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Fiscal policy shocks and stock prices in the United States

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Fiscal policy shocks and stock prices in the United States.

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August 2018

Abstract

This paper uses a range of structural VARs to show that the response of US stock prices to fiscal shocks changed in 1980. Over the period 1955-1979 an expansionary spending or revenue shock was associated with modestly higher stock prices. After 1980, along with a decline in the fiscal multiplier, the response of stock prices to the same shock became negative. We use an estimated DSGE model to show that this change is consistent with a switch from an economy characterised by a more active fiscal policy and passive monetary policy to one where fiscal policy was passive and the central bank acted aggressively in response to inflationary shocks.

Key words: Fiscal policy shocks, Stock prices, VAR, DSGE.

JEL codes: C5, E1, E5, E6

1 Introduction

Do tax cuts boost stock markets? In a recent interview given to the POLITICO Money podcast, the US treasury secretary Steven Mnuchin appeared to back this claim and warned that unless taxes were cut, the gains seen by the US stock market since the election of president Trump could be reversed. However, from the perspective of economic theory, the effect of fiscal policy on stock prices is ambiguous. This has been pointed out in a classic paper by Blanchard (1981) who shows that the sign of the impact of fiscal expansions on the stock market depends on whether agents expect the effect of higher future short-term interest rates to dominate the expected rise in profits.

While a large literature has focussed on estimating the multiplier of US output to government spending and taxation shocks (see for e.g. Mountford and Uhlig (2009), Ramey (2011), Mertens and Ravn (2014), and Mertens and Ravn (2013)), the issue of the transmission of fiscal shocks to asset prices such as stock prices has received far less attention from the empirical side. Two recent contributions include Afonso and Sousa (2011) and Chatziantoniou *et al.* (2013). Using an extended version of the Vector Autoregression (VAR) of Blanchard and Perotti (2002), they show that positive (negative) shocks to government spending (taxes) lead to a fall (rise) in stock prices in the US. However, Afonso and Sousa (2011) do not include any proxy for monetary policy in their VAR model, an omission criticised by Chatziantoniou *et al.* (2013).¹ These authors examine the impact of government spending on an expanded version of the VAR used by Afonso and Sousa (2011). They find that over the period spanning 1991 to 2010, government spending shocks appear to have little impact on real and financial variables. However, their relatively small sample excludes

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¹Using a panel regression, Ardagna (2009) report similar results—stock prices rise around periods of fiscal tightening.

important innovations in fiscal variables during the 1970s and the early 1980s and it is unclear if their conclusions are robust to using a longer span of data.

The current paper extends this literature along three dimensions. First, we provide VAR results on the transmission of US government spending and taxation shocks to real stock prices that are robust across different shock identification schemes, thus departing from earlier papers that use one method of identifying fiscal shocks. Second and more importantly, we show that there is a change in the sign and magnitude of the response of stock prices to fiscal shocks after 1980 – expansionary fiscal policy shocks were associated with a modest increase in the stock price before 1980, while after this date the same policy is associated with large declines. Although previous papers have documented a decline in the magnitude of the fiscal multiplier across these sub-samples, to our knowledge, our paper is one of the first to focus on the change in the response of stock prices to fiscal shocks.² Finally, in order to explain the possible source of the change in the response of stock prices, we present a DSGE model – following [Traum and Yang \(2011\)](#), we augment the model developed by [Christiano *et al.* \(2005\)](#) and [Smets and Wouters \(2007\)](#) with a simple non-productive government sector. Estimation of this DSGE model pre and post-1980 suggests changes in the behaviour of policy makers as highlighted in [Leeper \(1991\)](#). In particular, we estimate that monetary policy was likely to be passive between 1955Q4 and 1979Q4 with the fiscal authority not reacting strongly to public debt. The lack of sufficient response to inflation by monetary authorities caused inflation expectations to rise after an expansionary fiscal shock resulting in a decrease in the real interest rate. As a consequence, investment and consumption rose pushing up equity prices. After 1980, our results suggest that both monetary and fiscal authorities set policy in a manner that was consistent with their objectives of stabilising inflation and public debt, respectively. These policies suppressed inflation expectations after an expansionary fiscal shock, causing the real rate to rise and equity prices to fall. While previous research has highlighted the possibility of changes in fiscal and monetary policy activism (see [Leeper \(1991\)](#) and [Bianchi and Ilut \(2014\)](#)), our paper shows that such a shift may be a factor behind the changing response of stock prices to fiscal shocks. Therefore, our paper contributes to the literature linking changes in policy to the stock market (see [Blanchard \(1981\)](#) and [Galí and Gambetti \(2015\)](#)). While the focus of [Galí and Gambetti \(2015\)](#) is on the changing effects of monetary policy shocks, our contribution is to show that the impact of fiscal shocks on the stock market has been subject to a large shift.

The paper is organised as follows: The empirical analysis based on VAR models are presented in sections [2](#) and [3](#). Section [4](#) introduces the theoretical model and discusses the parameter estimates. Section [5](#) concludes.

2 Empirical Analysis

We estimate the following VAR model for the United States:

$$Y_t = \alpha\tau_t + \sum_{j=1}^P \beta_{t-j}Y_{t-j} + v_t$$

where $\text{var}(v_t) = \Omega$. Y_t is a $N \times T$ matrix of endogenous variables while τ_t is matrix of exogenous variables included in the specification. The benchmark model includes the following eight endogenous variable: (1) Real per-capita federal government spending (G_t), (2) Real per-capita GDP

²In a recent independent contribution, [Diercks and Waller \(2017\)](#) also investigate the changing effect of tax shocks on the stock market. We generalise their results by also considering shocks to government spending and employing a substantial wider range of structural VAR models.

(Y_t), (3) CPI inflation (π_t), (4) Real per-capita federal government revenue (T_t), (5) ratio of federal debt to nominal GDP (D_t), (6) a short-term interest rate (R_t), (7) the 1-year government bond yield (I_t) and (8) real stock prices (S_t). All variables except inflation and the interest rates are included in log levels. After 2008 Q4, R_t is proxied by the shadow interest rate estimated by [Wu and Xia \(2014\)](#). This provides a simple way to account for the zero lower bound (ZLB). We also verify below that our results are robust to truncating the sample before 2008. Following, [Gertler and Karadi \(2015\)](#), we include the 1-year rate I_t to account for unconventional monetary policy such as forward guidance. As we show below, the inclusion of longer term interest rates does not change the key results. The exogenous variables in the benchmark model include a constant, a linear trend, a quadratic trend and a dummy variable for 1975Q2³. The key results do not depend on assumptions about trends in the model. We chose the lag length P via the Akaike information criterion.

2.1 Identification of fiscal shocks

The covariance matrix of reduced form shocks Ω can be decomposed as $\Omega = A_0 A_0'$. We use four approaches to estimate the contemporaneous impact matrix A_0 and identify government spending and taxation shocks. Our starting point is a simple recursive strategy as described in [Caldara and Kamps \(2008\)](#). The ordering of the variables is as listed above with the implication that government spending is not affected contemporaneously by macroeconomic or financial shocks but taxes respond immediately to shocks to G_t, Y_t and π_t i.e. innovations that may affect tax receipts. Both fiscal shocks are assumed to affect the fast moving variables, i.e. interest rates and stock prices, immediately. The second identification strategy follows the procedure devised in [Blanchard and Perotti \(2002\)](#) and extended to systems involving nominal variables in [Perotti \(2005\)](#). Their method involves using external information to calibrate the output, inflation and interest rate elasticity of government spending and taxation. [Perotti \(2005\)](#) estimates the output and inflation elasticity of taxes to be 1.85 and 1.25 respectively.⁴ The output elasticity of government spending is set to zero as G_t is defined net of transfers and not affected by business cycle fluctuations contemporaneously. The inflation elasticity of G_t is set to -0.5 . [Perotti \(2005\)](#) argues that an increase in inflation leads to a reduction in wages of government employees in real terms. As wages form a large proportion of spending, the elasticity is negative. As G_t and T_t are defined net of interest payments, their interest elasticity is set to zero. As in the recursive scheme, we also assume that G_t and T_t do not react contemporaneously to shocks to the long-term interest rate and stock prices. These restrictions, together with the assumption that spending decisions precede decisions on taxes results in an identified structural VAR (SVAR). The third identification scheme is based on the seminal work of [Mountford and Uhlig \(2009\)](#) who use sign restrictions to identify spending and revenue shocks. Following these authors, positive shocks to these variables are assumed to increase spending and revenue for four quarters. In addition, these shocks are assumed to be orthogonal to a business cycle shock that moves taxes and output in the same direction for four quarters. The final identification scheme relies on narrative measures of tax and spending shocks. These proxies can be added to the VAR directly or used as external instruments to estimate the appropriate column of A_0 (see [Stock and Watson \(2008\)](#)). [Mertens and Ravn \(2012\)](#) have recently introduced a refined version of the tax shock estimated by [Romer and Romer \(2010\)](#). [Romer and Romer \(2010\)](#) build their shock measure by purging legislated tax changes from movement that are endogenous

³As discussed in [Blanchard and Perotti \(2002\)](#), there was a large, isolated temporary tax cut episode in 1975Q2 which is distinct from the estimated tax shocks and is therefore dummied out.

⁴[Perotti \(2005\)](#) also provides the estimates of these elasticities pre and post-1980. We use these sub-sample estimates when we estimate our VAR, pre and post-1980.

and driven by policy makers' concerns about growth. However, [Mertens and Ravn \(2012\)](#) argue that the [Romer and Romer \(2010\)](#) tax shock may not satisfy exogeneity as the proxy does not account for implementation lags. [Mertens and Ravn \(2012\)](#) propose a proxy based on exogenous tax changes where legislation and implementation are less than a quarter apart. In related work, [Ramey \(2011\)](#) proposes a measure for news in government defence spending, an estimate of the expected discounted value of G_t due to foreign political events. We use the [Mertens and Ravn \(2012\)](#) measure of tax changes as an instruments in a proxy SVAR to identify unanticipated tax shocks. In addition we attempt to capture anticipated changes in defence spending by using the [Ramey \(2011\)](#) news measure as an instrument for the spending shock.

The estimation of these three SVAR models and their applications to the transmission of fiscal shocks is now standard in the literature. We, therefore, confine estimation details to the on-line technical appendix.

2.2 Data and estimation samples

We follow [Mertens and Ravn \(2014\)](#) closely in defining government spending and taxes. Government spending is defined as the sum of federal government consumption and investment. Taxes are calculated as current receipts of the federal government plus contributions for social insurance less corporate income taxes from Federal Reserve Banks. Both variables are deflated by the GDP deflator and divided by total population. A full description of data sources and calculations is provided in Appendix A.

The benchmark sample runs from 1955Q1 to 2015Q4. When the Proxy VAR is employed the sample and data is altered slightly. Data for the [Mertens and Ravn \(2012\)](#) instrument is available until 2006Q4. In addition, note that we use federal government defense spending as G_t in the proxy SVAR that uses the [Ramey \(2011\)](#) measure to identify the (defense) spending shock. However, the results from this model are similar if G_t is calculated as in the benchmark model as the sum of federal government consumption and investment.

[Perotti \(2005\)](#) provides strong evidence that the transmission of fiscal shocks has changed after 1980. The estimates presented in [Perotti \(2005\)](#) suggest that the response of output to fiscal shocks is smaller after 1980. Similar results are reported by [Bilbiie *et al.* \(2008\)](#) who suggest that a change in monetary policy and asset market participation may have played a role. Given this evidence, we estimate our models over the full sample and present results over the two sub-samples, before and after 1979Q4.

It is interesting to note that the long-run (i.e. infinite horizon) impulse responses from the VAR indicate a change in the monetary and fiscal policy rules across the two sub-samples.⁵ For example, the median long-run cumulated response of R_t to a surprise increase in inflation in the first sub-sample is estimated to be -0.29 with a 68% highest posterior density interval (HPDI) of $[-3.8, 3.5]$. In contrast, the median estimate rises to 1.01 in the second sub-sample with a HPDI of $[-0.4, 2.6]$. While the error bands are large due to the fact that the estimates are based on limited samples, the results are consistent with the view that monetary policy was more active in its response to inflation in the post-1980 period.⁶ An examination of the response of T to exogenous shocks to federal debt also indicate a shift the behaviour of the fiscal authorities. Before 1979, taxes appear to be unaffected by positive innovations to debt with an estimated median long-run response of

⁵The responses to inflation and debt shocks described here are calculated using a Cholesky decomposition, with inflation and debt ordered first, respectively.

⁶The same result is reflected in the response of the one year rate I_t . The median response (68% HPDI) changes from -0.4 ($[-3.7, 3.5]$) pre-1980 to 1.2 ($[-0.12, 2.7]$) post-1980. This provides some evidence that agents expect a more robust response to inflationary shocks in the post-1980 period.

-0.009 with a HPDI of $[-3.0, 3.9]$. This changes after 1980 with the response of taxes to debt estimated to be substantially larger – the median response is 0.63 with a HPDI of $[-0.9, 2.2]$. This provides some evidence that fiscal authorities were more concerned with debt stabilisation in the post-1980 period. As discussed in a more structural setting in Section 4, these regime characteristics are important in explaining changes in the response of stock prices to fiscal shocks across the two regimes.

In the robustness analysis, we follow studies such as [Lubik and Schorfheide \(2004\)](#) and exclude the Volcker dis-inflation period when we split the sample. We also check if limiting the second subsample to 2007Q4 has an impact on the results. In both case, the benchmark estimates survive. Moreover, we show below that very similar results are obtained if, instead of splitting the sample, we allow the parameters of the VAR to change over time.

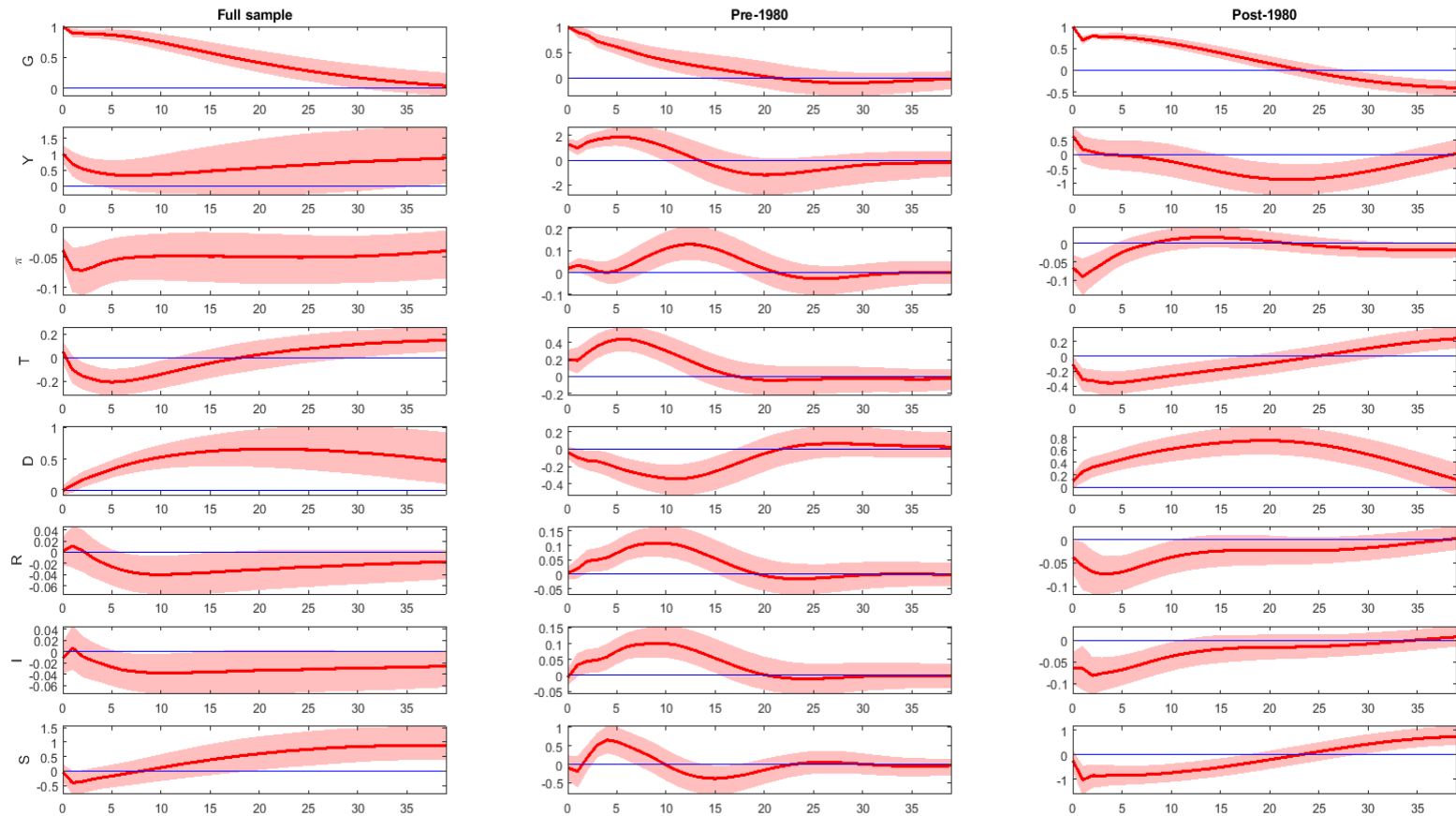


Figure 1: Response to a Government Spending shock using the benchmark identification. The Y-axis units are in percent for all variables except the interest rate where the unit is percentage points. The solid lines are median responses while the shaded area is the 68% error band. The Y-Axis labels are as follows: (1) Real per-capita government spending (G_t), (2) Real per-capita GDP (Y_t), (3) CPI inflation (π_t), (4) Real per-capita government revenue (T_t), (5) Debt to GDP ratio (D_t), (6) a short-term interest rate (R_t), (7) the 1-year rate (I_t) and (8) real stock prices (S_t). The response of Y is expressed as a multiplier.

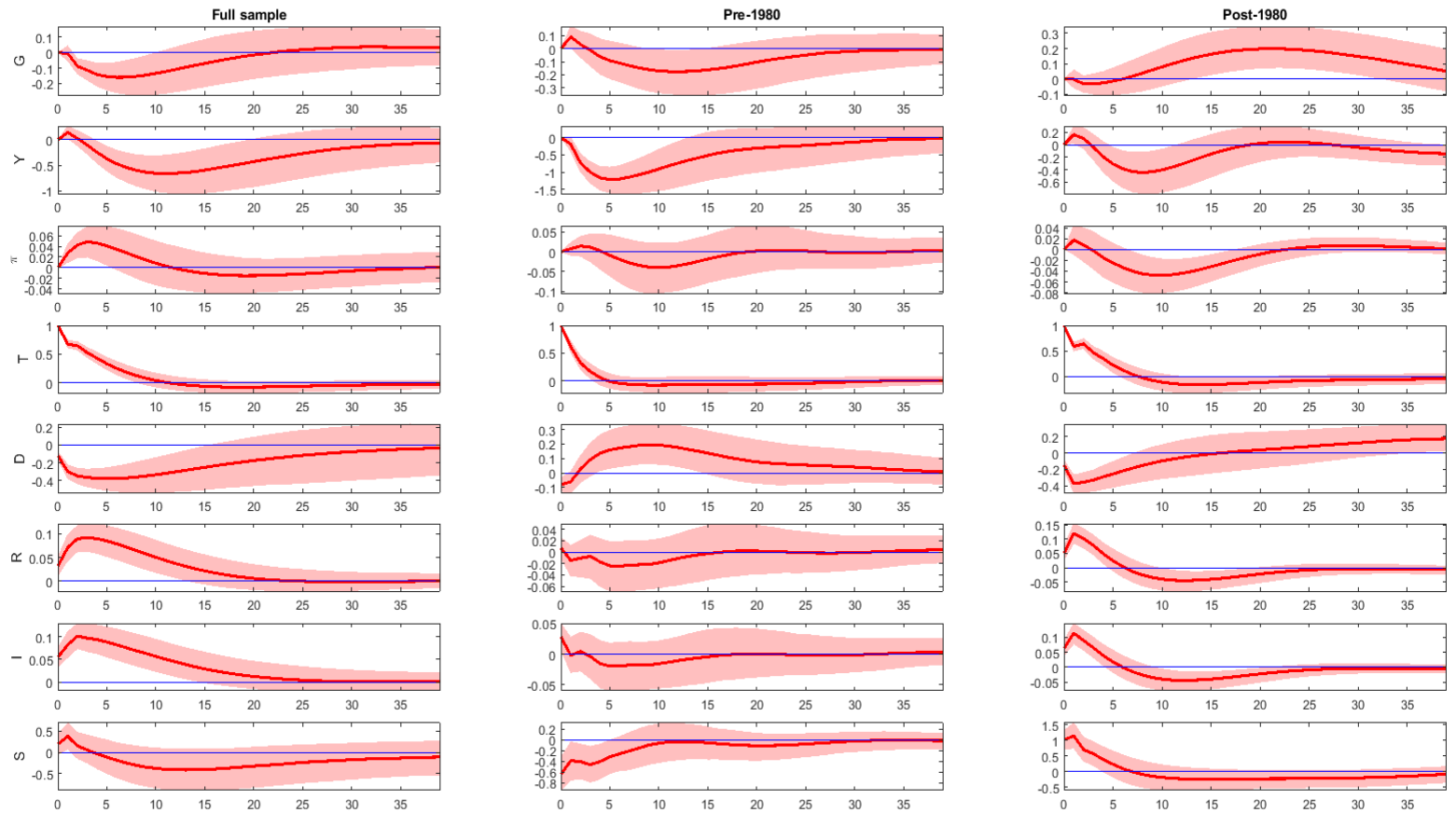


Figure 2: Response to a government revenue shock using the benchmark identification. See notes to Figure [1](#).

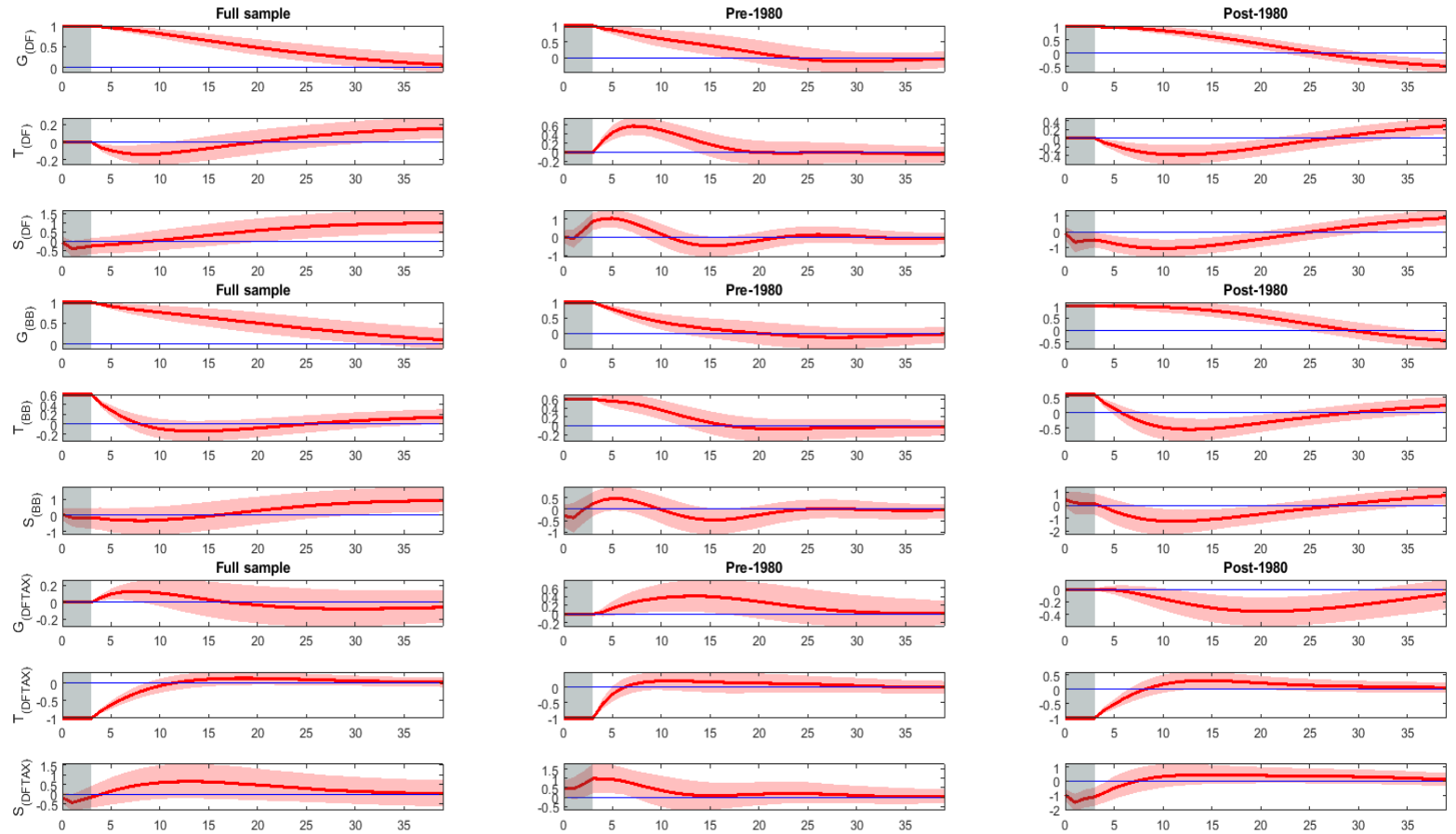


Figure 3: Policy experiments. DF refers to a deficit financed increase in G . BB refers to a balanced budget increase in G . DFTAX refers to a decrease in T which deficit financed. The shaded area represents the horizon over which these restrictions are imposed.

3 Results

3.1 Impulse response of stock prices to fiscal shocks

Figure 1 presents the response of the endogenous variables to a spending shock that raises G by 1% using the recursive identification scheme.⁷ We treat these results as a simple benchmark and discuss the estimates from the alternative identification schemes below. The response of Y is expressed in terms of a dollar change in GDP as a ratio of a dollar change in spending. Over the full sample, the peak output response is estimated to be about 1, a magnitude consistent with results reported in Perotti (2005). As in Perotti (2005), there is evidence for a decline in the multiplier with the GDP response substantially less persistent in the post-1980 period. While inflation and interest rates rise in response to the shock during the pre-1980 period, the hypothesis of a negative initial response cannot be rejected in the post-1980 period. Note, however, that after 1980, the initial decline in R_t is smaller than the estimated fall in inflation one period ahead, i.e. π_{t+1} . This implies that the real rate $R_t - \pi_{t+1}$ rises much more rapidly in this sub-sample when compared to the pre-1980 period where the corresponding response is only positive after 2 quarters. Over both sub-samples, the initial increase in spending is not matched by a corresponding rise in tax revenue. This aspect is more apparent in the second sub-sample where taxes show a decline in response to the shock.⁸

Over the full sample, the short and medium term response of real stock prices is imprecisely estimated – the median response shows an initial decline which is then followed by a persistent increase. However this hides a substantial change across the two subsamples. In the pre-1980 period, stock prices increase by about 0.5 percent at the 6 month horizon. In contrast, the response in the post-1980 period is characterised by a protracted decline which reaches about 1% at the one year horizon. The last row of Figure 2 shows that the stock price response to tax shocks also displays substantial variation across the two sub-samples. Before 1980, stock prices show a modest decline in response to a rise in taxes. After 1980, the response switches sign and stock prices rise by 1 percent on impact. The remaining responses display the pattern reported in earlier studies such as Perotti (2005) – for e.g. the response of output to tax shocks shows a decline in magnitude after 1980.

⁷As explained in the technical appendix, the error bands for impulse responses are approximated using a Gibbs sampling algorithm.

⁸We consider policy experiments below where either G or T is held fixed.

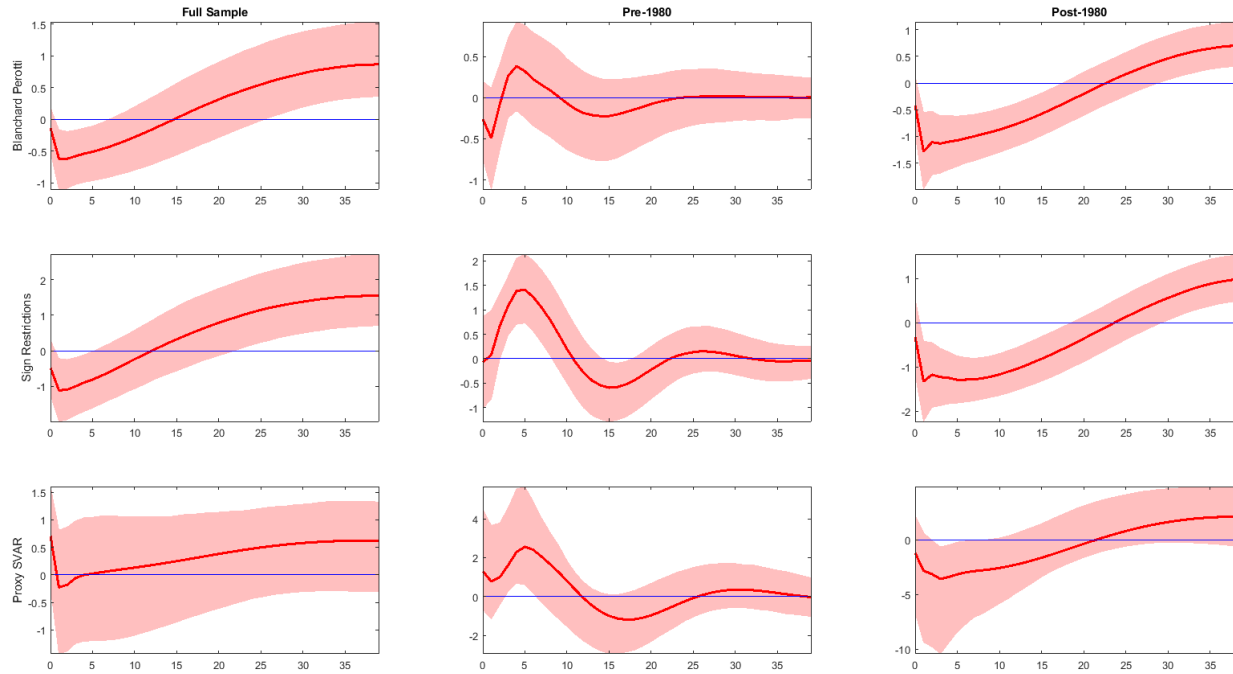


Figure 4: The response of real stock prices to a 1% increase in government spending. The proxy SVAR uses the spending shock of [Ramey \(2011\)](#) as an instrument.

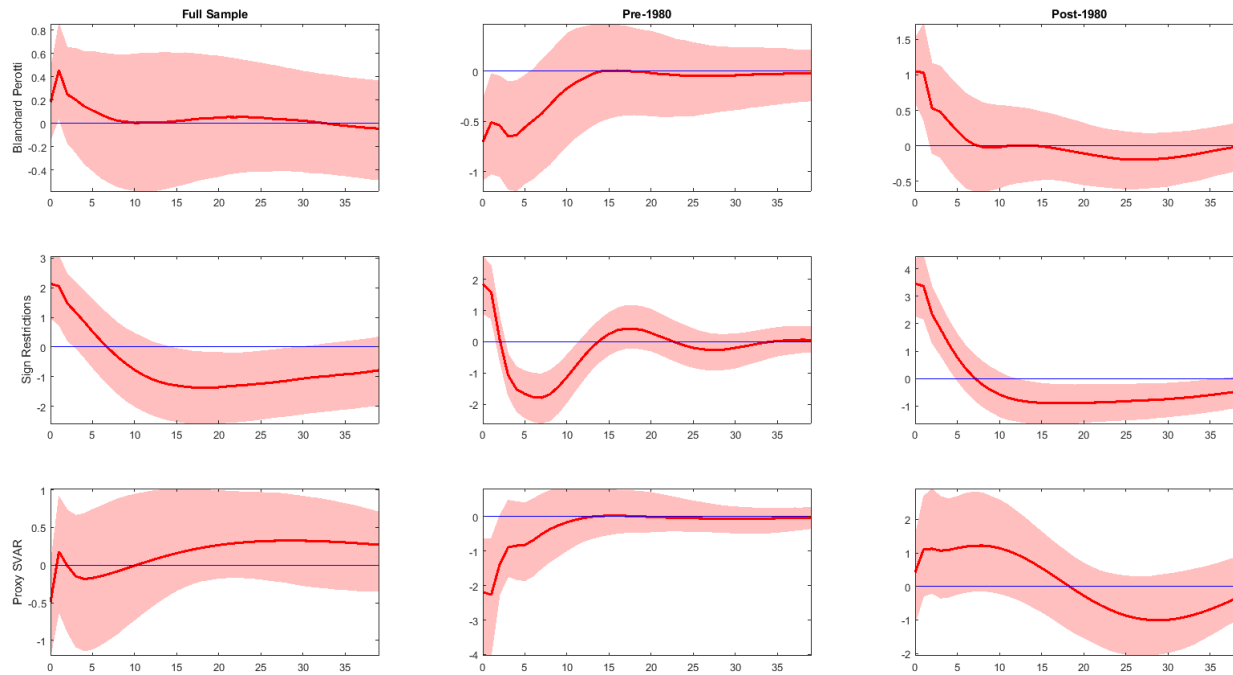


Figure 5: The response of real stock prices to a 1% increase in government revenue. The proxy SVAR uses the [Mertens and Ravn \(2012\)](#) tax shock as an instrument.

3.1.1 Policy experiments

The impulse responses in Figures 1 and 2 report results for ‘pure’ fiscal shocks where the time-path of the fiscal variables is left unconstrained. In the current application, this implies that the behaviour of taxes (spending) can differ across sub-samples after a spending (tax) shock. To check if the results are sensitive to this feature, we follow Mountford and Uhlig (2009) and consider three policy experiments which constrain the path of these fiscal variables. First, we consider a spending shock that is deficit financed – this shock increases spending by one percent for a year while taxes are constrained to remain at zero. The second policy experiment considers a balanced budget rise in spending – i.e. a spending increase of one percent for one year that is matched by a rise in taxes of 0.6 percent.⁹ Finally we consider a tax cut that is deficit financed – taxes fall by one percent for one year while there is no change in spending. As shown in Mountford and Uhlig (2009), these responses can be calculated by choosing the scale of the G and T shocks which delivers the scenarios set out above.

Figure 3 shows the key results from these three experiments. Consider the top three rows which show the impact of a deficit financed increase in spending – as indicated by the shaded area, G is constrained to be at 1% over the first year of the horizon while T remains at zero. The third row displays the response of stock prices and shows that even when these assumptions are imposed on the two sub-samples, the response of stock prices displays the same shift as indicated by the benchmark – in the post-1980 period stock prices fall while they appear to increase in the earlier sub-sample. The next three rows of the figure show the experiment based on a balanced budget increase in G . While the response of stock prices is more muted (and the error bands larger) due to the offsetting effects of the increase in G and T , the change in the response across sub-samples is qualitatively similar to the benchmark. Finally, the last three rows show the impact of the deficit financed tax cut. Before 1980, this policy is associated with an increase in stock prices. In contrast, stock prices fall in response to this policy change after 1980. These results support those estimated under the pure tax shock scenario shown in Figure 2.

3.1.2 Alternative identification schemes

In general, the estimated change in the response of stock prices across the two sub-samples is robust to different methods of identifying innovations to spending and revenue. Figures 4 and 5 present the response of stock prices when the shocks are identified using: (1) the Blanchard and Perotti (2002) and Perotti (2005) scheme, (2) sign restrictions scheme of Mountford and Uhlig (2009) and (3) external instruments in a proxy SVAR. Consider the response to spending shocks shown in Figure 4. The full sample results from the first two identification schemes suggest that the median response of stock prices is negative over, at least, the first year of the horizon while the corresponding response from the proxy SVAR is imprecisely estimated. However, as in the benchmark model, the full sample results hide a substantial amount of time-variation. In the pre-1980 period, the evidence for a negative response of stock prices is muted – stock prices are estimated to increase in the sign restricted and proxy SVARs while the hypothesis of a zero response cannot be rejected when using the Blanchard and Perotti (2002) scheme. In contrast after 1980, all the SVARs indicate that stock prices decline persistently in response to this shock.

Figure 5 shows that, one average across the sample, there is some evidence that a contractionary tax shock is associated with an increase in stock prices. However, this positive impact is missing (or very short-lived, as in the case of the VAR with sign restrictions) in the pre-1980 period, with

⁹The percent rise in G and T reflect the fact that the share of these variables in GDP over our sample is approximately 0.1 and 0.16, respectively.

the response estimated to be strongly negative in some cases. After 1980, however, there is strong evidence (from the Blanchard and Perotti (2002) and the sign restricted SVARs) that stock prices rise with a magnitude ranging from 1% to 3%.

3.1.3 Industry heterogeneity

While the main focus of our analysis is on the aggregate stock price, it is interesting to consider if the sub-sample differences in responses presented above are concentrated in certain industries. To investigate this further we use the 48 industry portfolio made available by Kenneth French. For each industry, we estimate our benchmark VAR model using the industry-specific returns data in place of S_t . Table 1 presents the full and sub-sample cumulated response of returns to fiscal shocks at the two year horizon. Consider the response to G shocks shown in the first three columns. In the pre-1980 period the median response of the stock price is estimated to be positive for 41 out of 48 industries. This pattern changes in the post-1980 period with the estimated median response negative for 35 out of 48 industries. It is interesting to note that large changes in the response occur in industries such as aircrafts, alcohol, trading, health care and defense. In contrast, the response is fairly constant in industries such as mining and precious metals possibly reflecting the fact that they are more sensitive to factors such as international commodity prices and less affected by changes in federal spending. Changes in the response to T shocks in 1980 are less dramatic but qualitatively similar to the results for spending innovations. After 1980 the median response is estimated to be positive for the vast majority of industries while close to half display a negative response in the first sub-sample. Overall, the results in Table 1 indicate that, while there is evidence of heterogeneity, changes in the response to fiscal shocks can be seen across the cross-section. In other words, on average across industries, expansionary fiscal shocks have a more negative impact after 1980.

3.1.4 Further sensitivity analysis

We carry out a number of further checks to investigate the robustness of the result that the response of stock prices to fiscal shocks has changed over time.

Information set First, we consider the possibility of omitted variable bias by trying to account for shocks that may be important for the US economy. In order to preserve degrees of freedom, we add the additional endogenous variables one at a time to the benchmark model which uses the recursive identification. These variables are ordered after the fiscal indicators.

A large number of recent papers have highlighted the role of uncertainty shocks in driving US macroeconomic and financial variables. To account for this we add the uncertainty index proposed by Jurado *et al.* (2015) to the benchmark model. The top row of Figure 14 in Appendix B shows that the estimated temporal change in the response of stock prices to fiscal shocks is largely unaffected by this change in model specification. While the pre-1980 response of stock prices to expansionary (contractionary) fiscal shocks is positive (negative), S falls in response to G shocks and rises on impact in response to T shocks during the post-1980 period.

We next consider if replacing the 1 year rate by a longer maturity alters the results. The second row of Figure 14 suggests that the estimated change in the response of stock prices pre and post-1980 survives this change.

Castelnuovo and Surico (2010) have shown that time-variation in the estimated impact of monetary policy can be affected by the addition of measures of expectations in the VAR model. However

	Full sample	Pre-1980	Post-1980	Full sample	Pre-1980	Post-1980
Industry	G			T		
Aircraft	0.045	0.7*	-0.43*	-0.062	-0.13	0.29*
Agriculture	-0.18	-0.079	-0.2	0.063	0.016	0.071
Autos	0.021	0.1	-0.23	-0.0064	-0.0061	0.21
Banking	-0.11	0.17	-0.42*	0.11	0.24*	0.22
Alcohol	0.17	0.29*	-0.28*	0.0047	0.12	0.16
Construction Material	0.11	0.28*	0.057	0.075	0.1	0.17
Printing, Publishing	0.077	0.32	-0.28	0.099	0.06	0.29*
Shipping Containers	0.23*	0.12	0.17	-0.12	0.075	-0.17
Business services	0.18	0.54*	-0.34	0.17*	-0.022	0.57*
Chemicals	0.031	0.031	0.071	-0.13	-0.11	0.049
Electronic Equipment	0.022	0.42*	-0.38	0.18	0.012	0.42*
Apparel	0.23	0.6*	0.018	-0.012	0.14	0.058
Construction	0.34*	0.97*	-0.1	-0.082	-0.32*	0.086
Coal	0.32	0.24	0.94*	-0.28	-0.31*	0.22
Computers	0.31	0.46*	0.024	0.32*	0.33*	0.38*
Pharmaceutical prod.	-0.19	-0.15	-0.58*	0.2*	0.065	0.45*
Electrical equip.	0.24*	0.33*	0.03	-0.0098	-0.12	0.38*
Fabricated prod.	-0.18	0.68*	-0.33	-0.061	-0.54*	0.2
Trading	0.012	0.37*	-0.49*	0.13	0.083	0.47*
Food	-0.015	-0.094	-0.076	-0.04	0.012	0.088
Entertainment	0.19	0.8*	-0.26	0.097	0.23	0.35*
Precious metals	0.38	0.61*	0.98*	-0.032	-0.29*	-0.36*
Defense	-0.26	0.7*	-0.72*	0.19*	0.082	0.092
Healthcare	-0.0033	4.4*	-0.61*	0.35*	0.84*	0.4*
Consumer Goods	0.082	0.048	-0.099	0.0027	0.042	0.14
Insurance	-0.033	0.31*	-0.45*	0.07	-0.029	0.32*
Measuring equip	0.15	0.46*	-0.26	0.3*	0.15	0.59*
Machinery	0.1	0.27*	0.0046	0.029	-0.041	0.28*
Restaurants	0.15	0.45	0.025	0.052	0.2	0.096
Medical equip	0.058	0.19	-0.3*	0.23*	-0.0079	0.42*
Mining	0.35*	0.48*	0.46*	-0.24*	-0.32*	0.091
Oil	0.0053	0.18	-0.18	-0.068	-0.22*	0.35*
Other	0.33*	0.95*	-0.27	0.27*	0.071	0.6*
Business Supplies	0.12	0.33*	-0.041	-0.068	0.013	0.026
Personal services	0.35*	0.8*	-0.069	0.15	0.22	0.22*
Real Estate	0.36*	1*	0.11	0.16	0.49*	-0.047
Retail	-0.052	-0.16	-0.061	-0.0035	-0.019	0.15
Rubber, plastic	0.28*	0.68*	-0.11	0.011	0.11	0.12
Shipbuilding, railroad	0.039	0.025	0.14	-0.11	-0.31*	0.16
Tobacco	-0.098	-0.22	-0.11	0.02	0.22*	0.14
Candy and Soda	0.14	0.24	-0.092	-0.26*	-0.23*	-0.1
Steel	0.04	0.29	-0.18	0.16	0.081	0.45*
Communication	-0.02	-0.052	-0.15	0.2*	0.18*	0.36*
Recreation	-0.11	0.064	-0.19	0.13	0.5*	0.025
Transportation	0.14	0.47*	-0.072	0.0053	-0.2	0.15
Textiles	0.14	0.36*	-0.082	-0.11	-0.13	-0.12
Utilities	-0.1	-0.065	-0.23	0.041	-0.035	0.31*
Wholesale	0.18	0.69* 14	-0.27	0.15*	0.11	0.31*

Table 1: Cumulated response at the two year horizon. * indicates that zero lies outside the 68 percent error band

when we add the Michigan survey measure of consumer sentiment to the model, the estimated median response of stock prices still displays the time-variation detected in the benchmark model (see third row of Figure 14).¹⁰ Next, we add oil price inflation to the benchmark model to account for oil shocks in the earlier part of the sample. The fourth row of Figure 14 again shows that the benchmark results are preserved.

The benchmark model does not necessarily account for fiscal news or anticipated fiscal shocks. While we try to tackle this issue by using the Ramey (2011) measure of fiscal news as an instrument in the proxy SVAR, papers such as Rossi and Zubairy (2011) pursue a different approach and add the fiscal news measure as an exogenous variable in a recursive VAR in order to ‘filter’ the spending shock. The fifth row of Figure 14 shows that when we adopt this approach and add the fiscal news measure as an additional exogenous variable in the benchmark model, the benchmark results survive. This suggests that estimated response of stock prices to proxies for both anticipated and unanticipated spending shocks shows a very similar temporal pattern.

Time-variation and sample-splits The benchmark results are based on splitting the sample in 1979Q4 as in Perotti (2005). The results from this simple approach are supported qualitatively by a more sophisticated version of the benchmark recursive VAR that allows for time-varying parameters and stochastic volatility à la Primiceri (2005). As the model contains a large number of endogenous variables and lags, estimation is carried out using the algorithm proposed in Koop and Potter (2011). The sixth row of Figure 14 presents the cumulated time-varying response of stock prices at the 2 year horizon to 1 unit increase in spending and revenue, respectively. While, the time-variation in the responses is sluggish by construction, the figure reinforces the point that, on average after 1980, the response of S to G and T shocks was substantially different when compared to the pre-1980 period.

The seventh row of the figure shows that if the Volcker dis-inflation period is removed from the sample (i.e. the VAR is estimated from 1955Q1 to 1979Q2 and then from 1983Q1 to 2015Q4), the results are qualitatively similar to the benchmark case. Similarly, when the sample is truncated at 2007Q4, the temporal changes in the stock price response are similar to benchmark (eighth row of Figure 14).

Trends Following the literature, we allow for a linear and quadratic trend in the benchmark specification. The ninth row of Figure 14, instead, presents the responses from a version of the benchmark model where the variables are first-differenced. As in the benchmark model, stock prices fall in response to spending shocks and rise in response to tax shocks in the post-1980 period. In the pre-1980 period, there is evidence that tax shocks reduce stock prices on impact, while spending shocks have a negligible impact. Finally, the last row of the figure shows results from a version of the benchmark model that only includes a linear trend. The results suggest that, as in the benchmark case, stock prices fall in response to expansionary G shocks after 1980 and appear to rise in response to T shocks in the medium term in this sub-sample. This pattern of responses is not present in the pre-1980 sample.

To summarise, the impulse response analysis from the numerous VAR models considered above suggests two main conclusions:

1. In the pre-1980 period, the median response of S to expansionary fiscal shocks is positive.

¹⁰We use consumer sentiment instead of a measure of inflation expectations as the latter is only available from 1970Q1 onwards making the estimates in the pre-1980 sub-sample possibly unreliable.

-
2. In the post-1980 period, the response of S appears to change sign. In fact, there is evidence that after 1980, expansionary fiscal shocks lead to a *reduction* in stock prices.

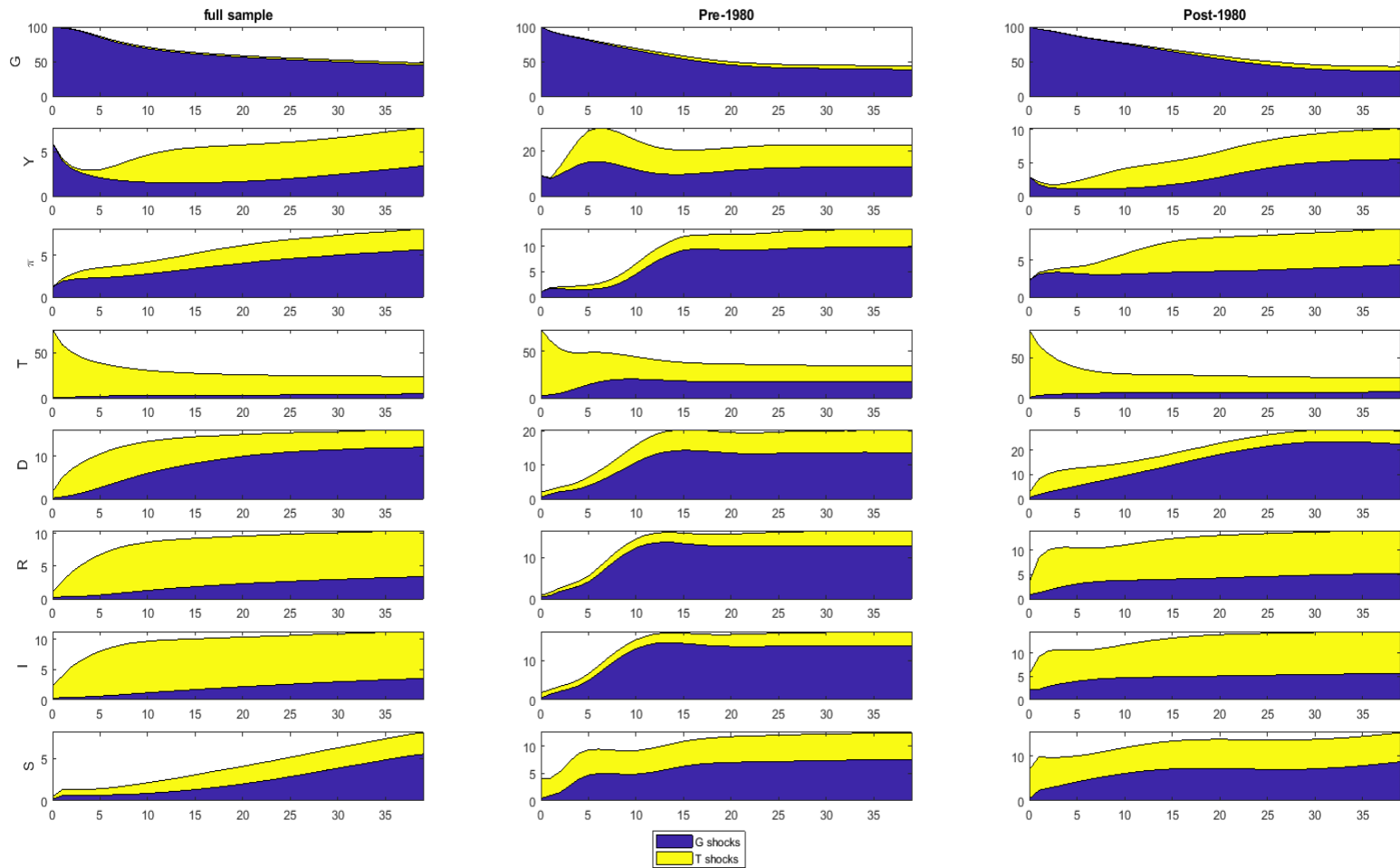


Figure 6: The percentage contribution of spending and revenue shocks to the forecast error variance

3.2 The contribution of fiscal shocks to stock prices

Figure 6 shows the estimated contribution of the fiscal shocks to the forecast error variance (FEV) of the endogenous variables using the benchmark VAR model. At the one year horizon, fiscal shocks contribute about 18% to the FEV of GDP. However, as in the case of impulse responses the results change over time. In particular, the contribution of fiscal shocks to GDP is substantially smaller in the post-1980 period. The same decline can be seen in the contribution of these shocks to inflation and the interest rates. However, in contrast, the contribution of these shocks to stock price FEV has increased somewhat after 1980. In the pre-1980 period, this contribution was about 7% at the one-year horizon reaching a maximum of 12% in the long-run. After 1980 the fiscal shocks contributed 10% at the one-year horizon with the contribution rising to 15% in the long-run.

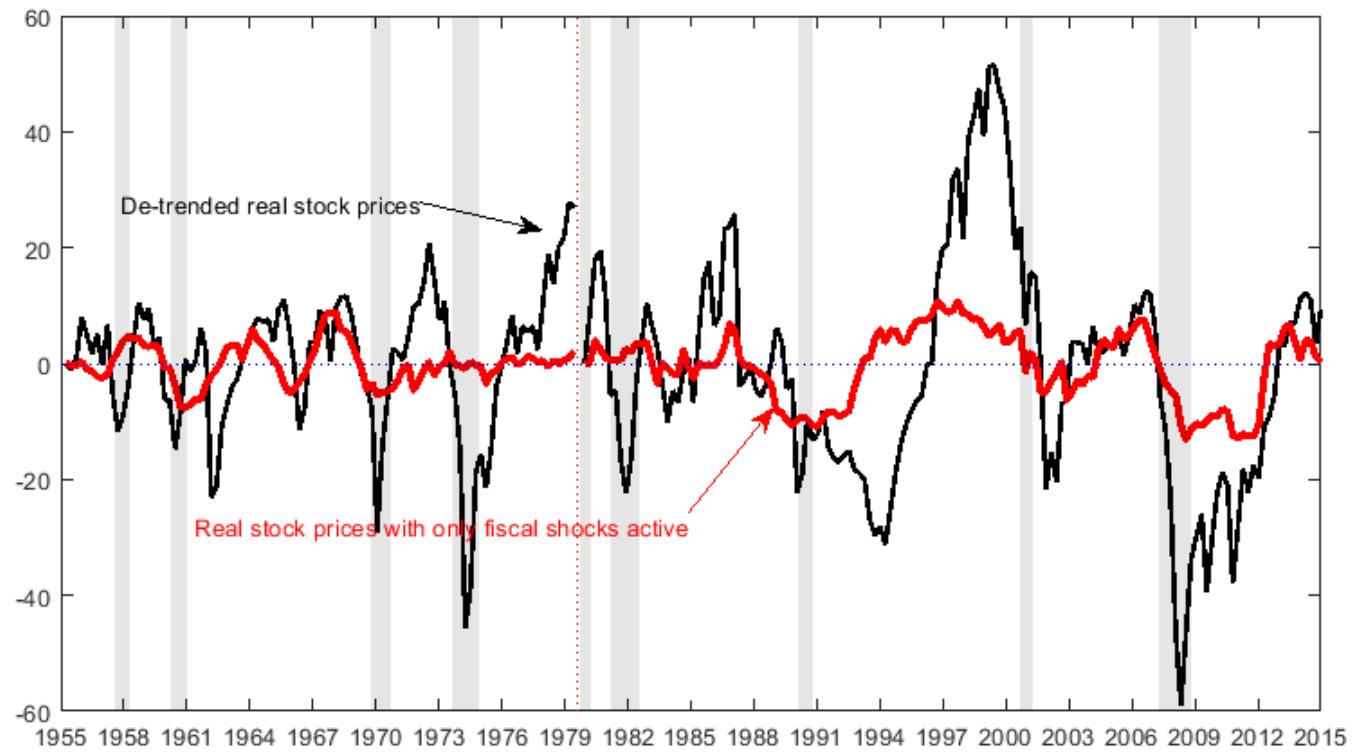


Figure 7: Real stock prices relative to VAR implied trend. The black line is actual data while the red line is the counter-factual estimate under the scenario that only G and T shocks are active. The grey-shaded areas represent NBER recession dates.

A similar picture emerges when the historical decomposition of stock prices is considered. Figure 7 presents stock prices relative to trend and the counter-factual estimate of S assuming only spending and revenue shocks are active. The figure presents this decomposition using the benchmark VAR estimated in the two sub-samples with the vertical line indicating the sample split. First, it is evident that the historical contribution of fiscal shocks is smaller in the pre-1980 period. The tax increases in 1982 coincide with a small positive contribution of fiscal shocks to stock prices. The Gulf war proved to be a boost to defense spending during the early 1990s and was associated with a negative contribution to stock prices. However, the tax increases under the Omnibus Budget reconciliation acts and the unwinding in military spending after the Gulf war reversed this pattern and fiscal shocks made a positive contribution to stock prices from the mid-1990s. Fiscal shocks make a modest negative contribution during the Bush tax cuts in early 2000s. It is interesting to note that the fiscal expansion via tax cuts associated with the stimulus acts 2008-2010 coincided with a large negative contribution of fiscal shocks to S .¹¹ These results re-enforce the conclusions reached above via impulse response analysis – after 1980 expansionary fiscal shocks are increasingly associated with a *reduction* in stock prices.

4 Explaining the change. A DSGE model

Why is the response of stock prices to fiscal shocks different after 1980? Two pieces of the VAR-based results presented above are supportive of the idea that a macroeconomic structural shift may play a part. First, as discussed in section 2.2, the long-run responses of interest rates to inflation shocks and of taxes to debt innovations change after 1980 and are consistent with a post-1980 economy where the monetary authority reacts more strongly to inflation and a fiscal authority that is more concerned with stabilising debt. Second, the industry-specific impulse responses in section 3.1.3 indicate that the temporal change in the response of stock prices is not limited to a few sectors but appears wide-spread. This is consistent with the argument that an economy-wide factor may be behind the change in the response of stock prices.

In this section we use an estimated DSGE model to explore this conjecture further – As in Traum and Yang (2011), we augment the model developed by Christiano *et al.* (2005) and Smets and Wouters (2007) with a *simple* non-productive government sector. In this section we present a description of the key features of this model. A complete description of each sector is provided in the technical appendix to the paper.

4.1 Key features of the model

The model features monopolistically competitive households who consume, supply labour and capital services. As in Erceg *et al.* (2000), the household supplies a differentiated labour service to the production sector. They set their nominal wage and supply any amount of labour demanded by the firms at that wage rate. In each period, a fraction of households receive a random signal and they are allowed to reset wages optimally while all other households can only partially index their wages to past inflation. The firm sector in the model consists of a continuum of intermediate producers that employ labour and capital services to produce the intermediate good for sale to the final producer. Intermediate producers operate in two stages: First, they take wage and rental rate of capital as given and decide about labour and capital demand by maximising their profits. Second, they decide about what price to charge with a fraction of firms allowed to reset their price

¹¹In the technical appendix, we show that this result is robust to assumptions about the trends and the choice of endogenous variables in the VAR model.

each period. The government sector consists of a fiscal authority and a monetary authority. Fiscal authorities finance government consumption and transfers by raising revenues from taxation and issuing new debt. The budget constraint of the fiscal authority is given by:

$$\frac{\tilde{B}_t}{R_t^G} + \tau_t \left(R_t^K v_t \tilde{K}_{t-1} + \tilde{W}_t L_t \right) = \frac{\tilde{B}_{t-1}}{\Pi_t} + \tilde{G}_t + \tilde{T} R_t \quad (1)$$

Here, \tilde{B}_t denotes government debt, τ_t is the tax rate, R_t^G is the effective interest rate faced by households, R_t^K is the rental rate of capital ($v_t \tilde{K}_{t-1}$), \tilde{W}_t is wage, L_t denotes hours worked, Π_t is inflation, while \tilde{G}_t and $\tilde{T} R_t$ denote government consumption and transfers, respectively.¹² Debt and tax decisions are based on the following simple rule:

$$\frac{\tau_t}{\tau} = \left(\frac{\tau_{t-1}}{\tau} \right)^{\rho_\tau} \left(\frac{\tilde{B}_{t-1}/B}{\tilde{Y}_{t-1}/Y} \right)^{(1-\rho_\tau)\zeta_\tau} \quad (2)$$

where \tilde{Y}_t is output. Government consumption evolves as a stationary exogenous process.

The monetary authority sets the policy interest rate R_t via the rule:

$$\frac{R_t}{R \Pi_t^*} = \left(\frac{R_{t-1}}{R \Pi_{t-1}^*} \right)^{\rho_R} \left(\frac{\Pi_t}{\Pi_t^*} \right)^{(1-\rho_R)\gamma_\pi} \left(\frac{Y_t}{Y} \right)^{(1-\rho_R)\gamma_y} \left(\frac{Y_t}{Y_{t-1}} \right)^{(1-\rho_R)\gamma_{\Delta y}} \exp^{\sigma_{R\varepsilon_{R,t}}} \quad (3)$$

where Π_t denotes inflation.

An equity security in the model is defined as a levered claim on the aggregate intermediate good producers' profits. Every period, the equity security pays a dividend equal to $\Xi_{I,t}^\vartheta$ where ϑ captures the degree of leverage and:

$$\Xi_{I,t} = Y_t - \tilde{W}_t L_t - R_t^K v_t \frac{K_{t-1}}{\Gamma_t}$$

(see the online Appendix). In this case the price of the equity is defined as:

$$q_t^e = E_t m_{t+1} \left(\Xi_{I,t+1}^\vartheta + q_{t+1}^e \right) \quad (4)$$

where $m_t = \beta \frac{\lambda_{t+1}}{\lambda_t \Gamma_{t+1}}$ is the stochastic discount factor. The observed equity price (log-linearly approximated around a non-stochastic steady-state) is defined as:

$$\hat{q}_t^{e,obs} = \hat{q}_t^e + eqrp_t$$

where the equity risk premium $eqrp_t$ equals:

$$eqrp_t = \rho_{eqrp} eqrp_{t-1} + \sigma_{eqrp} \varepsilon_{eqrp,t} \quad (5)$$

The equity risk premium captures the component of the observed equity prices that reflects a risk compensation requested by agents for holding this asset.

As emphasized in [Traum and Yang \(2011\)](#), a unique solution of the model is implied by two combinations of the parameter sub-space. Under the active monetary policy, passive fiscal policy

¹²Non stationary variables are denoted by the superscript $\tilde{\cdot}$. Variables without a time subscript are steady state values.

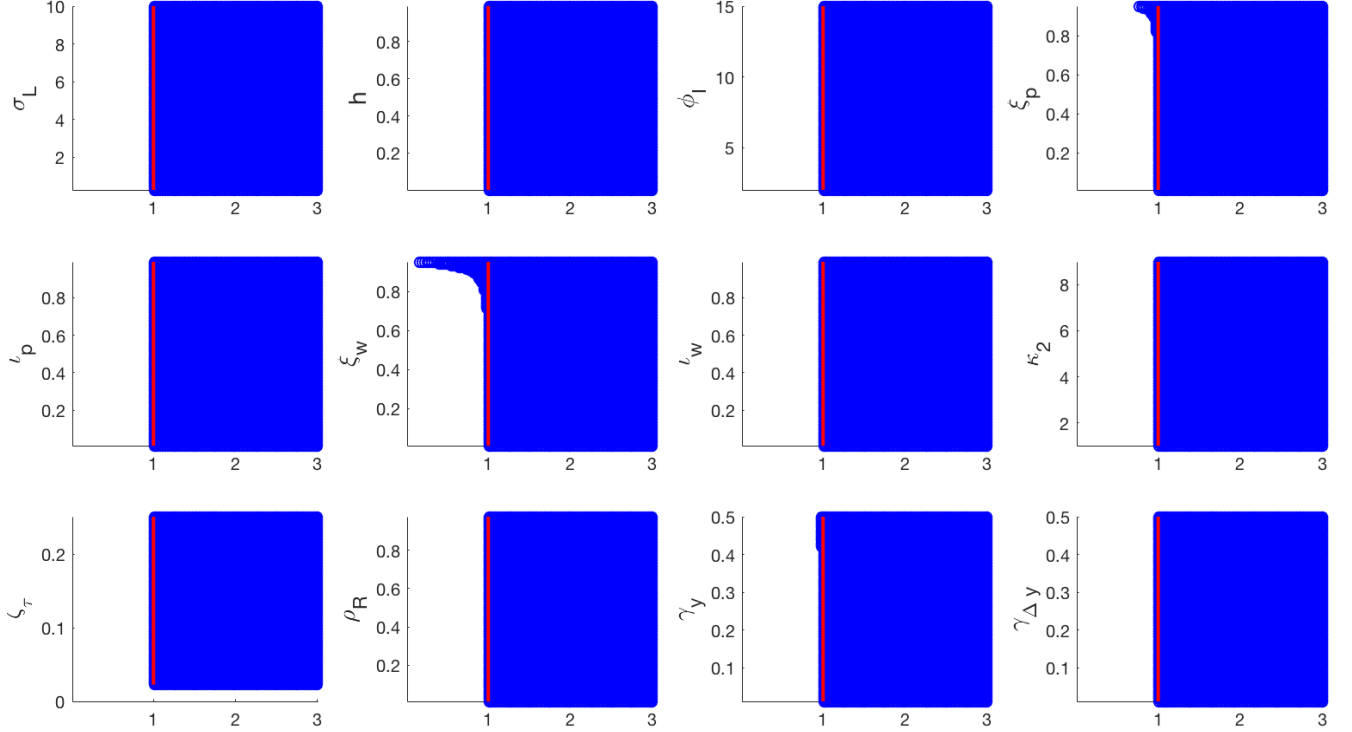


Figure 8: AMFP Parameter Combinations. For each parameter combination a two dimensional grid of 100×100 points is used. In all cases the x-axis denotes the value of the reaction of monetary authorities to CPI inflation. We set the value of the parameters not plotted here equal to their prior mean. For a definition of each parameter, see Table 3 in the technical appendix.

scenario (AMPF), the monetary authority reacts to deviations of inflation from its target by raising the interest rate sufficiently to stabilise inflation expectations while the fiscal authority adjusts spending or revenue to bring government debt back to its steady state value. Under the passive monetary policy, active fiscal policy scenario (PMAF), the monetary authority does not react strongly to deviations of inflation from target, while the fiscal authority does not react in a passive manner to stabilise the path of debt.

4.1.1 Determination of the policy regime

As explained in [Traum and Yang \(2011\)](#), the complexity of the model does not allow us to derive analytical conditions to identify the policy regimes. Instead, [Traum and Yang](#) propose a simulation exercise to infer these conditions numerically. In [Figure 8](#), we repeat this exercise for our model. To be precise, for each successful parameter combination, the model is solved twice. In the second solution attempt, the value of the reaction coefficient to debt – ζ_τ – is set equal to 0.5 and other parameters are held at their original values. If the model can be solved under this passive fiscal policy, then the original parameter combination implies an active monetary policy.

Our results are very similar to those reported by [Traum and Yang \(2011\)](#). In most cases, the policy reaction coefficient to CPI inflation – γ_π – has to exceed one for monetary policy to be active. There are exceptions, however. As either the price or the wage Phillips curve becomes flatter (i.e. ξ_W or ξ_p becomes larger), the policy reaction coefficient to CPI inflation – γ_π – could take values less than one. The intuition here is very simple, the flatter the Phillips curve is the more anchored

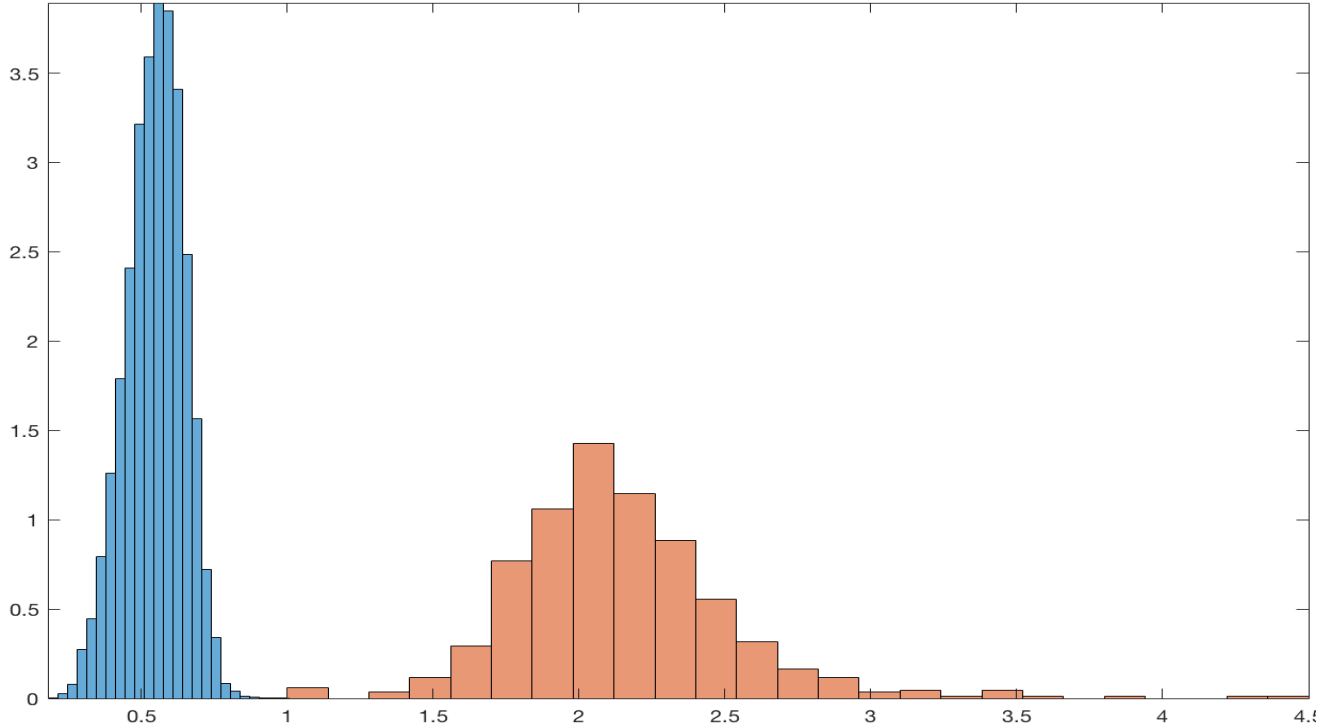


Figure 9: The distribution of the present value of the fiscal multiplier.

the inflation expectations are, consequently, the less inflation responds to expected marginal cost (Del Negro *et al.* (2015) and Fernandez-Villaverde and Rubio-Ramirez (2008)). The better the inflation expectations are anchored, the less the policy maker needs to adjust the instrument to move inflation expectations toward the target.

These simulations could be used to characterise an AMPF or PMAF policy regime. However, as each simulation holds a sub-set of parameters fixed, they are silent on the conditions under which the response of the real interest rate to a government spending shock changes sign or when the size of fiscal multiplier exceeds one. As discussed below, the behaviour of the real interest rate after a spending shock is instrumental in determining the response of stock prices. To investigate this further, we draw 20000 parameter vectors from the prior distribution and we use the model to calculate the magnitude of the present value of the fiscal multiplier (averaged across 12 periods).

The results shown in Figure (9) are quite revealing – the prior distribution of the multiplier is clearly bi-modal. As the model is linearised around a non-stochastic steady-state, the only feature that could generate such pattern is the solution of the model.

To understand the factors that generate this feature, Figure (10) plots the combinations of the policy parameters (i.e. ζ_τ and γ_π) that generate a multiplier greater than one (left hand side panel) and less than one (right hand side panel). In order to obtain a multiplier great than one (which is consistent with a fall in the real interest rate) ζ_τ must be less than $\frac{\mu\Gamma}{\beta} - 1$ and γ_π should be less than one. In our model a multiplier greater than one is obtained when simultaneously: (i) fiscal authorities do not adjust taxes sufficiently to stabilize the debt after a fiscal expansion and (ii) monetary policymakers do not increase the policy rate enough to keep inflation expectations well anchored.

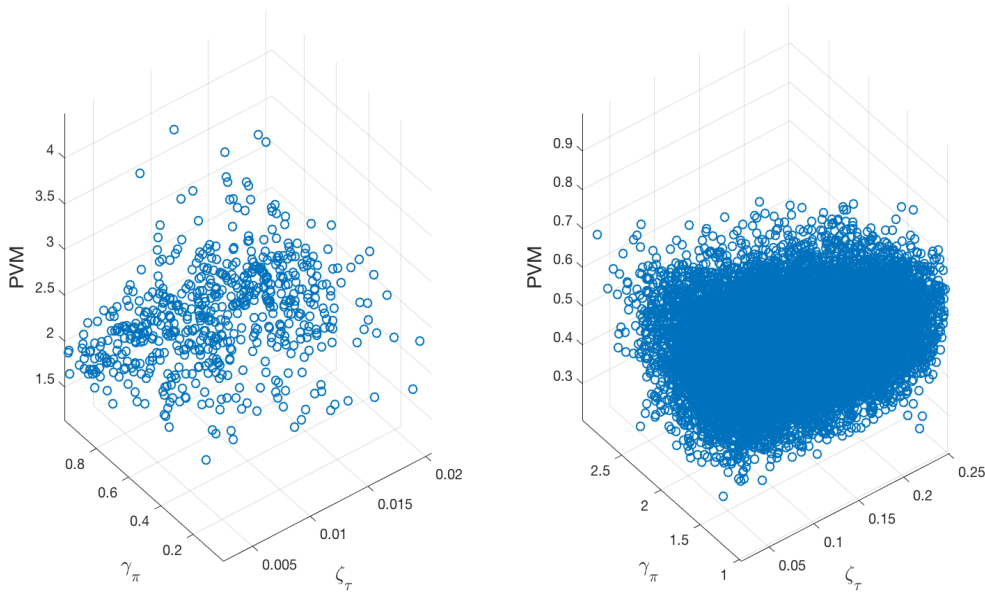


Figure 10: The present value multiplier as function of the fiscal and monetary policy reaction coefficients.

4.1.2 Estimation

We estimate the parameters of the model using Bayesian techniques. As in the case of the SVARs, the estimation is carried out on two sub-samples. The first sub-sample ranges from 1955 Q1 to 1979 Q4. The second subsample runs from 1980 Q1 to 2007 Q4. The DSGE model estimation uses the fiscal data included in the VAR models above (i.e. government spending, tax revenue and the debt to GDP ratio)¹³ The remaining observables in the DSGE estimation include, GDP per capita, consumption per capita, investment per capita, real wages, average hours, inflation, the policy rate, the 10 year government bond yield and equity prices.¹⁴ As the model does not directly account for the ZLB and unconventional policies, we restrict the second sub-sample to 2007.

The sample is split in 1980 to match the SVAR analysis. There are many studies in the literature (Traum and Yang (2011), Leeper *et al.* (2017), Kliem *et al.* (2016) among others) that adopt a very similar sub-sample analysis to investigate simultaneous changes in the preferences of both fiscal and monetary authorities. Furthermore, the studies of Bianchi and Ilut (2014) and Bianchi and Melosi (2017) seem to justify empirically a very similar split of the data. Their methodology allows the policy parameters to evolve stochastically from one regime to another. Although the process that ‘drives’ these switches is unobserved, it can be inferred from the data by using filtering techniques. This analysis reveals that the time period of changes in the policy parameters seems to coincide with the split of the sample adopted in the literature.

As described in detail in the technical appendix, we follow Del Negro and Schorfheide (2008) (among others) and use priors that are formed ‘endogenously’. In other words, the priors for the

¹³Since government spending is observed, a wedge has been added to the market clearing condition to facilitate the estimation of the model. This wedge captures the net-trade, residential investment and stock building components of the GDP definition not captured by the model.

¹⁴Note that variables that are non-stationary are first differenced for the estimation.

parameters (which are based on common choices in the literature) are conditioned on beliefs about data moments of interest. In our application these moments are impulse responses to government spending shocks and the beliefs are centered on the estimates obtained from the benchmark SVAR model. As shown above, the SVAR results are robust across numerous permutations of the empirical model and the approach of [Del Negro and Schorfheide \(2008\)](#) allows us to incorporate this information into the DSGE estimation thus ameliorating the effect of the short data span in the two sub-samples.

4.2 Results

The posterior estimates of the model parameters reveal a very interesting pattern of policy changes. The 90% HPDI for the parameter governing monetary policy activism, γ_π , is estimated to be (0.50, 0.73) in the first sub-sample and is thus more consistent with passive monetary policy. After 1980, there is stronger evidence in favour of more active monetary policy with the HPDI rising to (1.55, 2.2). The behaviour of the fiscal authorities is also estimated to be different across sub-samples. In the post-1980 period the 90% HPDI for ζ_τ is estimated to be (0.71, 0.74) while $\frac{\Pi}{\beta} - 1 = 0.023$. Before 1980 the HPDI of ζ_τ is estimated to be (0.003, 0.017) and $\frac{\Pi}{\beta} - 1 = 0.029$ implying a low reaction of fiscal authorities to debt. The posterior estimates of the remaining parameters fall well in the range reported in the literature ([Christiano *et al.* \(2005\)](#), [Smets and Wouters \(2007\)](#), [Justiniano *et al.* \(2010\)](#), [Del Negro *et al.* \(2015\)](#) among others) and are described in the technical appendix.

4.2.1 Impulse responses

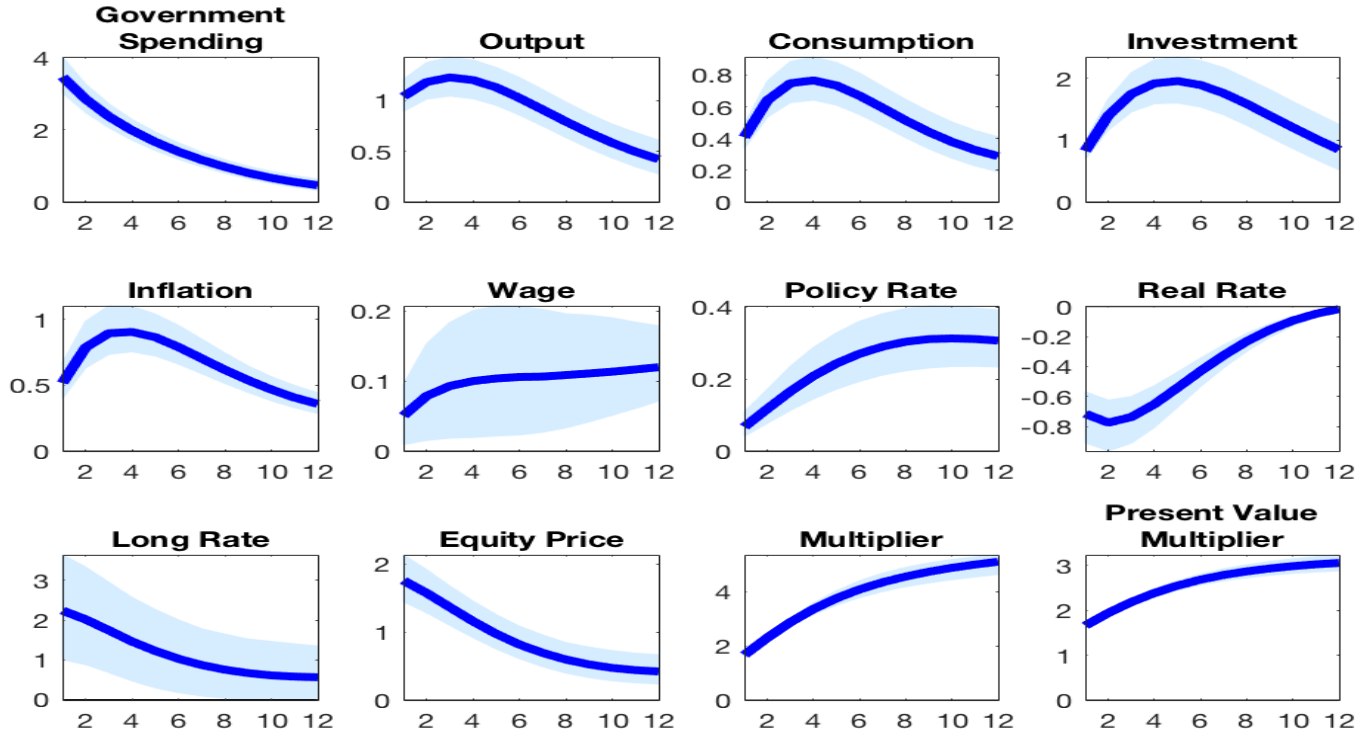


Figure 11: Pre-1980 estimates of the response to a government spending shock. The solid line represents the pointwise median impulse response function, and the shaded area is the corresponding 5th and 95th percentiles of the posterior distribution. The horizontal axes are in quarters, the vertical axes are in percentage points. The inflation rate is expressed in annualised terms, while the interest rates in annual terms. The multiplier is defined as $M_i = \frac{Y}{G} \frac{\hat{G}_i}{\hat{Y}_i}$, and the present value multiplier is defined as $PVM_i = \frac{Y}{G} \frac{\sum_{j=0}^i (\prod_{k=0}^i (1+\hat{R}_k)^{-1}) \hat{G}_j}{\sum_{j=0}^i (\prod_{k=0}^i (1+\hat{R}_k)^{-1}) \hat{Y}_j}$. The superscript $\hat{\cdot}$ denotes deviations from steady state.

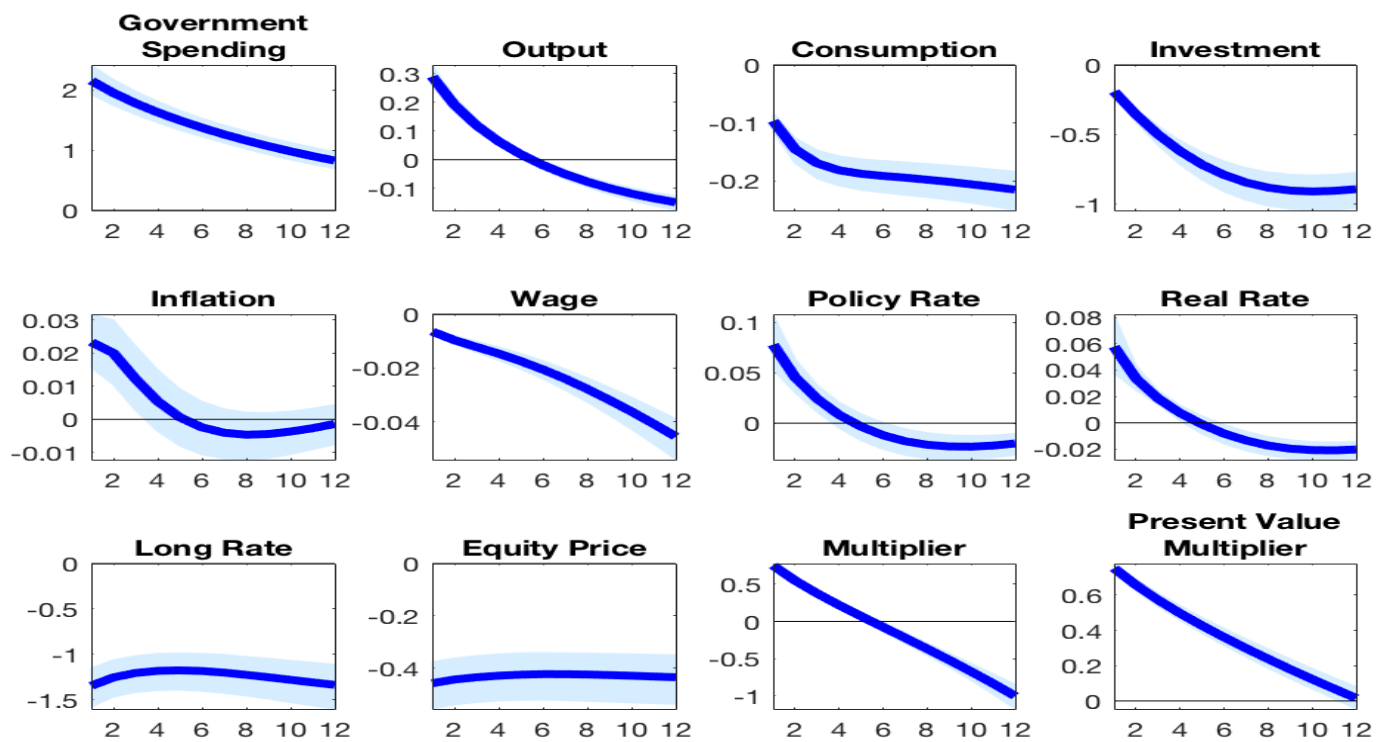


Figure 12: Post-1980 estimates of the response to a government spending shock. See notes to Figure [11](#)

Figures 11 and 12 present the estimated response to a government spending shock in the two subsamples. Consider the pre-1980 results. A passive monetary authority allows inflation expectations to rise after a positive government spending shock and the real interest rate declines. A lower real interest rate implies higher consumption and investment demand with an output multiplier that is greater than 1 at the two year horizon. Private demand is boosted further by the fact that fiscal authorities react to government debt only weakly. As discussed in Leeper *et al.* (2017), the latter effect is small as the existence of steady state taxes ensures that the tax revenue increases along with the expansion of the real economy and this reduces the wealth effects induced by active fiscal authorities. Given lower real rates after the shock, equity prices rise.¹⁵

The post-1980 estimates are a mirror image of the pre-1980 results. In this regime, both authorities set policy in a manner that it is consistent with their objectives. However, as these policies are uncoordinated, any stimulatory effect from a government spending shock is cancelled out by the higher real rates and higher taxes. As a result, the output multiplier is substantially smaller in this regime. Note that as the real interest rate rises and consumption falls, the expansionary spending shock causes the equity price to decline by a substantial amount.

While our DSGE model does not directly account for the ZLB or unconventional monetary policies, we use a number of nonlinear perfect foresight simulations (see technical appendix) to provide a tentative assessment of how these policy regimes might affect the main conclusions reached above.¹⁶ We fix the model parameters to post-1980 estimates and use a preference shock to force the policy-rate to the ZLB. We compare the response of the economy under this scenario with the response when the ZLB is not imposed and a monetary policy rule is operational. One can argue that the latter scenario is not implausible as it proxies for the presence of unconventional monetary policy. Under ZLB, a positive G shock leads to a fall in the real interest rate and stock prices rise. If, on the other hand, the short term rate is not held at zero, then monetary policy can react to the G shock and the increase in the real rate leads to a fall in equity prices.¹⁷ These results provide a caveat to the conclusions reached above via the DSGE model – if one believes the post-2009 period to be characterised by completely passive monetary policy then fiscal expansions are likely to be associated with an increase in asset prices. However, two pieces of VAR-based evidence (see Figure 14) suggest that this caveat might not apply fully to our results. First, excluding the post-2007 period from the VAR estimates does not change the stock price responses substantially. Secondly, the stock price impulse responses from the time-varying parameter VAR do not display a tendency to switch sign towards the end of the sample.

4.2.2 Discussion

In summary, the posterior estimates of the DSGE model provide one compelling explanation for the SVAR results. We find that the fall in equity prices in response to expansionary fiscal shocks estimated after 1980 may be a manifestation of the activism of monetary authorities over a period of passive fiscal policy. Before 1980, monetary policy is likely to be passive while the posterior estimates of the tax rule point to higher degree of fiscal activism. As a result, expansionary fiscal shocks over this period were associated with modest increases in equity prices.

One reason for giving weight to this explanation is the fact that estimates from the DSGE model are consistent with the VAR results along several dimensions. First, the estimated long run

¹⁵Equity prices consists of two components: i) the discount rate and ii) cash flows (profits), equity prices rise due to the decrease of the real interest rate and this is despite the fall in profits.

¹⁶Note that the VAR models do contain proxies for unconventional monetary policy as they include the shadow short-term interest rate over the ZLB period and the one year government bond yield.

¹⁷These results do not change substantially if fiscal policy is assumed to be more active.

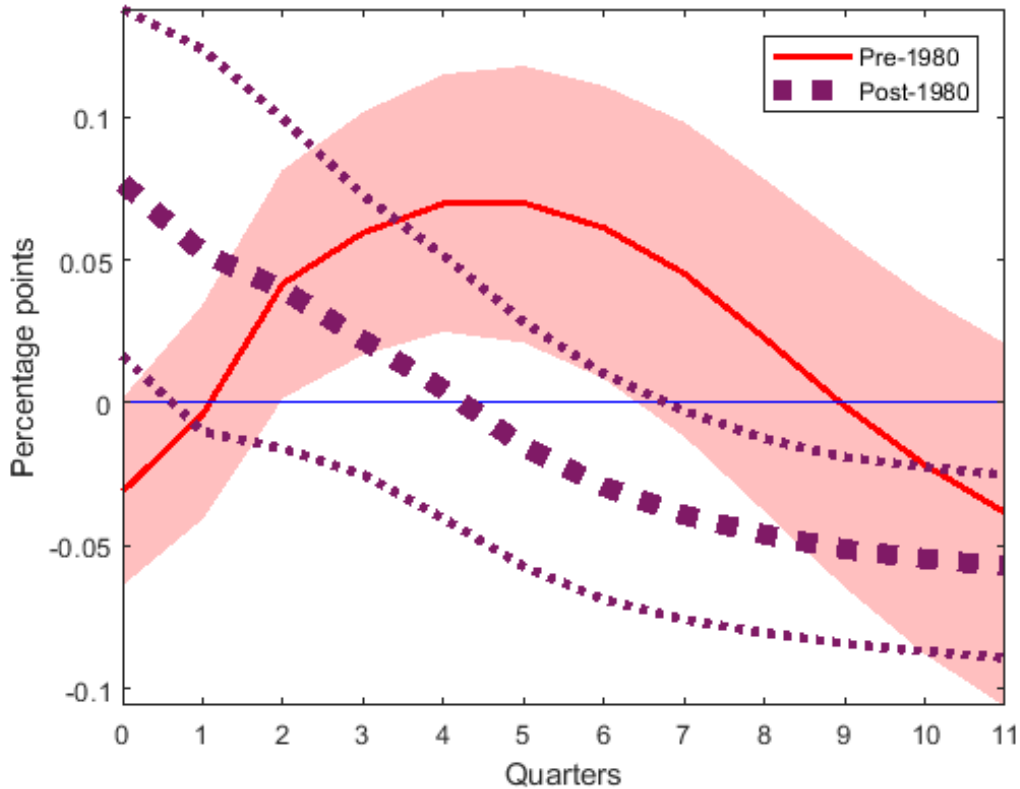


Figure 13: The response of the real rate $r_t - \pi_{t+1}$ to a G shock using the benchmark VAR. The response is estimated assuming the scenario of the deficit financed spending increase shown in Figure 3.

impulse responses to inflation and debt shocks in the VAR (see Section 2.2) support the notion that monetary policy was active after 1980 while taxes responded more to debt in this sub-sample. Second, when considering spending shocks, the VAR response of the real interest rate is consistent with the DSGE estimates, at least from a qualitative perspective.

This can be seen in Figure 13 which presents the response of $r_t - \pi_{t+1}$ to a government spending shock using the benchmark VAR model. As in Section 3.1.1, we assume that taxes are fixed at zero for the first four quarters, bringing this exercise closer to the DSGE simulations reported in Figures 11 and 12 (where debt rises after a G shock). In the pre-1980 period, the real rate is not positive until two quarters after the shock. In contrast, the real rate rises immediately in the post-1980 sub-sample, with the median initial increase larger than the peak rise in $r_t - \pi_{t+1}$ in the pre-1980 period. Taken together, these VAR results provide support for the mechanism highlighted in the DSGE model.

Our results are of relevance to the recent discussion about the switch from the passive monetary, active fiscal policy to active monetary, passive fiscal policy regime in papers such as Bianchi and Ilut (2014) and Bianchi and Melosi (2017). Our findings are consistent with the results of Bianchi and Ilut (2014) and Bianchi and Melosi (2017) even though we apply a very different methodology. Furthermore, our results contribute to the literature regarding the Great moderation and policy switches (Lubik and Schorfheide (2004), Sims and Zha (2006), Cogley and Sargent (2005), Cogley *et al.* (2010)). The DSGE analysis provides important results on the size of the fiscal multiplier. We

show that an estimated Smets and Wouters (2007) type model can deliver a multiplier greater than one without modelling features such long-run debt, rule of thumb consumers and complementarity between government and private consumption (Bianchi and Ilut (2014), Leeper *et al.* (2017), Bianchi and Melosi (2017)). Our analysis suggest that a fiscal expansion does not need to crowd out private demand if the real interest rate falls. This has direct implications for central banks and it suggests that successful fiscal expansions require a high degree of coordination between the two authorities. Finally, our results have implications for the literature that uses asset prices to identify the effects of policy actions (Wright (2012), Joyce *et al.* (2011), Gilchrist and Zakrajsek (2013)).

5 Conclusions

In this paper we use a battery of SVAR models to show that the response of US stock prices to an expansionary fiscal shock has changed after 1980. Before this date, an expansionary fiscal shock was associated with modest increases in stock prices. Post-1980, the same shock is associated with large declines in stock prices.

We then use an estimated DSGE model to show this shift in the response can be explained by a change in policy activism. The parameter estimates in the pre-1980 period are consistent with active fiscal policy and passive monetary policy. This policy mix allowed the real interest rate to fall after a fiscal expansion boosting equity prices. After 1980 monetary policy is estimated to be active while the fiscal authority is found to be passive. As a consequence positive fiscal shocks result in real interest rate increases causing consumption and equity prices to decline.

In future work it would be interesting to explore if the temporal shift documented in this paper also apply to other developed countries such as the United Kingdom. It may also be useful to investigate if fiscal shocks have economically significant effects on prices of other assets such as homes and whether the estimated impact is stable through time.

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A Appendix A: Main Data sources

BEA refers to Bureau of Economic Analysis (<http://www.bea.gov/>), FRED is Federal Reserve Economic data (<http://research.stlouisfed.org/fred2/>) and GFD refers to Global Financial Data.

Fiscal data

- Government spending: Federal spending (BEA Table 3.9.5 line 6) divided by population and deflated by the GDP deflator.
- Taxes: Federal tax receipts plus (Table 3.2 line 2) plus contributions for Government Social Insurance (Table 3.2 line 11) minus corporate income taxes from Federal Reserve Banks (line 8 in Table 3.2) divided by population and deflated by the GDP deflator.
- Federal defense spending: Defense Consumption Expenditures and Gross Investment (FRED series FDEFX) divided by population and deflated by the GDP deflator.
- Government Debt: Market value of Gross Federal Debt (FRED series id MVGFD027MNFBRBDAL) divided by nominal GDP.
- Tax shock calculated by [Mertens and Ravn \(2012\)](#).
Downloaded from <https://www.aeaweb.org/articles?id=10.1257/pol.4.2.145>.
- News in government defence spending calculated by [Ramey \(2011\)](#).
Downloaded from <http://econweb.ucsd.edu/~vramey/research.html#data>.

Macroeconomic/Financial data

- Real GDP per capita: Real GDP (FRED series id GDPC96) divided by population.
- CPI (FRED series id CPIAUCSL). We calculate inflation as the annual growth in CPI.
- 3 month Treasury Bill rate (FRED series id TB3MS). From 2009Q1 to 2015Q4, we use the shadow rate calculated by [Wu and Xia \(2014\)](#). This is obtained from the Federal Reserve Bank of [Atlanta](#).
- Real Stock Prices: S & P 500 total return index (GFD code _SPXTRD) deflated by CPI.
- 1-year government bond yield (GFD code IGUSA1D).
- 10-year government bond yield (GFD code IGUSA10D).

- Consumer Confidence index: University of Michigan Consumer sentiment (FRED id UMCSENT and UMCSSENT1).
- Uncertainty index calculated by [Jurado *et al.* \(2015\)](#).
Downloaded from <https://www.sydneyludvigson.com/data-and-appendixes/>.
- Oil prices: West Texas Intermediate Oil Price (GFD code: __WTC_D)
- Population (FRED series id POP)
- GDP deflator (FRED series id GDPDEF)
- The remaining variables for the DSGE estimation (consumption, investment, wages and hours) are taken from [Smets and Wouters \(2007\)](#).

B Appendix B: Robustness

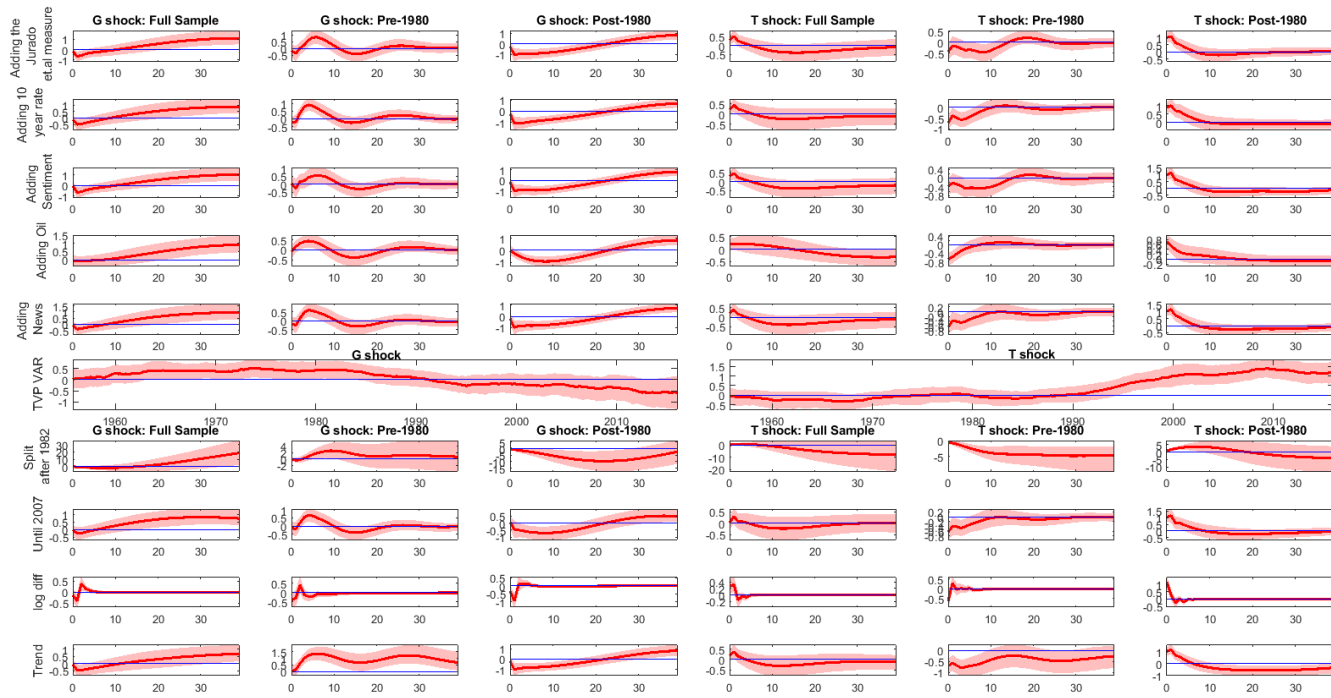


Figure 14: Sensitivity Analysis. Each row presents the response of S to spending and revenue shocks.

Technical Appendix: Fiscal policy shocks and stock prices in the United States.

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1 SVAR Estimation

1.1 Recursive VAR and VAR with Sign Restrictions

Consider the reduced form VAR

$$Y_t = \alpha \Gamma_t + \sum_{j=1}^P \beta_{t-j} Y_{t-j} + v_t, \text{var}(v_t) = \Omega$$

where Γ_t is $1 \times M$ vector of exogenous regressors. We adopt a Bayesian approach to estimation of the reduced form VAR model. We introduce a natural conjugate prior for the VAR parameters (see [Banbura *et al.* \(2010\)](#)):

$$Y_{D,1} = \begin{pmatrix} \frac{\text{diag}(\gamma_1 \sigma_1 \dots \gamma_N \sigma_N)}{\tau} \\ 0_{N \times (P-1) \times N} \\ \dots \\ \text{diag}(\sigma_1 \dots \sigma_N) \\ \dots \\ 0_{M \times N} \end{pmatrix}, \text{and } X_{D,1} = \begin{pmatrix} \frac{J_P \otimes \text{diag}(\sigma_1 \dots \sigma_N)}{\tau} & 0_{NP \times M} \\ 0_{N \times NP+M} \\ \dots \\ 0_{M \times NP} & I_M \times c \end{pmatrix} \quad (1)$$

where γ_1 to γ_N denotes the prior mean for the coefficients on the first lag, τ is the tightness of the prior on the VAR coefficients and c is the tightness of the prior on the constant terms. In our application, the prior means are chosen as the OLS estimates of the coefficients of an AR(1) regression estimated for each endogenous variable using a training sample. We set a loose prior, $\tau = 100000$. The scaling factors σ_i are set using the standard deviation of the error terms from these preliminary AR(1) regressions. Finally we set $c = 1/1000$ in our implementation indicating a flat prior on the constant. We also introduce a prior on the sum of the lagged dependent variables by adding the following dummy observations:

$$Y_{D,2} = \frac{\text{diag}(\gamma_1 \mu_1 \dots \gamma_N \mu_N)}{\lambda}, X_{D,2} = \begin{pmatrix} (1_{1 \times P}) \otimes \frac{\text{diag}(\gamma_1 \mu_1 \dots \gamma_N \mu_N)}{\lambda} & 0_{N \times M} \end{pmatrix} \quad (2)$$

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where μ_i denotes the sample means of the endogenous variables calculated using the training sample. As in [Banbura et al. \(2010\)](#), the tightness of this sum of coefficients prior is set as $\lambda = 10\tau$. Given the natural conjugate prior, the conditional posterior distributions of the VAR parameters $B = \text{vec}([\alpha, \beta_1; \beta_2 \dots; \beta_j])$ and Ω take a simple form and are defined as:

$$G(B|\Omega) \sim N(B^*, \Omega \otimes (X^*{}'X^*)^{-1}) \quad (3)$$

$$G(\Omega|B) \sim IW(S^*, T^*). \quad (4)$$

where X denotes the right hand side variables $\Gamma_t, Y_{t-1}, \dots, Y_{t-P}$. The posterior means are given by $B^* = (X^*{}'X^*)^{-1}(X^*{}'Y^*)$ and $S^* = (Y^* - X^*\tilde{B})(Y^* - X^*\tilde{B})'$, where $Y^* = [Y; Y_{D,1}; Y_{D,2}]$, $X^* = [X; X_{D,1}; X_{D,2}]$ and \tilde{B} is the draw of the VAR coefficients B reshaped to be conformable with X^* . T^* denotes the number of rows of Y^* . A Gibbs sampler offers a convenient method to simulate the posterior distribution of B and Ω by drawing successively from these conditional posteriors. We employ 25,000 iterations using the last 5000 for inference.

Once the iterations are past the burn-in stage, we draw the contemporaneous impact matrix:

1.1.1 Recursive SVAR

In this case $A_0 = \text{chol}(\Omega)$

1.1.2 Sign restrictions

This section explains briefly the identification scheme employed by [Mountford and Uhlig \(2009\)](#). The sign restrictions describe in [Table I](#) are imposed for four periods using the penalty function approach developed by [Uhlig \(2005\)](#).

Table 1: Sing Restrictions

Variables	Shocks			
	Government Spending	Tax	Business Cycle	Monetary Policy
Government Spending	+			
GDP			+	
CPI inflation			+	-
Government Revenue		+	+	
Short-Term Interest Rate			+	+
10-year Government Bond Yield				
Real Stock Prices				

Notes: All sing restrictions have been imposed for 4 periods.

As it has been discussed above the mapping between reduced and structural errors is given by

$$\omega_t = A_0 v_t \quad (5)$$

For any orthogonal matrix D ($DD' = I$, where I is the identity matrix) the above mapping can be written as

$$\omega_t = A_0 D v_t \quad (6)$$

Since

$$\Omega = A_0 D D' A_0' = A_0 A_0' \quad (7)$$

Using the companion form of the VAR(p) model, the impulse of variable j and the impulse of shock i in the period h can be expressed as

$$IRF_{i,j}(h) = J_j B^{h-1} A_0 D J_i' \quad (8)$$

where J_i and J_h are selection matrices of zeros and ones.

In Uhlig (2005) the matrix D results from the following minimisation problem

$$D^* = \arg \min \sum_{j \in \mathcal{I}_+} \sum_{h_j = \tilde{h}_j}^{H_{j,+} \in H_+} f \left(-\frac{J_j B^{h-1} A_0 D J_i'}{\sigma_j} \right) + \sum_{j \in \mathcal{I}_-} \sum_{h_j = \tilde{h}_j}^{H_{j,+} \in H_+} f \left(\frac{J_j B^{h-1} A_0 D J_i'}{\sigma_j} \right) \quad (9)$$

s.t.

$$D D' = I$$

where σ_j is the standard deviation of variable j and $f(x) = \begin{cases} 100x & \text{if } x \geq 0 \\ x & \text{otherwise} \end{cases}$. Finally, \mathcal{I}_+ is the index set of variables, for which identification of a given shock restricts the impulse response to be positive and \mathcal{I}_- is the index set of variables, for which identification restricts the impulse response to be negative.

1.2 Blanchard and Perotti (2002) VAR

We use the algorithm described in Sims and Zha (1999). The structural VAR can be written as¹

$$\underbrace{\begin{pmatrix} 1 & 0 & 0.5 & 0 & 0 & 0 & 0 \\ a_1 & 1 & 0 & a_2 & 0 & 0 & 0 \\ a_3 & a_4 & 1 & a_5 & 0 & 0 & 0 \\ 0 & -1.85 & -1.25 & 1 & 0 & 0 & 0 \\ a_6 & a_7 & a_8 & a_9 & 1 & 0 & 0 \\ a_{10} & a_{11} & a_{12} & a_{13} & a_{14} & 1 & 0 \\ a_{15} & a_{16} & a_{17} & a_{18} & a_{19} & a_{20} & 1 \end{pmatrix}}_{\tilde{A}} \begin{pmatrix} v_G \\ v_Y \\ v_\pi \\ v_T \\ v_R \\ v_I \\ v_S \end{pmatrix} =$$

¹The elasticities used in the two sub-samples are given in Perotti (2005).

$$\underbrace{\begin{pmatrix} b_1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & b_2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & b_3 & 0 & 0 & 0 & 0 \\ b_8 & 0 & 0 & b_4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & b_5 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & b_6 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & b_7 \end{pmatrix}}_{\hat{B}} \begin{pmatrix} u_G \\ u_Y \\ u_\pi \\ u_T \\ u_R \\ u_I \\ u_S \end{pmatrix}$$

Define $A = \tilde{B}^{-1}\tilde{A}$ and thus $\Omega = A^{-1}A^{-1'}$. [Sims and Zha \(1999\)](#) shows that the posterior distribution of A is given as:

$$H(A) \propto \det(A)^{T-K} \exp\left(-0.5 \text{trace}\left(AS(\hat{B})A'\right)\right) \quad (10)$$

where $S(\hat{B}) = \left(Y_t - \hat{B}X_t\right)' \left(Y_t - \hat{B}X_t\right)$ with \hat{B} the OLS estimates of the VAR coefficients. Conditional on A the distribution of B is normal and (assuming a flat prior) given by:

$$H(B|A) \sim N(\text{vec}(\hat{B}), \Omega \otimes (X_t'X_t)^{-1})$$

Therefore an MCMC algorithm can proceed via sampling from $H(A)$ and $H(B|A)$. As $H(A)$ is an unknown density, we use a random walk Metropolis Hastings step to sample from it. The steps are as follows:

1. Maximise $\log H(A)$ with respect to α the free elements of A to obtain the estimates at the posterior mode α^{ML} and the covariance V^{ML} .
2. Draw from $P(A)$: Draw a candidate draw $\alpha^{new} = \alpha^{old} + e, e \sim N(0, (V^{ML})^{1/2} \times c)$. Compute the acceptance probability $a = \frac{H(A(\alpha^{new}))}{H(A(\alpha^{old}))}$ and accept the draw if $a > U(0, 1)$.
3. Draw from $H(B|A)$: Calculate $\Omega = A^{-1}A^{-1'}$ where A is based on the accepted draw of α in the previous step. Draw from $N(\text{vec}(\hat{B}), \Omega \otimes (X_t'X_t)^{-1})$.
4. Repeat steps 2 and 3 until convergence. Adjust the scaling c to ensure that the acceptance rate is between 20% and 40%.

One important issue regarding step 2 needs to be highlighted. The sign of the columns of A can be switched without changing the likelihood function. Therefore a normalisation is required. We employ the normalisation rule proposed in [Waggoner and Zha \(1997\)](#) which preserves the shape of the likelihood.

1.3 Proxy SVAR

[Stock and Watson \(2008\)](#) and [Mertens and Ravn \(2014\)](#) have recently proposed a structural VAR approach that uses proxy variables as instruments rather than additional endogenous variables. The underlying VAR model is given by the following equation:

$$\tilde{Y}_t = c + \sum_{j=1}^P B_j \tilde{Y}_{t-p} + \tilde{A}_0 \tilde{\varepsilon}_t \quad (11)$$

The vector of endogenous variables \tilde{Y}_t does not contain the constructed measure of fiscal shocks directly but, instead, this is used as an instrument to estimate the structural shock of interest ε_t^c . Denoting the remaining shocks by $\tilde{\varepsilon}_t^\bullet$, this approach requires the proxy for fiscal shocks $\hat{\varepsilon}_t^c$ to satisfy the following conditions

$$\begin{aligned} E(\hat{\varepsilon}_t^c, \varepsilon_t^c) &= \alpha \neq 0 \\ E(\hat{\varepsilon}_t^c, \tilde{\varepsilon}_t^\bullet) &= 0 \\ VAR(\tilde{\varepsilon}_t) &= D = \text{diag}(\sigma_{\varepsilon_{1t}}, \dots, \sigma_{\varepsilon_{Nt}}) \end{aligned} \tag{12}$$

The first expression in equation [12](#) states that the instrument $\hat{\varepsilon}_t^c$ is correlated with the structural shock to be estimated, while the second expression rules out any correlation between $\hat{\varepsilon}_t^c$ and the remaining structural shocks and establishes exogeneity of the instrument. The final condition ensures that the shocks are contemporaneously uncorrelated. As shown in [Stock and Watson \(2008\)](#), [Mertens and Ravn \(2013\)](#) and [Mertens and Ravn \(2014\)](#), these conditions along with the requirement that the structural shocks $\tilde{\varepsilon}_t$ are contemporaneously uncorrelated can be used to derive a GMM estimator for the column of \tilde{A}_0 that corresponds to $\hat{\varepsilon}_t^c$. Letting $\tilde{A}_0 = [\tilde{A}_{0,1} \dots \tilde{A}_{0,N}]$ and $\tilde{A}_0 \tilde{\varepsilon}_t = u_t$ where $VAR(u_t) = \Omega$. Then [Stock and Watson \(2008\)](#) show that that ε_{1t} can be estimated via a regression of $\hat{\varepsilon}_t^c$ on u_t . Note that

$$E(u_t \hat{\varepsilon}_t^c) = E(\tilde{A}_0 \varepsilon_t \hat{\varepsilon}_t^c) = [\tilde{A}_{0,1} \dots \tilde{A}_{0,N}] \begin{bmatrix} E(\varepsilon_{1t} \hat{\varepsilon}_t^c) \\ \vdots \\ E(\varepsilon_{Nt} \hat{\varepsilon}_t^c) \end{bmatrix} = \tilde{A}_{0,1} \alpha. \text{ Let } \Pi \text{ denote the coefficient on } u_t.$$

Then the fitted value Πu_t equals the structural shock of interest up to sign and scale:

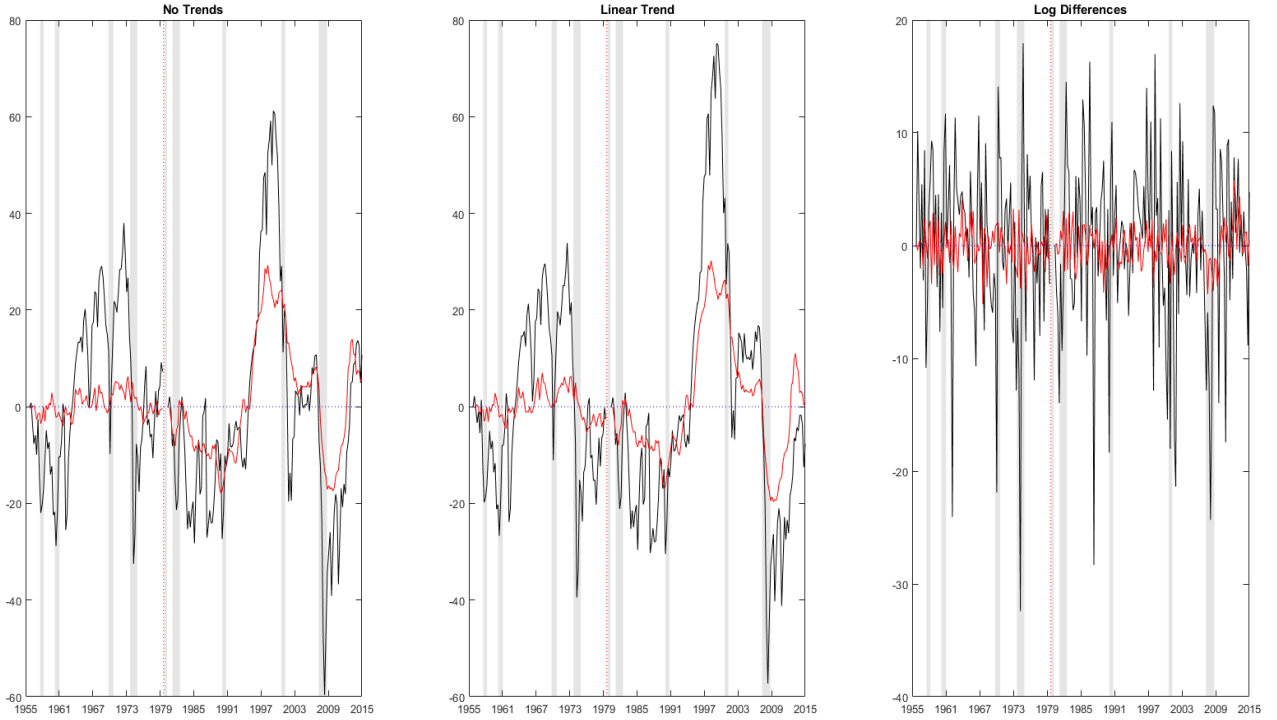
$$\begin{aligned} \Pi u_t &= E(\hat{\varepsilon}_t^c u_t') \Omega^{-1} u_t \\ &= \alpha \tilde{A}'_{0,1} (\tilde{A}_0 D \tilde{A}'_0)^{-1} u_t \\ &= \alpha (\tilde{A}'_{0,1} \tilde{A}_0^{-1'}) D^{-1} (\tilde{A}_0^{-1} u_t) \\ &= \frac{\alpha \varepsilon_{1t}}{D_{11}} \end{aligned} \tag{13}$$

where going from the third to the final line uses the fact that $(\tilde{A}'_{0,1} \tilde{A}_0^{-1'}) = [1, 0, \dots, 0]$ and $\tilde{A}_0^{-1} u_t = \varepsilon_t$. Note that equation [12](#) imposes less stringent conditions on the quality of $\hat{\varepsilon}_t^c$ than those required for unbiased estimation when the proxy variable is added directly to the VAR model. In particular, the only requirements are that $\hat{\varepsilon}_t^c$ is correlated with the shock of interest and uncorrelated with other shocks. These conditions can be satisfied even if $\hat{\varepsilon}_t^c$ is measured with error.

2 Further robustness checks

In this section, we present some further robustness checks carried out on the historical decomposition from the benchmark VAR model. We first consider if the choice of a linear and quadratic trend has an impact on the results. For this purpose, we re-estimate the benchmark model using a (1) a linear trend and an intercept, (2) only an intercept, (3) an intercept with the variables in differences. The contribution of the fiscal shocks to stock prices (relative to the VAR implied base-line) is shown in figure [1](#). In all three cases, the contribution of fiscal shocks is negative over the 2008-2010 period.

Figure 1: Contribution of Fiscal Shocks to Stock Prices



To check if the inclusion of the shadow-rate over the Great Recession period affects these results, we re-run the benchmark VAR and replace the shadow rate with three month treasury bill rate. Figure 2 shows that the contribution of the fiscal shocks follows the same pattern over the great recession period.

3 Model

This section reviews the theoretical model adopted in this study to understand the SVAR stylised facts discussed in the previous section. As in Traum and Yang (2011), we augment the model developed by Christiano *et al.* (2005) and Smets and Wouters (2007) with a *simple* non-productive government sector so we can investigate the effects of a government spending shock on the macroeconomic variables.

3.1 Household

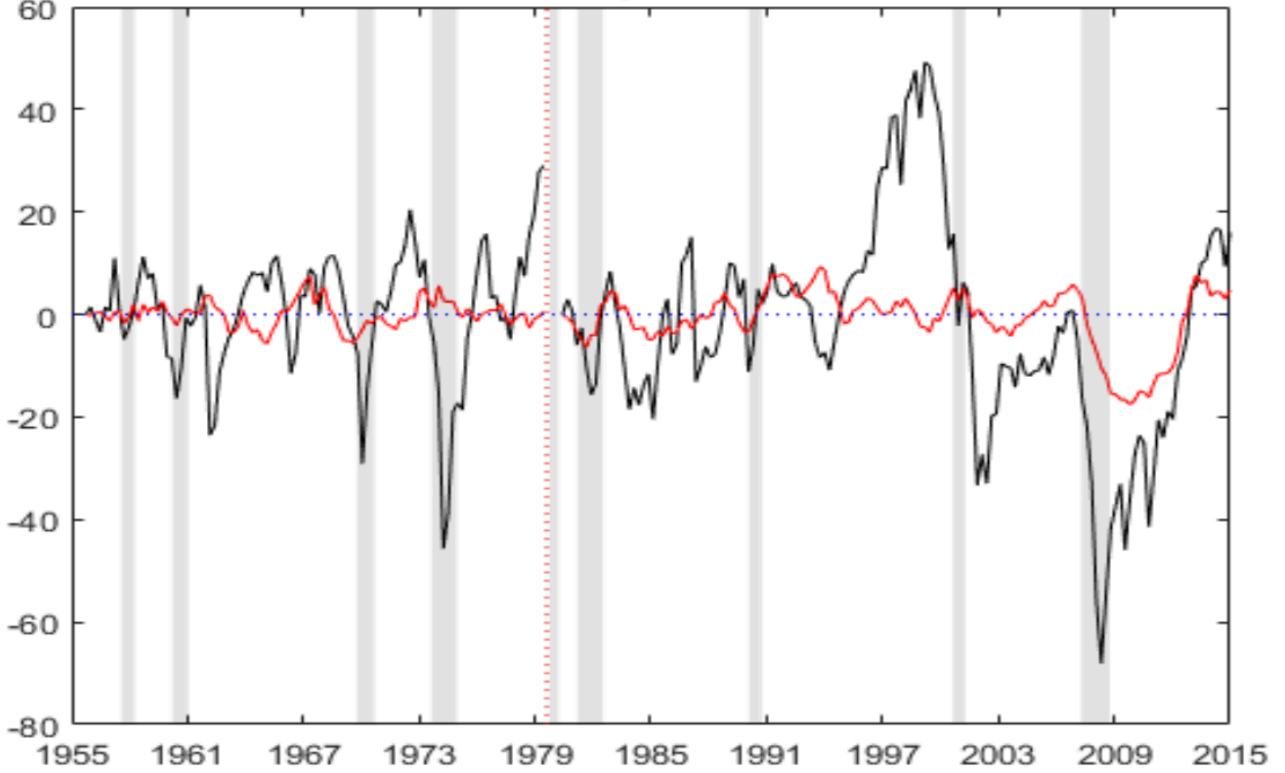
There is a continuum of agents who consume consumption (\tilde{C}_t), supply labour (L_t) and capital services ($v_t K_{t-1}$). The utility function is given by

$$U_t = E_t \sum_{i=0}^{\infty} \beta^i \left\{ \log \left(\tilde{C}_{t+i} - h \tilde{C}_{t+i-1} \right) - \chi_t \frac{L_{t+i}^{1+\sigma_L}}{1+\sigma_L} \right\} \quad (14)$$

where β denotes the time discount factor, σ_L is the labour supply elasticity, h is the consumption smoothing parameter and χ_t is a stationary labour supply shock.² Households choose how much to

²Non stationary variables are denoted with tilde ($\tilde{\cdot}$).

Figure 2: Including 3 mth Treasury Bill Rate



consume and to work by maximising the above objective function subject to the following budget constraint

$$\tilde{C}_t + \tilde{I}_t + \tilde{B}_t = (1 - \tau_t) \tilde{W}_t L_t + (1 - \tau_t) R_t^K v_t \tilde{K}_{t-1} - u(v_t) \tilde{K}_{t-1} + \frac{R_{t-1}^G \tilde{B}_{t-1}}{\Pi_t} + \tilde{TR}_t + \tilde{\Xi}_t \quad (15)$$

where \tilde{W}_t stands for nominal wages, R_t^K is the rental rate of capital, v_t is the degree of capital utilisation, $u(v)$ is the cost of capital utilisation, R_t^G is the effective interest rate faced by households

$$R_t^G = R_t \psi_t \quad (16)$$

which is the policy rate times an exogenous risk premium (*haircut* type) shock (ψ_t) that captures agents' losses from investing on government debt (\tilde{B}_t).³ \tilde{TR}_t and $\tilde{\Xi}_t$ denote transfers and profits, while I_t is investment used for the accumulation of physical capital

$$\tilde{K}_t = (1 - \delta) \tilde{K}_{t-1} + \mu_t \left(1 - \phi_I \left(\frac{\tilde{I}_t}{\tilde{I}_{t-1}} \right) \right) \tilde{I}_t \quad (17)$$

This process is subject to a quadratic adjustment cost $\left(\phi_I \left(\frac{\tilde{I}_t}{\tilde{I}_{t-1}} \right) \right)$ and investment specific stationary productivity shock (μ_t).⁴ δ is the depreciation rate and ϕ_I captures the severity of the real friction.

Agents' optimal decisions regarding to consumption, bond, utilisation, capital and investment are

³This is the shock that [Smets and Wouters \(2007\)](#) call a reduced-form net-worth shock.

⁴Although it is not stated explicitly, we follow the literature and we assume that households have access to Arrow-Debru security that individual consumption risks and give rise to a unique budget constraint.

given, respectively, by:

$$\frac{1}{\tilde{C}_t - h\tilde{C}_{t-1}} = \tilde{\lambda}_t \quad (18)$$

Where $\tilde{\lambda}$ is the marginal rate of consumption.

$$\tilde{\lambda}_t = \beta \frac{R_t^G \tilde{\lambda}_{t+1}}{\Pi_{t+1}} \quad (19)$$

$$R_t^K (1 - \tau_t) = u'(v_t) \quad (20)$$

$$\tilde{q}_t = \beta \frac{\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t} [\{(1 - \tau_{t+1}) R_{t+1}^K v_{t+1} - u(v_{t+1})\} + (1 - \delta) \tilde{q}_{t+1}] \quad (21)$$

$$1 = \tilde{q}_t \mu_t \left\{ 1 - \frac{\phi_I}{2} \left(\frac{\tilde{I}_t}{\tilde{I}_{t-1}} - \Gamma \right)^2 - \phi_I \left(\frac{\tilde{I}_t}{\tilde{I}_{t-1}} - \Gamma \right) \frac{\tilde{I}_t}{\tilde{I}_{t-1}} \right\} + \beta \mu_{t+1} \frac{\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t} \tilde{q}_{t+1} \phi_I \left(\frac{\tilde{I}_{t+1}}{\tilde{I}_t} - \Gamma \right) \left(\frac{\tilde{I}_{t+1}}{\tilde{I}_t} \right)^2 \quad (22)$$

3.2 Wages

We follow [Erceg *et al.* \(2000\)](#) and assume that each monopolistically competitive household supplies a differentiated labour service to the production section. They set their nominal wage and supply any amount of labour demanded by the firms at that wage rate. For convenience, we assume that there exist a representative firm that combines households' labour inputs into a homogenous input hood - L_t^d - using a CES production function

$$L_t^d = \left[\int_0^1 (L_t(\kappa))^{\frac{1}{\lambda_w}} d\kappa \right]^{\lambda_w} \quad (23)$$

where λ_w is the mark-up in the labour market. Taking w_t and $w_{\kappa,t}$ as given the aggregator's demand for the labour hours of household κ results its profit maximisation $\max_{h_{\kappa,t}} \left\{ \tilde{w}_t \left[\int_0^1 (L_t(\kappa))^{\frac{1}{\lambda_w}} d\kappa \right]^{\lambda_w} - \int_0^1 \tilde{w}_t(\kappa) L_t(\kappa) \right\}$

$$L_t(\kappa) = \left(\frac{\tilde{w}_t(\kappa)}{\tilde{w}_t} \right)^{-\frac{\lambda_w}{\lambda_w-1}} L_t^d \quad (24)$$

The aggregate wage arise from the profit condition and the demand curve

$$\tilde{w}_t = \left[\int_0^1 (\tilde{w}_t(\kappa))^{\frac{1}{1-\lambda_w}} d\kappa \right]^{1-\lambda_w} \quad (25)$$

In each period, a function $1 - \xi_w$ of households receive a random signal and they are allowed to reset wages optimally - w_t^{new} . All other households can only partially index their wages by past

inflation. The problem of setting wages can be described as follows

$$\max_{w_t^{new}} E_t \sum_{j=0}^{\infty} (\beta \xi_w)^j \left\{ -\chi_t \frac{(L_{t+j}(\kappa))^{1+\sigma_L}}{1+\sigma_L} + \lambda_{t+j} \prod_{s=1}^j \frac{\Pi_{t+s-1}^{\iota_w} (\Pi_{t+s}^*)^{1-\iota_w}}{\Pi_{t+s}} (1-\tau_{t+j}) \tilde{w}_{t+j}(\kappa) L_{t+j}(\kappa) \right\} \quad (26)$$

subject to

$$L_{t+j}(\kappa) = \left(\prod_{s=1}^j \frac{\Pi_{t+s-1}^{\iota_w} (\Pi_{t+s}^*)^{1-\iota_w}}{\Pi_{t+s}} \frac{w_t(\kappa)}{w_{t+j}} \right)^{-\frac{\lambda_w}{\lambda_w-1}} L_{t+j}^d \quad (27)$$

The first order is summarised by the following recursive equations

$$\tilde{v}_t = \tilde{\lambda}_t \frac{1}{\lambda_w} (\tilde{w}_t^{new})^{\frac{1}{1-\lambda_w}} \tilde{w}_t^{\frac{\lambda_w}{\lambda_w-1}} (1-\tau_t) L_t^d + \beta \xi_w E_t \left(\frac{\Pi_t^{\iota_w} (\Pi_{t+1}^*)^{1-\iota_w}}{\Pi_{t+1}} \right)^{\frac{1}{1-\lambda_w}} \left(\frac{\tilde{w}_{t+1}^{new}}{\tilde{w}_t^{new}} \right)^{\frac{1}{\lambda_w-1}} \quad (28)$$

$$\tilde{v}_t = \chi_t \left(\frac{\tilde{w}_t}{\tilde{w}_t^{new}} \right)^{\frac{(1+\sigma)\lambda_w}{\lambda_w-1}} (L_t^d)^{1+\sigma} + \beta \xi_w E_t \left(\frac{\Pi_t^{\iota_w} (\Pi_{t+1}^*)^{1-\iota_w}}{\Pi_{t+1}} \right)^{\frac{(1+\sigma)\lambda_w}{1-\lambda_w}} \left(\frac{\tilde{w}_{t+1}^{new}}{\tilde{w}_t^{new}} \right)^{\frac{(1+\sigma)\lambda_w}{\lambda_w-1}} \tilde{v}_{t+1} \quad (29)$$

$$\tilde{w}_t^{\frac{1}{1-\lambda_w}} = \xi_w \left(\frac{\Pi_{t-1}^{\iota_w} (\Pi_t^*)^{1-\iota_w}}{\Pi_t} \right)^{\frac{1}{1-\lambda_w}} \tilde{w}_{t-1}^{\frac{1}{1-\lambda_w}} + (1-\xi_w) (\tilde{w}_t^{new})^{\frac{1}{1-\lambda_w}} \quad (30)$$

3.3 Intermediate Firms

Again there is a continuum of intermediate producers that employ labour and capital services to produce using the the following technology

$$\tilde{Y}_t = \alpha_t \left(\tilde{Z}_t L_t \right)^{1-\phi} (v_t K_{t-1})^\phi$$

a product that is bought by the final producer. α_t is a stationary productivity shock, while \tilde{Z}_t is the stochastic trend and ϕ is the capital share. Intermediate producers operate in two stages, firstly, they take wage and rental rate of capital a given and decide about labour and capital demand by maximising their profits⁵

$$\tilde{\Xi}_{I,t} = \tilde{Y}_t - \tilde{W}_t L_t - R_t^K v_t K_{t-1} - MC_t \left\{ \tilde{Y}_t - \left(\tilde{Z}_t L_t \right)^{1-\phi} (v_t K_{t-1})^\phi \right\} \quad (31)$$

$$MC_t = \frac{\tilde{W}_t}{(1-\phi) \frac{\tilde{Y}_t}{L_t}} \quad (32)$$

$$MC_t = \frac{R_t^K v_t}{\phi \frac{\tilde{Y}_t}{K_{t-1}}} \quad (33)$$

⁵Again we follow the literature and assume that capital is distributed across firms so they all face the same marginal cost.

In the second stage, they decide about what price to charge. To be precise, a fraction $-(1 - \xi_p)$ of intermediate firms receive a random signal and they are allowed to optimally reset their prices $-p_{i,t}^{new}$. The proportion $-\xi_p$ of firms that cannot reoptimise prices will set p_t based on backward-looking rule

$$P_t = (\Pi_{t-1})^{\kappa_p} (\Pi_t^*)^{1-\iota_p} P_{t-1} \quad (34)$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation and κ_p is the indexation parameter. The pricing problem of firm i is then

$$\max_{p_{i,t}^{new}} E_t \sum_{j=0}^{\infty} (\beta \xi_p)^j \frac{\tilde{\lambda}_{t+j}}{\tilde{\lambda}_t} \left\{ \left(\prod_{s=1}^j \Pi_{t+s-1}^{\kappa_p} (\Pi_{t+s}^*)^{1-\iota_p} \frac{P_{i,t}^{new}}{P_{t+j}} - MC_{t+j} \right) Y_{i,t+j} \right\} \quad (35)$$

subject to

$$\tilde{Y}_{i,t+j} = \left(\prod_{s=1}^j \Pi_{t+s-1}^{\kappa_p} (\Pi_{t+s}^*)^{1-\iota_p} \frac{P_{i,t}^{new}}{P_{t+j}} \right)^{-\frac{\lambda_p}{\lambda_p-1}} \tilde{Y}_{t+j}^d \quad (36)$$

The first-order condition is expressed as system of difference equations

$$F_{1,t} = \tilde{\lambda}_t MC_t \tilde{Y}_t^d + \beta \xi_p E_t \left(\frac{\Pi_t^{i_p} (\Pi_{t+1}^*)^{1-\iota_p}}{\Pi_{t+1}} \right)^{-\frac{\lambda_p}{\lambda_p-1}} F_{1,t+1} \quad (37)$$

$$F_{2,t} = \tilde{\lambda}_t \bar{\Pi}_t \tilde{Y}_t^d + \beta \xi_d E_t \left(\frac{\Pi_t^{i_p} (\Pi_{t+1}^*)^{1-\iota_p}}{\Pi_{t+1}} \right)^{-\frac{1}{\lambda_p-1}} \left(\frac{\bar{\Pi}_t}{\bar{\Pi}_{t+1}} \right) F_{2,t+1} \quad (38)$$

$$0 = \lambda_p F_{1,t} - F_{2,t} \quad (39)$$

$$1 = \xi_p \left(\frac{\Pi_{t-1}^{i_p} (\Pi_t^*)^{1-\iota_p}}{\Pi_t} \right)^{-\frac{1}{\lambda_p-1}} + (1 - \xi_p) \bar{\Pi}_t^{-\frac{1}{\lambda_p-1}} \quad (40)$$

where $\bar{\Pi}_t \equiv \frac{P_t^{new}}{P_t}$.

3.4 Government

Fiscal authorities finance government consumption and transfers by rising revenues from taxation and issuing new debt. Both (tax and debt) decisions are based on simple rules

$$\frac{\tilde{B}_t}{R_t^G} + \tau_t \left(R_t^K v_t \tilde{K}_{t-1} + \tilde{W}_t L_t \right) = \frac{\tilde{B}_{t-1}}{\Pi_t} + \tilde{G}_t + \widetilde{TR}_t \quad (41)$$

$$\frac{\tau_t}{\tau} = \left(\frac{\tau_{t-1}}{\tau} \right)^{\rho_\tau} \left(\frac{\tilde{B}_{t-1}/B}{\tilde{Y}_{t-1}/Y} \right)^{(1-\rho_\tau)\zeta_\tau} \quad (42)$$

while proportion of final output consumed by the government follows a stationary exogenous process

$$\frac{\tilde{G}_t Z}{\tilde{Z}_t G} = \left(\frac{\tilde{G}_{t-1} Z}{\tilde{Z}_{t-1} G} \right)^{\rho_g} \exp^{\sigma_g \epsilon_{g,t}} \quad (43)$$

As it is discussed in [Leeper \(1991\)](#), a fiscal authority is characterised as ‘passive’ when it sets taxes in a way that ‘restores’ debt back to its steady state value. This is achieved by setting ζ_τ greater than $\frac{\Pi}{\beta} - 1$. When authorities’ tax reaction function does not satisfy the latter condition ($\zeta_\tau < \frac{\Pi}{\beta} - 1$), then they actively destabilise the debt.

The monetary policy reaction function is given by

$$\frac{R_t}{R \Pi_t^*} = \left(\frac{R_{t-1}}{R \Pi_{t-1}^*} \right)^{\rho_R} \left(\frac{\Pi_t}{\Pi_t^*} \right)^{(1-\rho_R)\gamma_\pi} \left(\frac{Y_t}{Y} \right)^{(1-\rho_R)\gamma_y} \left(\frac{Y_t}{Y_{t-1}} \right)^{(1-\rho_R)\gamma_{\Delta y}} \exp^{\sigma_R \epsilon_{R,t}} \quad (44)$$

Similarly, the monetary policy is considered as passive if the policy rate does not respond to changes in the inflation strong enough to stabilise inflation expectations ($\gamma_\pi < 1$). When $\gamma_\pi > 1$ monetary policy is viewed as active since it guarantees that the long run inflation expectation coincide with the inflation target.

3.5 Market Clearing Conditions

Market clearing condition in the final sector is

$$Y_t = \alpha_t L_t^{1-\phi} \left(v_t \frac{K_{t-1}}{\Gamma_t} \right)^\phi = \int_0^1 Y_{i,t} di = \int_0^1 \left(\frac{P_{i,t}}{P_t} \right)^{-\frac{\lambda_p}{\lambda_p-1}} di Y_t^d = v_t^p Y_t^d = v_t^p \left(c_t + i_t + u(v_t) \frac{K_{t-1}}{\Gamma_t} \right) \quad (45)$$

where $v_t^p = \int_0^1 \left(\frac{p_{i,t}}{p_t} \right)^{-\frac{\lambda_{d,t}}{\lambda_{d,t}-1}} di$ is the price dispersion term and it is given by

$$v_t^p = \xi_p \left(\frac{\Pi_{t-1}^{i_p} (\Pi_t^*)^{1-\iota_p}}{\Pi_t} \right)^{-\frac{\lambda_p}{\lambda_p-1}} v_{t-1}^p + (1 - \xi_p) \bar{\Pi}_t^{-\frac{\lambda_p}{\lambda_p-1}} \quad (46)$$

The market clearing condition in the labour market is

$$L_t = \int_0^1 L_{\kappa,t} d\kappa = v_t^w L_t^d \quad (47)$$

where $v_t^w = \int_0^1 \left(\frac{w_{i,t}}{w_t} \right)^{-\frac{\lambda_w}{\lambda_w-1}} di$ is the wage dispersion term and its evolution is described

$$v_t^w = \xi_w \left(\frac{\Pi_{t-1}^{i_w} (\Pi_t^*)^{1-\iota_w}}{\Pi_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} \left(\frac{\tilde{w}_{t-1}}{\tilde{w}_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} v_{t-1}^w + (1 - \xi_w) \left(\frac{\tilde{w}_t^{new}}{\tilde{w}_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} \quad (48)$$

3.6 Equity Price

An equity security in the model is defined as a levered claim on the aggregate intermediate good producers' profits. Every period, the equity security pays a dividend equal to $\Xi_{I,t}^\vartheta$ where ϑ captures the degree of leverage and

$$\Xi_{I,t} = Y_t - W_t L_t - R_t^K v_t \frac{K_{t-1}}{\Gamma_t}$$

(see above). In this case the price of the equity is defined as

$$q_{e,t} = E_t m_{t+1} \left(\Xi_{I,t+1}^\vartheta + q_{e,t+1} \right) \quad (49)$$

where $m_t = \beta \frac{R_t \lambda_{t+1}}{\lambda_t \Gamma_t}$ is the stochastic discount factor.

3.7 Calibrated Parameters

Table 2: Calibrated Parameters

Mnemonic	Description	Value
β	Time Discount Factor	0.99
ϕ	Capital Share	0.36
δ	Capital Depreciation Rate	0.03
τ	Steady State Tax Rate to GDP Ratio	0.20
λ_p	Steady State Price Markup	1.20
L	Steady State Hours	0.33
$\frac{G}{Y}$	Steady State Government Spending to GDP Ratio	0.18
λ_w	Steady State Wage Markup	1.20
$\frac{B}{Y}$	Steady State Debt to GDP Ratio	0.35

The model is estimated using full information Bayesian Maximum Likelihood technique, however, a small number of structural parameters – summarised by Table 2 – is actually calibrated prior to the estimation of the model. To be precise, the share of capital in the production (ϕ) and its depreciation rate (δ) have been calibrated to 0.36 and 0.025, numbers typically used in the literature (Christiano *et al.* (2005), Trabandt and Uhlig (2011) and Jermann and Quadrini (2012)). As in Smets and Wouters (2007) we assume that steady-state price (λ_p) and wage (λ_w) markups are equal to 20%. The calibration of the steady state value of the debt to GDP ratio ($\frac{B}{Y} = 0.35$), average tax rate ($\tau = 0.20$) and government spending to GDP ratio ($\frac{G}{Y} = 0.18$) is based on the studies of Leeper *et al.* (2010), Traum and Yang (2011) and Smets and Wouters (2007). The degree of leverage (ϑ) is set equal to 3 similar to Bansal and Yaron (2004), Campbell *et al.* (2014) and Swanson (2015). Finally, the values the time discount factor ($\beta = 0.99$) and the steady state value of hours ($L = 1/3$) are common choices in the literature.

3.8 Prior Distributions

Table 3 summarise the prior density probability function of the estimated parameters. Again, these choices are in line with those used in the literature (Smets and Wouters (2007), Justiniano *et al.* (2010), Traum and Yang (2011) among others) and we do not discuss them further here. It is perhaps

worthwhile to mention that the specification of the prior distribution of γ_π and ζ_τ permits (fiscal and monetary) policies to be either active or passive.

In addition, we follow [Del Negro and Schorfheide \(2008\)](#), [Liu et al. \(2013\)](#) and [Christiano et al. \(2011\)](#) (among others) and form our priors ‘endogenously’. This requires another set of ‘priors’ that reflect our beliefs regarding selected data moments. These moments are the responses of the set of the observable variables on a government spending shock. This approach offers a *natural way* to link the SVAR results with the DSGE analysis as the data counterpart of these moments are those estimated by the identified VAR model.

As explained in [Del Negro and Schorfheide \(2008\)](#), eliciting priors are derived by combining Bayesian techniques and calibration approaches. This intuitive approach formalises the decisions most researchers make when deciding the prior moments of the estimated structural parameters. We briefly outline the main idea here, though interested readers are advised to explore the preceding references.

Let $\mathcal{M}(\theta)$ denote a vector of DSGE model-implied data moments (expressed as function of the structural parameters vector θ) and $\widehat{\mathcal{M}}$ its empirical counterpart. Let us further assume that two vectors of moments are the same up to a vector of measurement errors \mathcal{V}

$$\widehat{\mathcal{M}} = \mathcal{M}(\theta) + \mathcal{V} \quad (50)$$

Then, as explained in [Del Negro and Schorfheide \(2008\)](#), a conditional distribution that reflects the beliefs about the above moment conditions can be obtained by combining the conditional density of [\(50\)](#), $\mathcal{L}(\mathcal{M}(\theta)|\widehat{\mathcal{M}})$, Bayes theorem, and the primitive prior distribution of the structural parameter vector:

$$p(\theta|\widehat{\mathcal{M}}) \propto \mathcal{L}(\mathcal{M}(\theta)|\widehat{\mathcal{M}}) \pi(\theta) \quad (51)$$

There are several advantages of using this type of prior. For instance, as we can infer from [\(51\)](#), structural parameters are no longer treated as independent, as is typically assumed in the DSGE literature. Furthermore, shock processes are unobserved variables which makes it difficult to justify beliefs regarding the persistence and the volatility of these exogenous processes. In this setup this is not a problem, since these prior moments adjust endogenously to ‘match’ the selected data moments. Finally, the empirical application in [Del Negro and Schorfheide \(2008\)](#) suggests that these priors can be helpful when DSGE parameters are not well identified.

In our exercise the small size of the two sub-samples impose further, and perhaps more severe, constraints on the estimation of the theoretical model and we hope these constraints could be alleviated by the prior information summarised in the vector of responses to a government spending shock ($\mathcal{M}(\theta)$). Consistently with the asymptotic theory ([Newey and McFadden \(1986\)](#), [Theodoridis \(2011\)](#)) and other researchers ([Christiano et al. \(2005\)](#), [Christiano et al. \(2010\)](#), [Christiano et al. \(2016\)](#)), we assume that $\mathcal{M}(\theta)_{i,j}$ is normally distributed with mean $\widehat{\mathcal{M}}_{i,j}$ and standard deviation $\sigma_{\widehat{\mathcal{M}}_{i,j}}$. The estimated moments ($\widehat{\mathcal{M}}_{i,j}$ and $\sigma_{\widehat{\mathcal{M}}_{i,j}}$) are obtained from the posterior distribution of the SVAR responses

$$\mathcal{M}(\theta)_{i,j} \sim N(\widehat{\mathcal{M}}_{i,j}, \sigma_{\widehat{\mathcal{M}}_{i,j}}) \quad (52)$$

3.9 Posterior Estimation

Table 4 reports the sample mean of the variables used in the estimation of the DSGE model. As the number of observations is reduced by splitting the sample into two periods, these values are obtained prior to and during the estimation of the structural model.

Table 5 reports from the estimation of the DSGE model over the two sub-samples (1955Q4 – 1979Q4 and 1980Q1 – 2015Q4).⁶ The vector of the observable variables is the one used by Smets and Wouters (2007), namely, GDP growth, consumption growth, investment growth, real wage growth, average hours, inflation and the policy rate.⁷

Although the split of the sample is based on prior information related to changes in the presidency of the FED (see Cogley *et al.* (2010), Lubik and Schorfheide (2004) among others), there are many studies in the literature (Traum and Yang (2011), Leeper *et al.* (2017), Kliem *et al.* (2016) among others) that adopt a very similar sub-sample analysis to investigate simultaneous changes in the preferences of both fiscal and monetary authorities. Furthermore, the studies of Bianchi and Ilut (2014) and Bianchi and Melosi (2017) seem to justify empirically a very similar split of the data. Their methodology allows the policy parameters to evolve stochastically from one regime to another. Although the process that ‘drives’ these switches is unobserved, it can be inferred from the data by using filtering techniques. This analysis reveals that the time period of changes in the policy parameters seems to coincide with the split of the sample adopted in the literature.

Table 5 reveals a very interesting pattern, monetary policy turns from ‘passive’ in the first part of the sample to ‘active’ in the second part of the sample. This change is associated with a ‘flatter’ Philips curve (resetting prices less frequently and less degree of indexation), which would be consistent with the view that inflation expectations are better ‘anchored’ between 1980Q1 – 2015Q4. Similarly, fiscal policy also switches from ‘active’ in period 1955Q4 – 1979Q4 to ‘passive’ in the second part of the sample. This result is consistent with the analysis of Bianchi and Ilut (2014) and Bianchi and Melosi (2017) who also provide evidence about the switch between passive-monetary & active-fiscal policy regime to active-monetary & passive-fiscal policy regime around the same time period.

The rest of the estimates fall well in the range of parameters reported in the literature (Christiano *et al.* (2005), Smets and Wouters (2007), Justiniano *et al.* (2010), Del Negro *et al.* (2015) among others) and, therefore, not discussed again here.⁸

⁶The estimation of the model has been carried out using Dynare 4.5.4. The Dynare *endogenous prior* function has been modified to implement the procedure discussed in the previous section. All the codes can be downloaded from authors’ web page.

⁷The definitions of the series is the same, we have simply updated Smets and Wouters (2007) spreadsheet till 2015Q4.

⁸The model has not been linearised around a deterministic steady-state and the structural disturbances have not been normalised like those in the above mentioned studies and this explains why the standard deviation estimates are different.

Table 3: Estimated Parameters: Prior Moments

Mnemonic	Description	Density	Mean	STD
σ_L	Inverse Labour Supply Elasticity	Normal	2.00	0.75
h	Consumption Smoothing	Beta	0.70	0.10
χ_I	Investment Adjustment Cost	Gamma	4.00	0.50
ξ_p	Calvo Price No Reset Probability	Beta	0.50	0.08
ν_p	Price Indexation	Beta	0.50	0.08
ξ_w	Calvo Wage No Reset Probability	Beta	0.50	0.08
ν_w	Wage Indexation	Beta	0.50	0.08
κ_2	Utilisation Cost Elasticity	Gamma	5.00	1.00
ζ_τ	Tax Debt to GDP Ration Reaction	Gamma	0.10	0.10
ρ_R	Policy Rate Smoothing	Beta	0.50	0.20
γ_π	Policy Reaction to Inflation	Normal	1.25	0.25
γ_y	Policy Reaction to Output Gap	Normal	0.12	0.05
$\gamma_{\Delta y}$	Policy Reaction to Output Gap Growth	Normal	0.12	0.05
ϑ	Degree of Leverage	Gamma	3.00	0.25
ρ_γ	Persistence of the Non-Stationary Growth Productivity Process	Beta	0.50	0.20
ρ_ψ	Persistence of the Risk Premium Process	Beta	0.50	0.20
ρ_p	AR Persistence of the Price Markup Process	Beta	0.50	0.20
ρ_w	AR Persistence of the Wage Markup Process	Beta	0.50	0.20
θ_p	MA Persistence of the Price Markup Process	Beta	0.50	0.20
θ_w	MA Persistence of the Wage Markup Process	Beta	0.50	0.20
ρ_μ	Persistence of the Investment Specific Process	Beta	0.50	0.20
ρ_α	Persistence of the Stationary Productivity Process	Beta	0.50	0.20
ρ_τ	Tax Persistence Process	Beta	0.50	0.20
ρ_g	Government Spending Persistence Process	Beta	0.50	0.20
ρ_z	Persistence of Government Transfers Process	Beta	0.50	0.20
$\rho_{\bar{\pi}}$	Persistence of the Stationary Productivity Process	Beta	0.60	0.20
ρ_{erp}	Persistence Equity Risk Premium Process	Beta	0.50	0.20
ρ_y	Persistence GDP Accounting Wedge Process	Beta	0.50	0.20
σ_γ	Non-Stationary Growth Productivity Shock Uncertainty	Inv-Gamma	0.50	0.20
σ_ψ	Risk Premium Shock Uncertainty	Inv-Gamma	0.50	0.20
σ_p	Price Markup Shock Uncertainty	Inv-Gamma	0.50	0.20
σ_w	Wage Markup Shock Uncertainty	Inv-Gamma	0.50	0.20
σ_R	Policy Exogenous Shock Uncertainty	Inv-Gamma	0.50	0.20
σ_μ	Investment Specific Shock Uncertainty	Inv-Gamma	0.50	0.20
σ_α	Stationary Productivity Shock Uncertainty	Inv-Gamma	0.50	0.20
σ_τ	Tax Shock Uncertainty	Inv-Gamma	0.50	0.20
σ_g	Government Spending Shock Uncertainty	Inv-Gamma	0.50	0.20
σ_z	Government Transfers Shock Uncertainty	Inv-Gamma	0.50	0.20
$\sigma_{\bar{\pi}}$	Inflation Target Shock Uncertainty	Inv-Gamma	0.05	0.20
σ_{TP}	Term Premium Shock Uncertainty	Inv-Gamma	0.50	0.20
σ_{erp}	Equity Risk Premium Shock Uncertainty	Inv-Gamma	0.50	0.20

Notes: STD denotes the standard deviation and Inv-Gamma the inverse gamma distribution.

Table 4: Sample Average of the Observed Series

Mnemonic	Description	1955Q4 – 1979Q4	1980Q1 – 2007Q4
$100\log(\Pi)$	Inflation Sample Mean	1.2	0.77
100γ	GDP Growth Sample Mean	0.67	0.48
$\log(L)$	Average Hours Sample Mean	455.20	465.47
R^L	10year Government Yield Sample Mean	1.58	1.88
$100\gamma^{Q^E}$	Equity Price Growth Sample Mean	0.19	2.14
$100\gamma^{\frac{B}{Y}}$	Debt to GDP Growth Sample Mean	-0.77	0.73
$100\gamma^G$	Government Spending Growth Sample Mean	-0.08	0.25
$100\gamma^T$	Tax Revenue Growth Sample Mean	0.57	0.43

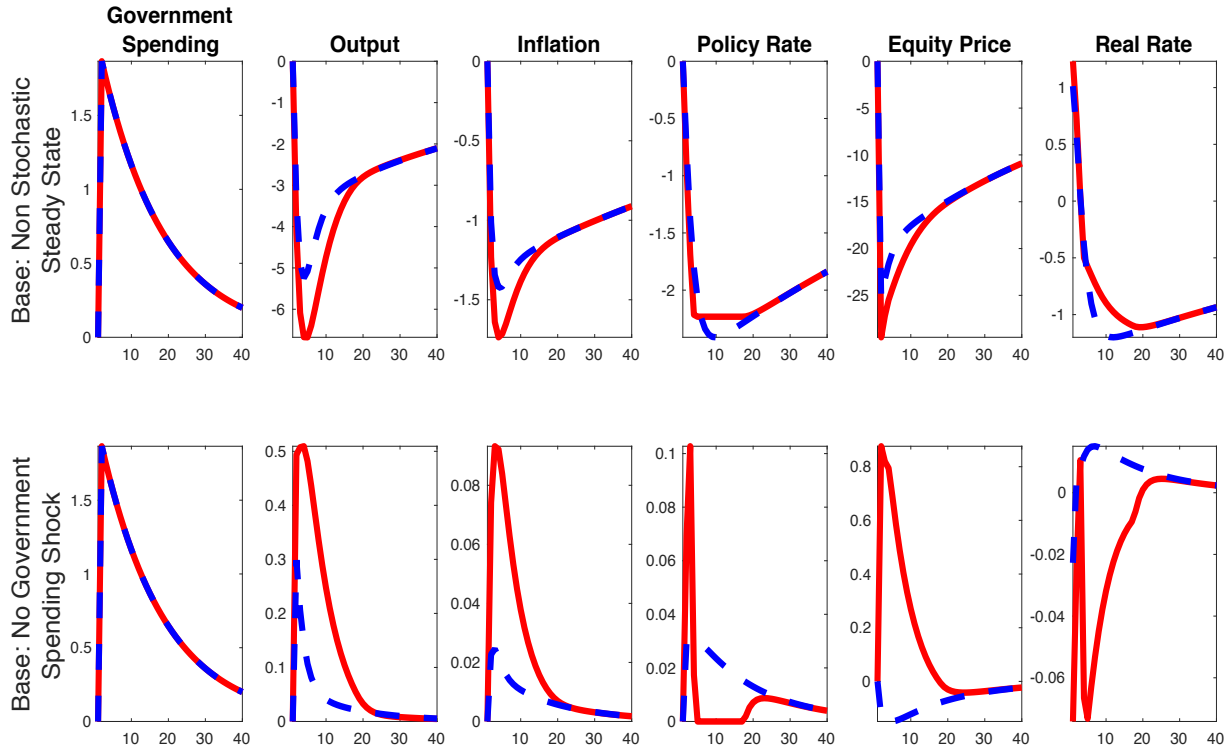
Table 5: Estimated Parameters: Posterior Moments

Mnemonic	Pre-80			Post-80		
	Mean	5 th	95 th	Mean	5 th	95 th
σ_L	2.513	1.438	3.607	3.071	2.140	3.996
h	0.708	0.666	0.751	0.570	0.509	0.629
χ_I	5.259	4.440	6.098	4.175	3.506	4.858
ξ_p	0.880	0.864	0.895	0.888	0.884	0.891
ι_p	0.611	0.518	0.706	0.315	0.228	0.400
ξ_w	0.794	0.753	0.834	0.875	0.857	0.891
ι_w	0.481	0.360	0.605	0.619	0.505	0.730
κ_2	5.063	3.378	6.731	5.061	3.548	6.580
ζ_τ	0.009	0.003	0.017	0.729	0.711	0.743
ρ_R	0.926	0.888	0.968	0.716	0.666	0.769
γ_π	0.613	0.501	0.728	1.966	1.745	2.186
γ_y	0.051	0.004	0.092	0.003	0.001	0.005
$\gamma_{\Delta y}$	0.111	0.028	0.188	0.196	0.132	0.255
ϑ	2.913	2.523	3.297	2.883	2.481	3.278
ρ_γ	0.497	0.328	0.664	0.268	0.155	0.377
ρ_ψ	0.287	0.096	0.472	0.191	0.051	0.323
ρ_p	0.952	0.916	0.991	0.987	0.976	0.998
ρ_w	0.497	0.162	0.823	0.507	0.181	0.827
θ_p	0.168	0.084	0.250	0.253	0.217	0.288
θ_w	0.510	0.186	0.837	0.509	0.175	0.833
ρ_μ	0.393	0.179	0.586	0.741	0.596	0.887
ρ_α	0.918	0.880	0.958	0.939	0.917	0.962
ρ_τ	0.563	0.478	0.648	0.682	0.634	0.730
ρ_g	0.685	0.645	0.728	0.943	0.931	0.955
ρ_z	0.831	0.795	0.866	0.992	0.985	0.999
$\rho_{\bar{\pi}}$	0.761	0.578	0.952	0.691	0.521	0.868
ρ_{erp}	0.163	0.037	0.276	0.113	0.021	0.196
ρ_y	0.892	0.840	0.946	0.944	0.924	0.965
σ_γ	0.625	0.533	0.713	0.794	0.697	0.887
σ_ψ	1.129	0.930	1.318	0.724	0.569	0.873
σ_p	0.402	0.338	0.462	0.172	0.146	0.197
σ_w	0.499	0.245	0.754	0.511	0.248	0.785
σ_R	0.229	0.190	0.266	0.205	0.177	0.232
σ_μ	6.789	4.934	8.682	2.399	1.762	3.024
σ_α	0.916	0.779	1.053	0.810	0.715	0.899
σ_τ	3.132	2.691	3.575	4.517	3.783	5.243
σ_g	2.464	2.093	2.814	1.866	1.657	2.075
σ_z	20.620	20.143	20.999	40.245	39.286	41.151
$\sigma_{\bar{\pi}}$	0.098	0.043	0.152	0.060	0.037	0.083
σ_{TP}	0.520	0.249	0.787	0.534	0.248	0.828
σ_{erp}	8.152	7.043	9.257	8.694	7.784	9.599

4 ZLB Simulations

We perform a number of full nonlinear perfect foresight simulation exercises to assess how the Zero Lower Bound (ZLB) constraint could alter our results. We would like to highlight that this investigation is far from complete, as a detailed discussion of how the ZLB could affect our main conclusions would require a paper itself.

Figure 3: Zero Lower Bound simulations: Post 1908Q1 estimates



Notes: The solid (red) line illustrate agents’ optimal responses when the ZLB is imposed. The dashed (blue) line reflects agents’ optimal responses when the ZLB is not imposed. The model is solved using a nonlinear perfect foresight algorithm and it is implemented using Dynare.

In the first exercise (Figure 3), we use the post 1980Q1 estimates (AMPF regime) and an adverse preference shock (commonly used in the literature) calibrated to “drag” the policy rate below zero. At the same time we shock the economy with one standard deviation government spending shock. We consider two cases: i) the ZLB is not imposed (dashed blue line) and ii) the ZLB is imposed (solid red line). The first row of Figure 3 illustrates the responses (to the two shocks) relative to a non-stochastic steady state, while the second row displays the effect of the government spending shock. This simulation reveals two features discussed in the ZLB literature widely:

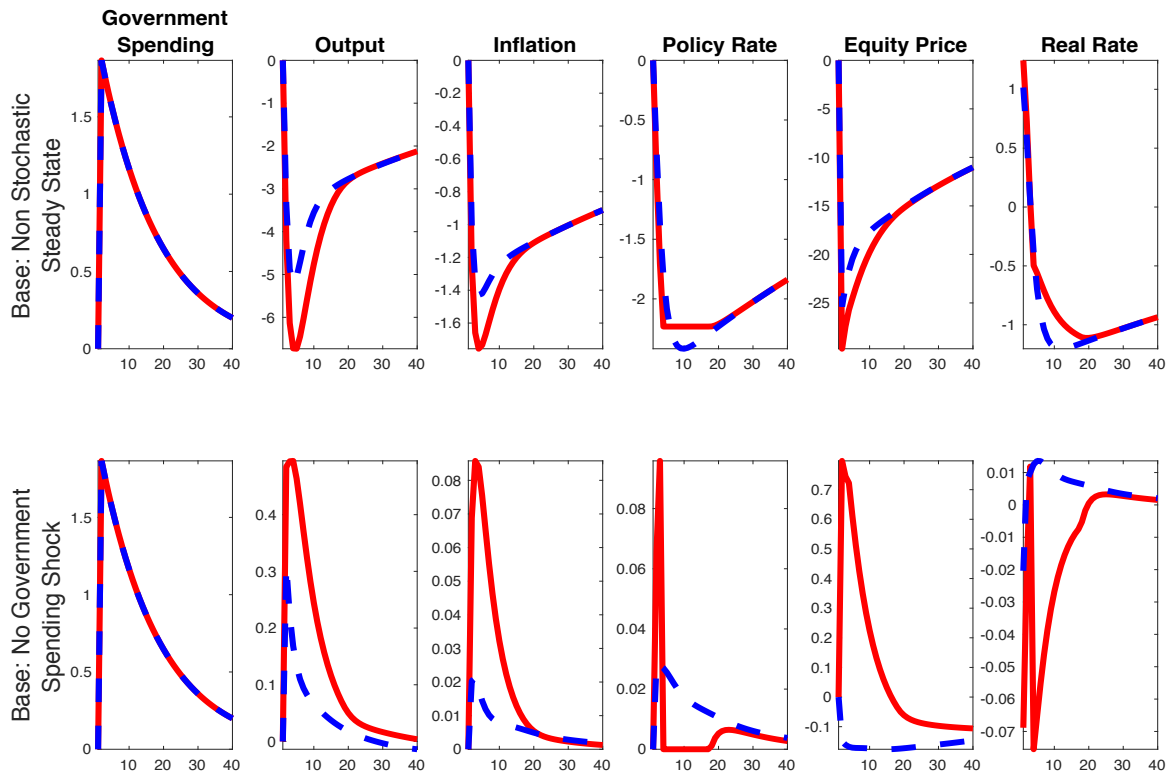
- The ZLB constraints escalates the adverse consequences of the shock (first row)
- The effectiveness of the fiscal policies increases when the economy is constrained by the ZLB (second row)

Even though the effect of the fiscal policy are enhanced by the ZLB, asset prices fall. Of course, this is hardly a surprise as a sizeable recession is required in order the ZLB constraint to bind (first row). However, when we control about the adverse preference shock (second row), asset prices increase when monetary authorities are restrained by the ZLB to adjust rates. This is related to the real interest

rate channel discussed in the text despite the fact that fiscal policy is passive.

In the above simulation the fiscal policy increase taxes sufficiently enough to bring the debt to GDP back to its steady state. Unfortunately, a solution of the model with policies being active could not be found (Leeper (1991)). We, therefore, proceed by reducing the tax response coefficient to its lower value where a solution of the model could be obtained. We repeat the exercises discussed above and Figure 4 illustrates agents' optimal responses. The results are little changed, however, the effects from the fiscal expansion are marginally lower in the second case. As the fiscal authority does not rise taxes aggressively to stabilise debt, the severity of the ZLB is marginally reduced and hence the effectiveness of the fiscal policy.

Figure 4: Zero Lower Bound simulations: Post 1908Q1 estimates ($\zeta_\tau = 0.025$)



Notes: The solid (red) line illustrate agents' optimal responses when the ZLB is imposed. The dashed (blue) line reflects agents' optimal responses when the ZLB is not imposed. The model is solved using a nonlinear perfect foresight algorithm and it is implemented using Dynare.

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A DSGE Model

A.1 Stationary Equations

$$\frac{1}{C_t - h \frac{C_{t-1}}{\Gamma_t}} = \lambda_t \quad (53)$$

$$\lambda_t = \beta \frac{R_t^G \lambda_{t+1}}{\Pi_{t+1} \Gamma_{t+1}} \quad (54)$$

$$Y_t = L_t^{1-\phi} \left(v_t \frac{K_{t-1}}{\Gamma_t} \right)^\phi \quad (55)$$

$$K_t = (1 - \delta) \frac{K_{t-1}}{\Gamma_t} + \left(1 - \phi_I \left(\frac{I_t \Gamma_t}{I_{t-1}} - \Gamma \right)^{Z_I} \right) I_t \quad (56)$$

$$R_t^K (1 - \tau_t) = u'(v_t) \quad (57)$$

$$q_t = \beta \frac{\lambda_{t+1}}{\lambda_t \Gamma_{t+1}} \left[\{(1 - \tau_{t+1}) R_{t+1}^K v_{t+1} - u(v_{t+1})\} + (1 - \delta) q_{t+1} \right] \quad (58)$$

$$1 = q_t \left\{ 1 - \frac{\phi_I}{2} \left(\frac{I_t \Gamma_t}{I_{t-1}} - \Gamma \right)^2 - \phi_I \left(\frac{I_t \Gamma_t}{I_{t-1}} - \Gamma \right) \frac{I_t \Gamma_t}{I_{t-1}} \right\} + \beta \frac{\lambda_{t+1}}{\lambda_t \Gamma_{t+1}} q_{t+1} \phi_I \left(\frac{I_{t+1} \Gamma_{t+1}}{I_t} - \Gamma \right) \left(\frac{I_{t+1} \Gamma_{t+1}}{I_t} \right)^2 \quad (59)$$

$$\Xi_{I,t} = Y_t - W_t L_t - R_t^K v_t \frac{K_{t-1}}{\Gamma_t} \quad (60)$$

$$MC_t = \frac{W_t}{(1 - \phi) \frac{Y_t}{L_t}} \quad (61)$$

$$MC_t = \frac{R_t^K v_t}{\phi \frac{Y_t \Gamma_t}{K_{t-1}}}$$

$$F_{1,t} = \lambda_t M C_t Y_t^d + \beta \xi_p E_t \left(\frac{\Pi_t^{\iota_p} (\Pi_{t+1}^*)^{1-\iota_p}}{\Pi_{t+1}} \right)^{-\frac{\lambda_p}{\lambda_p-1}} F_{1,t+1} \quad (62)$$

$$F_{2,t} = \lambda_t \bar{\Pi}_t Y_t^d + \beta \xi_d E_t \left(\frac{\Pi_t^{\iota_p} (\Pi_{t+1}^*)^{1-\iota_p}}{\Pi_{t+1}} \right)^{-\frac{1}{\lambda_p-1}} \left(\frac{\bar{\Pi}_t}{\bar{\Pi}_{t+1}} \right) F_{2,t+1} \quad (63)$$

$$0 = \lambda_p F_{1,t} - F_{2,t} \quad (64)$$

$$1 = \xi_p \left(\frac{\Pi_{t-1}^{\iota_p} (\Pi_t^*)^{1-\iota_p}}{\Pi_t} \right)^{-\frac{1}{\lambda_p-1}} + (1 - \xi_p) \bar{\Pi}_t^{-\frac{1}{\lambda_p-1}} \quad (65)$$

$$B_t + \tau_t \left(R_t^K v_t \frac{K_{t-1}}{\Gamma_t} + W_t L_t \right) = \frac{R_{t-1}^G B_{t-1}}{\Gamma_t \Pi_t} + G_t \quad (66)$$

$$\tau_t = \rho_\tau \tau_{t-1} + (1 - \rho_\tau) \phi_\tau \tau \frac{B_{t-1}}{Y_{t-1}} \quad (67)$$

$$g_t = \rho_g g_{t-1} - (1 - \rho_g) \phi_g g \frac{B_{t-1}}{Y_{t-1}} + \epsilon_{g,t} \quad (68)$$

$$\frac{Y_t}{v_t^p} = \left(C_t + I_t + G_t + u(v_t) \frac{K_{t-1}}{\Gamma_t} \right) RES_t \quad (69)$$

As all the component of the accounting equation are now observed, the wedge RES_t is added to the model to facilitate its estimation. This wedge captures the: (i) net-trade, (ii) residential investment and (iii) stock building, which are parts parts of the GDP definition in the data and not captured by the model.

$$v_t = \tilde{\lambda}_t \frac{1}{\lambda_w} (w_t^{new})^{\frac{1}{1-\lambda_w}} w_t^{\frac{\lambda_w}{\lambda_w-1}} (1 - \tau_t) L_t^d + \beta \xi_w E_t \left(\frac{\Pi_t^{\iota_w} \bar{\Pi}_{t+1}^{1-\iota_w}}{\Pi_{t+1}} \right)^{\frac{1}{1-\lambda_w}} \left(\frac{w_{t+1}^{new} \Gamma_{t+1}}{w_t^{new}} \right)^{\frac{1}{\lambda_w-1}} \quad (70)$$

$$v_t = \chi_t \left(\frac{w_t}{w_t^{new}} \right)^{\frac{(1+\sigma)\lambda_w}{\lambda_w-1}} (L_t^d)^{1+\sigma} + \beta \xi_w E_t \left(\frac{\Pi_t^{\iota_w} \bar{\Pi}_{t+1}^{1-\iota_w}}{\Pi_{t+1}} \right)^{\frac{(1+\sigma)\lambda_w}{1-\lambda_w}} \left(\frac{w_{t+1}^{new} \Gamma_{t+1}}{w_t^{new}} \right)^{\frac{(1+\sigma)\lambda_w}{\lambda_w-1}} v_{t+1} \quad (71)$$

$$w_t^{\frac{1}{1-\lambda_w}} = \xi_w \left(\frac{\Pi_{t-1}^{\iota_w} \bar{\Pi}_t^{1-\iota_w}}{\Pi_t} \right)^{\frac{1}{1-\lambda_w}} \left(\frac{w_{t-1}}{\Gamma_t} \right)^{\frac{1}{1-\lambda_w}} + (1 - \xi_w) (w_t^{new})^{\frac{1}{1-\lambda_w}} \quad (72)$$

A.2 Steady-States

$$R = \frac{\Pi \Gamma}{\beta} \quad (73)$$

$$R^K = \frac{\frac{\Gamma}{\beta} - (1 - \delta)}{1 - \tau} \quad (74)$$

$$u'(1) = R^K (1 - \tau) \quad (75)$$

$$\frac{Y\Gamma}{K} = \left(\frac{L}{Y}\right)^{\frac{1-\phi}{\phi}} \quad (76)$$

$$\begin{aligned} MC &= \frac{R^K}{\phi \frac{Y\Gamma}{K}} \\ \frac{Y\Gamma}{K} &= \frac{R^K}{\phi MC} \\ \frac{L}{Y} &= \left(\frac{R^K}{\phi MC}\right)^{\frac{\phi}{1-\phi}} \end{aligned} \quad (77)$$

$$\begin{aligned} W &= (1 - \phi) MC \frac{Y}{L} \\ W &= (1 - \phi) MC \left(\frac{R^K}{\phi MC}\right)^{-\frac{\phi}{1-\phi}} \end{aligned} \quad (78)$$

$$Y = \frac{Y}{L} L \quad (79)$$

$$K = \frac{K}{Y\Gamma} Y\Gamma \quad (80)$$

$$I = \left(\frac{\Gamma - 1 + \delta}{\Gamma}\right) K \quad (81)$$

$$C = Y - I - G \quad (82)$$

$$\lambda = \frac{1}{\left(1 - \frac{h}{\Gamma}\right) C} \quad (83)$$

$$F_1 = \frac{\lambda MC Y}{1 - \beta \xi_p} \quad (84)$$

$$F_2 = \frac{\lambda Y}{1 - \beta \xi_p} \quad (85)$$

$$v = \frac{\lambda w (1 - \tau) L^d}{\left(1 - \beta \xi_w \Gamma^{\frac{1}{\lambda_w - 1}}\right) \lambda_w} \quad (86)$$

$$\chi = \frac{v \left(1 - \beta \xi_w \Gamma^{\frac{(1+\sigma)\lambda_w}{\lambda_w - 1}} v\right)}{L^{1+\sigma}} \quad (87)$$

$$B = \frac{B}{Y} Y \quad (88)$$

$$\tau = \frac{\frac{R^G - \Gamma \Pi}{\Gamma \Pi} B + G}{\left(\frac{R^K K}{\Gamma} + WL\right)} \quad (89)$$

B Tables

Table 6: Endogenous Variables: A

Mnemonic	Description
C	Consumption
Y	Output
I	Investment
g	Government Spending
τ	Taxes
B	Government Debt
λ	Marginal Utility
Q	Tobins Q
R^k	Rental Rate of Capital
R	Policy Rate Growth
K	Capital
v	Capital Utilisation
MC	Marginal Cost
F_1	Price Philips Curve Numerator
F_2	Philips Curve Denominator
$\bar{\Pi}$	Optimal Relative Price
v^p	Price Dispersion
w	Real Wage
w^{new}	Optimal Wage
v^w	Wage Dispersion
Π	Inflation
L	Hours
v	Wage Philips Curve
TR	Transfers
Γ	Productivity Growth
\hat{y}	Output Log Deviation from SS
Ξ	Profits
Q_e	Equity Price
r	Real Rate
$\hat{\pi}$	Inflation Log Deviation from SS
\hat{R}	Policy Rate

Table 7: Endogenous Variables: B

Mnemonic	Description
\hat{c}	Consumption Log Deviation from SS
\hat{i}	Investment Log Deviation from SS
\hat{q}^F	Equity Price Log Deviation from SS
\hat{g}	Government Spending Log Deviation from SS
\hat{r}	Real Rate from SS
ψ	Risk Premium Exogenous Process
λ_p	Price Markup Exogenous Process
λ_w	Wage Markup Exogenous Process
μ	Investment Specific Productivity Exogenous Process
\hat{w}	Wage Log Deviation from SS
$\Delta\hat{y}$	Output Growth Log Deviation from SS
$\Delta\hat{c}$	Consumption Growth Log Deviation from SS
$\Delta\hat{i}$	Investment Growth Log Deviation from SS
$\Delta\hat{w}$	Wage Growth Log Deviation from SS
\hat{l}	Average Hours Log Deviation from SS
$\Delta\hat{g}$	Government Consumption Growth Log Deviation from SS
Tr	Tax Revenues
$\Delta\hat{tr}$	Tax Revenues Growth Log Deviation from SS
$\Delta\hat{b}$	Government Debt Growth Log Deviation from SS
α	Stationary Productivity Process
m_p	MA Price Markup Process
m_w	MA Wage Markup Process
q_c	Consumption Equity Price
R_c	Consumption Equity Return
\hat{q}_c	Consumption Equity Price Log Deviation from SS
R_L	Long Term Interest Rate
$\bar{\pi}$	Inflation Target Process
$\hat{\pi}_A$	CPI Annual Inflation
χ	Labour Supply Process
$\Delta\hat{b} - \Delta\hat{y}$	Growth of Debt to GDP Ratio
$\Delta\hat{Q}_e$	Equity Price Growth
\widehat{erp}	Equity Risk Premium
$\hat{b} - \hat{y}$	Debt to GDP Ratio Log Deviation from SS
\hat{tr}	Tax Revenues Log Deviation from SS
RES	GDP Accounting Wedge Process

Table 8: Exogenous Variables

Mnemonic	Description
ϵ_γ	Non Stationary Productivity Shock
ϵ_ψ	Risk Premium Shock
ϵ_R	Monetary Policy Shock
ϵ_μ	Investment Specific Productivity Shock
ϵ_α	Stationary Productivity Shock
ϵ_p	Price Markup Shock
ϵ_w	Wage Markup Shock
ϵ^T	Tax Shock
ϵ_g	Government Spending Shock
ϵ_z	Government Transfers Shock
ϵ_{π^*}	Inflation Target Shock
ϵ_{TP}	Term Premium Shock
ϵ_{erp}	Equity Risk Premium Shock
ϵ_y	GDP Accounting Wedge Shock

C Summary of Model Equations

$$\frac{\Gamma_t}{\Gamma} = \left(\frac{\Gamma_{t-1}}{\Gamma} \right)^{\rho_\gamma} \exp(\sigma_\gamma \epsilon_{\gamma t}) \quad (90)$$

$$\frac{1}{C_t - \frac{hC_{t-1}}{\Gamma_t}} = \lambda_t \quad (91)$$

$$\frac{\lambda_t}{\psi_t} = \frac{\beta R_t \lambda_{t+1}}{\Pi_{t+1} \Gamma_{t+1}} \quad (92)$$

$$Y_t = \alpha_t \left(\frac{L_t}{v^w_t} \right)^{1-\phi} \left(\frac{v_t K_{t-1}}{\Gamma_t} \right)^\phi \quad (93)$$

$$K_t = \frac{(1-\delta) K_{t-1}}{\Gamma_t} + I_t \mu_t \left(1 - 0.500 \chi_I \left(\frac{\Gamma_t I_t}{I_{t-1}} - \Gamma \right)^2 \right) \quad (94)$$

$$R^k_t (1 - \tau_t) = \kappa_1 + \kappa_2 (v_t - 1) \quad (95)$$

$$Q_t = \frac{\beta \lambda_{t+1}}{\lambda_t \Gamma_{t+1}} \left((1 - \tau_{t+1}) R^k_{t+1} v_{t+1} - \kappa_1 (v_{t+1} - 1) - 0.500 \kappa_2 (v_{t+1} - 1)^2 + (1 - \delta) Q_{t+1} \right) \quad (96)$$

$$1 = \mu_t Q_t \left(1 - 0.500 \chi_I \left(\frac{\Gamma_t I_t}{I_{t-1}} - \Gamma \right)^2 - \frac{\Gamma_t I_t \chi_I \left(\frac{\Gamma_t I_t}{I_{t-1}} - \Gamma \right)}{I_{t-1}} \right) + \chi_I \frac{\beta \lambda_{t+1}}{\lambda_t \Gamma_{t+1}} Q_{t+1} \mu_{t+1} \left(\frac{\Gamma_{t+1} I_{t+1}}{I_t} - \Gamma \right) \left(\frac{\Gamma_{t+1} I_{t+1}}{I_t} - \Gamma \right) \quad (97)$$

$$MC_t = \frac{w_t}{(1-\phi) \frac{Y_t}{\frac{L_t}{v^w_t}}} \quad (98)$$

$$MC_t = \frac{v_t R^k_t}{\frac{\Gamma_t \phi Y_t}{K_{t-1}}} \quad (99)$$

$$F_{1t} = \frac{Y_t \lambda_t MC_t}{v^p_t} + \beta \xi_p \left(\frac{\Pi_{t-1}^{\lambda_p} \bar{\pi}_t^{1-\lambda_p}}{\Pi_t} \right)^{\frac{(-\lambda_p)}{\lambda_p-1}} F_{1t+1} \quad (100)$$

$$F_{2t} = \frac{Y_t \lambda_t \bar{\Pi}_t}{v^p_t} + \beta \xi_p \left(\frac{\Pi_{t-1}^{\lambda_p} \bar{\pi}_t^{1-\lambda_p}}{\Pi_t} \right)^{\frac{(-1)}{\lambda_p-1}} \frac{\bar{\Pi}_t}{\bar{\Pi}_{t+1}} F_{2t+1} \quad (101)$$

$$0 = F_{1t} \lambda_p - F_{2t} \quad (102)$$

$$1 = \xi_p \left(\frac{\Pi_{t-1}^{\lambda_p} \bar{\pi}_t^{1-\lambda_p}}{\Pi_t} \right)^{\frac{(-1)}{\lambda_p-1}} + (1 - \xi_p) \bar{\Pi}_t^{\frac{(-1)}{\lambda_p-1}} \quad (103)$$

$$v_t^p = \xi_p \left(\frac{\Pi_{t-1}^{\lambda_p} \bar{\pi}_t^{1-\lambda_p}}{\Pi_t} \right)^{\frac{(-\lambda_p)}{\lambda_p-1}} v_{t-1}^p + (1 - \xi_p) \bar{\Pi}_t^{\frac{(-\lambda_p)}{\lambda_p-1}} \quad (104)$$

$$\frac{Y_t}{v_t^p} = C_t + I_t + g_t + \kappa_1 (v_t - 1) + \frac{K_{t-1} 0.500 \kappa_2 (v_t - 1)^2}{\Gamma_t} \quad (105)$$

$$\frac{B_t}{\psi_t} + \tau_t \left(L_t w_t + \frac{K_{t-1} v_t R^k_t}{\Gamma_t} \right) = TR_t + g_t + \frac{R_{t-1} B_{t-1}}{\Gamma_t \Pi_t} \quad (106)$$

$$\frac{\tau_t}{\tau} = \left(\frac{\tau_{t-1}}{\tau} \right)^{\rho_\tau} \left(\frac{B_{t-1}}{\bar{Y}} \right)^{(1-\rho_\tau)\zeta_\tau} \quad (107)$$

$$\frac{g_t}{g} = \left(\frac{g_{t-1}}{g} \right)^{\rho_g} \exp(\sigma_g \epsilon_{g_t}) \quad (108)$$

$$v_t = \frac{L_t (1 - \tau_t) \frac{\lambda_t}{\lambda_w} w^{new}_t \frac{1}{1-\lambda_w} w_t^{\frac{\lambda_w}{\lambda_w-1}}}{v^w_t} + \beta \xi_w \left(\frac{\Pi_t^{\lambda_w} \bar{\pi}_t^{1-\lambda_w}}{\Pi_{t+1}} \right)^{\frac{1}{1-\lambda_w}} \left(\frac{\Gamma_{t+1} w^{new}_{t+1}}{\Gamma_t w^{new}_t} \right)^{\frac{1}{\lambda_w-1}} v_{t+1} \quad (109)$$

$$v_t = \chi_t \left(\frac{w_t}{w^{new}_t} \right)^{\frac{(1+\sigma_L)\lambda_w}{\lambda_w-1}} \left(\frac{L_t}{v w_t} \right)^{1+\sigma_L} + v_{t+1} \beta \xi_w \left(\frac{\Pi_t^{\lambda_w} \bar{\pi}_t^{1-\lambda_w}}{\Pi_{t+1}} \right)^{\frac{(1+\sigma_L)\lambda_w}{1-\lambda_w}} \left(\frac{\Gamma_{t+1} w^{new}_{t+1}}{\Gamma_t w^{new}_t} \right)^{\frac{(1+\sigma_L)\lambda_w}{\lambda_w-1}} \quad (110)$$

$$1 = \xi_w \left(\frac{\bar{\pi}_t^{1-\lambda_w} \Pi_{t-1}^{\lambda_w}}{\Pi_t} \right)^{\frac{1}{1-\lambda_w}} \left(\frac{w_{t-1}}{w_t} \frac{\Gamma_{t-1}}{\Gamma_t} \right)^{\frac{1}{1-\lambda_w}} + (1 - \xi_w) \left(\frac{w^{new}_t}{w_t} \right)^{\frac{1}{1-\lambda_w}} \quad (111)$$

$$v_t^w = \xi_w \left(\frac{\bar{\pi}_t^{1-\lambda_w} \Pi_{t-1}^{\lambda_w}}{\Pi_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} \left(\frac{w_{t-1}}{w_t} \frac{\Gamma_{t-1}}{\Gamma_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} v_{t-1}^w + (1 - \xi_w) \left(\frac{w^{new}_t}{w_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} \quad (112)$$

$$\frac{R_t}{\frac{R \exp(\bar{\pi}_t)}{\Pi}} = \left(\frac{R_{t-1}}{\frac{R \exp(\bar{\pi}_{t-1})}{\Pi}} \right)^{\rho_R} \left(\frac{\Pi_t}{\exp(\bar{\pi}_t)} \right)^{(1-\rho_R)\gamma_\pi} \left(\frac{Y_t}{Y} \right)^{(1-\rho_R)\gamma_y} \exp(\sigma_R \epsilon_{R,t}) \quad (113)$$

$$\Xi_t = \frac{Y_t}{v_t^p} - \frac{L_t w_t}{v_t^w} - \frac{K_{t-1} v_t R^k_t}{\Gamma_t} \quad (114)$$

$$Q_{e,t} = \frac{\beta \lambda_{t+1}}{\Gamma_{t+1} \lambda_t} (Q_{e,t+1} + \Xi_{t+1}) \quad (115)$$

$$r_t = \frac{R_t}{\Pi_{t+1}} \quad (116)$$

$$\hat{y}_t = \log \left(\frac{Y_t}{Y} \right) \quad (117)$$

$$\hat{\pi}_t = \log(\Pi_t) \quad (118)$$

$$\hat{R}_t = \log \left(\frac{R_t}{R} \right) + 100 (R - 1) \quad (119)$$

$$\hat{c}_t = \log \left(\frac{C_t}{c} \right) \quad (120)$$

$$\hat{i}_t = \log \left(\frac{I_t}{i} \right) \quad (121)$$

$$\hat{q}_t^F = \log \left(\frac{Q_{e,t}}{Q_e} \right) \quad (122)$$

$$\hat{g}_t = \log \left(\frac{g_t}{g} \right) \quad (123)$$

$$\hat{r}_t = \log \left(\frac{r_t}{R} \right) \quad (124)$$

$$\hat{w}_t = \log \left(\frac{w_t}{w} \right) \quad (125)$$

$$\mu_t = \mu_{t-1}^{\rho_\mu} \exp(\sigma_\mu \epsilon_{\mu,t}) \quad (126)$$

$$\Delta \hat{y}_t = \gamma + \log \left(\frac{\frac{\Gamma_t}{\Gamma} Y_t}{Y_{t-1}} \right) \quad (127)$$

$$\Delta \hat{c}_t = \gamma + \log \left(\frac{\frac{\Gamma_t}{\Gamma} C_t}{C_{t-1}} \right) \quad (128)$$

$$\Delta \hat{i}_t = \gamma + \log \left(\frac{\frac{\Gamma_t}{\Gamma} I_t}{I_{t-1}} \right) \quad (129)$$

$$\Delta \hat{w}_t = \gamma + \log \left(\frac{\frac{\Gamma_t}{\Gamma} w_t}{w_{t-1}} \right) \quad (130)$$

$$\hat{l}_t = \log \left(\frac{L_t}{L} \right) \quad (131)$$

$$\Delta \hat{g}_t = \gamma + \log \left(\frac{\frac{\Gamma_t}{\Gamma} g_t}{g_{t-1}} \right) \quad (132)$$

$$TaxRev_t = \tau_t \left(L_t w_t + \frac{K_{t-1} v_t R_t^k}{\Gamma_t} \right) \quad (133)$$

$$\Delta \widehat{TaxRev}_t = \gamma + \log \left(\frac{\frac{\Gamma_t}{\Gamma} \widehat{TaxRev}_t}{\widehat{TaxRev}_{t-1}} \right) \quad (134)$$

$$\Delta \hat{b}_t = \gamma + \log \left(\frac{\frac{\Gamma_t}{\Gamma} B_t}{B_{t-1}} \right) \quad (135)$$

$$\alpha_t = \alpha_{t-1}^{\rho_\alpha} \exp(\sigma_\alpha \epsilon_{\alpha,t}) \quad (136)$$

$$\chi_t = \chi_{t-1}^{\rho_\chi} \exp(\sigma_\chi \epsilon_{\chi,t}) \quad (137)$$

$$\hat{q}_{e,t} = \log \left(\frac{q_{e,t}}{q_e} \right) \quad (138)$$