indicative of monetary policy responses to fiscal policy, and they may be important to future studies of coordination between fiscal policy and monetary policy. The short run decrease of interest rates indicate that monetary policy eases in accordance with the expansionary fiscal policy in face of deficit or recession. In the medium run, monetary policy tightens in response to an increase of output and inflation.

I do not attempt to calculate various fiscal multiples mainly because there are different definitions of multipliers in the literature. For example, Blanchard and Perotti (2002) defines spending multipliers as the ratio of outcome response at its peak to the initial change of government spendings. Mountford and Uhlig (2009) defines spending multipliers as the ratio of the PV of all future outcome responses to the PV of future spending changes. This second definition takes into account the effects of spending over time. However, what discount rate should we use is another complicated consideration.

3.2. Attenuation Effects of Longer Maturity

Fig 4 and Fig 5 show the $\beta_{1,h}$ and $\beta_{2,h}$ estimates for horizons $h = 0, 3, 6, ..., 21$ in equation (2) using the Blanchard-Perotti shock as an instrumental variable and post 1988 dummy as the maturity measure. Results with other instruments and maturity measures are shown in Appendix C. Heteroskedasticity and autocorrelation robust (HAR) standard errors are calculated and the 90 percentile confidence intervals are shown. The coefficients over time represent the impulses responses to government spending shocks over time. The first row of Fig 4 shows that output gap increases in response to a government spending shock pre

1988, while the expansionary effects on output are dampened post 1988 when the maturity/duration of government debt is higher. The second row of Fig 4 shows that inflation increases in response to a government spending shock pre 1988, while the inflationary effects are dampened post 1988 when the maturity/duration of government debt is higher. The third row of Fig 4 shows that market value debt/GDP decreases in response to a government spending shock pre 1988, while the reduction effects on debt value are dampened post 1988 when the maturity/duration of government debt is higher. The first and second row of Fig 5 show that both short term and long term interest rates increase in response to a government spending shock pre 1988, while the expansionary effects on interest rates are dampened post 1988 when the maturity/duration of government debt is higher. The third row of Fig 5 shows that TFP changes increase in response to a government spending shock pre 1988, while the expansionary effects are dampened post 1988 when the maturity/duration of government debt is higher. In summary, the significantly opposite signs of β_2 to β_1 for almost all variables highlight the punchline message that higher maturity/duration attenuates the fiscal policy effects. These are the main empirical results in this paper and they are new to the literature.

4. Mechanism: Fiscal Theory of Price Level

In the previous empirical analysis, I established some robust evidence that maturity structure as a state variable matters for the effects of fiscal policy. In this and the following sections, I want to understand why this is the case. It turns out that the fiscal theory of price level is consistent with my empirical evidence in section 3. The FTPL starts from the nominal government budget constraint:

$$B_{t-1}^{(t)} + \sum_{j=1}^{\infty} Q_t^{(t+j)} B_{t-1}^{(t+j)} = P_t s_t + \sum_{j=1}^{\infty} Q_t^{(t+j)} B_t^{(t+j)}, \tag{3}$$

where B_{t-1}^{t} denotes the one-period debt outstanding at time $t-1$ and maturing at time t, B_{t-1}^{t+j} denotes the long term debt outstanding at time $t-1$ and maturing at time $t+j$, Q_t^{t+j} denotes the market price of debt at time t maturing at time $t+j$, s_t denotes the real primary surplus, and P_t denotes the price level. By imposing equilibrium debt pricing conditions and recursive substitution, we can derive the debt valuation equation (mathematical derivations are provided in Appendix D):

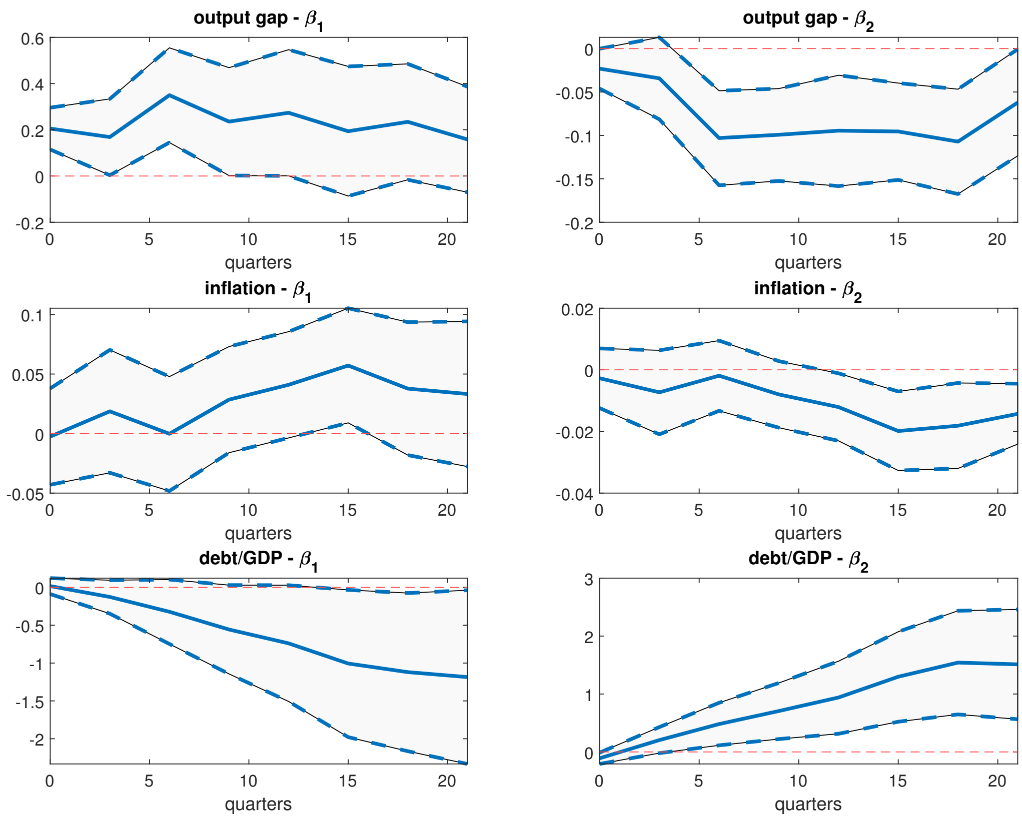

Fig. 4. Differential Effects of Fiscal Policy Shocks under Different Maturity Regimes

$$\frac{B_{t-1}^{(t)} + \sum_{j=1}^{\infty} Q_t^{(t+j)} B_{t-1}^{(t+j)}}{P_t} = E_t \left[\sum_{i=0}^{\infty} \Lambda_{t,t+i} s_{t+i} \right], \tag{4}$$

where $\Lambda_{t,t+i}$ denotes the real SDF from time t ti time $t+i$. This is what Cochrane called the debt valuation equation, the fundamental equation of FTPL. It says that the real market value of government liabilities is equal to the PV of future real primary surplus. Price level is determined by future fiscal variables such that this equality holds. The government liabilities including government debt and money have intrinsic value because they are backed by future fiscal surplus. In other words, people are willing to buy government debt or hold currency because they believe that the government will create sufficient fiscal resources in the future to pay off the liabilities. This theory gives a central role to fiscal policy in price level determination. However, this does not mean that monetary policy is out of the picture. We can think of FTPL as adding fiscal components to conventional structural models and

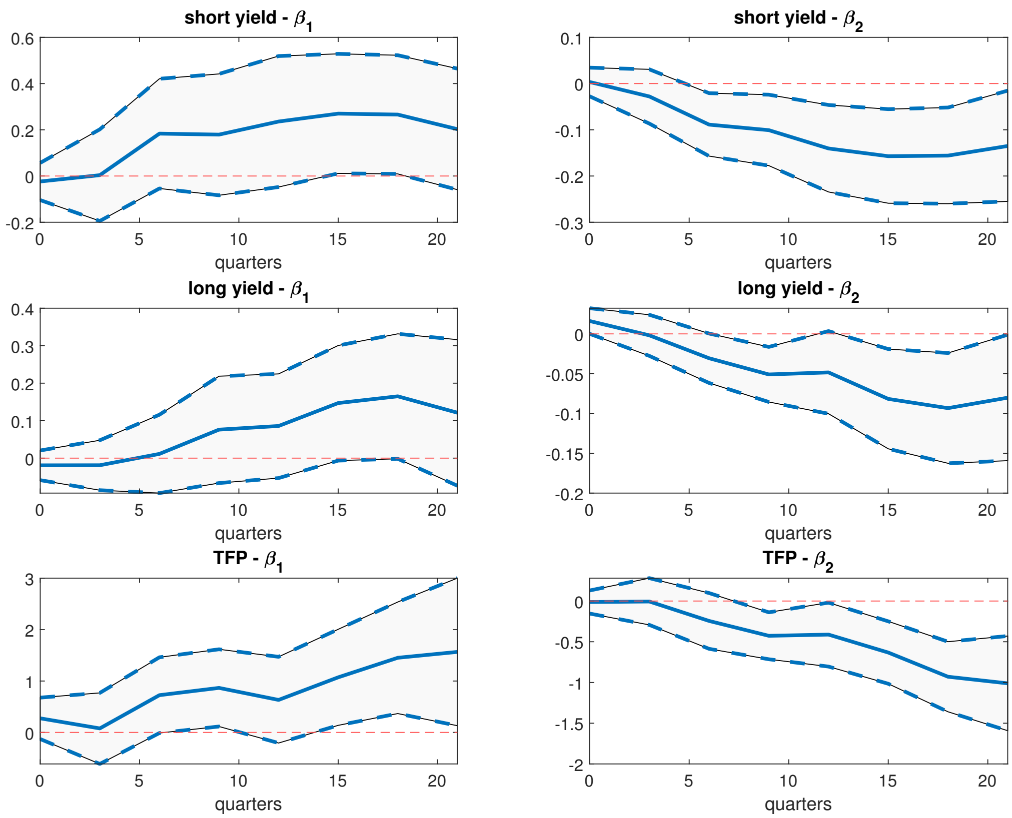

Fig. 5. Differential Effects of Fiscal Policy Shocks under Different Maturity Regimes

emphasizing the interactions between monetary policy and fiscal policy.

How would FTPL speaks to my previous empirical evidence? The theory says that government basically has two methods to finance its deficit (ignoring money and seigniorage): borrowing via debt issuance and inflating away existing debt. In the framework of equation (4), a deficit shock decreases the right-hand side. For now, let's assume constant long debt price Q_t^{t+j}. Since existing debt quantities B_{t-1}^t and B_{t-1}^{t+j} are end-of-previous period values, they are constant. Then, the numerator on the left-hand side is constant. For this equilibrium equation to hold, there are two scenarios happening simultaneously. First, the government increases the price level and inflation to erode existing debt so that the denominator on the left-hand side goes up, keeping a balance in equation (4) without changes in future primary surplus. This corresponds to my empirical findings that inflation rises in response to a deficit/spending shock. Second, the excess deficit or spending must be financed by more government borrowing, i.e. more issuance of government debt. If current inflation does not adjust sufficiently to keep equation (4) hold, it must be the case that future primary surplus rises to offset the decrease of the right-hand side. This channel corresponds to my empirical evidence that the surplus is always s-shaped: current deficits are almost surely followed by future surplus because the government promises to pay off their debt by future surplus in order to boost confidence in private investors to hold government debt. With higher current and future expected inflation, real value of investing in government debt is jeopardized, which makes government debt less attractive. Hence, private investors tend to move away from government debt and invest more in real assets, goods and services. This substitution channel boosts aggregate demand, and thus increase output. This explains the output expansionary effects of fiscal stimulus. Finally, since the monetary authority typically sets interest rates based on output gap and inflation, the interest rates rise in face of increases in both output gap and inflation. In summary, FTPL predictions are consistent with my empirical results with slight discrepancies. For example, FTPL seems not to be able to explain the empirical facts in Fig 3 that interest rates decline in a very short time interval after the fiscal stimulus.

Now I turn to think about different maturity structure regimes from the perspective of FTPL. Let's conduct a thought experiment. Imagine that all the government debt were one-period. Then, the numerator in equation (4) would be reduced from $B_{t-1}^{(t)} + \sum_{j=1}^{\infty} Q_t^{(t+j)} B_{t-1}^{(t+j)}$ to $B_{t-1}^{(t)}$, which would be fixed and constant. In this case, a decrease in the present value of primary surpluses (right-hand side) would be entirely soaked up by a current inflation surprise in the denominator on the left-hand side. Now, imagine that long term debt also exist. Long term debt provides an additional tool for the government to devalue existing debt and achieve capital gains against the private sector. Market price of long debt decreases because interest rates rise. The rise in interest rates can be interpreted in two ways. First, because output and inflation rise, the monetary authority responses to that by increasing interest rates. Second, because higher inflation is eroding the real value of holding government debt, debt holders will demand higher yields/interest rates for holding the debt. Anyway, the point is that the market price of long debt Q_t^{t+j} decreases, as an extra force devaluing existing debt, so that inflation does not need to increase as much as what would have been the case in the one-period debt-only economy. This corresponds to the second row of Fig 4 where the longer maturity, the smaller effects of fiscal shocks on inflation. As for the output expansionary effects, less current and future inflation implies that the real market value of debt will be less devalued. This further implies smaller substitution effects and smaller stimulus in aggregated demand. Thus, this rationalize my results in the first row of Fig 4 where the longer maturity, the smaller effects of fiscal shocks on output. In higher maturity/duration regimes, smaller effects of fiscal policy on both output and inflation naturally lead to smaller effects of fiscal policy on interest rates responses, corresponding the first and second row of Fig 5.

5. Model

In this section, I present a FTPL model from Cochrane (2019) and Cochrane (2022) which can rationalize my empirical findings. The model is built on the basic New Keynesian model, and it adds to the New Keynesian framework the fiscal side of the economy. My contribution is to bring this model to the data and estimate the model parameters by matching model-implied and empirical impulse responses.

5.1. New Keynesian Framework

The foundation of this model is the standard New Keynesian framework. Equation!(5) is the New Keynesian Phillips Curve (NKPC), which describes the relationship between output gap and inflation. Output is high when inflation is high relative to expected future inflation. Equation (6) is the New Keynesian Inter-temporal substitution equation, which says that higher real interest rates induce people to save more and consume less today relative to tomorrow. Equation!(7) is the monetary policy rule, where interest rates are connected to output gap and inflation. Equation!(8) is the AR(1) process for the monetary disturbances. The reason why this model distinguish between disturbances u_i and shocks ε_i is that disturbances can be persistent and predictable while structural shocks are unpredictable.

$$x_t = E_t x_{t+1} - \sigma\left(i_t - E_t \pi_{t+1}\right) \qquad \text{(NKIS)} \tag{5}$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t \qquad \text{(NKPC)} \tag{6}$$

$$i_{t+1} = \theta_{ix} x_{t+1} + \theta_{i\pi} \pi_{t+1} + u_{i,t+1} \qquad \text{(MP rule)} \tag{7}$$

$$u_{i,t+1} = \rho_i u_{i,t} + \varepsilon_{i,t+1} \qquad \text{(MP shock)} \tag{8}$$

Notice that this is a reduced-form linearized model without micro-foundations. It features sticky prices and an endowment economy. However, this reduced-form model can be rationalized by more complicated structural models.

5.2. Government Debt Valuation Equation

Denote the end-of-period market value of nominal debt as $V_t \equiv \sum_{j=1}^{\infty} Q_t^{(t+j)} B_t^{(t+j)}$, and the nominal (one-period) return of the government debt portfolio as $R_{t+1}^n \equiv \dfrac{\sum_{j=1}^{\infty} Q_{t+1}^{(t+j)} B_t^{(t+j)}}{\sum_{j=1}^{\infty} Q_t^{(t+j)} B_t^{(t+j)}}$.

Taking logs and use them in the log-linearization of the government budget constraint, we get (derivations are shown in Appendix D):

$$\rho v_{t+1} = v_t + r^{\$}_{t+1} - \pi_{t+1} - \bar{s}_{t+1} = v_t + r_{t+1} - \tilde{s}_{t+1}, \tag{9}$$

where $\rho = e^{-r}, v_t \equiv \log(V_t/P_t), \tilde{s}_{t+1} \equiv \rho s_{t+1}/(V/P)$. v_t is the log real market value of nominal debt, and $\tilde{s}$ is the real primary surplus level scaled by ρ and steady state value of real debt market value V/P. Equation (9) looks similar to the stock present value formula of Campbell and Shiller (1988). Solving equation (9) forward and take expectations yields:

$$v_t = E_t \sum_{j=1}^{\infty} \rho^{j-1} \tilde{s}_{t+j} - E_t \sum_{j=1}^{\infty} \rho^{j-1} r_{t+j}. \tag{10}$$

Equation (10) implies that the real market value of debt is determined by expected future (scaled) primary surpluses and expected future real discount rates.

5.3. Geometric Maturity Structure

The model considers both short term debt and long term debt. The simplest way to model government debt with a spectrum of maturity level is assume a geometric maturity structure (Eusepi and Preston, 2018; Leeper et al., 2021). It assumes that the face value of debt declines in maturity at a rate $1-\omega$, thus the j-maturity debt outstanding at time t will be a function of one-period debt outstanding: $B_t^{(t+j)} = \omega^{j-1} B_t^{(t+1)}$. We can then write the end-of-period market value of nominal debt as: $V_t \equiv \sum_{j=1}^{\infty} Q_t^{(t+j)} B_t^{(t+j)} = \sum_{j=1}^{\infty} \omega^{j-1} Q_t^{(t+j)} \cdot B_t^{(t+1)} \equiv Q_t \cdot B_t^{(t+1)}$, where Q_t is a hypothetical price of the government debt portfolio if we think of all debt as one-period debt. Log-linearization of the nominal (one-period) return of debt portfolio generates (derivations are shown in Appendix D):

$$r^{\$}_{t+1} = \omega q_{t+1} - q_t, \tag{11}$$

where $r^{\$}_t = \log R^{\$}_t$ and $q_t = \log Q_t$. Assume that expectations hypothesis holds, then expected returns on bonds of all maturities are the same and equal to the short rate:

$$E_t r^{\$}_{t+1} = i_t \tag{12}$$

The assumption of geometric maturity structure is consistent with the data. In Fig 6, I plot the U.S. government privately held debt market value by maturity. Each panel corresponds the average debt quantities in a time interval from 1960s to 2010s. The empirical evidence supports the modeling assumption of geometric maturity structure. Moreover, I can

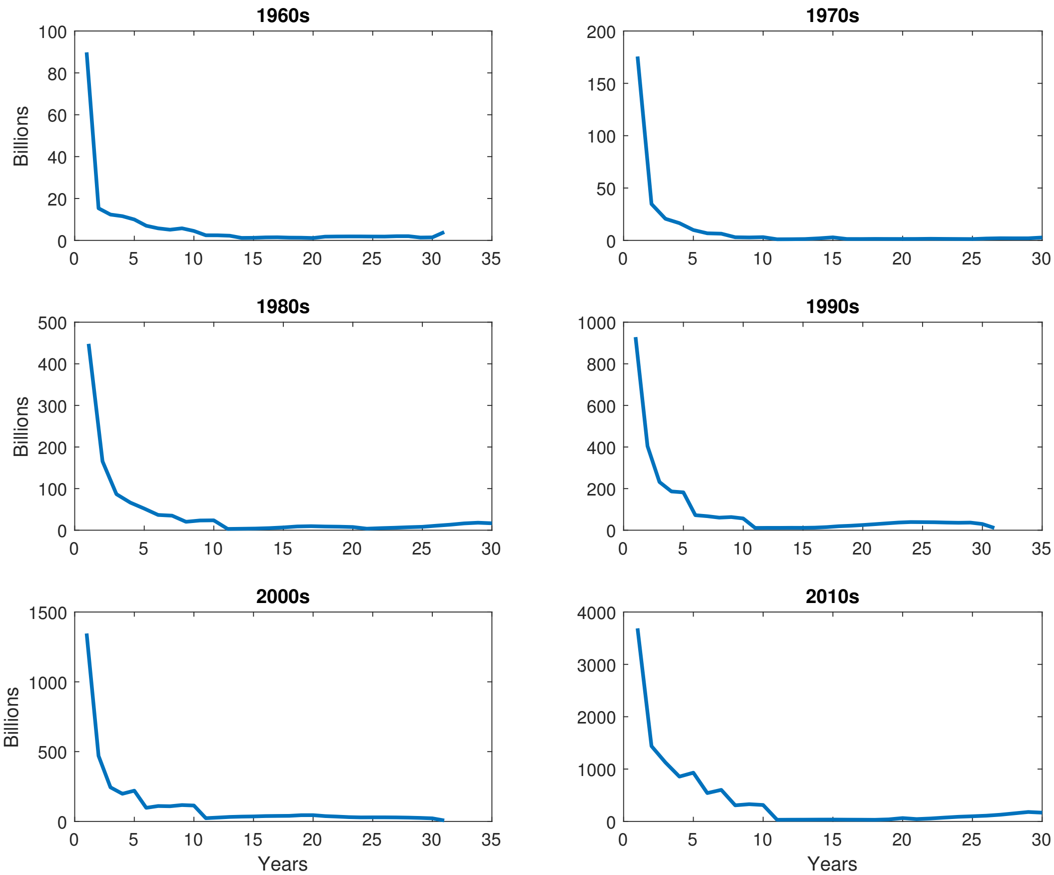

Fig. 6. U.S. government debt outstanding market value by maturity (average value)

easily calibrate the maturity structure coefficient ω from the data. Under the geometric assumption, the weighted average maturity of government debt is $\dfrac{1}{1-\omega}$, which equals to 19.23 quarters I computed from 1960-2019 in CRSP. Thus, the calibrated coefficient $\omega = 0.948$.

5.4. *S-shaped Primary Surplus*

The next step is to reasonably model the primary surplus (to GDP) process. Some papers use a simple AR(1) process for primary surplus/GDP, which is not appropriate. Two separate empirical evidence shows that the US primary surplus/GDP process exhibits an s-shaped property. First, Fig 3 shows the response of primary surplus/GDP to a deficit shock. I mentioned that primary surplus/GDP first declines and then rises, displaying an s-shape. Second, I plot the US primary surplus/GDP from 1960Q1 to 2022Q2 in Fig 7. Again, the s-shape is clearly observable. As I mentioned in the empirical section, an s-shaped primary

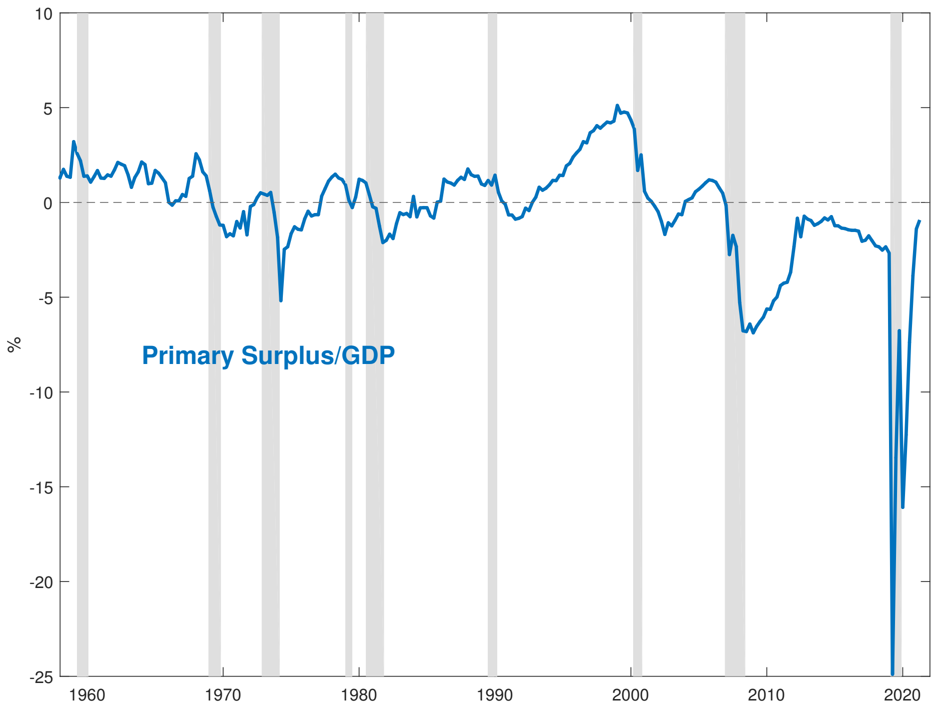

Fig. 7. U.S. Primary Surplus/GDP

surplus process indicates that the government borrows during a deficit shock and promises to pay off their liabilities in the future by higher primary surplus, and the government typically keeps this promise.

Cochrane (2022) proposes the following latent variable approach to model the s-shaped primary surplus (to GDP) process. Equation (13) is a fiscal policy rule, where primary surplus responses to output gap, inflation, and a latent variable v_t^*. Equation (14) is the transition equation for the latent variable v_t^*, where π_t^* is anotehr latent variable. Think of π_t^* as the government inflation target. Then equation (15) says the expected inflation equals to the expected inflation target, and equation (16) relates this inflation target to fiscal shocks and monetary shocks. Appendix D further proves that in equilibrium, $v_t^* = v_t$, $\pi_{t+1}^* = \pi_{t+1}$, and that this latent variable modeling approach captures that ideas that i) primary surplus/GDP is indeed s-shaped, i.e., current deficits are followed by future surplus. ii) deficits are always funded both by borrowing and by inflating away existing debt.

$$\tilde{s}_{t+1} = \theta_{sx} x_{t+1} + \theta_{s\pi} \pi_{t+1} + \alpha v_t^* + u_{s,t+1} \tag{13}$$

$$\rho v_{t+1}^* = v_t^* + r_{t+1}^{\$} - \pi_{t+1}^* - \tilde{s}_{t+1} \tag{14}$$

$$E_t \pi_{t+1}^* = E_t \pi_{t+1} \tag{15}$$

$$\Delta E_{t+1} \pi_{t+1}^* = -\beta_s \varepsilon_{s,t+1} - \beta_i \varepsilon_{i,t+1} \tag{16}$$

$$u_{s,t+1} = \rho_s u_{s,t} + \varepsilon_{s,t+1} \tag{17}$$

5.5. *Full Model and Solution*

The full model, after imposing the equilibrium condition $v_t^* = v_t$ and $\pi_{t+1}^* = \pi_{t+1}$, is:

$$x_t = E_t x_{t+1} - \sigma \left(i_t - E_t \pi_{t+1} \right) \quad \text{(NKIS)} \tag{18}$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t \quad \text{(NKPC)} \tag{19}$$

$$\rho v_{t+1} = v_t + r_{t+1}^{\$} - \pi_{t+1} - \tilde{s}_{t+1} \quad \text{(debt valuation)} \tag{20}$$

$$r_{t+1}^{\$} = \omega q_{t+1} - q_t \quad \text{(geometric MS)} \tag{21}$$

$$E_t r_{t+1}^{\$} = i_t \quad \text{(EH)} \tag{22}$$

$$\tilde{s}_{t+1} = \theta_{sx} x_{t+1} + \theta_{s\pi} \pi_{t+1} + \alpha v_t + u_{s,t+1} \quad \text{(FP rule)} \tag{23}$$

$$\Delta E_{t+1} \pi_{t+1} = -\beta_i \varepsilon_{i,t+1} - \beta_s \varepsilon_{s,t+1} \quad \text{(unexp. infl)} \tag{24}$$

$$i_{t+1} = \theta_{ix} x_{t+1} + \theta_{i\pi} \pi_{t+1} + u_{i,t+1} \quad \text{(MP rule)} \tag{25}$$

$$u_{s,t+1} = \rho_s u_{s,t} + \varepsilon_{s,t+1} \quad \text{(FP shock)} \tag{26}$$

$$u_{i,t+1} = \rho_i u_{i,t} + \varepsilon_{i,t+1} \quad \text{(MP shock)} \tag{27}$$

The linearized model can be solved using the Blanchard and Khan (1980) method. Model solution details can be found in Appendix D.

5.6. *Model Estimation*

Following Jørgensen and Ravn (2022), among other, I intend to estimate the model parameters by matching model-implied and empirical impulse responses. If it can be done, it will be ideal since the model can be perfectly matched with the data in the sense of producing similar impulse responses to fiscal policy shocks. However, this task is very difficult in this paper because my empirical strategy is local projections while the model produces VAR-like impulse responses through its VAR-form solutions. I would interpret my empirical impulse responses as the "true" impulse responses out of the true DGP. Because the model is a

Table 2: Model Parameter Estimation

Variables	Names	Values
α	latent state coefficient in surplus process	0.1557
σ	inverse of risk aversion	0.5768
κ	NKPC coefficient	0.2984
ρ_i	persistency of interest rate disturbances	0.5881
ρ_s	persistency of surplus disturbances	0.3000
θ_{ix}	interest rate response to output gap	0.7191
θ_{ip}	interest rate response to inflation	0.4880
θ_{sx}	surplus response to output gap	1.2993
θ_{sp}	surplus response to inflation	0.9885
β_i	unexpected inflation response to interest rate shocks	0.5002
β_s	unexpected inflation response to surplus shocks	0.2326

linearized approximation of the true DGP and the solution is a first-order VAR process, I suppose it will be extremely hard for me match the model-implied impulse responses to my empirical results. My solution to this problem is to construct a hypothetical linearized system of variables from the data, which makes sure that model linearized equations hold. In specific, instead of using the true primary surplus process, I derive a surplus process using model equation (27). Then, I estimate a SVAR(1) including the model endogenous variables. In this way, even though the SVAR estimates may be incorrect approximations of the true DGP, at least I make sure that the model impulse responses have their empirical counterparts.

There are three parameters I choose to calibrate: discount factor and debt valuation coefficient $\beta = \rho = e^{-r} = 0.99$ assuming an average real rate of 4% annually. The maturity structure coefficient has been calibrated: $\omega = 0.948$. The remaining parameters are to be estimated by matching impulse responses: $\Theta = \{\alpha, \sigma, \kappa, \rho_i, \rho_s, \theta_{ix}, \theta_{ip}, \theta_{sx}, \theta_{sp}, \beta_i, \beta_s\}$. Let $F(\Theta)$ denote the model-implied impulse responses, which are functions of the parameters, while $\hat{F}(\Theta)$ denotes the corresponding empirical estimates from our SVAR model. Let W be the identity weighting matrix. Then, the parameter estimates solves the following equation using numerical methods:

$$\hat{\Theta} = \arg\min_{\Theta} \left(F(\Theta) - \hat{F}(\Theta)\right)' W \left(F(\Theta) - \hat{F}(\Theta)\right)$$

I am matching the first 8 quarters of impulse responses to a deficit shock. The parameter estimates are reported in Table 2.

Fig 8 plots the empirical SVAR(1) v.s. the model-implied impulse responses to a deficit shock. Though not perfect, the figure shows that the model matches pretty well with the empirical SVAR(1).

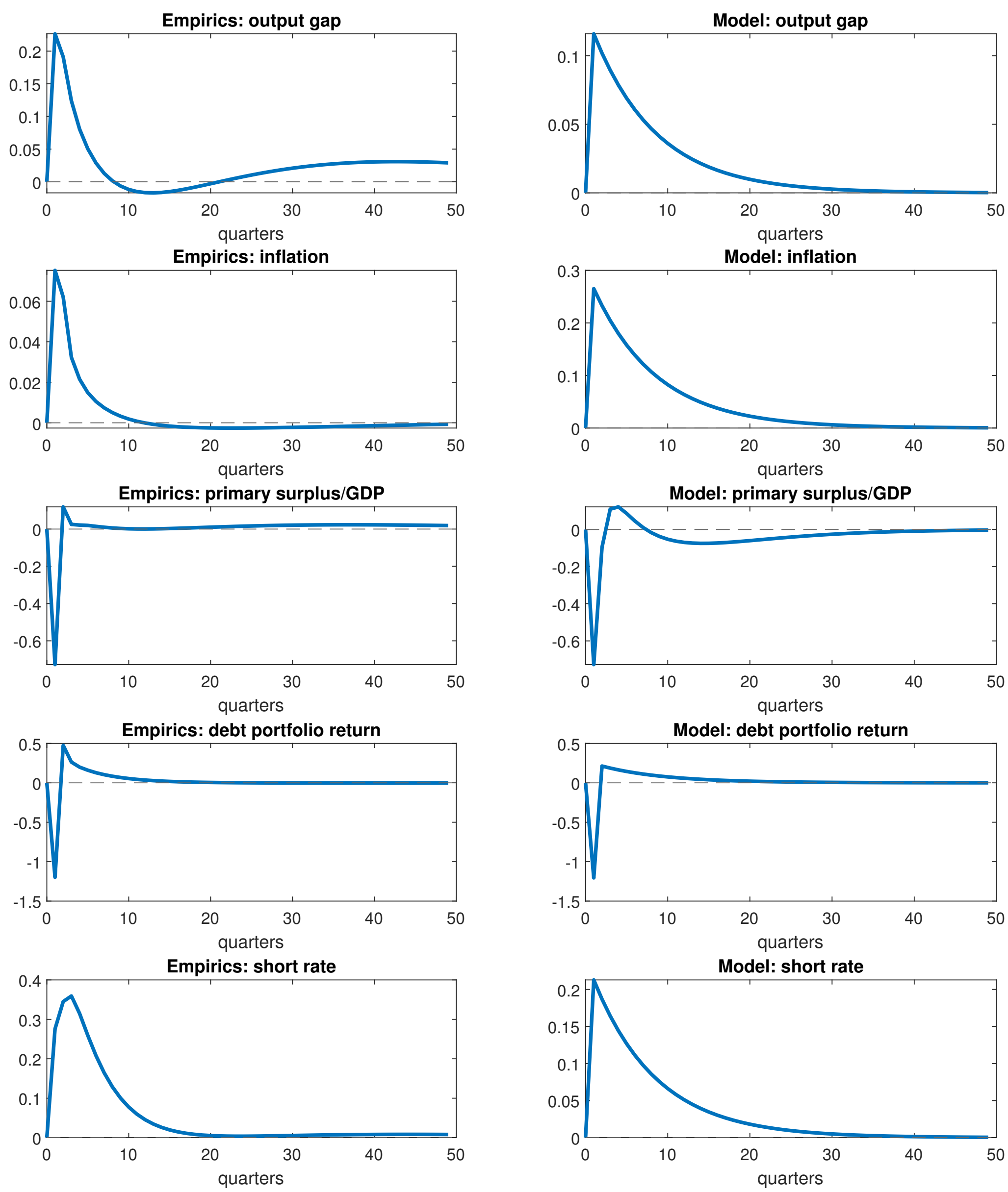

Fig. 8. Model v.s. SVAR(1) Impulse Responses to a Deficit Shock

It is worth mentioning that the estimated "Taylor rule" coefficient on inflation is not consistent with what the literature has suggested. Most recently, Carvalho et al. (2021) estimates the monetary policy response to inflation (θ_{ip} in this model) to be 1.97 Post-Volcker periods. Most of the empirical literature also provide an estimate above 1, indicating that the monetary policy is active in targeting inflation. However, I would not see a huge problem in this paper's estimate of 0.488. This is because the whole idea of FTPL is that fiscal policy may be active and monetary policy may be passive, resulting in an estimate $\theta_{ip} < 1$. Conventional models often implicitly assumes active monetary policy and passive fiscal policy, while FTPL may feature active fiscal policy and passive monetary policy. After all, it is difficult to distinguish between the above two regimes because they are observationally equivalent. Both regimes have debt valuation equation (4) hold in equilibrium. The difference between the two regimes lies in the direction of causality. In active monetary policy/passive fiscal policy, price is determined mainly by monetary policy. The fiscal surplus on the right-hand side is determined by the left-hand side to ensure debt solvency. In active fiscal policy/passive monetary policy, fiscal variables are endogenous. Price level on the left-hand side of equation (4) is determined by the surplus process on the right-hand side.

6. Model Impulse Responses

Having estimated the model and showed that the model matches pretty well with the data, I am able to use this model as a laboratory to explore the different fiscal policy effects under different maturity structure regimes by counter-factual analysis. In specific, I vary the maturity structure coefficient ω and keep other parameters constant, aiming to examine what happens when the only change in the economy is the maturity structure regime. Using structural model as a lab creates a randomized experiments by design, and this endogeneity problems are less of a concern. Notice that when ω changes, I will have to change β_s as well because it, by design, controls the current unexpected inflation surprise. If I held β_s constant, any maturity regimes would generate exactly the same first-period response in inflation, which is unintuitive. Instead, I allow changes in β_s but follows Cochrane (2022) to keep constant the ω-weighted sum of current and expected future unexpected inflation relative to the overall size of the fiscal shock. The idea is that no matter how different the state of the economy becomes, I assume that the overall lifetime proportion of deficit shocks been inflated away is kept constant. This is similar to controlling an additional confounding factor in my counter-factual analysis, which helps identify the impact of different maturity regimes.

I choose three values of ω: 0.01, 0.948, and 0.99, corresponding to all one-period debt maturity structure, real-world maturity structure, and all consol debt maturity structure, respectively. I plot the impulse responses in Fig 9. It clearly demonstrates the idea that longer maturity attenuates the effects of fiscal policy, in accordance with my empirical results.

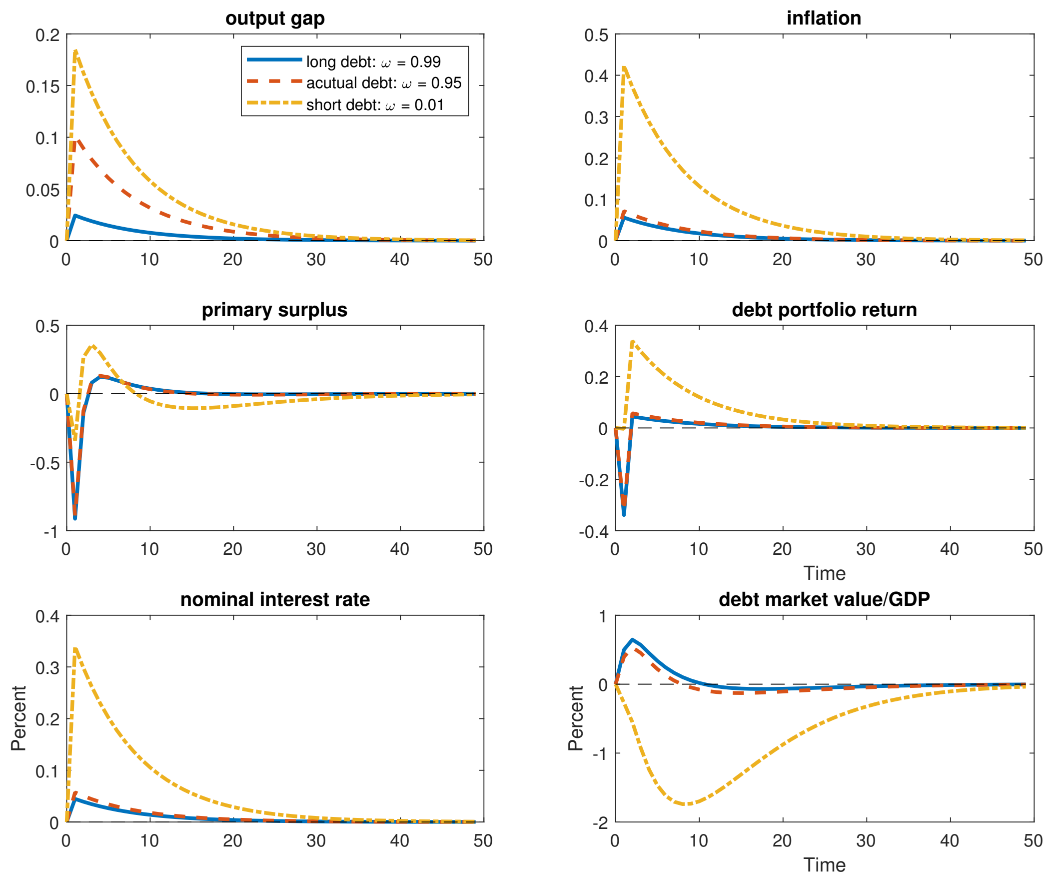

Fig. 9. Impulse Responses under different Maturity Regimes

7. Conclusions and Discussions

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Appendix A. Data Construction

Appendix B. Identification in LP-IV

Appendix C. Robustness Checks on Empirical Results

Appendix D. Model Derivation

Appendix E. S-shaped Primary Surplus