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Macroeconomic Implications of Fiscal Policy

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Alla mia famiglia

Abstract

This thesis investigates the macroeconomics effects of fiscal policy from a theoretical and empirical perspective.

The first part of the thesis surveys recent theoretical and empirical studies in the related literature. The analysis shows that while consensus has emerged on the positive effect that an expansionary fiscal policy has on output and hours worked, no widespread consensus exists on the effects that such a policy delivers to private consumption, real wages and investment. While in standard RBC models the negative wealth effect on households' lifetime resource constraint prevails, in more or less articulated new-Keynesian models a crowding-in effect of consumption and an increase in wages is made possible also under plausible calibrations. While early empirical contributions gave credit to the standard neoclassical predictions, the most recent econometric applications, generally making use of structural VARs, have supported and in many cases have inspired the latest new-Keynesian claims.

Next, this work applies graphical modelling theory to identify fiscal policy shocks in SVAR models of the US economy. Unlike other econometric approaches – which achieve identification by relying on potentially contentious *a priori* assumptions – graphical modelling is a data based tool. Our results are in line with Keynesian theoretical models, being also quantitatively similar to those obtained in the recent SVAR literature *à la* Blanchard and Perotti (2002), and contrast with neoclassical real business cycle predictions. Stability checks confirm that our findings are not driven by sample selection.

In its final part, the thesis empirically explores the information content of a large set of fiscal indicators for US real output growth and inflation. We provide evidence that fluctuations in certain fiscal variables contain valuable information to predict fluctuations in output and prices. The distinction between federal and state-local fiscal indicators yields useful insights and helps define a new set of stylized facts for US macroeconomic conditions. First, we find that variations in state-local indirect taxes as well as state government surplus or deficit help predict output growth. Next, the federal counterparts of these indicators contain valuable information for inflation. Finally, state-local expenditures help predict US inflation. A set of formal and informal stability tests confirm that these relationships are stable. The fiscal indicators in questions are also among the ones that yield the best in-sample and out-of-sample performances.

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Chapter 1

Fiscal policy in the theoretical and empirical macroeconomic literature

1.1 Introduction

Even though the effects of fiscal policy are of central importance in macroeconomics, there is no widespread consensus on its impact and transmission channels onto many macroeconomic variables. Both theoretical and empirical studies generally find a positive response of output and hours worked to a positive shock to government purchases and the disagreement is usually about the magnitude and timing of the response. On the contrary the sign of the responses of variables such as consumption, wages and investment is still a matter of debate. As shown by Baxter and King (1993), neoclassical Real Business Cycle (RBC) theory generally predicts a positive response of investment and a negative response of consumption and wages to a positive shock to government purchases. In contrast, textbook IS-LM theory predicts that consumption should rise and thus amplify the expansionary effects of government spending on output. As Gali, Lopez-Salido and Valles (2007) point out, this substantial difference across the two classes of models lay on the more or less implicit assumption made on the behaviour of consumers: in the IS-LM model consumption only depends on current disposable income, hence consumers are all non-Ricardian; in the RBC model consumption depends on life-time wealth, hence consumers are all optimising Ricardian agents. In the RBC model, an increase in government purchases, through an increase in current and/or future taxes, triggers a negative wealth effect that decreases consumption and leisure. Hence, it increases labour supply and decreases wages. The increase in the marginal product of capital, allowed by the increase in labour, causes also a positive reaction of investment. Baxter and King (1993) also show the differences obtained in the impulse responses depending on whether fiscal policy shocks are permanent or temporary; whether spending is financed by lump-sum or distortionary taxes; and whether the production function is augmented by public capital. Although the implications of such modifications of the standard model are important and we analyze them in the next section, the subsequent negative wealth effect of public spending is always at work. The empirical literature, mainly using vector-autoregressions (VAR), initially supported these claims. In particular empirical studies aiming at studying the effects of fiscal policy shocks confronted great difficulties in identifying such shocks, as they ought to be able to distinguish the role of automatic stabilisers responding to business cycles from the effects of discretionary fiscal policies. Ramey and Shapiro (1998) introduced the dummy-variable or narrative approach, due to Hamilton (1985), in the context of fiscal policy in a univariate setting. The methodology consists in constructing a dummy variable that takes value one at quarters when large military build-ups took place in the US, in order to identify episodes of discretionary fiscal policy. Edelberg, Eichenbaum and Fisher (1999) extended this methodology to a multivariate context, and Burnside, Eichenbaum and Fisher (2004), as well as Eichenbaum and Fisher (2005) made some modifications. Despite slight methodological differences, all these studies generally reached the same conclusions, at least from a qualitative point of view: in response to a discretionary substantial positive government spending shock, output increases, consumption and wages decline, non-residential investment rises, while residential investment falls. Therefore, at least qualitatively, these findings support the neoclassical business cycle literature. Within the field of RBC models, Edelberg, Eichenbaum and Fisher (1999), in addition to their econometric analysis, also built a variant of the neoclassical growth model distinguishing between residential and non-residential investment to match their empirical findings. Instead, Burnside, Eichenbaum and Fisher (2004) introduced habit formation in consumption and adjustment costs in investment to better mimic the timing and quantitative responses of hours worked, investment and consumption. In the meantime, empirical studies aiming at detecting the effects of government spending shocks began to make use of structural autoregressions in order to trace the impulse responses of the macroeconomic variables of interest. Fatas and Mihov (2001) found that there is a strong, positive e persistent impact of fiscal expansions on economic activity. Blanchard and Perotti (2002) achieved identification by relying on institutional information about the tax collection, constructing the automatic response of fiscal variables to the business cycle and, by implication, identifying discretionary fiscal policy shocks. The Blanchard-Perotti approach yields a positive effect of a government spending shock on output and consumption and negative effect on investment. While these findings are perfectly reasonable in a Keynesian world, they are difficult to reconcile with the RBC literature. Perotti (2005) extended the structural VAR methodology to other countries and reached similar conclusions. At the same time, Perotti (2007) proposed a variant of the narrative approach that allows the responses to each Ramey-Shapiro episode to have both a different intensity and a different shape. In addition, the author introduced a different method to build the dummy variable, which allows to isolate the abnormal fiscal events and to estimate the normal dynamic response of the non-fiscal variables to these events. Using this methodology the response of consumption is positive, in line with the structural VAR approach. Mountford and Uhlig (2008) extended Uhlig (2005)'s sign-restriction approach to fiscal policy and found a negative response of investment to a fiscal expansion. However, they found a small response of consumption, significant only on impact. In order to match the most recent empirical findings, the theoretical literature began working on models, able to explain the positive response of consumption to a fiscal expansion. Linneman (2006) used a non-additively separable utility function within a neoclassical growth model that is able to mimic a pattern for consumption similar to the one found by the structural VAR literature. Ravn, Schmitt-Grohe and Uribe (2006) assumed habit persistence on the consumption of individual differentiated goods, which implies a countercyclical mark-up of price over the marginal cost. A government spending shocks has a negative wealth effect. However, the government shock boosts aggregate demand, firms reduce their mark-up, labour demand increases and offsets the negative income effect affecting labour supply. As a result, wages and consumption rise. Gali, Lopez-Salido and Valles (2007) casted fiscal policy into a new-Keynesian sticky-price model modified to allow for the presence of rule-of-thumb behaviour. Non-Ricardian households are key for the purposes of the model, as they partly insulate aggregate demand from the negative wealth effects generated by the higher levels of current and future taxes needed to finance the fiscal expansion.

This chapter surveys the most recent theoretical and empirical studies that investigate the effects of fiscal policy on the macroeconomy. In order to be able to compare, also from a quantitative point of view, the predictions of the neoclassical and of the new-Keynesian models in the case of a fiscal expansion, we replicate the neoclassical RBC framework due to Baxter and King (1993) and the new-Keynesian model due to Gali, Lopez-Salido and Valles (2007) and trace impulses responses computed with the DYNARE toolkit, after taking a first-order linear approximation of the models around the steady state. For the purpose of comparability we prefer to depict percentage deviations from steady state, as opposed to commodity units, used instead by Baxter and King.

In analysing the new-Keynesian framework, we reach the conclusion that imperfect labour markets are a very useful addition to the baseline model as otherwise the possibility of crowding-in of consumption emerges only with an implausibly high proportion of non-Ricardian households. In other words, with perfectly competitive labour markets empirical findings would be matched only assuming that about three fourths of households in the economy do not save or invest. Whereas, imperfect labour markets, by implying countercyclical wage mark-ups and hence additional room for a simultaneous increase in consumption and hours worked, allow obtaining crowding-in of consumption also with a proportion of rule-of-thumb households of about one fourth.

The remainder of this chapter is structured as follows. Section 1.2 presents the effects of fiscal policy in the neoclassical RBC framework and performs several impulse-response exercises. Section 1.3 surveys more recent theoretical contributions. Section 1.4 analyses the effects of fiscal policy in the new-Keynesian framework. Section 1.5 compares several identification methods in VAR models aiming at unveiling the effects of discretionary fiscal policy shocks. Finally, Section 1.6 concludes.

1.2 Fiscal policy in the neoclassical general equilibrium model

The context of a quantitatively restricted dynamic model, such as Baxter and King (1993), is useful to answer four classic questions:

1. Does an increase in government purchases lead to a more than one-to-one increase in output?
2. How do the effects of a permanent shock differ from those of a temporary shock?
3. How does the introduction of distortionary taxes as opposed to lump-sum taxes alter the results?
4. How is the analysis altered by the introduction of public capital?

1.2.1 Model and equilibrium conditions

In the model, private capital evolves according to the following equation:

$$K_{t+1} = I_t + [1 - \delta_K]K_t \tag{1.1}$$

where K_t is the stock of private capital, I_t is private investment and δ_K is the depreciation rate of capital.

The economy faces the following overall resource constraint:

$$Y_t = C_t + I_t + G_t \tag{1.2}$$

where Y_t is total output, C_t is private consumption and G_t is government purchases.

In the case of distortionary taxes, the government budget constraint is:

$$G_t = \tau_t Y_t - TR_t \tag{1.3}$$

where τ_t is the tax rate and TR_t is government transfers. $G_t \equiv G_t^B + I_t^G$. G_t^B denotes basic government purchases and I_t^G denotes government investment. Combining the previous equations, the following holds:

$$Y_t(1-\tau_t) = C_t + I_t + TR_t \tag{1.4}$$

Analogously to private capital, public capital evolves according to:

$$K_{t+1}^G = I_t^G + [1-\delta_K]K_t^G \tag{1.5}$$

The equilibrium conditions are derived from the optimisation problems of households and firms. The representative household chooses C_t, N_t, and K_{t+1} subject to the budget constraint and to the capital accumulation equation. Hence the Lagrangian function can be written as:

$$\mathcal{L} = E_t \sum_{s=0}^{\infty} \beta^s \{[\ln(C_{t+s} + \theta_L \ln(1-N)_{t+s}] - \lambda_{t+s}[C_t + K_{t+1} - (1-\delta)K_t$$
$$+ TR_t - [w_t N_t + q_t k_t]\}$$

The first-order condition (FOC) with respect to (wrt) C_t is:

$$\frac{1}{C_t} = \lambda_t \tag{1.6}$$

The FOC wrt N_t is:

$$\frac{\theta_L}{1-N_t} = \lambda_t w_t \tag{1.7}$$

Finally, the FOC wrt K_{t+1} is:

$$\lambda_t = \beta E_t \{\lambda_{t+1}[1-\delta+q_{t+1}]\} \tag{1.8}$$

where λ_t is the Lagrange multiplier.

The Cobb-Douglas production function of the representative firm is augmented by public capital:

$$Y_t = A_t K_t^{\theta_K} N_t^{\theta_N} (K_t^G)^{\theta_G} \tag{1.9}$$

where A_t is total factor productivity.

The firm's profits are:

$$\Pi_t = (1 - \tau_t)Y_t - w_t N_t - q_t K_t$$

where w_t is the real wage and q_t is the cost of capital.

The FOC of the firm wrt K_t is:

$$(1 - \tau_t)\theta_K \frac{Y_t}{K_t} = q_t \tag{1.10}$$

The FOC of the firm wrt N_t is:

$$(1 - \tau_t)\theta_N \frac{Y_t}{N_t} = w_t \tag{1.11}$$

Most simulations in Baxter and King (1983) are carried out with lump-sum taxes. Moreover, if we are not concerned with transfers, the government resource constraint (1.3) becomes simply:

$$G_t = T_t \tag{1.12}$$

Hence, an increase in government purchases is reflected in an equal increase in taxes.[1]

In the case of lump-sum taxes, profits are:

$$\Pi_t = Y_t - w_t N_t - q_t K_t \tag{1.13}$$

The FOC wrt K_t becomes:

$$\theta_K \frac{Y_t}{K_t} = q_t \tag{1.14}$$

And the FOC of the firms wrt N_t becomes:

$$\theta_N \frac{Y_t}{N_t} = w_t \tag{1.15}$$

1.2.2 The steady state

At the steady state, great ratios are calibrated using stylized facts of the US economy:

[1] In the system of linearized equations we do not need to include the above equation since there is no tax rate do be determined and we know that taxes are equals to government expenditures at each and every period.

- From equation (1.1): $\frac{I}{Y} = \delta_K \frac{K}{Y}$.
- From the resource constraint: $\frac{C}{Y} = 1 - \frac{I}{Y} - \frac{G^b}{Y} - \frac{I^G}{Y}$. We distinguish two cases: if $\frac{I^G}{Y} = 0$ (no public capital) then $\frac{G}{Y} = 0.20$; else (with public capital) $\frac{G^b}{Y} = 0.15$ and $\frac{I^G}{Y} = 0.05$ to match historical experience in post-war period.
- From the Euler equation: $\beta = \frac{1}{1+r}$ where $1+r = q+1-\delta$ ($r = 0.065$, annual rate); therefore $q = r + \delta$.
- From equation (1.7): $\frac{Y}{K} = \frac{r+\delta}{(1-\tau)\theta_K}$.
- In the case of lump sum taxes: $\frac{Y}{K} = \frac{r+\delta}{\theta_K}$.
- $\theta_N = 0.58$, $\theta_K = 0.42$, $\delta_K = 0.10$, $L = 0.8$, $N = 1 - L = 0.2$.

1.2.3 The linearized model

Below, the system of linearized equilibrium conditions is summarized. A hat over a variable indicates its percentage deviation from its steady-state value.

Let us start with the case of distortionary taxes.

The FOC wrt consumption is:

$$-\hat{c}_t = \hat{\lambda}_t \tag{1.16}$$

The FOC wrt labour:

$$\frac{N}{1-N}\hat{N}_t = \hat{w}_t + \hat{\lambda}_t \tag{1.17}$$

The production function becomes:

$$\hat{Y}_t = \hat{A}_t + \theta_K \hat{K}_t + \theta_N \hat{N}_t + \theta_G \hat{K_t^G} \tag{1.18}$$

The linearised capital accumulation equation is:

$$\hat{K}_{t+1} = \frac{I}{K}\hat{I}_t + (1-\delta)\hat{K}_t \tag{1.19}$$

The linearised resource constraint is:

$$\hat{Y}_t = \frac{C}{Y}\hat{C}_t + \frac{I}{Y}\hat{I}_t + \frac{G}{Y}\hat{G}_t \tag{1.20}$$

The linearised Euler equation is:

$$\frac{r}{1+r}\hat{r}_{t+1} + \hat{\lambda}_{t+1} = \hat{\lambda}_t \tag{1.21}$$

Linearising the FOC wrt K yields:

$$\hat{Y}_t - \frac{\tau}{1-\tau}\hat{\tau}_t = \frac{r}{r+\delta}\hat{r}_t + \hat{K}_t \tag{1.22}$$

Linearising the FOC wrt L yields:

$$\hat{Y}_t - \frac{\tau}{1-\tau}\hat{\tau}_t = \hat{N}_t + \hat{w}_t \tag{1.23}$$

The linearised government resource constraint is:

$$\hat{Y}_t = \frac{1}{\tau}\frac{G}{Y}\hat{G}_t + \frac{1}{\tau}\frac{TR}{Y}\hat{TR}_t - \hat{\tau}_t \tag{1.24}$$

Therefore, in the case of distortionary taxes and no public capital, in the system there are 9 equations in 9 unknowns: $C_t, Y_t, I_t, N_t, r_t,\ w_t,\ \lambda_t, \tau, K_t$. The equations are (1.16) to (1.24). In all the experiment we set $TR = 0$. In the first experiments, we assume that $\frac{I^G}{Y} = 0$; in the last experiment (increase in public capital) we set $\frac{I^G}{Y} = 0.05$. The linearised public capital accumulation equation is analogously:

$$\hat{K}^G_{t+1} = \frac{I^G}{K^G}\hat{I}^G_t + (1-\delta)\hat{K}^G_t \tag{1.25}$$

Linearising $G_t = G^B_t + I^G_t$ yields:

$$\frac{G}{Y}\hat{G}_t = \frac{G^B}{Y}\hat{G}^B_t + \frac{I^G}{Y}\hat{I}^G_t \tag{1.26}$$

In the case of lump sum taxes and no public capital, there are 8 equations in 8 unknowns in the system: $C_t, Y_t, I_t, N_t, r_t,\ w_t,\ \lambda_t, K_t$. The equations are (1.16) to (1.21) plus the two following equations. Linearising the FOC wrt K (equation 1.14) yields:

$$\hat{Y}_t = \frac{r}{r+\delta}\hat{r}_t + \hat{K}_t \tag{1.27}$$

Linearising the FOC wrt L (equation 1.15) yields:

$$\hat{Y}_t = \hat{N}_t + \hat{w}_t \tag{1.28}$$

In the case of lump sum taxes and public capital, the system contains 9 equations in 9 unknowns: $C_t, Y_t, I_t, N_t, r_t, w_t, \lambda_t, K_t, K_t^G$. The equations are (1.16)-(1.21) plus (1.27), (1.28) and (1.25).

1.2.4 A permanent increase in government purchases

The increase in government purchases can be analyzed in a static and dynamic context.

In the static setting, with lump-sum taxes, disposable income is $Y_d = Y - T$, where T is the lump-sum taxes. Therefore, if G increase, Y_d decreases by the same amount and, as long as consumption and leisure are not inferior goods, they decrease. In symbols:

$$G \uparrow \Longrightarrow T \uparrow \Longrightarrow Y_a \downarrow \Longrightarrow C \,\text{and}\, l \downarrow \Longrightarrow L^s \uparrow (\Longrightarrow w \downarrow) \tag{1.29}$$

where l is leisure, L^s stands for labour supply and w stands for real wage. In the static setting the substituion effect (if wage decreases, the price of leisure decreases and therefore leisure should increase) is not working. This is justified by the fact that in the neoclassical model steady-state real wage does not depend on labour income. In addition, in the static setting, an increase in G increases Y, but less than proportionally (the multiplier of government spending is less than 1).

In the dynamic setting, the permanent change in government purchases has again a negative wealth effect on private individuals, as their income decreases. However, in this case the crucial difference lies in the amplification effect of capital, which cannot occur in a static setting. Continuing the mechanism described in equation (1.29):

$$L^s \uparrow \Longrightarrow MP_k \uparrow, r_k \uparrow, \Longrightarrow I \uparrow \tag{1.30}$$

In Figure 1.1, we depict the impulse responses of a one-percent permanent increase in government purchases financed by lump-sum taxes. On the x-axis we represent years, while on the y-axis we report percentage deviations from steady state.

Consumption and leisure permanently decrease due to the permanent reduction in lifetime wealth. A partial recovery in consumption is made possible by a larger stock of capital which increases output and partially offset the reduction in wealth at a later stage.

Labour permanently increases, although on impact the increase is greater both because of the stronger initial negative income effect and because of the sharp impact increase in the real interest rate which encourages postponement of consumption and enables the investment boom to take place.

The *real interest rate*, is high but declining along the transition path (see the Euler equation, where c_t decreases). Its sharp initial increase is due to the increase in the marginal product of capital, in turn allowed by the the increase in employment. In the long run the the capital-labour ratio is unchanged and the same applies to the wage-rental ratio.

Investment increases permanently as a higher level of capital stock has to be maintained, after the investment boom.

Wage decreases on impact as a consequence of the increase in labour supply. However, as capital-labour ratio and the wage-rental ratio go back to the steady state values, it returns to steady state.

Output permanently increases. In the dynamic setting the multiplier is greater than one and the amplification effect is due to capital accumulation.

1.2.5 A temporary increase in government purchases financed by lump-sum taxes

In this experiment, the increase in government spending is financed by lump-sum taxes; this increase lasts 4 years. The dynamic response is broken into two phases:

1. While the shock is occurring, private consumption, leisure and investment are reduced because of the increased government absorption of resources. In symbols:

$$\text{the shock:} G \uparrow \Longrightarrow T \uparrow \Longrightarrow Y_a \downarrow \Longrightarrow C, l \,\text{and}\, I \downarrow \Longrightarrow L^s \uparrow \tag{1.31}$$

2. When the shock has ended, investment is above the long-run level because the

economy needs to rebuild the capital stock. Private consumption and leisure are low along all the transition path while labour input increases more in the initial phase than it does along the transition path. In symbols:

$$\text{the shock is over:} I \uparrow . \text{Along the transition path} \, C \, \text{and} \, l \uparrow, L \downarrow \tag{1.32}$$

This is due to the fact that when the shock has ended, taxes are reduced and disposable income increases: consumption evolves smoothly because of the permanent income hypothesis, leisure increases and labour decreases.

Impulse responses are depicted in Figure 1.2. The factor prices move in opposite directions: $w \downarrow$ and $r^k \uparrow$ since labour input is high and capital is low during both phases. The pattern of interest rate is similar to that observed for permanent changes. Compared to the permanent change in G, the impact effect on output is smaller for the temporary change: the impact effect of temporary purchases is smaller the shorter is the duration of the spending shock.[2]

1.2.6 A temporary increase in government purchases financed by distortionary taxes

In this experiment, the government finances current expenditures from current distortionary tax revenues; the revenue from the output tax is equal to expenditures on a period-by-period basis. The path of transfer payment is constant (the analysis would be more complicated otherwise).

In this case the increase in G financed by a corresponding increase in the tax rate reduces individual's incentive to work and invest, therefore reducing the tax base. As a result, the tax rate must increase by more than $\Delta G/Y$ to finance the increase in G. In symbol:

$$G \uparrow \Longrightarrow \tau \uparrow \Longrightarrow \text{the incentive to work and invest} \downarrow \Longrightarrow Y \downarrow \Longrightarrow \tau \uparrow \tag{1.33}$$

As in the previous section, the case of a four-year shock is considered, but now the

[2]Barro (1981) and Hall (1980) obtained the opposite result because the substitution effect between leisure and consumption prevails in their model.

change in government purchases is financed by current distortionary taxation. There is a strong incentive to substitute intertemporally work effort (i.e. to postpone labour) and to reduce investment during this period. We can distinguish two phases:

1. During the first phase:

$$G \uparrow \Longrightarrow \tau \uparrow \Longrightarrow L,\, I,\, C \,\text{and}\, Y \downarrow \tag{1.34}$$

2. During the second phase, when the shock has ended:

$$L,\, I,\, C \,\text{and}\, Y \uparrow \tag{1.35}$$

The tax distortion has a strong negative effect, compared to the case analysed in the previous section. The distortionary effect of taxes induces a reduction of labour and output which does not occur in the case of lump-sum taxes. According to Baxter and King, the poor timing of tax distortions would be avoided by taxation smoothing over time and the related use of public debt for financing temporary high purchases.

In Figure 1.3 we report the responses of the principal macroeconomic variables:

Labour decreases during shock-time, since wage is taxed more and hence is optimal to postpone it. Then it immediately shifts upwards when the shock is over to smoothly go back to steady state. Here the substitution effect prevails over the income effect.

Output follows closely what happens to labour.

The *tax rate* has to increase more than the increase in government/output ratio and continues to grow as output decline to allow a balanced budget.

Consumption decreases during the occurrence of the shock given decreasing income to recover after the shock is over.

Wages and the *real interest rates* reflect the path of output.

Investment declines during the shock both because of the absorption of resources by government spending and because of low rates of return. Hence the negative effect here is amplified.

1.2.7 A permanent increase in public investment

As evident from the production function, an increase in government capital works like a productivity shock. Baxter and King distinguish between short-run and long-run effect of public investment.

In the *long-run* the effect of K^G on output depends on: (i) the direct effect of higher K^G, holding private capital and labour fixed; (ii) a supply-side effect due to the response of capital and labour. When public capital in unproductive, $\theta_G = 0$ and the results are the same as in the previous experiments. As the productivity parameter, θ_G, increases, there are larger direct effects. When $\theta_G = 0.4$ the direct output effect is eight times the change in public investment; therefore there is a high amplification effect (Baxter and King 1993, page 330).

In the *short-run* three *forces* operate along the transition path to the new steady state:

1. there is a government absorption of resource, as in the previous cases.
2. As K^G increases, the flow of output increases.
3. The marginal product of private capital and labour increases (recall that $MP_k = \theta_K \frac{Y_t}{K_t}$ and $MP_L = \theta_N \frac{Y_t}{N_t}$). Therefore capital and labour increase: the return to investment, MP_k, is higher, hence more capital is accumulated.

If K^G increases, the resources available for private consumption and investment decrease; this loss equal the shift in public investment (*force 1*). With variable private capital and labour, *force 3* operates and it has significant effects, i.e. the response of output is strongly amplified by the increase in K^G. Therefore, the effects of increasing public capital depend strongly on whether this change directly affects private marginal products.

In figure 1.4 we report the responses of the principal macroeconomic variables.

Consumption and leisure decrease due to the reduction in wealth. In later years, the steady additional supply of labour and capital stimulates output, and therefore consumption increases.

Labour increases as leisure decreases and the marginal product of labour increases.

Private investment permanently increases because its marginal product has increased. The return to investment is higher, hence more capital is accumulated.

Output follows closely what happens to investment in a larger scale, due to the increase in public capital.

The *real interest rate* is high but declining along the transition path. Its initial increase is due to the increase in the marginal product of capital, in turn allowed by the the increase in employment.

Wage decreases on impact as a consequence of the increase in labour supply; then it increases.

1.3 Advances in the recent theoretical literature

Edelberg, Eichenbaum, and Fisher (1999) conduct an empirical analysis in order to build a theoretical model consistent with their empirical findings. Their empirical strategy is based on the narrative approach previously utilised by Ramey and Shapiro (1998), who identify exogenous government shocks by indentifying political events that led to large military buildups.Their main empirical finding is that an expansionary shock in government purchases causes an increase in output, hours worked and nonresidential investment, whereas real wages, residential investment and consumption of durables and nondurables decrease.[3] To match their empirical findings, they build a simple variant of the neoclassical growth model distinguishing between residential and nonresidential investment. Nonresidential investment augments capital used to produce goods, whereas residential investment augments capital that yields consumption services. In their theoretical model, a persistent positive shock to government purchases, financed by lump-sum taxes, reduces the representative agent's permanent income, which in turn induces a fall in consumption of durables and nondurables and an increase in employment. As a result, the marginal product of labour and real wages fall. The fall in residential investment is due to the reduction in consumption of durables (consumption services), whereas the increase in nonresidential investment is due to the complementarity of hours worked and market capital. An increase in output accommodates the increase in government purchases.

[3]Section 1.5 covers the various estimation strategies to identify fiscal shocks in the empirical literature.

Although Baxter and King have shown that, when taxes are distortionary, a positive fiscal shock reduces both hours worked and after-tax real wages, Burnside, Eichenbaum, and Fisher (2004), adopting the empirical narrative approach, find that government purchases increase tax rates on labor and income, but hours worked persistently rise. In addition, they test two different theoretical neoclassical models subject to the sequences of changes in government purchases and tax rates equal to their point estimates obtained with the empirical narrative approach. The first model corresponds to the standard neoclassical growth model, whereas in the second model they introduce habit formation in consumption and adjustment costs in investment. Allowing for distortionary taxes, the standard neoclassical model is able to reproduce all the qualitative features of their empirical responses following a fiscal policy shock: a rise in government purchases, hours worked and investment and a fall in consumption and real wages. There are, however, some shortcomings: hours worked counterfactually rise close to the time of the fiscal shock and the quantitative responses of consumption and investment are overstated. Allowing for habit formation in consumption and adjustment costs in investment, they are able to better mimic the timing of how hours worked respond to a fiscal shock and to improve the quantitative responses of investment and consumption, although the theoretical model has to rely on quite a high labour elasticity.

King, Plosser, and Rebelo (1988) have shown the conditions under which the utility function satisfies the long run restrictions implied by the basic neoclassical growth model i.e. continuing trend growth of labor productivity and no trend growth in per capita labor supply. A utility function that allows offsetting substitution and income effect in labor supply in the long run must be *either* logarithmic in consumption (and additively separable in consumption and leisure) with a unit intertemporal elasticity of substitution *or* non additively separable with an intertemporal elasticity of substitution smaller than one. Linneman (2006) uses a non additively separable utility function and, under a plausible calibration, is able to build a neoclassical growth model which can show a pattern for consumption similar to the recent structural VAR literature, surveryed in section 1.3. A government spending shock implies a negative wealth effect which reduces leisure. The non-additively separable utility function implies that consumption and leisure are substitutes. The reduction in leisure increases the marginal utility of consumption, and if the complementarity between consumption and employment is strong enough, consumption can increase after a fiscal spending shock.

Ravn, Schmitt-Grohe, and Uribe (2006), in contrast to standard habit-persistence models – where households are assumed to form habits from consumption on a single aggregate good – assume that habits are formed from the consumption of individual goods. Such an assumption has a key implication for the supply side of the economy. With imperfectly competitive product markets, the higher is the current demand for a particular good, the higher will be the demand in the future via habit formation, implying a countercyclical mark-up of price over marginal cost. In other words, since in the model the demand faced by an individual firm has an elastic component linked to the aggregate demand and an inelastic component linked to habits, an increase in the aggregate demand makes the price-elastic component of the demand predominant and leads the firm to cut the mark-up. At the same time, the current reduction in the mark-up induces agents to form habits that the firm will later exploits at a higher mark-up. A government spending shock makes agents poorer and they will consequently work more. However, the government shock boosts aggregate demand. Therefore, firms will reduce their mark-up, which in turn induces an expansion in labor demand, which offsets the negative income effect affecting labor supply. As a result, real wages and consumption rise.

1.4 Fiscal policy in the new-Keynesian framework

As we have seen in section 1.2, the standard Real Business Cycle (RBC) model generally predicts a decline in consumption in response to a rise government purchases. In constrast, the IS-LM model predicts that consumption should rise, amplifying the effects of the expansion in government spending on output.

The reason for such a differential impact across the two models lies on how consumers are assumed to behave. In fact, the RBC model features infinitely-lived Ricardian households who base their consumption decisions at any point in time on an intertemporal budget constraint. On the contrary, in the IS-LM model consumers behave in a non-Ricardian fashion, i.e. their consumption is a function of their current disposable income and not of their life-time resources. In the latter model, the implied effect of an increase in government spending will depend critically on how spending itself is financed: the multiplier will be an increasing function of the extent of deficit financing.

As we document in section 1.5, some recent empirical contributions find a positive response of consumption to an expansionary shock in government purchases. Galí, López-Salido, and Valles (2007) develop a dynamic general equilibrium model that is able to account for that evidence. In particular, they cast fiscal policy into a new-Keynesian sticky-price model modified in order to allow for the presence of rule-of-thumb behaviour by a fraction of households. Consistently with Campbell and Mankiw (1989), they assume that rule-of-thumb consumers do not borrow or save: they are simply assumed to consume their current income fully and coexist with conventional infinite-horizon Ricardian consumers. This assumption is motivated by an extensive empirical literature that provided evidence of excessive dependence of consumption on current income.[4]

In order to obtain a positive response of consumption to a rise in government spending, the presence of rule-of-thumb consumers is complemented with the presence of sticky prices in goods markets. To see that such an assumption is necessary, consider the following equilibrium condition in logarithmic terms:

$$mpn_t = \mu_t + c_t + \varphi n_t \tag{1.36}$$

where mpn_t is the marginal product of labour, c_t is consumption, n_t is hours worked and $\varphi > 0$ measures the curvature of the marginal disutility of labour. $c_t + \varphi n_t$ represents the log marginal rate of substitution. Hence μ_t is the wedge between the marginal rate of substitution and the marginal product of labour. Galí, López-Salido, and Vallés (2004) show that μ_t is the sum of the log wage and price mark-ups. If $\mu_t = \mu \ \forall t$ ($\mu = 0$ in the neoclassical RBC framework), an increase in government purchases raises hours and lowers the marginal product of labour, hence consumption must drop. Therefore, a necessary condition for consumption to rise, in response to a fiscal expansion, is that there must be a simultaneous decline the wedge μ_t, which occurs if prices are sticky in the goods markets.

[4]See Campbell and Mankiw (1989) for a survey.

1.4.1 Model and equilibrium conditions

In the model, a fraction $1-\lambda$ of households have access to capital markets and can buy and sell physical capital which they can rent out to firms. These households are referred to as *optimizing* or *Ricardian*. A fraction λ of households just consume their labour income. They are referred to as *rule-of-thumb*.

A typical optimizing household solves the following problem:

$$\max_{C_t^O, N_t^O, \frac{B_{t+1}}{P_t}, K_{t+1}} E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t^O - \frac{N_t^{O^{1+\varphi}}}{1+\varphi} \right) \tag{1.37}$$

subject to a sequence of budget constraints:

$$P_t \left(C_t^0 + I_t^O \right) + R_t^{-1} B_{t+1}^O = W_t P_t N_t^O + R_t^k P_t K_t^O + B_t^O + D_t^O - P_t T_t^O \tag{1.38}$$

and the law of capital accumulation:

$$K_{t+1}^O = (1-\delta) K_t^O + \phi \left(\frac{I_t^O}{K_t^O} \right) K_t^O \tag{1.39}$$

where W_t, P_t, N_t^O, K_t^O, R_t^k, B_t^O, R_t, D_t^O, T_t^O, C_t^O, I_t^O, δ are real wages, the price of the final good, hours of work of optimising households, capital holdings rented to firms, the quantity of nominal one-period bonds carried over from period $t-1$, the gross nominal return on bonds purchased in period t, dividends from ownership of firms, lump-sum taxes from this type of households, their consumption, their investment expenditures, the depreciation rate of capital, respectively. The term $\phi \left(\frac{I_t^O}{K_t^O} \right) K_t^O$ determines the change in the capital stock induced by investment spending. The function $\phi(\cdot)$ introduces capital adjustment costs. Further assumptions are: $\phi' > 0$, $\phi'' \leq 0$, $\phi'(\delta) = 1$, $\phi(\delta) = \delta$, $\varphi \leq 0$.

From (1.39), we can write investment as:

$$I_t^O = K_t^O \phi^{-1} \left[\frac{K_{t+1}^O}{K_t} - (1-\delta) \right] \tag{1.40}$$

Hence the Lagrangian function for the maximisation problem will be:

$$\mathcal{L}\left(C_t^O, N_t^O, \frac{B_{t+1}^O}{P_t}, K_{t+1}^O, \lambda_t\right) = E_0 \sum_{t=0}^{\infty} \beta^t \{\log C_t^O - \frac{N_t^{O^{1+\varphi}}}{1+\varphi}$$
$$+ \lambda_t [W_t N_t^O + R_t^k K_t^O + \frac{B_t^O}{P_t} + \frac{D_t^O}{P_t} - T_t^O - C_t^0$$
$$- K_t^O \phi^{-1} \left[\frac{K_{t+1}^O}{K_t} - (1-\delta)\right] - R_t^{-1} \frac{B_{t+1}^O}{P_t}]\}$$

The FOC wrt C_t^O is:

$$\frac{1}{C_t^O} = \lambda_t \tag{1.41}$$

The FOC wrt N_t^O is:

$$\lambda_t = \frac{N_t^{O^\varphi}}{W_t} \tag{1.42}$$

Combining (1.41) and (1.42) yields:

$$W_t = C_t^O N_t^{O^\varphi} \tag{1.43}$$

which holds in the case of competitive labour markets.[5]

The FOC wrt $\frac{B_{t+1}^O}{P_t}$ is:

$$\lambda_t R_t^{-1} = \beta E_t \left[\lambda_{t+1} \frac{P_t}{P_{t+1}}\right] \Leftrightarrow 1 = R_t E_t \left[\Lambda_{t,t+1} \frac{P_t}{P_{t+1}}\right] \tag{1.44}$$

where $\Lambda_{t,t+k}$ is the stochastic discount factor:

$$\Lambda_{t,t+k} \equiv \beta^k \left(\frac{C_{t+k}^O}{C_t^O}\right)^{-1} \tag{1.45}$$

By the theorem of the derivative of the inverse function:

$$\frac{\partial}{\partial K_{t+1}^O} \phi^{-1} \left[\frac{K_{t+1}^O}{K_t^O} - (1-\delta)\right] = \frac{1}{K_t^O \phi' \left(\frac{I_t^O}{K_t^O}\right)} \tag{1.46}$$

[5]The authors present two versions of the model: one with competitive labour markets, one with wages set by unions. Below we will present the results obtained with non-competitive labour markets. This assumption can be removed by using equation (1.43) and the analogous condition for rule-of-thumb households.

Hence the FOC wrt K_{t+1} is:

$$\lambda_t \frac{K_t^O}{K_t^O \phi'\left(\frac{I_t^O}{K_t^O}\right)} = \beta E_t \left\{ \lambda_{t+1} \left[R_{t+1}^k - \phi^{-1} \left[\frac{K_{t+1}^O}{K_t^O} - (1-\delta) \right] + \frac{K_{t+1}^O}{\phi'\left(\frac{I_{t+1}^O}{K_{t+1}^O}\right)} \frac{K_{t+2}^O}{K_{t+1}^2} \right] \right\}$$

Defining the real shadow value of capital in place, i.e. Tobin's Q, as follows:

$$Q_t \equiv \frac{1}{\phi'\left(\frac{I_t^O}{K_t^O}\right)} \tag{1.47}$$

we can write the FOC wrt capital as:

$$Q_t = E_t \left\{ \Lambda_{t,t+1} \left[R_{t+1}^k + Q_{t+1} \left((1-\delta) + \phi_{t+1} - \left(\frac{I_{t+1}^O}{K_{t+1}^O} \right) \phi_{t+1}^{'} \right) \right] \right\} \tag{1.48}$$

A typical rule-of-thumb household solves the following problem:

$$\max_{C_t^r, N_t^r} E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t^r - \frac{N_t^{r^{1+\varphi}}}{1+\varphi} \right) \tag{1.49}$$

subject to a sequence of budget constraints:

$$P_t C_t^r = W_t P_t N_t^r - P_t T_t^r \tag{1.50}$$

Therefore, the level of consumption will equate net labour income:

$$C_t^r = W_t N_t^r - T_t^r \tag{1.51}$$

If labour markets are competitive, then the following holds:

$$W_t = C_t^r N_t^{r^{\varphi}} \tag{1.52}$$

In order to obtain the aggregate level of consumption, hours, investment and the stock of capital, we simply take a weighted average across the two types of households:

$$C_t \equiv \lambda C_t^r + (1-\lambda)\, C_t^O \tag{1.53}$$

$$N_t \equiv \lambda N_t^r + (1-\lambda) N_t^O \tag{1.54}$$

$$I_t \equiv (1-\lambda) I_t^O \tag{1.55}$$

$$K_t \equiv (1-\lambda) K_t^O \tag{1.56}$$

In order to introduce wage-setting in the model, a continuum of unions can be assumed, each of which represents workers of a certain type. Labour input hired by firm j is a function of the quantities of the different labour types employed:

$$N_t(j) = \left(\int_0^1 N_t(j,i)^{\frac{\epsilon_w - 1}{\epsilon_w}} di \right)^{\frac{\epsilon_w}{\epsilon_w - 1}}$$

where ϵ_w is the elasticity of substitution across different types of households. The fraction of rule-of-thumb and Ricardian consumers is uniformly distributed across unions. Hence, a typical union, representing worker type z, sets the wage for its workers in order to maximize the following objective function:

$$\lambda \left[\frac{1}{C_t^r(z)} W_t(z) N_t(z) - \frac{N_t^{1+\varphi}(z)}{1+\varphi} \right] + (1-\lambda) \left[\frac{1}{C_t^r(z)} W_t(z) N_t(z) - \frac{N_t^{1+\varphi}(z)}{1+\varphi} \right]$$

subject to a labour demand schedule:

$$N_t(z) = \left(\frac{W_t(z)}{W_t} \right)^{-\epsilon_w} N_t$$

In the objective function, the union weighs labour income with the marginal utilities of consumption of the two types of households as their consumption will generally differ. As firms allocate labour demand uniformly across different workers of type z, independently of their household type, in aggregate $N_t^r = N_t^O = N_t$. Invoking symmetry, the FOC of the above problem can be written as:

$$\left(\frac{\lambda}{MRS_t^r} + \frac{1-\lambda}{MRS_t^O} \right) W_t = \mu^w \tag{1.57}$$

where: $MRS_t^r = C_t^r N_t^\varphi$, $MRS_t^O = C_t^O N_t^\varphi$ and $\mu^w = \frac{\epsilon_w}{\epsilon_w - 1}$.

On the firms' side, in line with new-Keynesian models, there is a continuum of monipolistically competitive firms producing differentiated intermediate goods used by a representative perfectly competitive firm producing a single final good.

The final good firm's production function is with constant returns:

$$Y_t = \left(\int_0^1 X_t\left(j\right)^{\frac{\epsilon_p - 1}{\epsilon_p}} dj \right)^{\frac{\epsilon_p}{\epsilon_p - 1}} \tag{1.58}$$

where $X_t\left(j\right)$ is the quantity of intermediate good j used as input and $\epsilon_p > 1$. Hence the Lagrangian for the cost minimisation problem of the final good producer:

$$\mathcal{L} = \int_0^1 P_t\left(j\right) X_t\left(j\right) dj - \lambda_t \left[\left(\int_0^1 X_t\left(j\right)^{\frac{\epsilon_p - 1}{\epsilon_p}} dj \right)^{\frac{\epsilon_p}{\epsilon_p - 1}} - \bar{Y} \right] \tag{1.59}$$

Taking the final good price P_t and the intermediate good prices $P_t\left(j\right)$ as given, the FOC wrt $X_t\left(j\right)$ yields the firm's demand for the intermediate goods:

$$X_t\left(j\right) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon_p} Y_t \tag{1.60}$$

Substituting for (1.60) into (1.58) and rearranging yields the aggregate price index:

$$P_t = \left(\int_0^1 P_t\left(j\right)^{1-\epsilon_p} dj \right)^{\frac{1}{1-\epsilon_p}} \tag{1.61}$$

The production function for a typical intermediate good firm is:

$$Y_t\left(j\right) = K_t(j)^{\alpha} N_t(j)^{1-\alpha} \tag{1.62}$$

Taking wages and the rental cost of capital as given, the Lagrangian for the cost minimisation problem is:

$$\mathcal{L} = W_t N_t(j) + R_t^k K_t(j) - \lambda_t \left(K_t(j)^{\alpha} N_t(j)^{1-\alpha} - Y\bar{(j)} \right) \tag{1.63}$$

The FOC wrt N_t is:

$$W_t = \lambda_t (1-\alpha) \left(\frac{K_t(j)}{N_t(j)} \right)^{\alpha} \tag{1.64}$$

The FOC wrt K_t is:

$$R_t^k = \lambda_t \alpha \left(\frac{K_t(j)}{N_t(j)} \right)^{\alpha - 1} \tag{1.65}$$

Combining (1.64) and (1.65) yields:

$$\frac{K_t(j)}{N_t(j)} = \left(\frac{\alpha}{1-\alpha}\right)\frac{W_t}{R_t^k} \tag{1.66}$$

The Lagrange multiplier λ_t represents the real marginal cost:

$$MC_t = \lambda_t = R_t^k \frac{1}{\alpha}\left(\frac{K_t(j)}{N_t(j)}\right)^{1-\alpha} \tag{1.67}$$

Substituting for (1.66), the marginal cost turns out to be common to all firms:

$$MC_t = \Psi(R_t^k)^{\alpha}(W_t)^{1-\alpha} \tag{1.68}$$

where $\Psi = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}$.

Intermediate goods producers set nominal prices according to the stochastic time dependent rule proposed by Calvo (1983). Each period a measure $1-\theta$ of producers reset their prices, while a measure θ keep their prices unchanged.

A firm resetting its price at time t will solve the following optimisation problem:

$$\max_{P_t^*}\sum_{k=0}^{\infty}\theta^k E_t\left\{\Lambda_{t,t+k}Y_{t+k}(j)\left[\frac{P_t^*}{P_{t+k}} - MC_{t+k}\right]\right\} \tag{1.69}$$

subject to the following sequence of budget constraints:

$$Y_{t+k}(j) = X_{t+k}(j) = \left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon_p} Y_{t+k} \tag{1.70}$$

Substituting for (1.70) into (1.69) yields:

$$\max_{P_t^*}\sum_{k=0}^{\infty}\theta^k E_t\left\{\Lambda_{t,t+k}\left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon_p} Y_{t+k}\left[\frac{P_t^*}{P_{t+k}} - MC_{t+k}\right]\right\} \tag{1.71}$$

Taking the FOC wrt P_t^* and dividing through by $\epsilon_p - 1$ yields:

$$\sum_{k=0}^{\infty}\theta^k E_t\left\{\Lambda_{t,t+k}Y_{t+k}(j)\left[\frac{P_t^*}{P_{t+k}} - \mu^p MC_{t+k}\right]\right\} = 0 \tag{1.72}$$

where $\mu^p \equiv \frac{\epsilon_p}{\epsilon_p - 1}$ is the gross frictionless mark-up.

The price index is described in equation (1.61). However, in equilibrium, each producer that chooses a new price $P_t(z)$ in period t will chose the same price $P_t(z)$ and the same level of output. Hence the dynamics of the price index will obey:

$$P_t = \left[\theta P_{t-1}^{1-\epsilon_p} + (1-\theta)\left(P_t^*\right)^{1-\epsilon_p}\right]^{\frac{1}{1-\epsilon_p}} \tag{1.73}$$

The central bank is assumed to set the nominal interest rate $r_t \equiv R_t - 1$ according to a simple Taylor rule:

$$r_t = r + \phi_\pi \pi_t \tag{1.74}$$

where $\phi_\pi > 1$ to satisfy the Taylor principle.

The government budget constraint is:

$$P_t T_t + R_t^{-1} B_{t+1} = B_t + P_t G_t \tag{1.75}$$

where $T_t \equiv \lambda T_t^r + (1-\lambda) T_t^O$. Fiscal policy follows the following rule:

$$t_t = \phi_b b_t + \phi_g g_t \tag{1.76}$$

where ϕ_b and ϕ_g are positive constant, $t_t \equiv \frac{T_t - T}{T}$, $g_t \equiv \frac{G_t - G}{G}$, and $b_t \equiv \frac{\frac{B_t}{P_{t-1}} - \frac{B}{P}}{Y}$. Finally government purchases (also in deviations from steady state and normalised by steady state output) evolve exogenously according to a first-order autoregressive process:

$$g_t = \rho_g g_{t-1} + \epsilon_t \tag{1.77}$$

where $\rho_g \in (0,1)$ and ϵ_t is an i.i.d. shock with constant variance σ_ϵ^2.

1.4.2 Linearised equilibrium conditions

To solve the model and trace impulse responses of fiscal policy shocks, we need to linearise the model equilibrium conditions around the steady state and build a linear system of dynamic stochastic equations. We represent percentage deviations from steady state with a hat on the variable of interest and steady states with variables with no subscripts.

Let us start from households' optimality conditions. It is useful to note that the elasticity of the investment-to-capital ratio with respect to Tobin's Q, from (1.47) is: $\eta = -\frac{1}{\delta\phi''(\delta)}$. Hence, linearising (1.47) and taking the assumptions made on $\phi(\cdot)$ into account, the relationship between Tobin's Q and investment is given by the following:

$$\hat{i}_t - \hat{k}_t = \eta \hat{q}_t \tag{1.78}$$

Linearising the capital accumulation equation (1.39) yields:

$$\hat{k}_{t+1} = \delta \hat{i}_t + (1-\delta)\hat{k}_t \tag{1.79}$$

Substituting for the definition of the stochastic discount factor (1.45) into the Euler equation (1.44), linearising the latter around the steady state and noting that $R^{-1} = \beta$, yields the linearised Euler equation for optimizing households:

$$\hat{c}_t^O = E_t[\hat{c}_{t+1}^O] - (\hat{r}_t - E_t[\pi_{t+1}]) \tag{1.80}$$

where $\pi_{t+1} = \hat{p}_{t+1} - \hat{p}_t = \log(P_{t+1}/P) - \log(P_t/P) = \log(P_{t+1}/P_t) \approx \frac{P_{t+1}-P_t}{P_t}$ represents inflation.

To obtain a linear expression describing the dynamics of Tobin's Q, note that, at the steady state, (1.48) implies $\beta^{-1} = R = R^K + (1-\delta)$. Then, linearising (1.48) around the steady state and substituting for (1.78) and (1.80) yields:

$$\hat{q}_t = \beta E_t[\hat{q}_{t+1} + [1-\beta(1-\delta)]E_t[\hat{r}_{t+1}^K] - (r_t - E_t[\pi_{t+1}])] \tag{1.81}$$

Linearising the level of consumption of rule-of-thumb households (1.51) yields:

$$\hat{c}_t^r = (WN^r/C^r)(\hat{w}_t + \hat{n}_t^r) - (Y/C^r)t_t^r \tag{1.82}$$

where $t_t \equiv \frac{T_t - T}{T}$ as previously defined.

To simplify the algebra, we can assume that $C^r = C^O = C$. As marginal rates of substitutions are equal across households, equality of steady state consumption also implies $N^r = N^O = N$.[6] Using this assumption, linearising equations (1.53) and (1.54)

[6] Since the focus of impulse-response analysis is the differential response to shocks, this assumption is largely innocuous.

yields expressions for aggregate consumption and employment in percentage deviations from steady state:

$$\hat{c}_t = \lambda \hat{c}_t^r + (1-\lambda)\,\hat{c}_t^O \tag{1.83}$$

$$\hat{n}_t = \lambda \hat{n}_t^r + (1-\lambda)\,\hat{n}_t^O \tag{1.84}$$

Linearising equation (1.57) yields the wage schedule:

$$\hat{w}_t = \chi_r m\hat{r}s_t^r + \chi_O m\hat{r}s_t^O = \tilde{c}_t + \varphi(\chi_r + \chi_O)\hat{n}_t \tag{1.85}$$

where $\chi_r = \lambda W/MRS^r\mu^w$, $\chi_O = (1-\lambda)W/MRS^O\mu^w$, and $\tilde{c}_t = \chi_r\hat{c}_t^r + \chi_O\hat{c}_t^O$. Provided that tax policy is such that steady state consumption is the same across households, $MRS^r = MRS^O$, $\chi_r = \lambda$ and $\chi_O = 1-\lambda$. Therefore, the following holds:

$$\hat{w}_t = \hat{c}_t + \phi\hat{n}_t \tag{1.86}$$

On the firms's side, a linerised version of the aggregate production function can be derived by noticing that, in order to aggregate the output of producers of intermediate goods, we should use equation (1.57):

$$Y_t = \left(\int_0^1 \left[K_t(j)^\alpha N_t(j)^{1-\alpha}\right]^{\frac{\epsilon_p-1}{\epsilon_p}} dj\right)^{\frac{\epsilon_p}{\epsilon_p-1}}$$

However, in a neighbourhood of the steady state, we can approximate equation (1.87) with a simple sum across all firms:

$$Y_t = \int_0^1 K_t(j)^\alpha N_t(j)^{1-\alpha} = K_t^\alpha N_t^{1-\alpha}$$

where: $K_t = \int_0^1 K_t(j)dj$ and $N_t = \int_0^1 N_t(j)dj$. Linearising the above equation yields:

$$\hat{y}_t = (1-\alpha)\hat{n}_t + \alpha\hat{k}_t \tag{1.87}$$

To obtain a linearised expression of the price mark-up, note that in general the gross price mark-up is the inverse of the marginal cost: $\mu_t^p = MC_t^{-1}$, which can be linearised around the steady state as: $\hat{\mu}_t = -\hat{mc}_t$. Equation (1.64) can be rewritten as:

$$R_t^K = MC_t \alpha \frac{Y_t}{K_t}$$

which can be linearised as:

$$\hat{r}_t^K = \hat{mc}_t + \hat{y} - \hat{k}_t$$

and rearranged as:

$$\hat{\mu}_t = (\hat{y}_t - \hat{k}) - \hat{r}_t^K \tag{1.88}$$

Equivalently and analogously:

$$\hat{\mu}_t = (\hat{y}_t - \hat{n}) - \hat{w}_t \tag{1.89}$$

To obtain the new-Keynesian Phillips curve, describing the dynamics of inflation as a function of percentage deviations of the average markup from its steady state level, it is convenient to first linearise equation (1.72) around the steady state:

$$\hat{p}_t = \theta \hat{p}_{t-1} + (1-\theta)\hat{p}_t^*$$

that can be rearranged as follows:

$$\hat{p}_t^* = \frac{1}{1-\theta}(\hat{p}_t - \theta \hat{p}_{t-1})$$

Next, we linearise equation (1.71) to get:

$$0 = \sum_{k=0}^{\infty} (\theta\beta)^k \hat{p}_t^* - \sum_{k=0}^{\infty} (\theta\beta)^k \hat{p}_{t+k} - \sum_{k=0}^{\infty} (\theta\beta)^k \hat{mc}_{t+k}$$

The first term in the right-hand side does not depend on k and $\hat{mc}_{t+k} = -\hat{\mu}_{t+k}$, therefore:

$$\frac{1}{1-\theta\beta}\hat{p}_t^* = \sum_{k=0}^{\infty} (\theta\beta)^k \hat{p}_{t+k} - \sum_{k=0}^{\infty} (\theta\beta)^k \hat{\mu}_{t+k}$$

$$\Longrightarrow \hat{p}_t^* = (1-\theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k (\hat{p}_{t+k} - \hat{\mu}_{t+k})$$

Substituting for $\hat{p}_t^*$ and using the properties of first-order stochastic difference equations, we can write:

$$\frac{1}{1-\theta}(\hat{p}_t - \theta\hat{p}_{t-1}) = (1-\theta\beta)(\hat{p}_t - \hat{\mu}_t) + (\theta\beta)\frac{1}{1-\theta}(\hat{p}_{t+1} - \theta\hat{p}_t)$$

Some algebraic manipulations yield the following:

$$\hat{\pi}_t = \beta\hat{\pi}_{t+1} - \lambda_p\hat{\mu}_t \tag{1.90}$$

where $\lambda_p = (1-\beta\theta)(1-\theta)\theta^{-1}$.

Market clearing requires $Y_t = C_t + I_t + G_t$, which, expressed in percentage deviations from steady state, becomes:

$$\hat{y}_t = \gamma_c\hat{c}_t + \gamma_i\hat{i}_t + g_t \tag{1.91}$$

where $\gamma_c = C/Y$, $\gamma_i = I/Y$ and g_t represents the deviation of government purchases from steady state, normalised by steady state output.

Linearising the government budget constraint (1.74) around the steady state with zero debt and balanced primary budget, and substituting for the fiscal policy rule (1.75) yields the following linear expression describing the dynamics of government debt:

$$b_{t+1} = (1+\rho)(1-\phi_b)b_t + (1+\rho)(1-\phi_g)g_t \tag{1.92}$$

where $R = 1 + \rho = \beta^{-1}$ and $\phi_b > \frac{\rho}{1+\rho}$ in order to ensure non-explosive debt dynamics.

Equations (1.78) to (1.83), (1.86) to (1.92) in addition to the Taylor rule (1.74), the fiscal policy rule (1.76) and the process for the exogenous government purchases (1.77) form a system of 16 linear dynamic equations in 15 endogenous variables and one exogenous variable. Assuming $\hat{n}_t^r = \hat{n}_t^O = \hat{n}_t$ and $tr_t = t_t$, the endogenous variables are: $\hat{y}_t$, $\hat{c}_t$, $\hat{c}_t^O$, $\hat{c}_t^r$, $\hat{i}_t$, $\hat{k}_t$, $\hat{q}_t$, $\hat{n}_t$, $\hat{w}_t$, $\hat{r}_t$, $\hat{r}_t^k$, $\hat{\mu}_t$, π_t, b_t and t_t. $\hat{k}_t$ and b_t are predetermined and g_t is exogenous.

1.4.3 Impulse-response analysis

The system described above can be used to analyse the dynamic responses of the principal macroeconomic variables to a shock to government purchases. Following Galí, López-Salido, and Valles (2007), we calibrate model parameters to match the US experience.

Parameter	Value
δ	0.025
λ	0.5
β	0.99
α	1/3
θ	0.75
$\bar{\mu}$	1.2
ϕ	0.2
η	1
ϕ_π	1.5
ρ_g	0.9
ϕ_g	0.10
ϕ_b	0.33
γ_g	0.20
ρ	$\beta^{-1} - 1$
λ_p	$(1-\beta\theta)(1-\theta)\theta^{-1}$
R^k	$\beta^{-1} - (1-\delta)$
$\frac{K}{Y}$	$\bar{\mu}^{-1}\alpha R^{k^{-1}}$
γ_I	$\frac{I}{Y} = \delta\frac{K}{Y} = 0.20$
γ_C	$1 - \gamma_G - \gamma_I = 0.60$
$\frac{Y}{C}$	γ_C^{-1}
$\frac{WN}{C}$	$\lambda(1-\alpha)\frac{Y}{C}$

Table 1.1: Parameter calibration for the new-Keynesian framework (Source: Galí, López-Salido, and Valles (2007)).

Parameter values are summarized in Table 1.1.[7]

In Figure 1.5, we depict the effects that a positive shock in government purchases has on the principal macroeconomic variables. We normalise the size of the shock to a 1 percent of steady state output.

We use the baseline calibration as in Galí, López-Salido, and Valles (2007), and report the results obtained using non-competitive labour markets. In fact, with competitive labour markets, a positive response in consumption can be obtained only with implausibly high values of the proportion of rule-of-thumb households (about 3/4). This would imply that 3/4 of households in the economy, for some reason, should not be able to save or invest. On the contrary, when imperfect labour markets are assumed, the possibility of crowding-in of consumption emerges for values of λ above a threshold of about 1/4. This is due to the fact that imperfect labour markets imply countercyclical wage mark-ups, which in turn provides additional room for a simultaneous increase in

[7]Some parameters are estimated by the authors using VAR techniques, others are taken from the relevant literature, the remaining values are computed, combining the expressions for steady state values.

consumption and hours. Therefore, in order for both the assumptions and the predictions of the model to be plausible, we believe that imperfect labour markets, together with monopolistic competition in the intermediate good market – which in turn causes price-stickiness – and the presence of a fraction of rule-of-thumb households should all be important features of a DSGE model aiming at matching the recent empirical evidence of a positive comovement of private consumption and government spending.

Galí, López-Salido, and Valles (2007) show how the extent of the crowding-in effect of consumption increases with λ, reflecting the offsetting role of rule-of-thumb behaviour on the conventional negative wealth and intertemporal substitution effects triggered by the fiscal expansion. The presence of non-Ricardian households is key for the purposes of the model, as they partly insulate aggregate demand from the negative wealth effects generated by the higher levels of current and future taxes needed to finance the fiscal expansion, while making it more sensitive to current disposable income.

Figure 1.5 shows that the response of output and consumption is systematically above that generated by the neoclassical model, presented in the previous sections. In addition, the increase in aggregate hours coexists with an increase in real wages. This response of wages is made possible by sticky-prices. In fact, even in the face of a drop in the marginal product of labour, real wages can increase as the price mark-up may adjust sufficiently downward to absorb the resulting gap. The combined effect of higher real wages and higher employment raises labour income and stimulates consumption of rule-of-thumb households. Investment presents a typical hump-shaped response. Debt-dynamics, in the baseline calibration, allows a lagged response of taxes to the shock in spending hence the response of the deficit, on impact, is almost one-to-one with expenditures.

1.5 The effects of fiscal shocks in VAR models

1.5.1 The recursive approach

Within a broad comparative analysis on several estimation strategies that can be found in the empirical literature on fiscal policy, Caldara and Kamps (2008) include the recursive approach.

More generally, colleting the endogenous variables in a k-dimensional vector X_t, a reduced-form VAR model can be expressed as:

$$X_t = \mu_0 + \mu_1 t + A(L) X_{t-1} + u_t \tag{1.93}$$

where μ_0 is a constant, t is a linear time trend, $A(L)$ is a polynomial in the lag operator and u_t is a k-dimensional vector of reduced-form disturbances with $E[u_t] = 0$, $E\left[u_t u_t^{'}\right] = \Sigma_u$. As the reduced-form disturbances are, in general, correlated, it is necessary to transform the reduced-form model into a structural model. The structural form is obtained by pre-multiplying equation (1) by the $(k \times k)$ matrix A_0:

$$A_0 X_t = A_0 \mu_0 + A_0 \mu_1 t + A_0 A(L) X_{t-1} + B e_t \tag{1.94}$$

where $Be_t = A_0 u_t$ describes the relationship between the structural disturbances and reduced-form disturbances. Matrix A_0 describes the contemporaneous relations among the variables in vector X. One key assumption of the structural model is that the structural disturbances are uncorrelated, i.e. Σ_e is a diagonal matrix.

Without restrictions on the parameters in A_0 and in B the structural model is not identified. The recursive approach restricts B to a k-dimensional identity matrix and A_0 to a lower triangular matrix with unit diagonal. These restrictions implies $u_t = A_0^{-1} e_t$ and $\Sigma_u = A_0^{-1} \Sigma_e \left(A_0^{-1}\right)'$. Identification of A_0 is obtained by: (i) Cholesky decomposition of the covariance matrix of the reduced-form disturbances $\Sigma_u = PP'$; (ii) defining a diagonal matrix D with the same main diagonal as P; and (iii) specifying $A_0^{-1} = PD^{-1}$. The elements on the main diagonal of D and P are equal to the standard deviations of the respective structural shocks. By construction, the covariance matrix of the structural disturbances will be diagonal. In fact $A_0 = \left(PD^{-1}\right)^{-1} = DP^{-1}$; $e_t = A_0 u_t = DP^{-1} u_t$; and $\Sigma_e = DP^{-1} \Sigma_u \left(DP^{-1}\right)' = DP^{-1} PP' \left(P'\right)^{-1} D' = DD'$, which is clearly diagonal.

The recursive approach implies a casual ordering of the model variables. There are in total $k!$ possible orderings. Caldara and Kamps (2008) order the variables of a VAR estimated with US data as follows: government spending, output, inflation, tax revenue and the interest rate. They add other variables of interest one at a time. This particular ordering of variables captures the effects of automatic stabilizers on government revenue, while it rules out potentially important contemporaneous effects of discretionary tax changes on output and inflation.

By using this identification approach, the impulse responses to a pure spending shock are positive for taxes, positive and hump-shaped for output, consumption and wages, and flat for hours. These empirical findings provide support for theoretical models which generate an increase in private consumption and the real wage. However, they do not support the increase in employment implied by many new-Keynesian DSGE models.

1.5.2 The event-study approach

The *event-study* or *narrative* approach was first used in the context of the identification of fiscal policy shocks by Ramey and Shapiro (1998). This procedure is similar to the one used by Hamilton (1985) for oil shocks and by Romer and Romer (1989) for monetary shocks.

The authors use military build-ups as events of large fiscal policy shocks. To identify exact dates, they take information from historical accounts and *Business Week*, which discusses the economic details of the episodes. Military build-ups are seen as appropriate examples of fiscal shocks as they occur rapidly and unexpectedly, they are driven by imperatives of foreign policy, and they are likely to be exogenous with respect to macroeconomic variables.

In the post-World War II period, Ramey and Shapiro (1998) identify three large build-ups: (i) the Korean War; (ii) the Vietnam War; (iii) the Carter-Regan build-up that followed the Soviet invasion of Afghanistan. In similar frameworks, Eichenbaum and Fisher (2005) and Ramey (2008) also consider (iv) the 9/11 terrorist attacks. In terms of exact dates, in empirical works that deal with quarterly data, the shocks occurred in 1950:3, 1965:1, 1980:1, and 2001:3.

Ramey and Shapiro (1998) use the first three of the above episodes to construct a dummy variable that takes the value of one at the mentioned quarters and zero otherwise. To assess the effect of a military shock on key macroeconomic variables, they estimate univariate autoregressive models where current and lagged values of the military build-up dummy are included as exogenous regressors. Allowing for a break in the trend component, the estimating equation takes the following specification:

$$y_t = \alpha_0 + \alpha_1 t + \alpha_2 (t \geq 1973:2) + \sum_{i=1}^{8} b_i y_{t-i} + \sum_{i=0}^{8} c_i D_{t-i} + \epsilon_t \quad (1.95)$$

where y_t is the endogenous variable, t is a linear time trend, D_t is the military build-up dummy and ϵ_t is an error term.

The authors estimate the regression described above for a set of macroeconomic variables. Then, they simulate the impact of an "average" large military shock, i.e. setting the military shock variable equal to one. The average is taken over the Korean War, the Vietnam War and the Carter-Regan build-up. Even if the dummy variable takes value one only three times, it has considerable explanatory power, as its inclusion increases the regression goodness of fit, and the lags of the dummy variable are jointly significant.

Impulse-response analysis shows that while a military build-up leads to a sustained increase in defence purchases, non-defence purchases fall. Both total GDP and private (less total government purchases) GDP increase in the first few quarters. Then, while total GDP remains positive for three years, private GDP becomes negative after two years. Immediately after the shock, durable consumption purchases rise substantially but then turn significantly negative. In contrast, nondurable and service consumption show a statistically significant fall after the shock. The point estimates of responses in hours are positive, yet not statistically significant. Real wage per hour declines in response to a military build-up. In sum, the empirical responses of key macroeconomic variables to an exogenous fiscal policy shock are consistent with a neoclassical framework.

Edelberg, Eichenbaum and Fisher (1999) apply the event-study approach to a VAR framework. They estimate a reduced-form VAR such as:

$$X_t = A(L) X_{t-1} + B(L) D_t + u_t \quad (1.96)$$

where $A(L)$ and $B(L)$ are finite ordered vector polynomials in nonnegative powers of the lag operator whose coefficients can be estimated using equation-by-equation least squares. The response of the endogenous variables X_{t+k} to a unit shock to the dummy variable in t is given by the estimate of the coefficient on L^k in the expansion of $(I - A(L)L)^{-1}B(L)$.

As the dummy variable appears in all the equations of the system, this methodology assumes that during a Ramey-Shapiro episode, not only the fiscal variable can change, but also the dynamic response of all variables. Moreover, equation (1.96) assumes that the shape and the size of the responses of all variables to the shock are the same in each Ramey-Shapiro episode.

The above methodology yields results consistent with Ramey and Shapiro (1998). In response to an exogenous fiscal policy shock, total government purchases, employment, output, and non-residential investment rise, while real wages, residential investment, and, after a slight delay, consumption expenditures on non-durable goods and services and durable goods fall. These findings again support neoclassical business cycle models. In addition, Edelberg, Eichenbaum and Fisher (1999) propose a variant of the neoclassical growth model in which residential investment is thought as a form of investment in the stock of durable consumption goods. They argue that this modification can account for the finding that residential investment falls while non-residential investment rises in response to an increase in government purchases.

Burnside, Eichenbaum, and Fisher (2004) introduce a less stringent version of equation (1.96) that allows each episode to have a different intensity, though their dynamic effects are the same up to a scale factor. Analogously to the univariate approach due to Ramey and Shapiro (1998), they consider a VAR where they allow for a break in the time trend component:

$$Z_t = A_0 + A_1 t + A_2 \left(t \geq 1973:2\right) + A_3\left(L\right) Z_{t-1} + \sum_{i=1}^{3} A_4\left(L\right) \psi_i D_{it} + u_t \tag{1.97}$$

The ψ_i in (1.97) are scalars with ψ_1 normalized to unity. The parameters ψ_2 and ψ_3 measure the intensity of the second and third Ramey-Shapiro episodes relative to the first. These weights are obtained by comparing the percentage peak rise after the onset of the Vietnam and the Carter-Regan defence build-up episodes to the analogous rise after the Korea episode.

To estimate the effect of a fiscal policy shock on some other variable, the latter is added to the list of variables in Z_t. In all cases the specification of Z_t includes the log of per-capita real GDP, the log of per-capita real government purchases and average capital and labour income tax rates. Using post-war US data, this approach allows identifying fiscal policy shocks that are followed by persistent declines in real wages and rises in tax rates. Also in the case of Burnside, Eichenbaum, and Fisher (2004), the empirical findings are at least qualitatively consistent to a benchmark neoclassical model. Additionally, the authors argue that incorporating habit formation in consumption and investment adjustment costs into the model enhances its quantitative performance.

Eichenbaum and Fisher (2005), use the same model as in equation (1.97) to argue that fiscal policy in the aftermath of 9/11 is not explained as the normal response of the US economy to a large exogenous increase in government consumption. In particular it is difficult to explain the dramatic fall in the government surplus and the large fall in labour and capital tax rates. Although the authors do not argue whether the decline in tax rates and in the surplus after 9/11 were desirable or not, they use the model as in Burnside, Eichenbaum, and Fisher (2004) to show how the economy would have responded had the government reacted in the same way as they responded to other exogenous increases in military spending. They argue that the effect on aggregate output and surplus would have been small. Moreover, conditional on the observed path of government spending, a cut in tax rates similar to those actually observed would have resulted in a slight rise in output and a persistent decline in the government surplus. This is taken to provide additional evidence that the observed sharp drop in the surplus to GDP ratio reflects tax policy choices that are atypical relative to post-war US experience.

Fats and Mihov (2001) also point out the differences among the Ramey-Shapiro episodes. Building on these accounts, Perotti (2007) proposes a variant of the narrative approach that allows the responses to each Ramey-Shapiro episodes to have both a different intensity and a different shape:

$$X_t = A\left(L\right) X_{t-1} + \sum_{i=1}^{4} B_i \left(L\right) D_t + u_t \tag{1.98}$$

where each is an $n_B + 1$-order vector polynomial. As Perotti points out, the approach outlined in equation (1.98) suffers from an extreme version of a problem already present in the previous approaches: as each dummy appears separately in all equations, the residuals of each equation at the beginning of each of the four events are set to zero. In other words, it is as if the abnormal fiscal events were responsible for all the deviation from normal of all the variables for $n_B + 1$ quarters. Hence, the author proposes a *modified* dummy-variable approach to isolate the *abnormal* fiscal events and to estimate the normal dynamic response of the non-fiscal endogenous variables to these events. Operationally, the procedure consists in including lags 0 to n_B of the dummy variables in the equations of the fiscal variables and only lag 0 in the other equations. This can be done both in an equation such as (1.98) or in equations such as (1.96) and (1.97). Using this methodology, the estimated normal response of consumption to abnormal events is positive, consistently with the results obtained using a structural VAR approach.

1.5.3 The structural auto-regression approach

The Fatas-Mihov approach

Fats and Mihov (2001) first assess fiscal policy as an automatic stabilizer. By looking at data from OECD countries in the post-war period they document that revenues are procyclical and expenditures are acyclical. Next, they provide evidence that large governments are associated with less volatile business cycles. Finally, they focus on US data to construct a measure of discretionary fiscal policy via a semi-structural VAR. Their baseline VAR contains logarithms of private output, the implicit GDP deflator, the ratio of primary deficit to output and the nominal T-bill rate. The semi-structural framework of their approach is summarized by the following two equations:

$$Y_t = \sum_{i=0}^{k} B_i Y_{t-i} + \sum_{i=0}^{k} C_i fp_{t-i} + A^y \nu_t^y \tag{1.99}$$

$$fp_t = \sum_{i=0}^{k} D_i Y_{t-i} + \sum_{i=0}^{k} g_i fp_{t-i} + A^y \nu_t^{fp} \tag{1.100}$$

Y is the set of macroeconomic variables useful to estimate the induced changes in the budget balance. fp is a measure of the fiscal policy stance. This set of equation is unrestricted, thus v_t^{fp} cannot be recovered without further assumptions. Identification is achieved following Leeper, Sims, and Zha (1996), i.e. partitioning the vector of endogenous variables into three blocks:

1. sluggish private sector variables that do not respond contemporaneously to shifts

in taxes and transfers, but react to changes in government spending (output and prices). Restriction on C_0, B_0 and A^y are imposed to ensure no response to tax and transfers;

2. the rest of vector Y contains prices that respond immediately to any changes in the economy. These variables are left unrestricted;

3. the fiscal policy equation (equation 1.100) is restricted not to respond to financial markets shocks within a quarter; taxes and transfers react to the current state of the economy; spending components do not react immediately to macroeconomic conditions.

Via the above estimation strategy, the authors find that there is a strong, positive and persistent impact of fiscal expansions on economic activity. Moreover, changes in taxes, transfers and government employment are the most effective tools of fiscal policy. These results are difficult to compare with calibrated DSGE models, as the latter do not take into account the determinants of different components of government expenditures and taxes.

The Blanchard-Perotti approach

Blanchard and Perotti (2002) also investigate the dynamic effects of shocks in government spending and taxes on economic activity in the United States during the post-war period. They use a structural VAR approach where identification is achieved by relying on institutional information about the tax collections. This allows constructing the automatic response of fiscal variables to the business cycle and, by implication, to identify the shocks to fiscal policy.

The main equation specification is a three-variable VAR:

$$Y_t = A(L)Y_{t-1} + U_t \tag{1.101}$$

where $Y_t = [T_t, G_t, X_t]'$ is a vector in the log of quarterly taxes, spending and GDP, in real, per capita terms. $U_t = [t_t, g_t, x_t]'$ is the vector of the respective reduced-form residuals, which have in general nonzero cross correlations. Four lags are used in the VAR to take the presence of seasonal patterns in the response of some taxes.

To recover the corresponding mutually uncorrelated structural shocks e_t^t, e_t^g, e_t^x, the authors write the following system:

$$t_t = a_1 x_t + a_2 e_t^g + e_t^t$$

$$g_t = b_1 x_t + b_2 e_t^t + e_t^g \tag{1.102}$$

$$x_t = c_1 t_t + c_2 g_t + e_t^x$$

To identify this system a three-step procedure is used:

1. a_1 and b_1 are identified by noticing that using quarterly data eliminates the discretionary policy channel from economic activity to fiscal variables, because of the typical institutional lags present in fiscal policymaking. Hence the effect of output on reduced-form fiscal shocks are assumed to be due exclusively to automatic stabilizers and are constructed as elasticities to output of government purchases and of taxes minus tranfers. b_1 is found to be zero. a_1 is computed as a weighted average of the elasticities of taxes to the their tax base times the elasticities of the tax base to GDP.

2. With the estimates of a_1 and b_1, cyclically adjusted reduced-form tax and spending residuals can be constructed: $t_t^{'} = t_t - a_1 x_t$ and $g_t^{'} = g_t - b_1 x_t = g_t$. Since $t_t^{'}$ and $g_t^{'}$ are not correlated with e_t^x, they can be used as instruments to estimate the third equation of the system.

3. In estimating a_2 and b_2, the issue is whether taxes respond to spending ($a_2 \neq 0$, $b_2 \neq 0$) or the reverse. Blanchard and Perotti present results under the two opposite assumptions. In practice, it turns out that the correlation between $t_t^{'}$ and $g_t^{'}$ is sufficiently small that the ordering makes little difference to impulse responses of output.

Impulse responses obtained with the Blanchard-Perotti approach show that a positive government spending shock has a positive effect on output, and a positive tax shock has a negative effect. Government spending shocks have also a positive effect on private consumption. While the latter is a straightforward implication of Keynesian models, such a result is difficult to reconcile with neoclassical models. Yet, according to Blanchard and Perotti (2002), both increases in taxes and increases in government spending have a strong negative effect on private investment spending. This result is in line with a neoclassical model with distortionary taxes, but more difficult to reconcile with a Keynesian view. In fact, Keynesian models predict opposite effects of tax and spending on private investment. Perotti (2005) extends the structural VAR methodology developed in Blanchard and Perotti (2002) to study the effects of fiscal policy in five countries: the US, West Germany, the UK, Canada and Australia. The principal conclusions of the analysis are that: (i) the estimated effects of fiscal policy on GDP tend to be small; (ii) there is no evidence that tax cuts work faster or have higher multipliers than spending increases; (iii) the effects of government spending shocks and of tax cuts on GDP and its components have become weaker over time.

1.5.4 The sign-restriction approach

Unlike the recursive approach and the Blanchard-Perotti approach, the sign-restrictions approach does not impose linear restrictions on the contemporaneous relation between reduced-form and structural disturbances. Mountford and Uhlig (2008) extend Uhlig (2005)'s agnostic identification method of imposing sign restrictions on impulse response functions and identify four shocks: (i) a business cycle shock; (ii) a monetary policy shock; (iii) a government spending shock; and (iv) a tax shock.

They impose that the fiscal shock is orthogonal to both the business cycle shock and to the monetary policy shock, in order to filter out the automatic responses of fiscal variables to business cycle and monetary policy shocks. Moreover, the authors consider macroeconomic fiscal shocks as existing in a two-dimensional space spanned by two basic shocks: a government revenue shock and a government spending shock. They see different fiscal policies as different linear combinations of the two basic shocks. Finally, they also take into account the fact that there is often a lag between the announcement and the implementation of fiscal policy and that the announcement may cause movements in macroeconomic variables before there are movements in the fiscal variables. To address this issue, they identify fiscal shocks also with the identifying restriction that the fiscal variable in question does not respond for four quarters and then rises for a defined period afterwards.

Mountford and Uhlig (2008) use a ten-variable VAR at a quarterly frequency and the same definition for the two fiscal variables as in Blanchard and Perotti (2002). They impose that a business cycle shock jointly moves output, consumption, non-residential investment and government revenue in the same direction for four quarters following the shock. In other words, when output and government revenues move in the same direction, the assumption is that this must be due to some improvement in the business cycle, generating the increase in revenues, and not the other way around. On the other hand fiscal policy shocks are identified only through restricting the impulse responses of the fiscal variables.

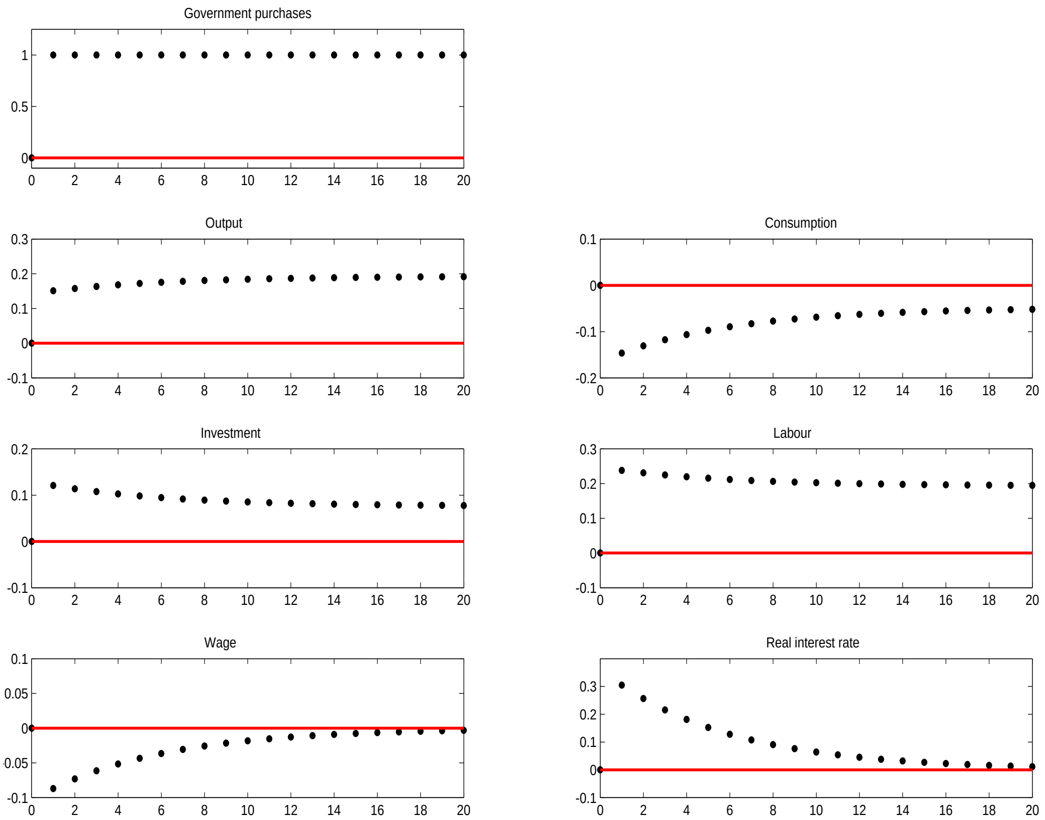
One of the main results obtained via the sign-restriction approach is that a surprise deficit-financed tax cut is the best fiscal policy to stimulate the economy. Deficit spending weakly stimulates the economy, it crowds out private investment without causing interest rates to rise, and it does not cause a rise in real wages. As in Blanchard and Perotti (2002), investment falls in response to both tax increases and government spending increases. In contrast to Blanchard and Perotti (2002), consumption does not rise strongly; in fact the response of consumption is small and significant only on impact. This is more in line with Burnside, Eichenbaum and Fisher (2004). Finally, real wages do not rise in response to an increase in government spending and have a negative response on impact and at longer horizons. Hence, the responses of investment, consumption and real wages to a government spending shock are difficult to reconcile with the standard Keynesian approach, although they are not the responses predicted by the benchmark real business cycle model either.

1.6 Concluding remarks

We have analysed the theoretical and empirical literature that studies the effects of fiscal policy on the macroeconomy. While consensus has emerged on the positive effect that an expansionary fiscal policy has on output and hours worked, no widespread consensus exists on the effects that such a policy delivers to private consumption, real wages and investment.

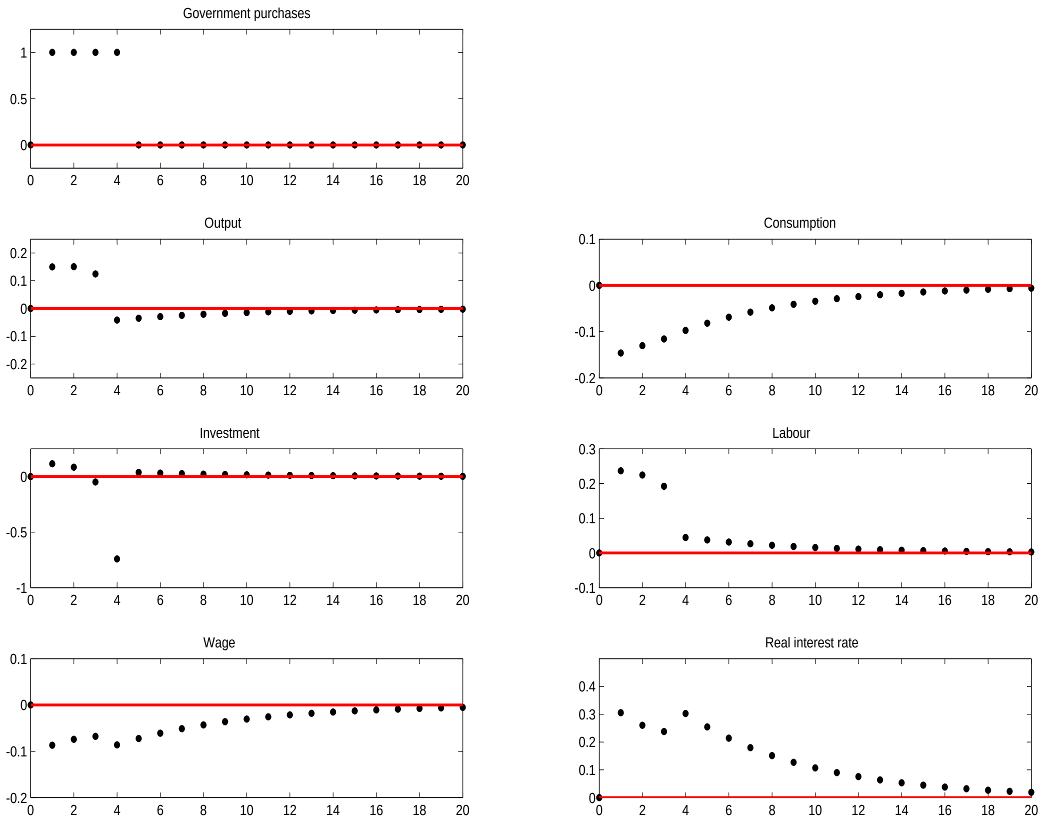
On one hand, in standard RBC models the negative wealth effect on households' lifetime resource constraint prevails, leading to a decrease in private consumption and wages, and an increase in hours worked and investment. On the other hand, in more or less articulated new-Keynesian models a crowding-in effect of consumption and an increase in wages is made possible also under plausible calibrations.

While early empirical contributions gave credit to the standard neoclassical predictions, the most recent econometric applications, generally making use of structural VARs, have supported and in many cases have inspired the latest new-Keynesian claims.



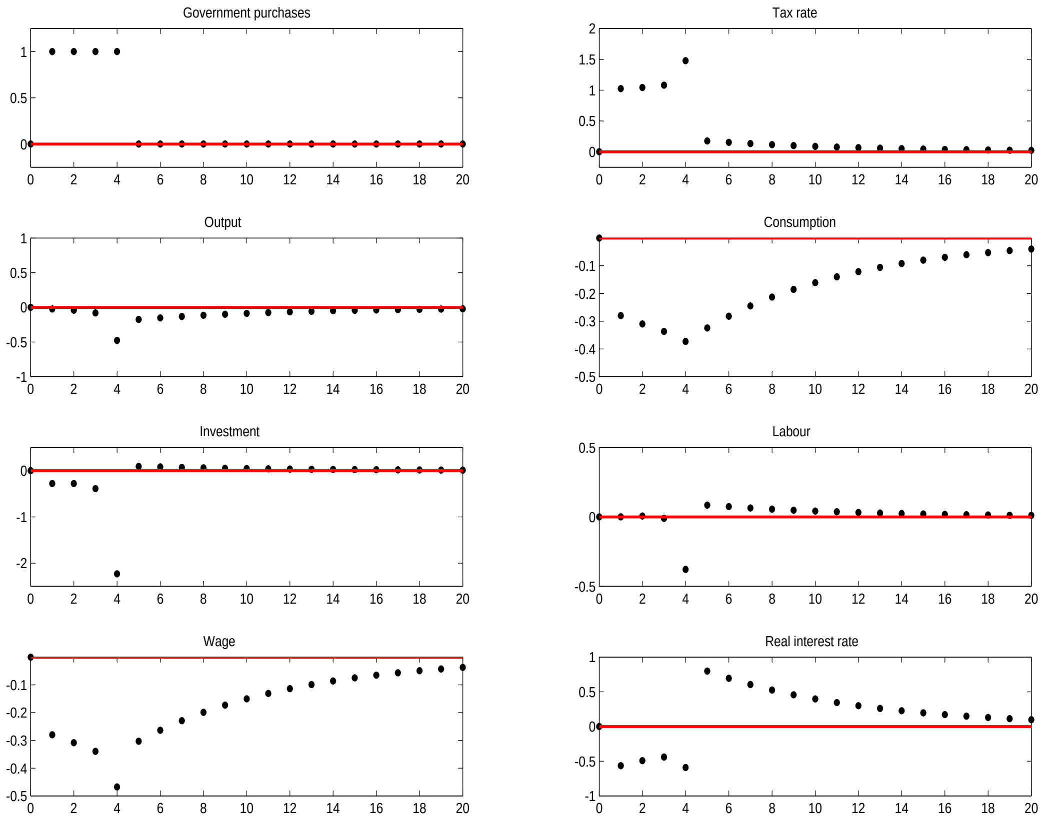
Source: Our DYNARE computations based on Baxter and King (1993).

Figure 1.1: A permanent increase in government purchases financed by lump-sum taxes.



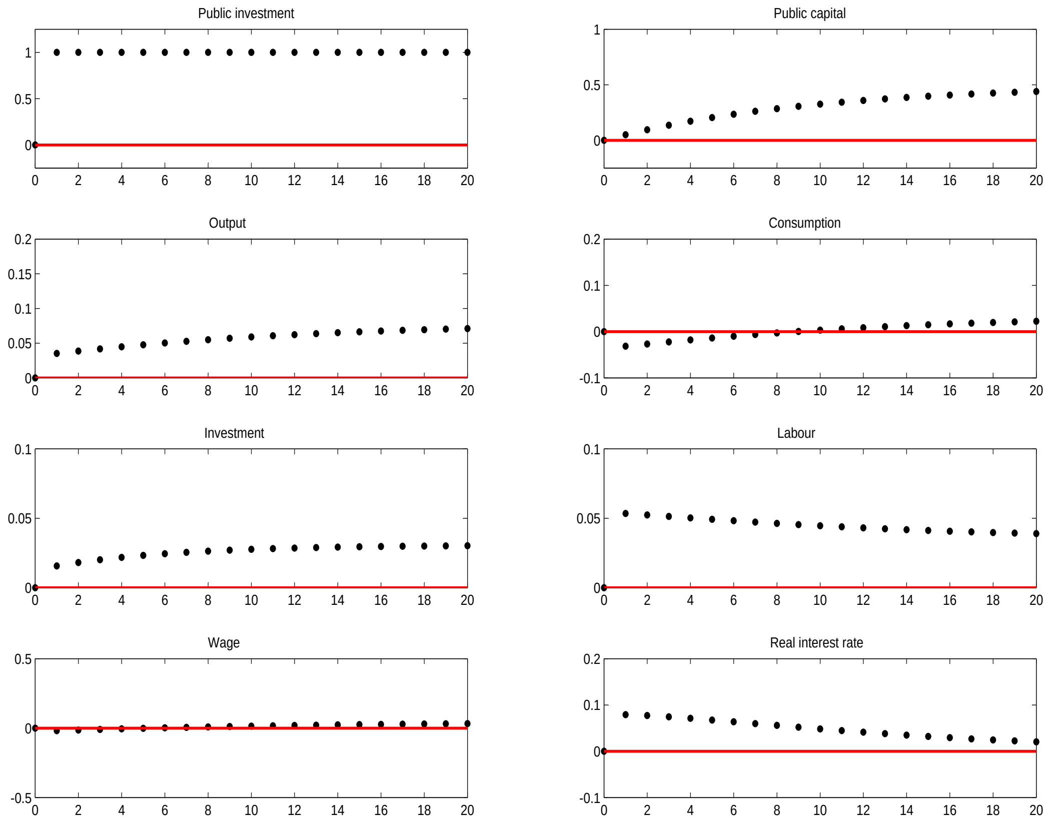
Source: Our DYNARE computations based on Baxter and King (1993).

Figure 1.2: A temporary increase in government purchases financed by lump-sum taxes.



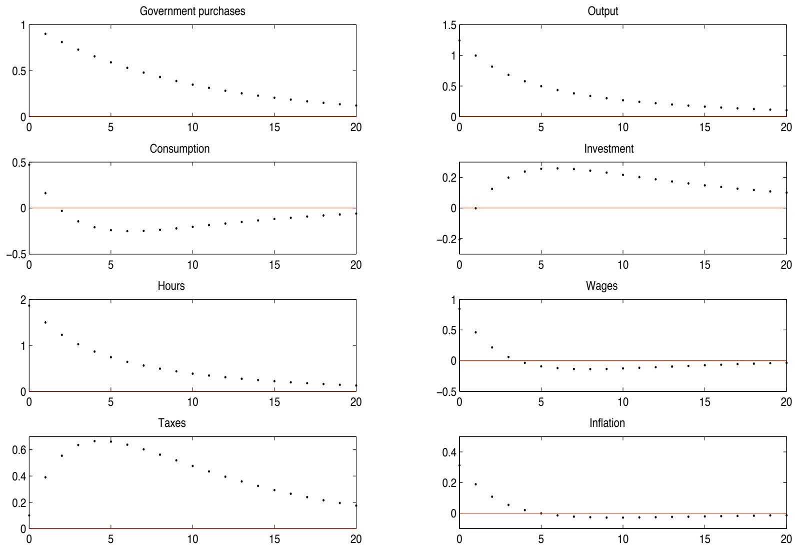
Source: Our DYNARE computations based on Baxter and King (1993).

Figure 1.3: A temporary increase in government purchases financed by distortionary taxes.



Source: Our DYNARE computations based on Baxter and King (1993).

Figure 1.4: A permanent increase in public investment financed by lump-sum taxes.



Source: Our DYNARE computations based on Galí, López-Salido, and Valles (2007).

Figure 1.5: A positive shock in government purchases in a New-Keynesian framework.

Chapter 2

The Effects of Fiscal Shocks in SVAR Models: A Graphical Modelling Approach [1]

2.1 Introduction

In macroeconomics there is still no widespread consensus on the impact and transmission channels of fiscal policy on many variables. Both theoretical and empirical studies generally find a positive response of output and hours worked to a positive shock to government purchases and the disagreement is usually about the magnitude and timing of the response. On the contrary, the sign of the responses of variables such as consumption, wages and investment is still a matter of debate.

In the theoretical literature, on one hand neoclassical Real Business Cycle (RBC) theory claims that a positive government spending shock triggers a negative wealth effect that dampens consumption, fosters labour supply and curbs real wages (e.g. Baxter and King (1993)). On the other hand, Keynesian theories and recent dynamic stochastic general equilibrium (DSGE) models such as Linnemann (2006), Ravn et al. (2006) and Gali et al. (2007) among others, assert that an expansionary fiscal policy boosts con-

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sumption, hours worked and real wages. In addition, while RBC theories predict that real output should rise less than proportionally to the increase in government spending, due to the crowding-out effect on consumption, Keynesian theories foresee that the increase in consumption should amplify the expansionary effect on output.

The empirical literature of the late 1990s, such as Ramey and Shapiro (1998) and Edelberg et al. (1999), mostly relying on vector-autoregressions (VAR) employing a narrative approach to identify discretionary fiscal policy shocks, supports RBC predictions. More recent empirical studies, starting from Blanchard and Perotti (2002), adopt structural VARs (SVAR) for the purpose of identification and obtain results more in line with Keynesian claims.

Indeed, VAR analysis is a standard tool to understand what happens in actual economies and to evaluate competing theoretical economic models. SVARs, however, generally require the imposition of a number of restrictions, which is often a complex and contentious task, as they may be based on possibly arguable assumptions.

In this chapter we conduct a SVAR analysis for the US economy that combines Graphical Modelling (GM) theory. Such an approach allows us to obtain identifying restrictions from statistical properties of the data. The starting point is the computation of partial correlations among the variables in the model and the subsequent construction of a Conditional Independence Graph (CIG), a graphical representation of all statistically significant interconnections among all variables. From the CIG, based on well defined statistical rules, we derive Directed Acyclic Graphs (DAGs), graphical representations of the many possible structural VARs, which are later evaluated by means of statistical information criteria.

Our results are generally in line with the recent SVAR literature (Blanchard and Perotti (2002), Perotti (2005), Caldara and Kamps (2008) among others) and hence give credit to Keynesian claims. In response to a positive government spending shock, we detect a partially deficit-financed fiscal policy and obtain a fiscal multiplier of output greater than one. Adding more recent data increases the magnitude of the fiscal multiplier compared to earlier studies such as Blanchard and Perotti (2002). Private consumption shows a positive and persistent response to a spending shock. While non-residential investment is significantly crowded out by the fiscal expansion, residential investment rises, comoving with output. However, the crowding-out effect on non-residential investment is not stable over the sample considered. Lastly, a positive response of real wages coexists with an increase in hours worked. As far as the effects of a positive tax shock are concerned, we find that peak responses of consumption, non-residential investment and the initial response of hours worked show signs consistent with a negative wealth effect. Subsample checks confirm that results are stable over the sample.

The remainder of the chapter is structured as follows. Section 2.2 provides an overview of recent theoretical and empirical contributions in the field of the macroeconomic implications of fiscal policy. Section 2.3 illustrates the principles of graphical modelling and how it can be used to identify SVARs. Section 2.4 presents the data. Section 2.5 identifies a number of SVARs to evaluate the effects of fiscal policy shocks on the US economy. Section 6 describes the econometric results and conduct some stability checks. Finally, Section 2.7 concludes.

2.2 Literature review

Following a positive shock to government spending, textbook IS-LM theory predicts that consumption should rise and thus amplify the expansionary effects of spending on output. In constrast, as shown by Baxter and King (1993), neoclassical Real Business Cycle (RBC) theory generally predicts a positive response of investment and a negative response of consumption and wages. As Galí, López-Salido, and Valles (2007) point out, this substantial difference across the two classes of models lays on the more or less implicit assumption made on the behaviour of consumers: in the IS-LM model, consumption only depends on current disposable income, hence consumers are all non-Ricardian; in the RBC model consumption depends on life-time wealth, hence consumers are all optimising Ricardian agents. In the RBC model, an increase in government purchases, through an increase in current and/or future taxes, triggers a negative wealth effect that decreases consumption, increases labour supply and decreases wages. The increase in the marginal product of capital, allowed by the increase in labour, causes also a positive reaction of investment.

The early empirical literature, mainly using vector-autoregressions (VAR), supports the RBC claims. In general, empirical studies aiming at studying the effects of fiscal policy shocks confront great difficulties in identifying such shocks, as they have to disentangle the role of automatic stabilisers responding to business cycles from the effects of discretionary fiscal policies. Ramey and Shapiro (1998) introduce the dummy-variable or narrative approach, due to Hamilton (1985), in the context of fiscal policy, though in a univariate setting. The methodology consists in constructing a dummy variable that takes value one at quarters when large military build-ups took place in the US, in order to identify episodes of discretionary fiscal policy. Edelberg, Eichenbaum, and Fisher (1999) extend this methodology to a multivariate context, and Burnside, Eichenbaum, and Fisher (2000),[2] as well as Eichenbaum and Fisher (2005) make some modifications. Despite slight methodological differences, all these studies generally reach the same conclusions, at least from a qualitative point of view: in response to a discretionary substantial positive government spending shock, output increases, consumption and wages decline, non-residential investment rises, while residential investment falls. Therefore, these findings support the neoclassical business cycle literature.

More recent empirical studies aiming at detecting the effects of government spending shocks make use of structural vector-autoregressions in order to trace the impulse responses of the macroeconomic variables of interest. Fats and Mihov (2001) find that there is a strong, positive and persistent impact of fiscal expansions on economic activity. Blanchard and Perotti (2002) achieve identification by relying on institutional information about the tax collection, constructing the automatic response of fiscal variables to the business cycle and, by implication, identifying discretionary fiscal policy shocks. The Blanchard-Perotti approach yields a positive effect of a government spending shock on output and consumption and a negative effect on investment. While these findings are perfectly reasonable in a Keynesian world, they are difficult to reconcile with the RBC literature. Perotti (2005) extends the structural VAR methodology to other countries and reaches similar conclusions. Moreover, Perotti (2007) proposes a variant of the narrative approach that allows the responses to each Ramey-Shapiro episode to have both a different intensity and a different shape. In addition, the author introduces a different

[2] Within the field of RBC models, Edelberg, Eichenbaum, and Fisher (1999), in addition to their econometric analysis, also build a variant of the neoclassical growth model distinguishing between residential and non-residential investment to match their empirical findings. Instead, Burnside, Eichenbaum, and Fisher (2000) introduce habit formation in consumption and adjustment costs in investment to better mimic the timing and quantitative responses of hours worked, investment and consumption.

method to build the dummy variable, which allows to isolate the abnormal fiscal events and to estimate the normal dynamic response of the non-fiscal variables to these events. Using this methodology the response of consumption is positive, in line with the structural VAR approach. Mountford and Uhlig (2008) extends Uhlig (2005)'s sign-restriction approach to fiscal policy and find a negative response of investment to a fiscal expansion. However, they find a small response of consumption, significant only on impact.

In order to match the most recent empirical findings, the theoretical literature has recently worked on models able to explain the positive response of consumption to a fiscal expansion. Linneman (2006) uses a non-additively separable utility function within a neoclassical growth model that is able to mimic a pattern for consumption similar to the one found by the structural VAR literature. Ravn, Schmitt-Grohe, and Uribe (2006) assume habit persistence on the consumption of individual differentiated goods, which implies a countercyclical mark-up of price over the marginal cost. A government spending shock has a negative wealth effect, yet it also boosts aggregate demand, firms reduce their mark-up, labour demand increases and offsets the negative income effect affecting labour supply. As a result, wages and consumption rise. Galí, López-Salido, and Valles (2007) cast fiscal policy into a new-Keynesian sticky-price model modified to allow for the presence of rule-of-thumb behaviour. Non-Ricardian households are key for the purposes of the model, as they partly insulate aggregate demand from the negative wealth effects generated by the higher levels of current and future taxes needed to finance the fiscal expansion. In this model, the magnitudes of the responses of output and consumption are systematically greater than those generated by the neoclassical model. In addition, the increase in aggregate hours coexists with an increase in real wages. This response of wages is made possible by sticky prices. In fact, even in the face of a drop in the marginal product of labour, real wages can increase as the price mark-up may adjust sufficiently downward to absorb the resulting gap. The combined effect of higher real wages and higher employment raises labour income and stimulates consumption of rule-of-thumb households, and the overall effect on consumption is positive.

Table 2.1 summarises the results of the theoretical and empirical literature surveyed.

2.3 Econometric methodology

This section outlines the econometric methodology that we employ to analyze the effects of fiscal policy shocks. Subsection 2.3.1 explains the basic principles of graphical modelling. Subsection 2.3.2 illustrates how graphical modelling can be used to identify structural shocks in a VAR framework.

2.3.1 Graphical modelling

Graphical modelling is a statistical approach aiming at uncovering statistical causality from partial correlations observed in the data, which can be interpreted as linear predictability in the case of a linear regression model.[3] Primal contributions to the methodology are due to Dempster (1972) and Darroch, Lauritzen, and Speed (1980).

The initial step of the procedure is to compute partial correlations between variables, the significance of which can be tested by using appropriate statistics. Statistically significant partial correlations can be then represented by an undirected graph called *Conditional Independence Graph* (CIG), where random variables are represented by nodes and a significant partial correlation between any two random variables – conditioned on all the remaining variables of the model – represented by a line known as *undirected edge*. In Figure 2.1.A, we show an example of a CIG. For instance, the edge connecting nodes A and B represents a significant partial correlation between A and B conditioned on C. A significant partial correlation implies conditional dependence if the variables are jointly distributed as a multivariate Gaussian distribution, hence the name Conditional Independence Graph.

When an arrow links the nodes of a CIG, we obtain what is called *Directed Acyclic Graph* (DAG). DAGs and CIGs imply a different definition of joint probability. For example, if we consider Figure 2.1.A, we can assert that A and C are independent, conditional on C. Therefore, the joint distribution implied by the CIG is the following:

$$f_{A,C|B} = f_{A|B} f_{C|B}$$

while a corresponding DAG such as the one in Figure 2.1.C2 has a joint distribution

[3] In this context least squares and maximum likelihood estimation are equivalent.

equal to:

$$f_{A,B,C} = f_{C|B} f_{B|A} f_A.$$

Nevertheless, there is a correspondence between the two, represented by the so-called *moralization rule*, as firstly shown by Lauritzen and Spiegelhalter (1988). In fact, there is always a unique CIG deriving from a given DAG, obtained by transforming arrows into undirected edges and linking unlinked *parents* of a *common child* with a *moral edge*. In the DAG shown in Figure 2.1.B1, A and C are parents of B. In order to obtain the corresponding unique CIG we must transform arrows into edges and add a moral edge between parents A and C as in Figure 2.1.B2. Statistically, when both A and C determine B, a significant partial correlation due to moralization should be observed between A and C.[4]

While there is a unique CIG deriving from a given DAG, the reverse is not true. What we can observe in the data is a CIG, where every edge can assume two possible directions. Therefore, for any given CIG, there are 2^n hypothetical DAGs, where n is the number of edges. Figure 2.1.C shows all the hypothetical DAGs corresponding to the CIG in Figure 2.1.A. According to what we have said above, the DAG in Figure 2.1.C1 is not compatible with the CIG, because the moralization rule requires a moral edge between A and C, which is not captured by the CIG.

In the process of obtaining plausible DAGs from an observed CIG, it might also be possible that some of the links captured by the CIG are due to moralization and hence must be eliminated in a corresponding DAG. Such *demoralization* process, in most cases, can be assessed by considering some quantitative rules. Let us suppose we observe a CIG such as the one in Figure 2.1.B2. If the true corresponding DAG were the one in Figure 2.1.B1, then the partial correlation between A and C, $\rho_{A,C|B}$, should be equal to $-\rho_{A,B|C} \times \rho_{B,C|A}$. In such a case, when tracing DAG 1.B1, the edge between A and C must be removed.

Any DAG, by definition, has to satisfy the principle of acyclicality. Therefore, the

[4]An example should provide a more intuitive insight into the moralization rule: if one wants to become a famous football player (P), he/she must have good skills (S) and/or must work hard (W). Therefore S and W are determinants of P. Conditional on P, there may be cases where S is high and W is low; cases where W is high and S is low; and cases where both S and W are high. There cannot be cases where S and W are both low, otherwise we would not observe P. This example shows that S and W are (negatively) correlated given P.

graph depicted in Figure 2.2 cannot be a DAG as it is clearly cyclic. The acyclicality in a DAG allows to completely determine the distribution of a set of variables and implies a recursive ordering of the variables, where each element in turn depends on none, one or more elements. For example, in the DAG in Figure 2.1.C2, A depends on no other variables, B depends on A and C on B.

2.3.2 Graphical modelling in the identification of a SVAR

Graphical Modelling (GM) theory can be applied to obtain identification of structural VARs (SVAR), as shown by Reale and Wilson (2001) and Oxley, Wilson, and Reale (2009) among others. This literature considers GM as a data-driven approach that represents a possible solution to the problem of imposing restrictions to identify a SVAR.

Any SVAR may be turned into a DAG where current and lagged variables are represented by nodes and causal dependence by arrows. To do so, we need to establish pairwise relationships among contemporaneous variables in terms of partial correlations conditioned on all the remaining contemporaneous and lagged values. In many cases, it is possible to obtain more parsimonious models since some lagged variables do not play any significant role in explaining contemporaneous variables and the corresponding coefficient vectors present some zeros.[5] In this chapter, however, we will consider SVARs where the data generating process presents all the lagged values, as it is standard practice in the applied econometric literature aiming at analyzing the impulse responses of a set of macroeconomic variables. The first step in constructing a DAG representation of a SVAR is the determination of the lag order through the minimization of an order selection criterion such as the Akaike Information Criterion (AIC), the Hannan and Quinn Information Criterion (HIC) or the Schwarz Information Criterion (SIC). We can then derive a pth-order vector autoregressive model, m-dimensional time series $X_t = (x_{t,1}, x_{t,2}, ..., x_{t,m})$ in canonical (or reduced) form, which can be expressed as:

$$X_t = c + A_1 X_{t-1} + A_2 X_{t-2} + ... + A_p X_{t-p} + u_t$$

where c allows for a non-zero mean of X_t, each variable is expressed as a linear function of

[5] Reale and Tunnicliffe (2001) and Oxley et al. (2009) argue that, in some cases, a sparse lag structure may yield models with better statistical properties.

its own past values, the past values of all other variables being considered and a serially uncorrelated innovation u_t, whose covariance matrix V is generally not diagonal. The correlation between two errors represents the partial correlation of two contemporaneous variables conditioned on all the lagged values. Hence, in order to construct the CIG among contemporaneous variables conditioned on all the remaining contemporaneous and lagged variables, we can derive the sample partial correlation between the innovations, conditioned on the remaining innovations of the canonical VAR,[6] calculated from the inverse $\hat{W}$ of the sample covariance matrix $\hat{V}$ of the whole set of innovations as:

$$\hat{\rho}(u_{i,t}, u_{j,t}|\{u_{k,t}\}) = -\hat{W}_{ij}/\sqrt{(\hat{W}_{ii}\hat{W}_{jj})}$$

where $\{u_{k,t}\}$ is the whole set of innovations excluding the two considered.

The critical value utilised to test for the significance of the sample partial correlations can be calculated by using the relationship between a regression t-value and the sample partial correlation, as shown by Greene (2003), and considering the asymptotic normal distribution of the t-value for time series regression coefficients. This is given by:

$$\frac{z}{\sqrt{(z^2+\nu)}} \approx \frac{z}{\sqrt{n-p}}$$

where n is the sample size, $\nu = n-k-1$ are the residual degrees of freedom obtained as a regression of one variable on all the remaining variables and z represents a critical value at a chosen significance level of the standard normal distribution. Whenever a sample partial correlation is greater than the calculated critical value, a link is retained.

All arrows end in nodes representing contemporaneous variables. At this point, the only causality we can assume is the relationship between lagged and contemporaneous variables determined by the flow of time. Next, we need to consider all the possible DAGs representing alternative competitive models of the relationships among contemporaneous variables. Finally, we compare the DAGs compatible with the estimated CIG by using likelihood based methods,[7] such as AIC, HIC and SIC, and choose the best-performing

[6] Granger and Swanson (1997) have applied a similar strategy to sort out causal flows among contemporaneous variables, i.e. applying a residual orthogonalization of the innovations from a canonical VAR.

[7] In some cases, the distributional properties of the variables for different DAGs are likelihood equivalent, although the residual series are different. In such cases, it is possible to construct DAG models by

DAG.[8]

In order to construct an empirically well-founded SVAR, we have to assure that the covariance matrix of the resulting residuals is diagonal. A first diagnostic check is thus inspecting the significance of such correlations. Further diagnostic checks are possible. For instance, as this procedure typically imposes over-identifying restrictions, a χ^2 likelihood-ratio test can be conducted.

2.4 Data

In order to make our results comparable with the previous literature, we use the same sample period and data sources as Caldara and Kamps (2008). Therefore, we use quarterly US data over the period 1955:1-2006:4. All series are seasonally adjusted by the source.

Our baseline model is a three-variable VAR that includes the log of real per capita government spending (g_t), the log of real per capita net taxes (t_t) and the log of real per capita GDP (y_t). Government spending and taxes are net of social transfers. Government spending is the sum of government consumption and investment, while net taxes are obtained as government current receipts less current transfers and interest payments.[9] To assess the effects of fiscal policy shocks on a set of key macroeconomic variables, we follow Blanchard and Perotti (2002) and specify four-variable VAR models by adding one variable at a time to the baseline model. The other variables are the log of real per capita private consumption (c_t), the log of per capita hours worked (h_t), the log of the real wage (w_t), the log of real per capita private residential investment (R), and the log of real per capita private non-residential investment (NR).

We extracted the components of GDP, government receipts, and the GDP deflator from the NIPA tables of the Bureau of Economic Analysis. We obtained real hourly compensation from the Bureau of Labor Statistics and the measure of per capita hours

considering only the lagged variables that play a significant role in explaining contemporaneous variables determined by the significant partial correlation. This can help, via comparison of information criteria, determine the best DAG for contemporaneous variables.

[8] Even in the presence of non-stationary variables, the sampling properties of GM and the outlined procedure are still valid, as shown by Wilson and Reale (2008).

[9] We converted the components of national income and net taxes into real per-capita terms by dividing their nominal values by the GDP deflator and the civilian population. The latter is available in the ALFRED database of the Federal Reserve Bank of Saint Louis.

worked used in Francis and Ramey (2005) from Ramey's webpage.

2.5 Identification of structural vector-autoregressions

We study the effects of fiscal policy shocks from a macroeconomic perspective by means of structural VAR models identified through DAGs.

After collecting the endogenous variables of interest in the k-dimensional vector X_t, the reduced-form VAR model associated to it can be written as:

$$X_t = A(L)X_{t-1} + u_t \tag{2.1}$$

where $A(L)$ is a polynomial in the lag operator L and u_t is a k-dimensional vector of reduced-form disturbances with $E[u_t] = 0$ and $E[u_t u_t'] = \Sigma_u$.[10]

As the reduced-form disturbances are correlated, in order to identify fiscal policy shocks, we need to transform the reduced-form models into structural models. Premultiplying both sides of equation (2.1) by the $(k \times k)$ matrix A_0, yields the structural form:

$$A_0 X_t = A_0 A(L) X_{t-1} + B e_t \tag{2.2}$$

In our benchmark case we also include a constant and a linear trend among regressors. The relationship between the structural disturbances e_t and the reduced-form disturbances u_t is described by the following:

$$A_0 u_t = B e_t \tag{2.3}$$

where A_0 also describes the contemporaneous relation among the endogenous variables and B is a $(k \times k)$ matrix. In the structural model, disturbances are assumed to be uncorrelated with each other. In other words, the covariance matrix of the structural disturbances Σ_e is diagonal.

As it is, the model described by equation 2.2 is not identified. Therefore, first we restrict matrix B to be a $(k \times k)$ diagonal matrix. As a result, the diagonal elements

[10] We report results obtained by using a 4-th order lag polynomial for all models, as it is the usual choice with quartely data and is in line with the related literature. However, using the number of lags suggested by information criteria yields no differences, as we obtain CIGs with the same edges.

of B will represent estimated standard deviations of the structural shocks. In order to impose identifying restrictions on matrix A_0, we apply *graphical modeling* theory and trace DAGs of the reduced-form residuals.

A feature of DAGs is acyclicality, which implies a recursive ordering of the variables that makes A_0 a lower-triangular matrix. A_0 has generally zero elements also in its lower triangular part, hence, in general, the model is over-identified. The GM methodology has the distinctive feature that the variable ordering and any further restrictions come from statistical properties of the data.

Consistently with the methodology described in Section 2.3, we build DAGs of the residuals obtained by fitting the various specifications to equation (2.1). In Table 2.2 we report the estimated partial correlation matrices of the series innovations and their significance at 0.10, 0.05 and 0.01 levels. These allows us to draw the CIGs reported in the left column of Figure 2.3. The statistical strength of the links is represented by dashed, thin or thick lines, which reflect significance at the 0.10, 0.05 and 0.01 levels, respectively.

Applying the GM procedure allows us to define the DAGs reported in the right column of Figure 2.3.

DAG a2- baseline. The two edges in CIG a1 cannot be moral, as moral edges link parents of a common child. The four possible DAGs implied by CIG *a1* are reported in Figure 2.4. DAG (B) can be discarded because a moral edge between u_t^g and u_t^t is not captured in the CIG. Hence, we need to compare the three remaining models. Table 2.3 shows that the three information criteria reported are minimised by the model implied by DAG (A). The best performing DAG implies that government spending is not affected contemporaneously by shocks originating in the private sector. As we employ quarterly data and definitions of fiscal variables that exclude most of the automatic stabilizers, this finding makes economic sense in the light of the typical decision and implementation lags present in the budgeting process. Such an argument is shared by virtually all other related empirical studies. However, while the related literature uses this argument as an *a-priori* identifying assumption,[11] in this chapter we obtain it as a result. If we fit DAG

[11] First, Blanchard and Perotti (2002) argue that in contrast to monetary policy, decision and implementation lags in fiscal policy imply that, within a quarter, there is little discretionary response of fiscal policy to unexpected contemporaneous movements in activity. Next, Caldara and Kamps (2008), when they apply a recursive approach *à la* Choleski, order government spending first. Last, Mountford

(A) to the estimated residuals, we get significant coefficients (t-statistics are reported adjacent to directed edges) and signs compatible with economic arguments. An increase in government spending has a contemporaneous (within a quarter) effect on real output, the tax base increases and, thus, tax receipts contemporaneously rise. As a diagnostic check, we inspect the cross-correlations matrix of the resulting residuals in Table 2.4 and find that all cross-correlations lie within two standard errors from zero. We use the directions obtained for the baseline variables also in the DAGs that follow.

DAG b2- consumption. Same arguments apply to baseline variables. In addition, $u_t^y \to u_t^c$, as the opposite would imply a moral link between u_t^g and u_c^t, which does not appear in CIG b1. Fitting this DAG yields significant coefficients and signs are compatible with economic arguments. In particular, a positive shock to income has a contemporaneous positive effect on consumption. All cross-correlations of the resulting residuals are insignificant.

DAG c2- hours worked. Our best DAG selected on the basis of the information criteria (not reported) indicates a strongly significant coefficient for the contemporaneous output in the hours equation. Moreover an increase in contemporaneous hours worked has a contemporaneous positive effect on tax receipts. The resulting cross correlation between the residual series are all not statistically different from zero.

DAG d2- real wage. The link between u_t^g and u_t^w, significant at a 0.10 level, may be a moral link in the case in which $u_t^w \to u_t^y$. However, information criteria suggest that $u_t^y \to u_t^w$. The positive coefficient of u_t^y in the regression of u_t^w captures a positive contemporaneous effect on real wages of a shock to economic activity.

DAG e2- residential investment. We apply analogous arguments to those applied to DAG b2. Here $u_t^y \to u_t^R$, as the opposite would imply a moral link between u_t^g and u_c^R, which does not appear in CIG e1. Fitting this DAG yields significant coefficients and signs are compatible with economic arguments. In particular, a boom in economic activity has a contemporaneous positive effect on residential investment. All cross-correlations of the resulting residuals are insignificant.

DAG f2- non-residential investment. The CIG for non residential investment is the

and Uhlig (2008), when using the sign-restriction approach, define a business cycle shock as a shock which jointly moves output, consumption, non-residential investment and government revenue, but not government spending.

one with the richest set of contemporaneous relationships among variables. In addition to the relationships already established for the baseline variables, government spending has a contemporaneous (negative) effect on non-residential investment. Therefore we need to establish the relationship between taxes and non residential investment and between output and non residential investment. This makes $2^2 = 4$ potential DAGs. The information criteria select the model in which output has a contemporaneous positive effect on non-residential investment and the latter has a contemporaneous positive effect on tax receipts. The resulting cross correlations between the residuals do not differ statistically from zero.

Now, we can use the DAGs depicted in Figure 2.3 to impose restrictions on matrix A_0. This allows us to identify our structural VAR models. For illustrative purposes we show what the relationship between the structural disturbances e_t and the reduced-form disturbances u_t looks like in the model for private consumption:

$$\underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ -a_{21} & 1 & 0 & 0 \\ 0 & -a_{32} & 1 & 0 \\ 0 & -a_{42} & 0 & 1 \end{bmatrix}}_{A_0} \underbrace{\begin{bmatrix} u_t^g \\ u_t^y \\ u_t^t \\ u_t^c \end{bmatrix}}_{u_t} = \underbrace{\begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{bmatrix}}_{B} \underbrace{\begin{bmatrix} e_t^g \\ e_t^y \\ e_t^t \\ e_t^c \end{bmatrix}}_{e_t} \tag{2.4}$$

In the appendix, we report matrices for all models.

As anticipated above, matrix A_0 is over-identified, as the assumption of orthonormal structural innovations imposes $k(k+1)/2$ restrictions on the k^2 unknown elements of A_0, where k is the number of endogenous variables. In the case of four variables, this makes six restrictions. It follows that we have three over-identifying restrictions.

In Table 2.5, for all models we report the variable ordering in vector X_t, the maximum-likelihood estimates of matrices A_0 and B, and the likelihood-ratio (LR) test for over-identification. All estimated coefficients have the right signs and are significant at least at a 0.05 level. Moreover, we fail to reject LR-tests for over-identification of all models at any reasonable level of significance.

All the estimated SVAR models identify identical structural fiscal policy shocks. This is clearly depicted in Figure 2.5, where the identified spending and tax shock deriving from the six models above are coincident series.

2.6 Results

In this section we present empirical results for government spending and tax shocks by analyzing the impulse responses obtained from the SVARs identified above.

Following the procedure by Blanchard and Perotti (2002), we transform the impulse responses of output and its components in such a way that they can be interpreted as multipliers. In other words, they represent the dollar response of the respective variable when the economy is hit by a fiscal shock of size one dollar. To achieve this, first, we divide the original impulse responses by the standard deviation of the respective fiscal shock. This allows us to deal with shocks of size one percent. Second, we multiply the resulting responses by the ratio of the responding variable to the shocked fiscal variable, evaluated at the sample mean.

As far as the impulse responses of hours worked and wages are concerned, we simply express them as percentage-point changes subsequent to a fiscal shock of size one percent. For each variable we report responses for a 40-quarter horizon and 90 percent confidence intervals obtained by applying the procedure due to Hall (1992) with 2000 boostrap replications.

2.6.1 Government spending shock

In Figure 2.6 we report results for a government spending shock of one dollar.

Government spending reacts strongly and persistently to its own shock. It reaches its peak of 1.15 dollars after one year and persistently stays above baseline (more 95 percent of the shock is still present after two years).

Real output increases on impact by almost 1.10 dollars, slightly decreases after two quarters, and then rises again up to a peak of 1.75 dollars two years after the shock. Then, it persistently and significantly stays above baseline. The spending multiplier is greater than one both on impact and at a longer time horizon.

Taxes partly offset the one-dollar increase in government spending, since they rise up to 30 cents, probably as an automatic response to the increase in output (note that the shape of the tax response mimic that of output). Taxes reach their peak of more than 50 cents four quarters after the shock. This suggests that the fiscal expansion is at least partially deficit-financed. The response of taxes is also long lasting and statistically significant on impact, after a year, and at longer horizons.

Private consumption shows a positive, smooth and hump-shaped response to the government spending shock. It increases on impact by 35 cents to reach a peak of almost 90 cents ten quarters after the shock has occurred. Then, it persistently stays above baseline.

Private non-residential investment does not move on impact, but declines afterwards showing a peak crowding-out effect of almost -75 cents one year after the spending shock.

Residential investment reacts positively on impact to the fiscal expansion, probably following the increase in output, rising by almost 10 cents and reaching a peak of 20 cents after one year.

Hours worked react positively to a fiscal expansion of one percent from baseline, rising by 0.10 percent on impact and by 0.14 percent after three quarters. Even if the response of hours is not statistically significant at all quarters, significance is achieved at the mentioned quarters and at a longer horizon.

The response of real wages is slightly negative on impact, as they fall by 0.06 percent. They turn positive after a quarter reaching a peak of 0.20 percent after two years and persistently stay above baseline.

2.6.2 Tax shock

In Figure 2.7 we report results for a tax shock of size one dollar.

The tax response reaches its peak on impact and then declines quite smoothly till dying out. The policy experiment shows that a tax increase does not yield any statistically significant effect on output, residential investment, and real wages. Instead, the peak responses of consumption, non-residential investment and hours worked are statistically significant. While consumption decreases by 10 cents two quarters after the shock, non-residential investment rises up to 7 cents three quarters ahead. Last, hours worked reach their peak at 3 percent, three quarters after the tax shock.

As far as the tax policy shock is concerned, from a statistical point of view, we are able to comment only on the peak responses of the mentioned variables. Nevertheless, from an economic point of view, these results are sufficient to detect that a negative wealth effect affects the US economy when the latter is hit by a positive tax shock. In fact, as a consequence of a negative wealth effect we would expect consumption and leisure to decline, i.e. hours worked to rise and private non-residential investment to increase, given the increase in the marginal product of capital determined by the increase in employment. The signs of the peak responses of consumption, non-residential investment and hours worked are consistent with this transmission mechanism.

2.6.3 Subsample stability

We first employ forecast Chow tests to check the overall stability of the parameters of the estimated models. Once the sample has been split into two parts, this test allows us to detect whether a structural change has occurred, by comparing the full sample residual variance with the residual variance of the whole sample. In other words, the test checks whether forecasts made exploiting the first subsample are compatible with the observations contained in the second subsample. We start from 1961:3 and recursively repeat the test at each subsequent data point. Given the tendency of the test to over-reject the null, i.e. to yield a high type I error (Lütkephol, 2005), we recover p-values with a procedure based on 2000 bootstrap replications. As we observe in Figure 2.8, the test fails to reject the null of parameter constancy on every occasion at any reasonable significance level.

Then we replicate SVAR estimation and impulse response analysis by removing ten years of observations at a time.

In Figure 2.9, we report responses to a government spending shock. For all responding variables but non-residential investment, subsample variability does not produce changes in the impulse responses able to controvert the main findings outlined above.

Figure 2.10 depicts responses to a tax shock. Except for the responses of government spending and real wages, also in this case, removing a decade of observations at a time does not yield very different responses compared to the ones obtained by exploiting the full sample.

In Table 2.6, we report peak responses and their significance. As far as the government spending shock is concerned, the peak responses of all variables except non-residential investment, systematically show the same sign across subsample even if their magnitude varies over time.[12] In particular, removing the last ten years in the sample decreases the fiscal multiplier.

Signs of the peak responses obtained by exerting a positive tax shock are stable for tax revenue itself, consumption, residential and non-residential investment. Hours worked show negative, though insignificant, peak responses. However, for at least two quarters after the shock, responses are positive and statistically significant.

2.6.4 Relation with other studies

As discussed in Section 2.2, the recent DSGE literature regards as a stylized fact that private consumption increases when the economy is hit by an expansionary fiscal spending shock. Our empirical results for the US economy, relying on an alternative identification approach to those commonly employed in the related literature, support this claim.

With respect to Blanchard and Perotti (2002), the fiscal multiplier on output is greater: 1.75 against 1.29. This difference depends on the inclusion of more recent data. In fact, when we remove data from 1995:1 to 2006:4, the peak multiplier declines to 1.31.

Consistently with new-generation DSGE models, we also find that while non-residential investment falls, hours worked and real wages rise as a consequence of a positive government spending shock. As in Caldara and Kamps (2008), our results also show quite persistent impulse responses for consumption and real wages. This is not the case in theoretical models such as Gali et al. (2007) where the responses of consumption and wages are initially positive but they turn negative after one year.

As far as the tax shock is concerned, in principle one may argue that real output does not respond on impact to tax shocks because the graphical modelling approach imposes a unique contemporaneous relation from output to taxes, when the contemporaneous effect of taxes on output may be conceptually important. Caldara and Kamps (2008) in applying the Blanchard-Perotti methodology to their data find that the impact response of output to taxes does not significantly differ from zero, which is also captured by our DAGs. Moreover this result is in line with the results reported by Perotti (2005).

[12] Unlike in the full sample, taxes and hours worked show negative peak responses when the decade 1965:1-1974:4 is removed but these are not statistically significant.

2.7 Concluding remarks

We have applied graphical modelling theory to identify fiscal policy shocks in SVAR models of the US economy. This approach has allowed us to rely on statistical properties of the data for the purpose of identification.

In response to a positive government spending shock we obtain results in line with Keynesian views. First, real output responds positively and more than proportionally. Next, private consumption shows a positive and persistent response to a spending shock. While non-residential investment is significantly crowded out by the fiscal expansion, residential investment rises, comoving with output. Last, a positive response of real wages coexists with an increase in hours worked.

When we analyse the effects of a positive tax shock, in general, we do not obtain statistically significant impulse responses. However, peak responses of consumption and non-residential investment, as well as the initial response of hours worked are statistically significant and their signs are consistent with a negative wealth effect incepted by the increase in taxation.

The outlined results are stable over the sample period. In general, adding more recent data increases the magnitude of the fiscal multiplier compared to earlier studies. The crowding-out effect on non-residential investment is not systematically captured in all subsamples.

Appendix: Identification of SVAR models

Baseline:

$$\underbrace{\begin{bmatrix} 1 & 0 & 0 \\ -a_{21} & 1 & 0 \\ 0 & -a_{32} & 1 \end{bmatrix}}_{A_0} \underbrace{\begin{bmatrix} u_t^g \\ u_t^y \\ u_t^t \end{bmatrix}}_{u_t} = \underbrace{\begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix}}_{B} \underbrace{\begin{bmatrix} e_t^g \\ e_t^y \\ e_t^t \end{bmatrix}}_{e_t} \tag{A1}$$

Consumption:

$$\underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ -a_{21} & 1 & 0 & 0 \\ 0 & -a_{32} & 1 & 0 \\ 0 & -a_{42} & 0 & 1 \end{bmatrix}}_{A_0} \underbrace{\begin{bmatrix} u_t^g \\ u_t^y \\ u_t^t \\ u_t^c \end{bmatrix}}_{u_t} = \underbrace{\begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{bmatrix}}_{B} \underbrace{\begin{bmatrix} e_t^g \\ e_t^y \\ e_t^t \\ e_t^c \end{bmatrix}}_{e_t} \tag{A2}$$

Hours worked:

$$\underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ -a_{21} & 1 & 0 & 0 \\ 0 & -a_{32} & 1 & 0 \\ 0 & -a_{42} & -a_{43} & 1 \end{bmatrix}}_{A_0} \underbrace{\begin{bmatrix} u_t^g \\ u_t^y \\ u_t^h \\ u_t^t \end{bmatrix}}_{u_t} = \underbrace{\begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{bmatrix}}_{B} \underbrace{\begin{bmatrix} e_t^g \\ e_t^y \\ e_t^h \\ e_t^t \end{bmatrix}}_{e_t} \tag{A3}$$

Real wage:

$$\underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ -a_{21} & 1 & 0 & 0 \\ 0 & -a_{32} & 1 & 0 \\ -a_{41} & -a_{42} & 0 & 1 \end{bmatrix}}_{A_0} \underbrace{\begin{bmatrix} u_t^g \\ u_t^y \\ u_t^t \\ u_t^w \end{bmatrix}}_{u_t} = \underbrace{\begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{bmatrix}}_{B} \underbrace{\begin{bmatrix} e_t^g \\ e_t^y \\ e_t^t \\ e_t^w \end{bmatrix}}_{e_t} \tag{A4}$$

Residential investment:

$$\underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ -a_{21} & 1 & 0 & 0 \\ 0 & -a_{32} & 1 & 0 \\ 0 & -a_{42} & 0 & 1 \end{bmatrix}}_{A_0} \underbrace{\begin{bmatrix} u_t^g \\ u_t^y \\ u_t^t \\ u_t^R \end{bmatrix}}_{u_t} = \underbrace{\begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{bmatrix}}_{B} \underbrace{\begin{bmatrix} e_t^g \\ e_t^y \\ e_t^t \\ e_t^R \end{bmatrix}}_{e_t} \tag{A5}$$

Non-residential investment:

$$\underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ -a_{21} & 1 & 0 & 0 \\ -a_{31} & -a_{32} & 1 & 0 \\ 0 & -a_{42} & -a_{43} & 1 \end{bmatrix}}_{A_0} \underbrace{\begin{bmatrix} u_t^g \\ u_t^y \\ u_t^{NR} \\ u_t^t \end{bmatrix}}_{u_t} = \underbrace{\begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{bmatrix}}_{B} \underbrace{\begin{bmatrix} e_t^g \\ e_t^y \\ e_t^{NR} \\ e_t^t \end{bmatrix}}_{e_t} \tag{A6}$$

Paper	Output	Consumption	Hours	Wage	Investment
Theoretical models:					
Baxter and King (1993)	+	-	+	-	+
Edelberg, Eichenbaum and Fisher (1999)	+	-	+	-	+ -*
Burnside, Eichenbaum and Fisher (2004)	+	-	+	-	+
Linneman (2006)	+	+	+	+	
Ravn, Schmitt-Grohe and Uribe (2006)	+	+	+	+	
Gali, Lopez-Salido and Valles (2007)	+	+	+	+	-
Empirical analyses:					
Ramey and Shapiro (1998)	+	-	+	-	
Edelberg, Eichenbaum and Fisher (1999)	+	-	+	-	+ -*
Blanchard and Perotti (2002)	+	+			-
Burnside, Eichenbaum and Fisher (2004)	+	-	+	-	+
Perotti (2005)	+	+			
Perotti (2007)	+	+			
Caldara and Kamps (2008)	+	+	+	+	
Mountford and Uhlig (2008)	+	+	+	-	-

* Edelberg, Eichenbaum and Fisher (1999) find that while the impact response of non-residential investment is positive, residential investment has instead a negative response.

Table 2.1: The sign of impact responses of key macroeconomic variables to a fiscal expansion according to theoretical and empirical studies.

	u_t^g	u_t^y	u_t^t
u_t^g	1.000		
u_t^y	0.248***	1.000	
u_t^t	0.016	0.395***	1.000

(a) baseline

	u_t^g	u_t^y	u_t^t	u_t^c
u_t^g	1.000			
u_t^y	0.143**	1.000		
u_t^t	0.026	0.347***	1.000	
u_t^c	0.064	0.638***	-0.104	1.000

(b) consumption

	u_t^g	u_t^y	u_t^t	u_t^h
u_t^g	1.000			
u_t^y	0.216***	1.000		
u_t^t	-0.000	0.170**	1.000	
u_t^h	0.016	0.558***	0.250***	1.000

(c) hours worked

	u_t^g	u_t^y	u_t^t	u_t^w
u_t^g	1.000			
u_t^y	0.257***	1.000		
u_t^t	0.030	0.384***	1.000	
u_t^w	-0.146**	0.150**	0.043	1.000

(d) real wage

	u_t^g	u_t^y	u_t^t	u_t^R
u_t^g	1.000			
u_t^y	0.305***	1.000		
u_t^t	0.015	0.291***	1.000	
u_t^R	-0.099	0.350***	0.041	1.000

(e) residential investment

	u_t^g	u_t^y	u_t^t	u_t^{NR}
u_t^g	1.000			
u_t^y	0.429***	1.000		
u_t^t	0.091	0.170**	1.000	
u_t^{NR}	-0.363***	0.656***	0.169**	1.000

(f) non-residential investment

Note: *,** and *** denote significance at 0.10, 0.05 and 0.01 levels, respectively. The corresponding threshold values for the baseline model are 0.1189, 0.1408 and 0.1840, respectively. For all the other models, they are 0.1204, 0.1426 and 0.11864, respectively.

Table 2.2: Estimated partial correlations of the series innovations.

Model	AIC	HIC	SIC
A	506.00	530.16	565.73
C	507.04	531.20	566.76
D	571.64	551.80	587.37

Table 2.3: Information criteria associated to the feasible DAGs of the baseline model.

	ε_t^g	ε_t^y	ε_t^t
ε_t^g	1.000		
ε_t^y	0.000	1.000	
ε_t^t	0.066	-0.008	1.000

(a) baseline

	ε_t^g	ε_t^y	ε_t^t	ε_t^c
ε_t^g	1.000			
ε_t^y	0.000	1.000		
ε_t^t	0.018	-0.005	1.000	
ε_t^c	0.060	-0.013	-0.093	

(b) consumption

	ε_t^g	ε_t^y	ε_t^t	ε_t^h
ε_t^g	1.000			
ε_t^y	0.000	1.000		
ε_t^t	0.000	0.000	1.000	
ε_t^h	0.015	-0.004	0.000	1.000

(c) hours worked

	ε_t^g	ε_t^y	ε_t^t	ε_t^w
ε_t^g	1.000			
ε_t^y	0.000	1.000		
ε_t^t	0.024	-0.007	1.000	
ε_t^w	-0.000	0.000	0.044	1.000

(d) real wage

	ε_t^g	ε_t^y	ε_t^t	ε_t^R
ε_t^g	1.000			
ε_t^y	0.000	1.000		
ε_t^t	0.011	-0.035	1.000	
ε_t^R	0.094	0.031	0.040	1.000

(e) residential investment

	ε_t^g	ε_t^y	ε_t^t	ε_t^{NR}
ε_t^g	1.000			
ε_t^y	0.000	1.000		
ε_t^t	0.081	-0.026	1.000	
ε_t^{NR}	-0.000	0.000	0.032	1.000

(f) non-residential investment

Note: The two-standard-error band for a sample size of 204 is ± 0.1400.

Table 2.4: Correlations between residuals of the DAGs fitted to the VAR(4) estimated innovations.

Models	X_t	$-a_{21}$	$-a_{31}$	$-a_{32}$	$-a_{41}$	$-a_{42}$	$-a_{43}$	b_{11}	b_{22}	b_{33}	b_{44}	m	LR-$\chi^2(m)$
Baseline	$g\,y\,t$	-0.22***	0	-1.90***	-	-	-	1.10***	0.82***	3.42***	-	1	0.27
		(0.05)	-	(0.28)	-	-	-	(0.05)	(0.04)	(0.17)	-		[0.87]
Consumption	$g\,y\,t\,c$	-0.20***	0	-1.72***	0	-0.53***	0	1.11***	0.80***	3.34***	0.49***	3	2.29
		(0.05)	-	(0.28)	-	(0.04)	-	(0.05)	(0.04)	(0.16)	(0.02)		[0.51]
Hours worked	$g\,y\,h\,t$	-0.23***	0	-0.004***	0	-0.95***	-193.75***	1.10***	0.81***	0.004***	3.26***	2	0.07
		(0.05)	-	(0.0004)	-	(0.35)	(51.24)	(0.05)	(0.04)	(0.0002)	(0.16)		[0.97]
Real wage	$g\,y\,t\,w$	-0.22***	0	-1.91***	0.001	-0.001**	0	1.09***	0.82***	3.43***	0.01***	2	0.14
		(0.05)	-	(0.28)	(00004)	(0.0005)	-	(0.05)	(0.04)	(0.17)	(0.0003)		[0.93]
Residential investment	$g\,y\,t\,R$	-0.23***	0	-1.65***	0	-1.66***	0	1.10***	0.76***	3.35***	3.41***	3	2.59
		(0.05)	-	(0.29)	-	(0.30)	-	(0.05)	(0.04)	(0.17)	(0.17)		[0.46]
Non-residential investment	$g\,y\,NR\,t$	-0.23***	1.35***	-4.78***	-	-1.41***	-0.11**	1.10***	0.78***	3.69***	3.32***	1	1.44
		(0.05	(0.25)	(0.33)	0	(0.38)	(0.06)	(0.05)	(0.04)	(0.18)	(0.16)		[0.23]

Note: Estimation method: maximum likelihood. Standard errors in parentheses. *,** and *** denote significance at a 0.10, 0.05 and 0.01 level respectively. m = number of over-identifying restrictions. LR = likelihood-ratio χ^2 statistics. P-values in square brackets.

Table 2.5: Structural factorisations.

		Excluded period				
	full sample	1955:1-1964:4	1965:1-1974:4	1975:1-1984:4	1985:1-1994:4	1995:1-2006:4
Government spending shock						
Government spending	1.15*	1.24*	1.00*	1.11*	1.03*	1.15*
	(4)	(4)	(1)	(4)	(2)	(4)
Output	1.75*	1.42*	1.59*	1.76*	2.24*	1.31*
	(8)	(3)	(5)	(3)	(4)	(10)
Tax	0.51*	0.58*	-0.49	0.54*	1.20*	1.05*
	(6)	(20)	(2)	(6)	(10)	(11)
Consumption	0.87*	0.91*	0.82*	1.15*	1.63*	0.71*
	(10)	(20)	(1)	(2)	(4)	(10)
Hours worked	0.15*	0.12*	-0.08	0.20*	0.34*	0.29*
	(6)	(3)	(2)	(3)	(4)	(11)
Real wage	0.24*	0.23*	0.73*	0.37*	0.34*	0.31*
	(15)	(8)	(1)	(4)	(8)	(19)
Residential investment	0.20*	0.22*	0.25*	0.29*	0.25*	0.26*
	(5)	(12)	(5)	(2)	(12)	(8)
Non-residential investment	-0.73*	-0.75*	0.70*	0.50	0.18	-0.41
	(2)	(11)	(7)	(3)	(8)	(2)
Tax shock						
Government spending	-0.07	-0.09	0.18*	0.15	-0.11*	-0.12*
	(6)	(7)	(19)	(18)	(26)	(15)
Output	0.17	-0.24	0.45*	-0.39	-1.16*	-0.63
	(3)	(13)	(3)	(11)	(11)	(8)
Tax	1.00*	1.00*	1.00*	1.15*	1.00*	1.00*
	(1)	(1)	(1)	(3)	(1)	(1)
Consumption	-0.11*	-0.13	0.24	-0.61*	-0.73*	-0.37*
	(2)	(8)	(3)	(12)	(10)	(9)
Hours worked	-0.04	-0.06	-0.05	0.09	-0.09	-0.09
	(15)	(16)	(15)	(5)	(12)	(9)
Real wage	0.03	0.07*	0.20*	0.12*	0.02	-0.06*
	(10)	(10)	(17)	(20)	(4)	(10)
Residential investment	-0.08	-0.12	-0.18*	-0.12*	-0.30*	-0.21*
	(5)	(6)	(8)	(8)	(7)	(6)
Non-residential investment	0.07*	0.37*	0.36*	0.35*	0.36*	0.19
	(3)	(3)	(3)	(3)	(3)	(3)

Note: Quarters in parentheses. * denotes significance at a 0.10 level.

Table 2.6: Subsample stability: peak responses.

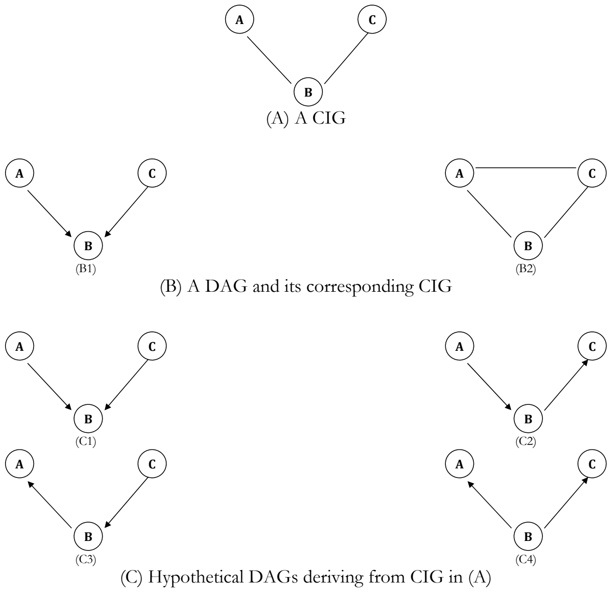


Figure 2.1: Conditional independence graphs and directed acyclic graphs.

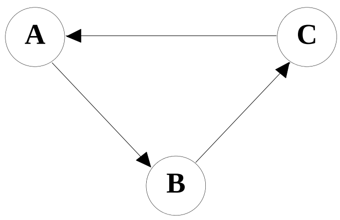
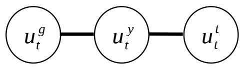
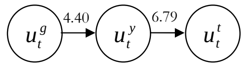


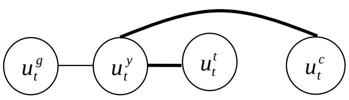
Figure 2.2: Directed cyclic graph.



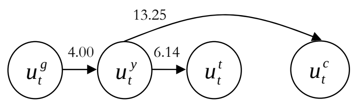
(a1) CIG baseline



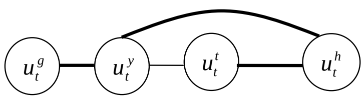
(a2) DAG baseline



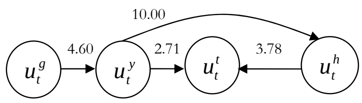
(b1) CIG consumption



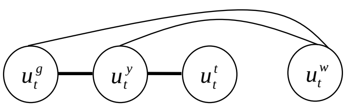
(b2) DAG consumption



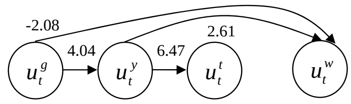
(c1) CIG hours worked



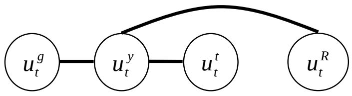
(c2) DAG hours worked



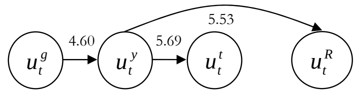
(d1) CIG real wage



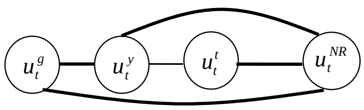
(d2) DAG real wage



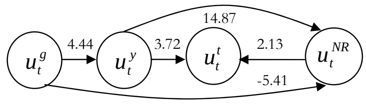
(e1) CIG residential investment



(e2) DAG residential investment



(f1) CIG non-residential investment



(f2) DAG non-residential investment

Note: In the CIGs (left column), the strengths of the links are indicated by significance at the 0.10 level (dashed line), 0.05 level (thin line), 0.01 level (bold line). In the DAGs (right column), t-statistics of the estimated regression coefficients are shown adjacent to the directed links.

Figure 2.3: Sample CIGs and estimated DAGs fitted to VAR(4) residuals.

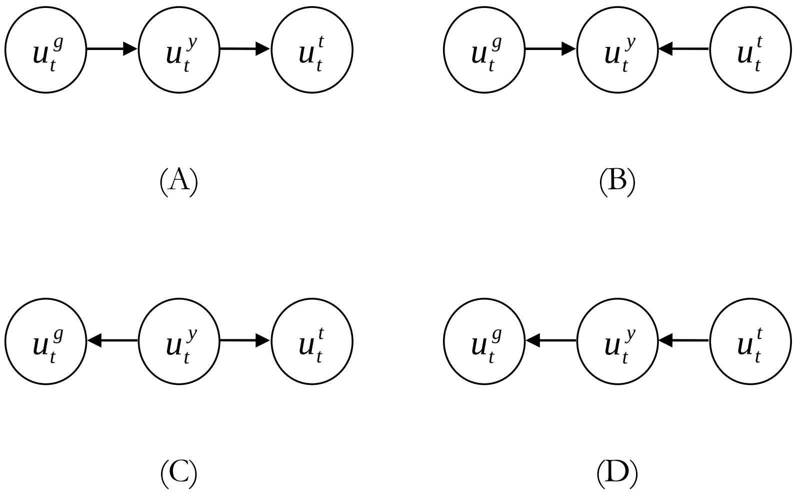
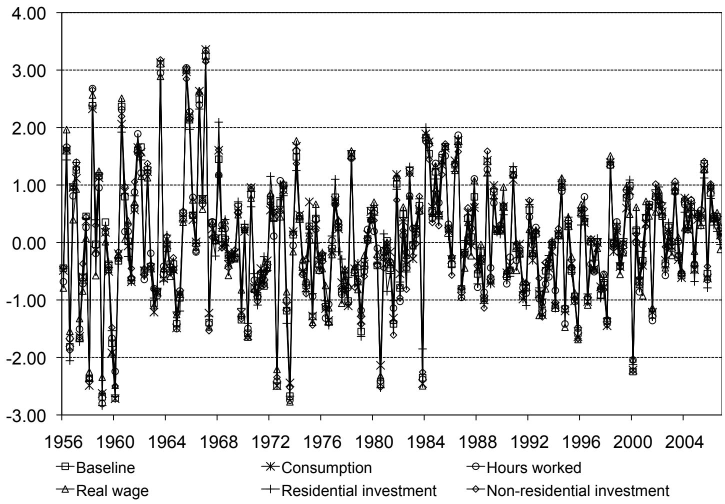
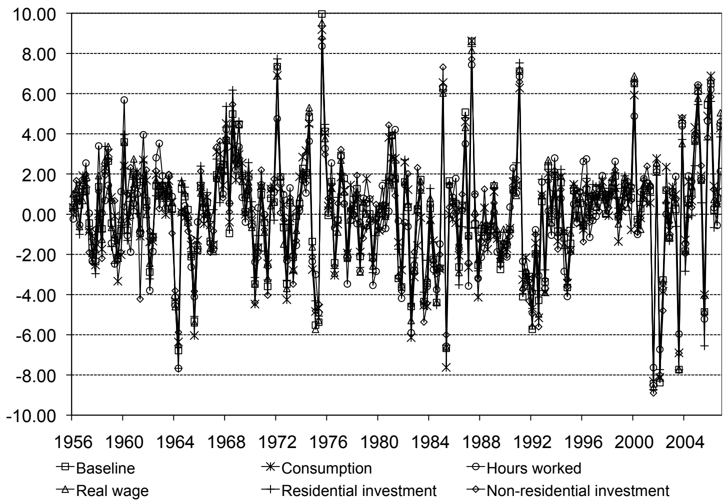


Figure 2.4: All possible DAGs deriving from the CIG of the baseline model.

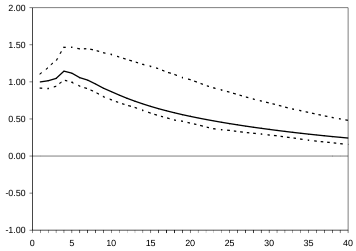


(a) Government spending shocks.

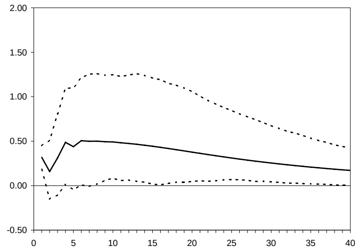


(b) Tax shocks.

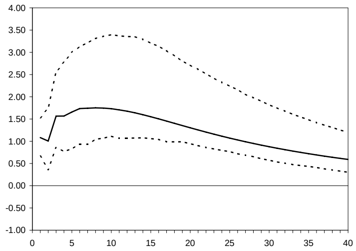
Figure 2.5: Identified fiscal policy shocks across models.



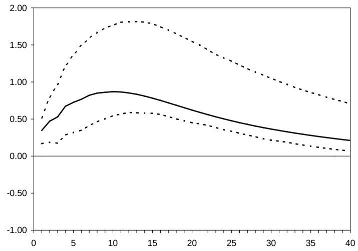
(a) Government spending



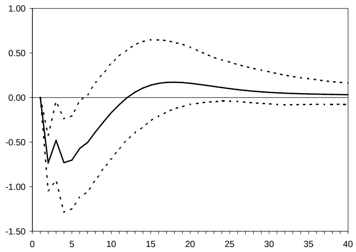
(b) Taxes



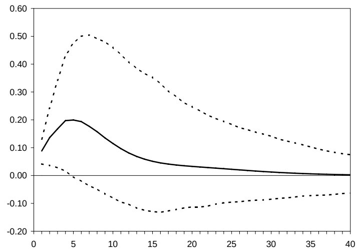
(c) Real output



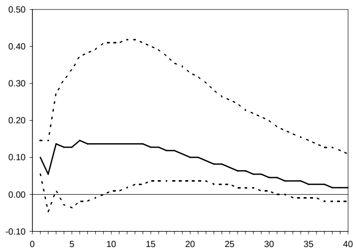
(d) Consumption



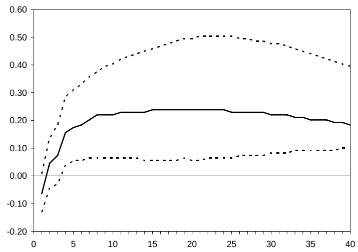
(e) Non-residential investment



(f) Residential investment



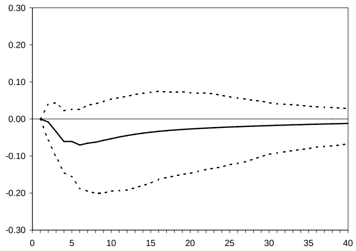
(g) Hours worked



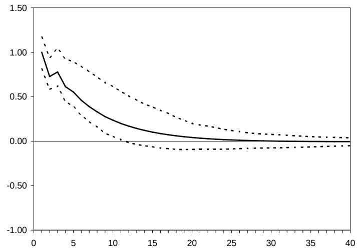
(h) Real wages

Note: Dashed lines represent 90% confidence intervals computed according to Hall's (1992) algorithm with 2000 bootstrap replications. Responses are shown for a 40-quarter horizon. The impulse responses of government spending, taxes and real output are computed on the basis of the baseline 3-variable SVAR. The impulse responses of the remaining variables are obtained from 4-variable models obtained by adding one variable at a time to the baseline model. Impulse response of real output and its components are rescaled to represent the dollar change of the variables to a shock to government spending of size one dollar. The impulse responses of hours worked and real wages are rescaled to represent the percentage change subsequent to a government spending shock of size one percent.

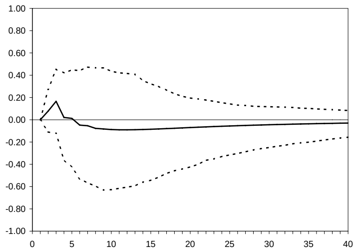
Figure 2.6: Impulse responses to a government spending shock.



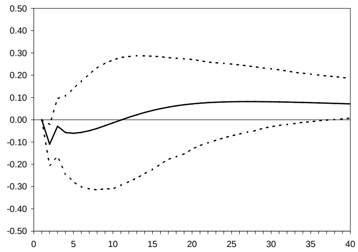
(a) Government spending



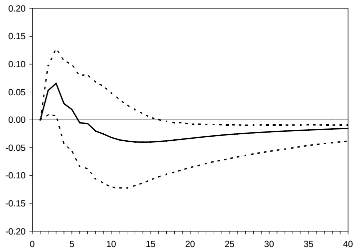
(b) Taxes



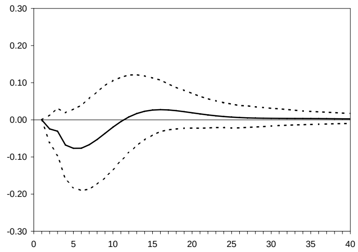
(c) Real output



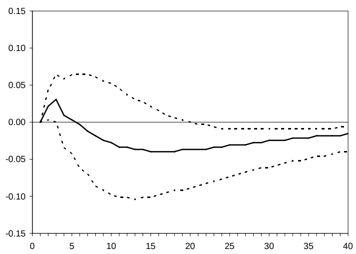
(d) Consumption



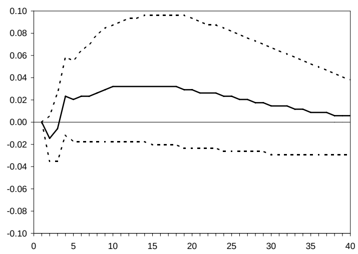
(e) Non-residential investment



(f) Residential investment



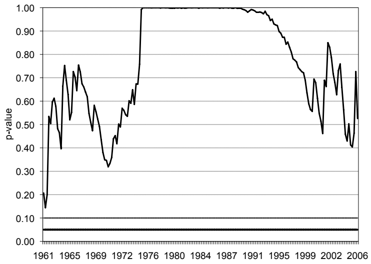
(g) Hours worked



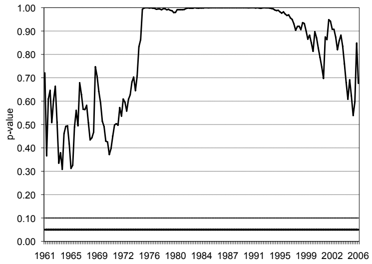
(h) Real wages

Note: Dashed lines represent 90% confidence intervals computed according to Hall's (1992) algorithm with 2000 bootstrap replications. Responses are shown for a 40-quarter horizon. The impulse responses of government spending, taxes and real output are computed on the basis of the baseline 3-variable SVAR. The impulse responses of the remaining variables are obtained from 4-variable models obtained by adding one variable at a time to the baseline model. Impulse response of real output and its components are rescaled to represent the dollar change of the variables to a shock to tax revenues of size one dollar. The impulse responses of hours worked and real wages are rescaled to represent the percentage change subsequent to a tax revenue shock of size one percent.

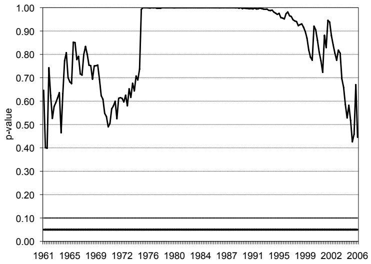
Figure 2.7: Impulse responses to a tax shock.



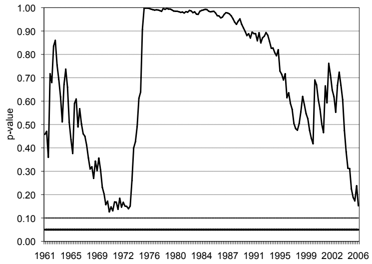
(a) Baseline



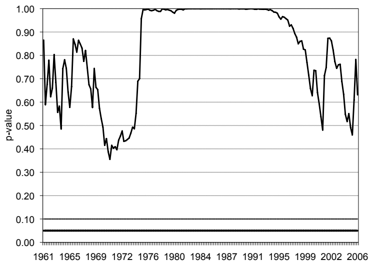
(b) Consumption



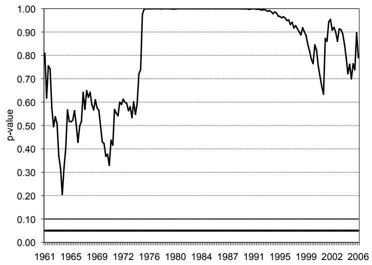
(c) Hours worked



(d) Real wage



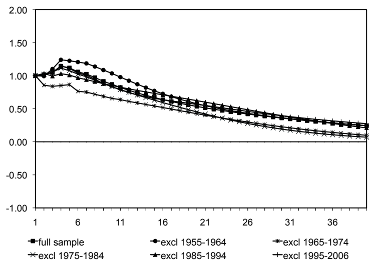
(e) Non-residential investment



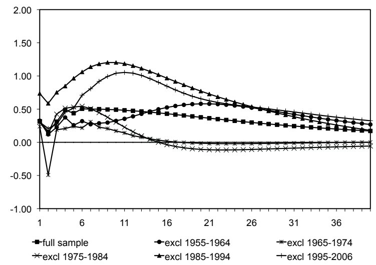
(f) Residential investment

Note: Bold horizontal lines represent the 0.05 significance level. Thin horizonal lines represent the 0.10 significance level. Chow forecast test recursively run at every quarter from 1961:3 to 2006:3. Null hypothesis: parameter constancy. P-values computed with 2000 bootstrap replications.

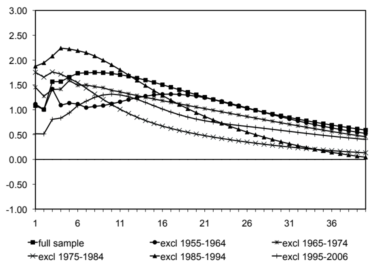
Figure 2.8: Chow forecast test (recursive p-values).



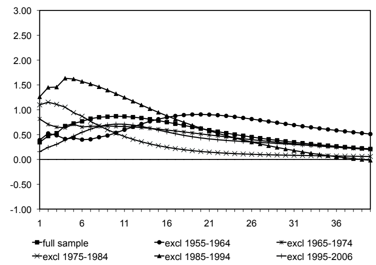
(a) Government spending



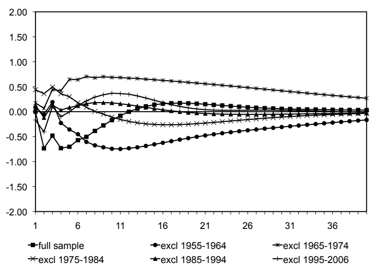
(b) Taxes



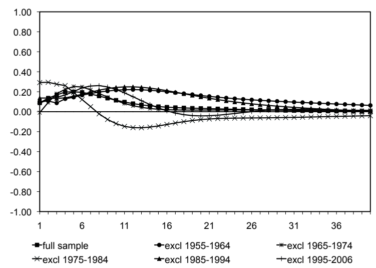
(c) Real output



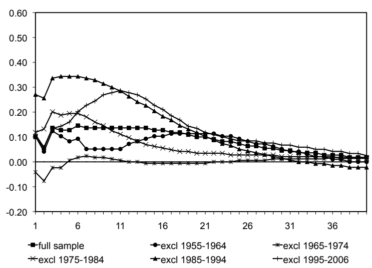
(d) Consumption



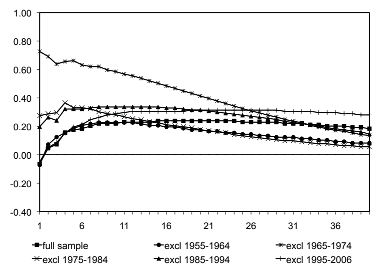
(e) Non-residential investment



(f) Residential investment

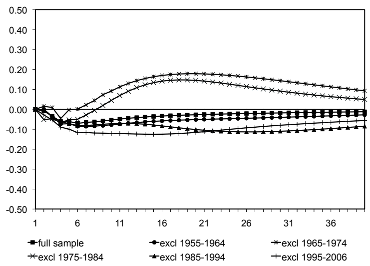


(g) Hours worked

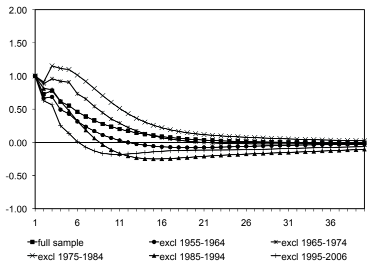


(h) Real wages

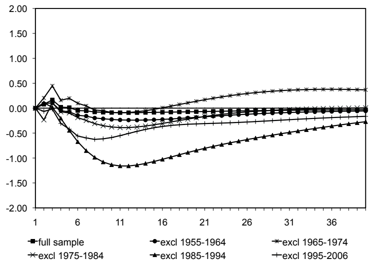
Figure 2.9: Subsample stability: government spending shock.



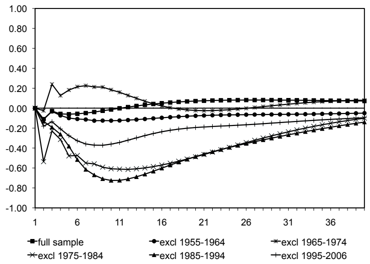
(a) Government spending



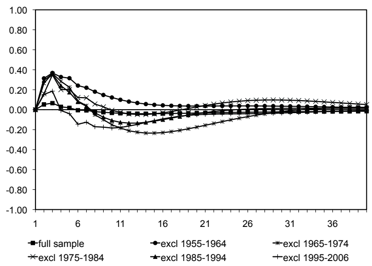
(b) Taxes



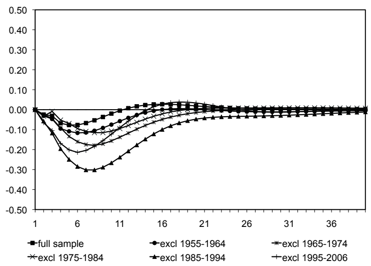
(c) Real output



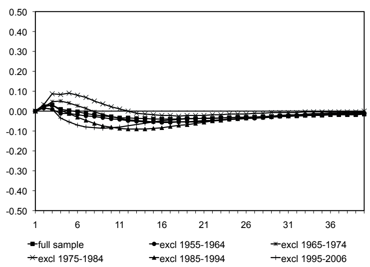
(d) Consumption



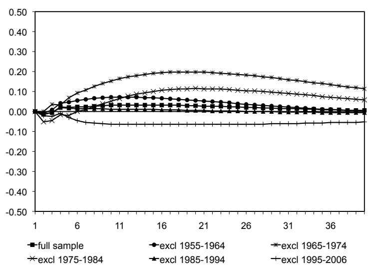
(e) Non-residential investment



(f) Residential investment



(g) Hours worked



(h) Real wages

Figure 2.10: Subsample stability: tax shock.

Chapter 3

US Fiscal Indicators, Inflation and Output [1]

3.1 Introduction

Economists often rely on non-structural autoregressive econometric models such as unrestricted VARs, to explain or to forecast in a parsimonious way variations in key macroeconomic variables such as inflation and output. While US output variations can be explained somewhat reliably with the use of a set of relevant variables such as Federal Funds rate and certain monetary aggregates next to past variations in real output itself, empirical work confronts significant difficulties in assigning informative variables to explain US inflation movements. Even the Federal Funds rate fails to provide statistically significant information content to explain inflation variations in a stable way (see for example Friedman and Kuttner (1992); Stock and Watson (2003)).

Macroeconomic theory is paying increasing attention to the interaction between fiscal and monetary policymaking in stabilizing inflation, employment and real output. Such an interaction and its consequences for macro-fundamentals are usually studied within theoretical general equilibrium modelling. However current theoretical models typically focus on aggregate spending and taxes. We believe that some government expenditure/revenues subcomponents may be better related with macroeconomic variables due to certain institutional features or preferences of policymakers. In the literature, there is already evidence that different institutional arrangements across US states yield different macroeconomic outcomes at least as far as business cycle

[1] This chapter draws on Aksoy, Y. and Melina, G. (2009) US Fiscal Indicators, Inflation and Output, Birkbeck Working Papers in Economics and Finance, 0918. Comments and suggestions by Sergio Destefanis, John Driffill, Miguel Leon-Ledesma, Ron Smith, Martin Sola, Peter Tinsley, Stefania Villa, audiences at the 24th Annual Congress of European Economic Association, the 41st Annual Conference of the Money Macro and Finance Research Group, and seminar participants at Birkbeck College are gratefully acknowledged. The usual disclaimer applies.

fluctuations are concerned. For instance, Fats and Mihov (2006) provide a thorough empirical analysis of the macroeconomic effects of the constraints on fiscal policy and find that states that face tighter restrictions show less volatile business cycles.

In this chapter, we provide new stylized facts for the US economy that may motivate economic theory to explore new transmission channels of fiscal policymaking on macroeconomic outcomes. We take a non-structural, direct, statistical approach as suggested by Friedman and Kuttner (1992) and Sims (1972, 1980) and perform a systematic analysis on the informational role of a wide range of fiscal policy indicators to explain US inflation and real output movements. Reduced form/information value approach, as a preliminary test of statistical connection between certain variables, is immune to questions of causality, exogeneity or controllability of potential instruments.

The discretionary motive or the automatic stabilizers' role in fiscal policymaking is an important and complex topic, but is not the subject matter of this chapter. For a survey of the macroeconometric literature on the identification of discretionary fiscal policy see Chapter 1.

By relying on straightforward statistical tests, we find that certain fiscal indicators, contain additional statistically significant information to explain US inflation and output growth next to the information contained in the Federal Funds rate and autoregressive components of inflation and real output. In particular, we find that changes in the federal budget, federal indirect taxes, as well as state-local expenditures contain valuable lead information for US inflation. Moreover, state-local budget and state-local indirect taxes are helpful in predicting US real output growth. Furthermore, informal and formal statistical tests suggest that the information content present in these variables is stable over time.

To the best of our knowledge, there is neither a theoretical explanation nor other empirical contribution highlighting the different information content of state-local fiscal variables as opposed to the federal counterparts. We suppose that one possible determinant has to do with the different institutional frameworks of the federal and state-local budgets, which we also document.

The remainder of the chapter is organized as follows. Section 3.2 summarizes the conduct of US fiscal policy in postwar years and reviews some existing literature on state-local finances. Section 3.3 presents the dataset used in the chapter. Section 3.4 reports Granger-style regressions based on inflation and real output equations that include a set of alternative fiscal indicators together with the Federal Funds rate. Section 3.5 conducts stability tests. Finally, Section 3.6 concludes.

3.2 Fiscal evolution in the US

Since the 1930s the presence of government in the US economy has steadily increased. Figure 3.1-(a) shows that in postwar times government expenditures have increased from 15 percent of GDP to reach almost 25 percent in the late 1950s and be around 20 percent in more recent times. If we add also transfers - which do not enter the definition of GDP - and consider total government expenditures, which we plot in Figure 3.2-(b), the share is even higher. In 2008 total expenditures have exceeded 35 percent of GDP.

The increase in government expenditures has been recorded both at the federal and at the state-local level. Nevertheless, while state-local receipts have always accompanied the pattern of expenditures, at the federal level expenditures have been higher than revenues for long periods of time. As Figure 3.1-(c) shows, in the first part of the post-war period, the federal budget followed a pattern of deficits during wartime and economic crises and surpluses during peacetime and economic expansion. From 1970 to 1997, the federal deficit was sustained and the budget never balanced. Only in 1998 the federal budget reported its first surplus since 1969. The budget was again in deficit in 2004. In 2005, it began to shrink as a consequence of an increase in tax revenues. Afterwards, a pronounced increase in the federal deficit was recorded.

As Figure 3.1-(c) shows, the sum of state-local budgets behaved in a different way. In aggregate terms, state-local finances have been close to balanced budget. Indeed, when it comes to US state budgets, the leitmotif is balanced budget rules. Although across the US there are disparities in the set of fiscal rules that governs a state's ability to raise and spend revenue, all states but Vermont have a more or less stringent fiscal discipline that foresees balanced budgets. The requirements of the other 49 states can be divided into four groups (Poterba, 1996):

1. In 44 states, the governor must submit a balanced budget, but the state does not have to enact a budget that matches expenditures and revenues.

2. In 37 states, the legislature must enact a balanced budget, yet actual revenues and expenditures may diverge if there are unexpected fiscal shocks after the budget is adopted.

3. In 6 states, when an unexpected deficit develops during the fiscal year, the governor has to correct the deficit in the next budget cycle. Because budget cycles in some states are biennial, this requirement permits substantial periods of budget deficits.

4. In 24 out of the 37 states with balanced budget requirements, the constitution prohibits the government from carrying deficits into the next budget cycle. This provision represents the strictest anti-deficit rule, as it requires the legislature either:

    i. to cut spending; or

ii. to raise taxes in the fiscal year when the deficit emerges; or

iii. to float short-term debt to be retired in the next fiscal year.

In 1987, the Advisory Council on Intergovernmental Relations (ACIR) constructed an index that characterizes fiscal discipline among state governments and ranges from 0 (lax) to 10 (stringent). Only eight states received ACIR scores of 5 or below, whereas 26 received a score of 10 (see Figure 3.2).

Some researchers investigated implications of these institutional arrangements, for key macroeconomic variables, particularly for real output, and for macroeconomic policy. Sørensen and Yosha (2001), for instance, use panel estimation to show that state fiscal policy has a stabilizing influence on output, but this influence differ across business cycles expansions and downturns. When state income rises, government revenue initially increases and then reverts to its initial level, while expenditure remains roughly constant. However, when state income falls, both revenue and expenditure decline with revenue remaining low for a sustained period. Such asymmetries appear to be associated with balanced budget rules or political conservatism (that may in turn lead to constitutional balanced budget rules). More precisely, the tighter the budget rules, the less effective is fiscal policy at stimulating the economy than it is at slowing it. On the contrary, in states with relatively less strict budget rules, such as Massachusetts and New York, fiscal policy appears to mitigate economic slowdowns more than it mutes booms.

Traditionally fiscal policy has received less attention than monetary policy in the macroeconomic literature and, with few exceptions, state fiscal policy has almost been neglected. Among others, Poterba and Rueben (1999) evaluate the effects of state-level revenue and expenditure limits on borrowing costs; Bahl and Martinez-Vazquez (1990) estimate the impact of inflation on the real expenditures of US state-local government; and Sørensen, Wu, and Yosha (2001) investigate the cyclical properties of US state-local government finances.

State-local expenditures currently account for 15 percent of US GDP, while federal expenditures have reached more than 20 percent of GDP. Hence both federal and state budgets represent large shares of the US economy. Moreover, federal and state fiscal policy are intrinsically different because institutional and constitutional arrangements foresee a different discipline for their conduct.

In the remainder of this chapter we distinguish among a large set of aggregate, federal and state-local fiscal indicators and perform a systematic evaluation of their information-content role on US output growth and inflation.

3.3 The data

In the following empirical analysis we use quarterly seasonally-adjusted data covering the period 1955:1-2007:4. We consider US macroeconomic variables, including (i) the real output, represented by GDP expressed in chained 2000 US dollars; (ii) the price level, represented by the GDP deflator; (iii) the interest rate, represented by the three-month federal funds rate (middle rate for each quarter); (iv) thirty-one fiscal indicators belonging to government current receipts and expenditures at the national, federal and state-local levels; (v) a set of price indices for government consumption expenditures and gross investment. Most series are extracted from the database of the Bureau of Economic Analysis (BEA). Federal funds rates are extracted from the database of the Federal Reserve Board of Governors. Table 3.1 reports full descriptions and sources of all the series.

As the detailed fiscal variables under investigation are provided in nominal terms, we deflate them using appropriate price indices. Then, we compute percentage changes in the form of annualized log-differences.[2] Only in the cases of government deficits or surpluses we use proper percentage changes, as they may be negative numbers. We also express the real output growth and the rate of inflation as annualized log-differences. For the sake of comparability, we also annualize the interest rate. We report details of all data transformations in Table 3.2.

In Table 3.3, we report the results of unit root tests performed on all the series constructed as explained above. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests reject the null hypothesis of a unit root for real output growth and the growth rates of all the fiscal variables. The level of the interest rate satisfies stationarity properties according to the PP test at a 5 percent significant level and also according to the ADF test at a 10 percent significance level. The rate of inflation is stationary only according to the PP test. In the remainder of the chapter we rely on the stationarity of all the aforementioned series.

3.4 Granger non-causality tests

In this section, we investigate the information content of fluctuations of fiscal indicators for output growth and inflation by means of Granger non-causality tests. By definition of Granger causality itself (Granger, 1969; Sims, 1972), we are not looking for a proper causality relationship. Instead, we aim at detecting whether, in the fluctuations of some fiscal indicators, there is exploitable information that helps predict fluctuations in output and prices, beyond those already predictable on the basis of fluctuations in output and prices themselves and other promptly observable variables, such as the interest rate.

[2] Given a quarterly variable X_t, $\Delta x_t = 400 \times (\ln X_t - \ln X_{t-1})$.

Our specifications for real output changes and inflation follow closely Friedman and Kuttner (1992). However, while they try a number of alternative financial variables and monetary aggregates as a proxy of the monetary policy instrument, we simply use the short-term interest rate. This choice depends on the fact that we are interested in the information content of fiscal indicators and not in the comparative performance of alternative financial variables.

The specification for real output changes Δy_t is given by the following equation:

$$\Delta y_t = \alpha + \sum_{j=1}^{4} \beta_j \Delta y_{t-j} + \sum_{j=1}^{4} \lambda_j \Delta p_{t-j} + \sum_{j=1}^{4} \delta_j i_{t-j} + \sum_{j=1}^{4} \gamma_j \Delta g_{t-j} + \nu_t \tag{3.1}$$

The terms Δy_t, Δp_t, i_t, Δg_t, ν_t represent output growth, inflation, the short term interest rate, the change in an alternative fiscal indicator and an error term respectively.

The inflation equation takes the following specification:

$$\Delta p_t = \alpha + \sum_{j=1}^{4} \beta_j \Delta p_{t-j} + \sum_{j=1}^{4} \lambda_j \Delta y_{t-j} + \sum_{j=1}^{4} \delta_j i_{t-j} + \sum_{j=1}^{4} \gamma_j \Delta g_{t-j} + \nu_t \tag{3.2}$$

where all variables are defined as in equation (1).[3]

In Table 3.4, we report a set of specification tests. With the exception of two cases, the Breusch-Pagan-Godfrey test and the White test always reject the null hypothesis of homoskedastic errors. The Breusch-Godfrey Lagrange-multiplier test fails to reject the null of uncorrelated errors. Therefore, throughout the chapter we choose to run all tests based on Wald-type χ-square statistics computed by taking White heteroskedasticity-consistent standard errors. Finally, the Ramsey RESET test does not unveil further mispecification issues.

We test for Granger non-causality of the fiscal indicators by imposing the null hypothesis that all the lags of each alternative indicator are jointly insignificant, i.e. $H_O : \gamma_i = 0, \forall i = 1, ..., 4$. In Table 3.5, we show that fluctuations in government indirect taxes (taxes on production and import) and in the government surplus/deficit have information content on both output growth and inflation. At a more disaggregated level, fluctuations in state-local indirect taxes and deficit contain useful information for output growth (at a 1 percent significance level); for inflation it is the federal analogues to be informative (at 1 percent and 5 percent significance levels, respectively). Moreover, contributions for government social insurance at the national and federal level and the non-defense component of federal expenditures help predict output growth. Finally, state-local total expenditures, and gross investment help predict inflation at a 10 percent significance level.

Some previous studies have explored state-local finances and we surveyed them in Section 3.2.

[3] We also run the tests described below using first differences of the Federal funds rate but differences in the results are negligible.

However, to our knowledge, there are no other contributions that find an information-content role for state-local expenditures on US inflation and state-local revenues or deficits on output growth.

We also report Granger causality tests run on the Federal funds rate. In all specifications, this is significant at a 1 percent level in the output growth equation and insignificant in the inflation equation.[4] However, adding more lags of the interest rate (results not reported) helps retrieve significance also in the inflation equation. Thus, in the cases in which we find an information-content role for the fiscal variable, the latter does not substitute but adds further information to that already contained in past values of the interest rate.

In Table 3.6, as a measure of comparative goodness of fit, we report the Akaike information criteria (AIC) of all the estimated specifications of equations (1) and (2) in ascending order. All the specifications in which we find information content in the fiscal variable are among the ones with the lowest AIC (top ten items in Table 3.5). According to AIC, the specifications including indirect taxes are the ones with the best fit.

3.5 Stability tests

3.5.1 Stability of recursive p-values

To gain initial guidance about the stability of the Granger-causality relationships above, we plot the recursive p-values of the Wald tests on the joint insignificance of the lags of each alternative fiscal indicator.

The methodology consists in computing the p-values of the Wald tests above by recursively changing the sample in the estimation. The resulting plots, using the alternative fiscal indicators, are depicted in Figures 3.3 and 3.4. From top to bottom we report stability of p-values at: (a) the national government level; (b) the federal government level; and (c) the state-local government level.

We obtain recursive p-values in three different ways:

1. by fixing the endpoint (end) of the sample and making the starting point shift quarter by quarter from an intermediate point in the sample up to the initial observation. The first p-value reported refers to the sample 1980:3-2007:4; the second p-value refers to the sample 1980:2-2007:4 and so on. The last considered sample is the full sample 1955:1-2007:4.

2. by fixing the starting point (str) of the sample and making the end point shift quarter by quarter from an intermediate point of the sample up to the last available observation. The

[4] In the inflation equation, using four lags, the Federal funds rate is insignificant also in the absence of any fiscal variables.

first considered sample is 1955:1-1979:4. The second sample we consider is 1955:1-1980:1 and so on up to 1955:1-2007:4.

3. by rolling the sample (rol), i.e. by shifting the starting point and the endpoint of the sample quarter by quarter. Hence the initial sample is 1955:1-1979:4, the second sample is 1955:2-1980:1 and so on up to 1980:3-2007:4.

The straight horizontal line in each quadrant of Figures 3.3 and 3.4 represents the 10 percent significance level. Thus, anything below the line represents rejection of the Granger non-causality null hypothesis.

Figure 3.3 shows that, in the output growth equation, recursive p-values of indirect taxes are stable at the national level and less stable at the state-local level. For government surplus/deficit, we find that both at the national and the state-local level, they are statistically significant in most subsample though not in all of them. The p-values of the non-defense part of federal expenditures and contributions for government social insurance are not stable.

Figure 3.4 shows that, apart from some subsamples for government deficit and state-local investment expenditures, the remaining recursive p-values of the fiscal components for which we find an information-content role for inflation are stable.

3.5.2 Formal stability tests

To formally evaluate the stability of coefficients in the Granger-style specifications, we run stability tests for one or more unknown structural breakpoints in the autoregressive coefficients of the fiscal variables.

We compute three different statistics: the Quandt likelihood ratio statistic in Wald form (sup-Wald) as in Andrews (1993); the Andrews and Ploberger (1994) exponential average Wald statistic (exp-Wald); and the Andrews and Ploberger (1994) average Wald statistic (mean-Wald). We apply a 15 percent symmetric sample trimming, which allows us to check whether a breakpoint has occurred in the interval 1963:1-1998:4.

Table 3.7 displays the results of the tests. They fail to reject the null hypothesis of parameter constancy in all cases.[5]

3.5.3 Out-of-sample properties

To evaluate the out-of-sample performances of the estimated equations, we use recursive least squares. For each equation specification, we compute all feasible cases, starting from the smallest

[5] The approximate asymptotic p-values are provided by Hansen (1997).

possible sample size and adding one observation at a time. At each step, we save the one-step ahead forecast error to obtain a series of recursive residuals.[6]

We use each series of recursive residuals to compute the correspondent root mean squared errors (RMSE), which we report in Table 3.8 in ascending order. A relatively low RMSE can be interpreted as a further indicator of stability of the specification in question in comparative terms. The ordering obtained in Table 3.8 is virtually coincident to the ordering implied by AIC in Table 3.6. The specifications where fiscal variables have stable information content for output growth or inflation are also the ones with the best out-of-sample performances. Indirect taxes yield the lowest RMSE both in the output growth and in the inflation equation.

3.6 Concluding remarks

By running a number of straightforward statistical tests, we provide evidence that fluctuations in certain fiscal variables contain valuable information to predict fluctuations in output and prices. Our analysis also shows that the distinction between federal and state-local fiscal indicators provides useful insights.

First, we find that variations in state-local indirect taxes as well as state government surplus or deficit help predict output growth. Next, the federal counterparts of these indicators contain valuable information for inflation. Finally, state-local expenditures help predict US inflation.

A set of formal and informal stability tests confirm that these relationships are stable. The fiscal indicators in questions are also among the ones that yield the best in-sample and out-of-sample performances.

In sum, we provide new stylized facts for US macroeconomic conditions related to fiscal indicators. We believe that these new stylized facts can help identify possible fiscal and monetary policy transmission channels that can be explored in future empirical and theoretical research.

[6]To obtain the recursive residuals we scale each one-step ahead forecast error by a term proportional to the forecast variance. Namely, let $x_t'b_{t-1}$ be the forecast, where x_t' is the row vector of observations on the regressors in period t and b_{t-1} is the estimated vector of coefficients obtained by using data up to period $t-1$. The forecast error is $y_t - x_t'b_{t-1}$, where y_t is the actual observation of the dependent variable, while the forecast variance is $\sigma^2\left(1 + x_t'\left(X_t'X_t\right)^{-1}x_t\right)$. We compute the recursive residual r_t as $r_t = \frac{\left(y_t - x_t'b_{t-1}\right)}{\left(1+x_t'\left(X_t'X_t\right)^{-1}x_t\right)^{1/2}}$.

Variables	Measurement unit	Type	Freq.	Sample	Source		
Gross domestic product	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	1.1.5
Real Gross Domestic Product	Billions of 2000 dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	1.1.6
Implicit GDP deflator	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	1.1.9
Three-month federal funds rate	Percentage	MR	Q.ly	1955:1-2007:4	Federal Reserve Board		
Government Current Receipts and Expenditures:							
Current tax receipts	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.1
Personal current taxes	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.1
Taxes on production and imports	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.1
Taxes on corporate income	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.1
Contributions for government social insurance	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.1
Total expenditures	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.1
Current expenditures	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.1
Gross government investment	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.1
Net lending or net borrowing (-)	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.1
Federal Government Current Receipts and Expenditures:							
Total receipts	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.2
Current tax receipts	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.2
Personal current taxes	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.2
Taxes on production and imports	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.2
Taxes on corporate income	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.2
Contributions for government social insurance	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.2
Total expenditures	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.2
Current expenditures	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.2
Gross government investment	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.2
Federal defense expenditures	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	1.1.5
Federal nondefense expenditures	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	1.1.5
Net lending or net borrowing (-)	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.2
State and Local Government Current Receipts and Expenditures:							
Total receipts	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.3
Current tax receipts	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.3
Personal current taxes	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.3
Taxes on production and imports	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.3
Taxes on corporate income	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.3
Current transfer receipts	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.3
Total expenditures	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.3
Current expenditures	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.3
Gross government investment	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.3
Net lending or net borrowing (-)	Billions of current dollars	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.3
Price Indices for Government Consumption Expenditures and Gross Investment:							
Government expenditures	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.9.4
Government consumption expenditures	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.9.4
Government gross investment	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.9.4
Federal expenditures	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.9.4
Federal consumption expenditures	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.9.4
Federal gross investment	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.9.4
National defense	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.9.4
Federal nondefense expenditures	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.9.4
State and local expenditures	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.9.4
State and local consumption expenditures	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.9.4
State and local gross investment	Index numbers 2000=100	SA	Q.ly	1955:1-2007:4	BEA	NIPA Table	3.9.4

SA = seasonally adjusted; MR = middle rate; Q.ly = quarterly; BEA = Bureau of Economic Analysis; NIPA = National Income and Product Accounts

Table 3.1: Data sources and description.

Keywords	Variables	Transformations
gdp	Real GDP growth rate	Annualized log-difference in real GDP
inf	Inflation rate	Annualized log-difference of the Implicit GDP deflator
int	Interest rate	Annualized three-month Federal funds rate
	Government Current Receipts and Expenditures:	
gov.cur.tax	Current tax receipts	Annualized log-difference (deflated using government expenditures price index)
gov.per.tax	Personal current taxes	Annualized log-difference (deflated using government expenditures price index)
gov.pro.tax	Taxes on production and imports	Annualized log-difference (deflated using government expenditures price index)
gov.cor.tax	Taxes on corporate income	Annualized log-difference (deflated using government expenditures price index)
gov.soc.con	Contributions for government social insurance	Annualized log-difference (deflated using government expenditures price index)
gov.tot.exp	Total expenditures	Annualized log-difference (deflated using government expenditures price index)
gov.cur.exp	Current expenditures	Annualized log-difference (deflated using government consumption expenditures price index)
gov.inv.exp	Gross government investment	Annualized log-difference (deflated using government gross investment expenditures price index)
gov.sur.def	Net lending or net borrowing (-)	Annualized growth rate (deflated using government expenditures price index)
	Federal Government Current Receipts and Expenditures:	
fed.tot.rec	Total receipts	Annualized log-difference (deflated using federal expenditures price index)
fed.cur.tax	Current tax receipts	Annualized log-difference (deflated using federal expenditures price index)
fed.per.tax	Personal current taxes	Annualized log-difference (deflated using federal expenditures price index)
fed.pro.tax	Taxes on production and imports	Annualized log-difference (deflated using federal expenditures price index)
fed.cor.tax	Taxes on corporate income	Annualized log-difference (deflated using federal expenditures price index)
fed.soc.con	Contributions for government social insurance	Annualized log-difference (deflated using federal expenditures price index)
fed.tot.exp	Total expenditures	Annualized log-difference (deflated using federal expenditures price index)
fed.cur.exp	Current expenditures	Annualized log-difference (deflated using federal consumption expenditures price index)
fed.inv.exp	Gross government investment	Annualized log-difference (deflated using federal gross investment expenditures price index)
fed.def.exp	Federal defense expenditures	Annualized log-difference (deflated using national defense expenditures price index)
fed.non.exp	Federal nondefense expenditures	Annualized log-difference (deflated using federal nondefense expenditures price index)
fed.sur.def	Net lending or net borrowing (-)	Annualized growth rate (deflated using federal expenditures price index)
	State and Local Government Current Receipts and Expenditures:	
stl.tot.rec	Total receipts	Annualized log-difference (deflated using state and local expenditures price index)
stl.cur.tax	Current tax receipts	Annualized log-difference (deflated using state and local expenditures price index)
stl.per.tax.	Personal current taxes	Annualized log-difference (deflated using state and local expenditures price index)
stl.pro.tax	Taxes on production and imports	Annualized log-difference (deflated using state and local expenditures price index)
stl.cor.tax	Taxes on corporate income	Annualized log-difference (deflated using state and local expenditures price index)
stl.cur.tra	Current transfer receipts	Annualized log-difference (deflated using state and local expenditures price index)
stl.tot.exp	Total expenditures	Annualized log-difference (deflated using state and local expenditures price index)
stl.cur.exp	Current expenditures	Annualized log-difference (deflated using state and local consumption expenditures price index)
stl.inv.exp.	Gross government investment	Annualized log-difference (deflated using state and local investment expenditures price index)
stl.sur.def	Net lending or net borrowing (-)	Annualized growth rate (deflated using state and local expenditures price index)

Table 3.2: Data transformations.

Variables	Augmented Dickey-Fuller test (ADF)		Phillips-Perron test (PP)	
	t-stats	*p-values*	*t-stats*	*p-values*
gdp	-10.9112	(0.0000)	-10.9812	(0.0000)
inf	-2.1274	(0.2342)	-4.190879	(0.0009)
int	-2.8568	(0.0523)	-3.132269	(0.0257)
gov.cur.tax	-8.5639	(0.0000)	-16.2127	(0.0000)
gov.per.tax	-18.3438	(0.0000)	-17.9302	(0.0000)
gov.pro.tax	-7.6636	(0.0000)	-12.4060	(0.0000)
gov.cor.tax	-13.5744	(0.0000)	-13.5755	(0.0000)
gov.soc.con	-2.8618	(0.0517)	-15.8516	(0.0000)
gov.tot.exp	-9.3278	(0.0000)	-16.7690	(0.0000)
gov.cur.exp	-17.7244	(0.0000)	-17.4116	(0.0000)
gov.inv.exp	-16.2586	(0.0000)	-16.2882	(0.0000)
gov.sur.def	-13.9264	(0.0000)	-13.9145	(0.0000)
fed.tot.rec	-8.5575	(0.0000)	-15.3287	(0.0000)
fed.cur.tax	-9.1224	(0.0000)	-17.2200	(0.0000)
fed.per.tax	-19.1650	(0.0000)	-18.6149	(0.0000)
fed.pro.tax	-12.9510	(0.0000)	-12.9510	(0.0000)
fed.cor.tax	-13.0793	(0.0000)	-13.0852	(0.0000)
fed.soc.con	-2.9523	(0.0413)	-15.6640	(0.0000)
fed.tot.exp	-19.2433	(0.0000)	-18.6956	(0.0000)
fed.cur.exp	-19.4290	(0.0000)	-18.9807	(0.0000)
fed.inv.exp	-17.7737	(0.0000)	-17.6694	(0.0000)
fed.def.exp	-3.9773	(0.0018)	-15.0505	(0.0000)
fed.non.exp	-20.5565	(0.0000)	-20.5565	(0.0000)
fed.sur.def	-14.4366	(0.0000)	-14.4776	(0.0000)
stl.tot.rec	-6.0987	(0.0000)	-16.2525	(0.0000)
stl.cur.tax	-7.7403	(0.0000)	-13.0661	(0.0000)
stl.per.tax.	-15.4744	(0.0000)	-15.4320	(0.0000)
stl.pro.tax	-4.5269	(0.0002)	-12.1120	(0.0000)
stl.cor.tax	-17.5813	(0.0000)	-17.6033	(0.0000)
stl.cur.tra	-6.8350	(0.0000)	-22.0017	(0.0000)
stl.tot.exp	-5.5520	(0.0000)	-14.0800	(0.0000)
stl.cur.exp	-4.2078	(0.0008)	-12.2308	(0.0000)
stl.inv.exp.	-14.5562	(0.0000)	-14.5566	(0.0000)
stl.sur.def	-13.5389	(0.0000)	-13.5801	(0.0000)

ADF and PP tests run with the inclusion of a constant; Lag length chosen using the Schwarz Information Criterion in ADF.

Table 3.3: Unit root tests.

Fiscal variables	Output growth equation								Inflation equation							
	Breuch-Pagan-Godfrey		White test		Breuch-Godfrey-LM		Ramsey RESET		Breuch-Pagan-Godfrey		White test		Breuch-Godfrey-LM		Ramsey RESET	
gov.cur.tax	30.0535	(0.0177)	27.7301	(0.0340)	3.0189	(0.2210)	0.4665	(0.4946)	47.5318	(0.0001)	51.9701	(0.0000)	2.1697	(0.3380)	0.0652	(0.7984)
gov.per.tax	28.3064	(0.0291)	28.7500	(0.0257)	2.9638	(0.2272)	0.4351	(0.5095)	48.3758	(0.0000)	55.8647	(0.0000)	2.2359	(0.3269)	0.1042	(0.7469)
gov.pro.tax	21.7666	(0.1509)	17.6906	(0.3423)	2.0222	(0.3638)	0.1537	(0.6950)	39.8267	(0.0008)	44.1568	(0.0002)	0.7144	(0.6996)	0.4329	(0.5105)
gov.cor.tax	28.3674	(0.0286)	25.8150	(0.0567)	2.9231	(0.2319)	0.4035	(0.5253)	46.9386	(0.0001)	45.4516	(0.0001)	2.6063	(0.2717)	0.5991	(0.4389)
gov.soc.con	36.9278	(0.0021)	36.8698	(0.0022)	2.8672	(0.2384)	0.5367	(0.4638)	45.7168	(0.0001)	41.5154	(0.0005)	1.8356	(0.3994)	0.3145	(0.5750)
gov.tot.exp	27.1995	(0.0393)	26.8702	(0.0429)	3.4646	(0.1769)	0.5543	(0.4566)	54.1273	(0.0000)	53.2898	(0.0000)	0.6445	(0.7245)	0.6068	(0.4360)
gov.cur.exp	30.2789	(0.0166)	31.4963	(0.0116)	1.2681	(0.5304)	1.3156	(0.2514)	52.9811	(0.0000)	53.3006	(0.0000)	0.2395	(0.8871)	0.5589	(0.4547)
gov.inv.exp	29.0233	(0.0238)	30.0920	(0.0175)	7.3572	(0.0253)	0.4978	(0.4805)	42.7754	(0.0003)	35.7204	(0.0032)	4.0705	(0.1306)	1.3200	(0.2506)
gov.sur.def	37.8796	(0.0016)	43.0142	(0.0003)	2.2070	(0.3317)	0.2243	(0.6358)	40.3884	(0.0007)	39.8234	(0.0008)	2.1146	(0.3474)	0.2097	(0.6470)
fed.tot.rec	29.9266	(0.0184)	24.7488	(0.0744)	3.4300	(0.1800)	0.5644	(0.4525)	50.8298	(0.0000)	49.3910	(0.0000)	4.4853	(0.1062)	0.2476	(0.6188)
fed.cur.tax	30.6764	(0.0148)	27.3490	(0.0378)	2.8090	(0.2455)	0.2230	(0.6367)	49.9212	(0.0000)	53.5791	(0.0000)	3.1599	(0.2060)	0.1294	(0.7191)
fed.per.tax	28.1606	(0.0303)	28.2717	(0.0293)	2.5759	(0.2758)	0.1576	(0.6914)	50.3500	(0.0000)	56.7215	(0.0000)	2.6886	(0.2607)	0.1248	(0.7239)
fed.pro.tax	19.4931	(0.2439)	18.0494	(0.3210)	3.0350	(0.2193)	0.9599	(0.3272)	48.2659	(0.0000)	42.9252	(0.0003)	1.5885	(0.4519)	0.4899	(0.4840)
fed.cor.tax	27.9604	(0.0320)	25.4442	(0.0624)	3.0681	(0.2157)	0.3613	(0.5478)	45.1146	(0.0001)	42.9545	(0.0003)	2.6855	(0.2611)	0.8573	(0.3545)
fed.soc.con	35.1224	(0.0038)	36.3413	(0.0026)	2.7468	(0.2532)	0.3382	(0.5608)	46.2750	(0.0001)	38.8735	(0.0011)	1.2927	(0.5240)	0.5943	(0.4408)
fed.tot.exp	25.7500	(0.0576)	27.2292	(0.0390)	2.6871	(0.2609)	0.7787	(0.3775)	50.3289	(0.0000)	51.8220	(0.0000)	0.2669	(0.8751)	1.2105	(0.2712)
fed.cur.exp	29.3493	(0.0217)	32.8053	(0.0078)	1.9718	(0.3731)	1.3402	(0.2470)	46.0234	(0.0001)	49.8820	(0.0000)	0.1092	(0.9469)	0.8037	(0.3700)
fed.inv.exp	31.5819	(0.0113)	30.5065	(0.0155)	1.1587	(0.5603)	0.3909	(0.5318)	52.7107	(0.0000)	44.5924	(0.0002)	5.4007	(0.0672)	1.2695	(0.2599)
fed.def.exp	29.4603	(0.0210)	30.6385	(0.0150)	2.4090	(0.2998)	0.5526	(0.4573)	54.3580	(0.0000)	45.8918	(0.0001)	0.5145	(0.7732)	0.5220	(0.4700)
fed.non.exp	28.9334	(0.0244)	38.3792	(0.0013)	2.0776	(0.3539)	1.1684	(0.2797)	44.6951	(0.0002)	44.9907	(0.0001)	3.2753	(0.1944)	0.2615	(0.6091)
fed.sur.def	24.6926	(0.0754)	26.2359	(0.0508)	2.4907	(0.2878)	0.3106	(0.5773)	40.8779	(0.0006)	35.1980	(0.0037)	2.0516	(0.3585)	0.8923	(0.3449)
stl.tot.rec	30.2291	(0.0169)	23.8421	(0.0930)	2.2923	(0.3179)	0.0500	(0.8230)	44.2123	(0.0002)	46.0552	(0.0001)	3.8550	(0.1455)	0.0281	(0.8668)
stl.cur.tax	27.9141	(0.0324)	26.8247	(0.0435)	4.0794	(0.1301)	0.7210	(0.3958)	47.0357	(0.0001)	48.9691	(0.0000)	1.6514	(0.4379)	0.1654	(0.6842)
stl.per.tax.	27.8255	(0.0332)	26.8129	(0.0436)	3.5965	(0.1656)	0.9835	(0.3213)	46.2838	(0.0001)	43.3272	(0.0002)	2.1096	(0.3483)	0.1420	(0.7063)
stl.pro.tax	32.2064	(0.0094)	27.1750	(0.0396)	5.8823	(0.0528)	0.2622	(0.6086)	43.2851	(0.0003)	41.5307	(0.0005)	0.4488	(0.7990)	0.2475	(0.6188)
stl.cor.tax	34.3212	(0.0049)	30.3233	(0.0164)	3.0819	(0.2142)	0.0673	(0.7954)	48.1193	(0.0000)	49.6300	(0.0000)	2.0602	(0.3570)	0.1668	(0.6829)
stl.cur.tra	28.8225	(0.0252)	26.3949	(0.0487)	3.1574	(0.2062)	0.2996	(0.5841)	45.2999	(0.0001)	45.5043	(0.0001)	5.7273	(0.0571)	0.0883	(0.7663)
stl.tot.exp	30.6818	(0.0148)	30.1497	(0.0172)	3.3484	(0.1875)	1.0278	(0.3107)	38.7131	(0.0012)	37.4528	(0.0018)	2.7220	(0.2564)	0.5453	(0.4602)
stl.cur.exp	33.3712	(0.0066)	33.8621	(0.0057)	1.2353	(0.5392)	0.0802	(0.7771)	50.7820	(0.0000)	51.5933	(0.0000)	3.6920	(0.1579)	0.1310	(0.7174)
stl.inv.exp.	23.2621	(0.1069)	28.6264	(0.0266)	3.4686	(0.1765)	0.0756	(0.7833)	35.7884	(0.0031)	41.0812	(0.0005)	3.3281	(0.1894)	0.2161	(0.6420)
stl.sur.def	29.9090	(0.0185)	23.9147	(0.0914)	1.4805	(0.4770)	0.1695	(0.6806)	46.1062	(0.0001)	41.1203	(0.0005)	4.4023	(0.1107)	1.0180	(0.3130)

p-values in parenthesis

Table 3.4: Specification tests.

Fiscal variables	Output growth equation				Inflation equation			
	Fiscal variables		Federal funds rate		Fiscal variables		Federal funds rate	
	c-square	p-values	c-square	p-values	c-square	p-values	c-square	p-values
gov.cur.tax	3.5462	(0.4709)	19.0550	(0.0008)	2.1616	(0.7061)	1.4633	(0.8331)
gov.per.tax	3.0623	(0.5475)	18.4839	(0.0010)	2.0391	(0.7286)	1.4795	(0.8303)
gov.pro.tax	14.9401	(0.0048)	23.0491	(0.0001)	20.5659	(0.0004)	1.7041	(0.7900)
gov.cor.tax	1.8696	(0.7597)	17.5770	(0.0015)	5.5539	(0.2350)	1.7759	(0.7769)
gov.soc.con	10.4189	(0.0339)	15.3063	(0.0041)	2.1430	(0.7095)	1.3928	(0.8454)
gov.tot.exp	0.1661	(0.9967)	15.5148	(0.0037)	1.9437	(0.7461)	0.9218	(0.9214)
gov.cur.exp	3.8270	(0.4299)	18.5037	(0.0010)	4.3615	(0.3593)	1.3653	(0.8502)
gov.inv.exp	6.7417	(0.1502)	19.1063	(0.0007)	6.1831	(0.1859)	1.4585	(0.8340)
gov.sur.def	11.6294	(0.0203)	19.4145	(0.0007)	29.7478	(0.0000)	1.3872	(0.8464)
fed.tot.rec	2.7049	(0.6084)	15.7454	(0.0034)	1.9299	(0.7486)	1.3772	(0.8481)
fed.cur.tax	2.3115	(0.6787)	17.8673	(0.0013)	1.7567	(0.7804)	1.3025	(0.8609)
fed.per.tax	3.0183	(0.5548)	18.1214	(0.0012)	0.8239	(0.9352)	1.4074	(0.8429)
fed.pro.tax	6.1482	(0.1883)	20.1472	(0.0005)	17.4563	(0.0016)	1.4264	(0.8396)
fed.cor.tax	2.2163	(0.6960)	18.1791	(0.0011)	5.5229	(0.2377)	1.7569	(0.7804)
fed.soc.con	11.9526	(0.0177)	14.0641	(0.0071)	3.2944	(0.5098)	1.5173	(0.8236)
fed.tot.exp	0.6503	(0.9573)	15.7254	(0.0034)	4.4439	(0.3493)	1.3198	(0.8580)
fed.cur.exp	2.7462	(0.6011)	17.5932	(0.0015)	5.0941	(0.2778)	1.4917	(0.8281)
fed.inv.exp	2.1053	(0.7164)	18.0301	(0.0012)	7.3973	(0.1163)	1.4480	(0.8358)
fed.def.exp	2.8284	(0.5869)	16.6178	(0.0023)	4.4005	(0.3545)	1.3658	(0.8501)
fed.non.exp	8.3429	(0.0798)	15.2296	(0.0042)	0.8795	(0.9275)	1.4301	(0.8390)
fed.sur.def	2.4737	(0.6494)	15.8904	(0.0032)	10.0731	(0.0392)	1.6371	(0.8021)
stl.tot.rec	7.6172	(0.1066)	14.2508	(0.0065)	7.2555	(0.1230)	1.6687	(0.7964)
stl.cur.tax	6.7594	(0.1492)	16.6685	(0.0022)	5.8524	(0.2104)	1.4378	(0.8376)
stl.per.tax.	4.8029	(0.3081)	16.8764	(0.0020)	6.4619	(0.1672)	1.5752	(0.8133)
stl.pro.tax	17.6625	(0.0014)	15.8133	(0.0033)	7.1507	(0.1281)	1.2723	(0.8661)
stl.cor.tax	5.3520	(0.2530)	17.0132	(0.0019)	3.2190	(0.5219)	1.4893	(0.8285)
stl.cur.tra	0.5540	(0.9680)	16.0980	(0.0029)	4.2655	(0.3713)	1.6877	(0.7930)
stl.tot.exp	1.8923	(0.7556)	17.3636	(0.0016)	7.8744	(0.0963)	1.6760	(0.7951)
stl.cur.exp	1.2100	(0.8765)	17.3008	(0.0017)	1.3549	(0.8520)	1.4468	(0.8360)
stl.inv.exp.	7.3464	(0.1187)	16.8990	(0.0020)	8.8755	(0.0643)	1.7774	(0.7766)
stl.sur.def	29.7698	(0.0000)	16.3544	(0.0026)	7.6090	(0.1070)	1.2648	(0.8673)

Table 3.5: Granger non-causality tests.

Output growth equation				Inflation equation			
AIC	Fiscal variable	AIC	Fiscal variable	AIC	Fiscal variable	AIC	Fiscal variable
5.2164	gov.pro.tax	5.2732	stl.cor.tax	3.1024	gov.pro.tax	3.1529	gov.cor.tax
5.2260	stl.pro.tax	5.2772	gov.cur.tax	3.1126	fed.pro.tax	3.1541	stl.sur.def
5.2266	fed.non.exp	5.2786	fed.def.exp	3.1129	gov.sur.def	3.1546	stl.tot.rec
5.2370	fed.soc.con	5.2793	fed.inv.exp	3.1315	fed.sur.def	3.1556	fed.soc.con
5.2420	gov.soc.con	5.2811	fed.sur.def	3.1319	stl.pro.tax	3.1588	stl.cur.tra
5.2424	stl.sur.def	5.2814	stl.tot.exp	3.1339	fed.cur.exp	3.1629	gov.tot.exp
5.2480	gov.sur.def	5.2816	fed.cur.tax	3.1343	fed.inv.exp	3.1634	gov.soc.con
5.2525	stl.inv.exp.	5.2824	fed.per.tax	3.1363	stl.inv.exp.	3.1646	stl.cor.tax
5.2558	stl.tot.rec	5.2827	gov.per.tax	3.1381	stl.tot.exp	3.1663	gov.per.tax
5.2583	fed.pro.tax	5.2832	fed.cor.tax	3.1382	fed.tot.exp	3.1669	gov.cur.tax
5.2605	stl.cur.tax	5.2851	gov.cor.tax	3.1412	gov.cur.exp	3.1677	fed.tot.rec
5.2626	gov.inv.exp	5.2862	stl.cur.exp	3.1425	stl.cur.tax	3.1699	fed.cur.tax
5.2659	gov.cur.exp	5.2873	fed.tot.exp	3.1429	gov.inv.exp	3.1724	stl.cur.exp
5.2715	stl.per.tax.	5.2878	stl.cur.tra	3.1447	stl.per.tax.	3.1725	fed.non.exp
5.2716	fed.cur.exp	5.2904	gov.tot.exp	3.1500	fed.cor.tax	3.1727	fed.per.tax
5.2723	fed.tot.rec			3.1514	fed.def.exp		

Table 3.6: Akaike information criteria (AIC).

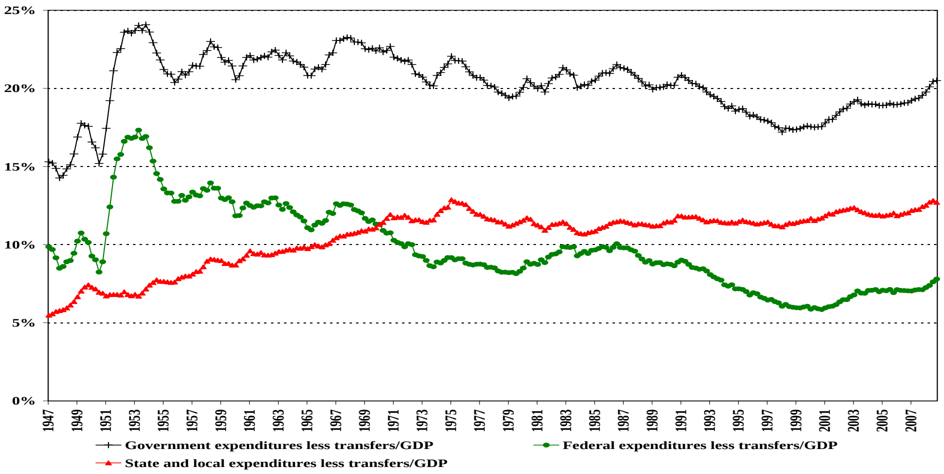
Fiscal variables	Output growth equation						Inflation equation					
	sup-Wald	p-values	exp-Wald	p-values	mean-Wald	p-values	sup-Wald	p-values	exp-Wald	p-values	mean-Wald	p-values
gov.cur.tax	3.4857	(0.9949)	0.8313	(0.9893)	1.6046	(0.9743)	2.0068	(1.0000)	0.4355	(1.0000)	0.8182	(1.0000)
gov.per.tax	6.2488	(0.8163)	0.7653	(0.9959)	1.1998	(0.9998)	2.1585	(1.0000)	0.4797	(1.0000)	0.9192	(1.0000)
gov.pro.tax	3.6859	(0.9913)	0.6293	(1.0000)	1.1685	(1.0000)	2.1380	(1.0000)	0.3874	(1.0000)	0.7272	(1.0000)
gov.cor.tax	3.9246	(0.9854)	1.1305	(0.9264)	2.0496	(0.8976)	3.9605	(0.9844)	0.9977	(0.9602)	1.6846	(0.9638)
gov.soc.con	2.9049	(0.9995)	0.4370	(1.0000)	0.8135	(1.0000)	3.2725	(0.9974)	0.9894	(0.9621)	1.7891	(0.9477)
gov.tot.exp	4.6004	(0.9571)	1.1852	(0.9103)	1.9160	(0.9249)	9.2532	(0.4563)	1.8696	(0.6615)	1.3541	(0.9956)
gov.cur.exp	6.7665	(0.7569)	1.4605	(0.8167)	2.0970	(0.8872)	6.7172	(0.7627)	1.2083	(0.9032)	1.2773	(0.9985)
gov.inv.exp	3.2391	(0.9977)	0.6918	(0.9995)	1.2691	(0.9987)	1.7932	(1.0000)	0.5309	(1.0000)	1.0441	(1.0000)
gov.sur.def	3.2011	(0.9980)	0.8185	(0.9908)	1.5689	(0.9784)	1.8732	(1.0000)	0.5818	(1.0000)	1.1377	(1.0000)
fed.tot.rec	2.9396	(0.9994)	0.8770	(0.9830)	1.6759	(0.9650)	1.8589	(1.0000)	0.4965	(1.0000)	0.9580	(1.0000)
fed.cur.tax	3.8175	(0.9883)	0.9805	(0.9640)	1.8820	(0.9313)	1.9801	(1.0000)	0.4813	(1.0000)	0.9186	(1.0000)
fed.per.tax	6.7575	(0.7579)	0.8831	(0.9821)	1.3377	(0.9964)	2.3799	(1.0000)	0.5696	(1.0000)	1.0754	(1.0000)
fed.pro.tax	3.2919	(0.9972)	0.9468	(0.9709)	1.7714	(0.9506)	2.9089	(0.9995)	0.5796	(1.0000)	1.0213	(1.0000)
fed.cor.tax	4.9948	(0.9321)	1.4144	(0.8335)	2.5471	(0.7764)	4.2364	(0.9746)	1.0575	(0.9460)	1.7772	(0.9497)
fed.soc.con	1.7895	(1.0000)	0.3882	(1.0000)	0.7444	(1.0000)	4.4583	(0.9645)	1.1141	(0.9310)	1.8468	(0.9377)
fed.tot.exp	5.4252	(0.8980)	1.3873	(0.8431)	2.1949	(0.8648)	5.9551	(0.8476)	1.0870	(0.9384)	1.3764	(0.9945)
fed.cur.exp	4.4282	(0.9660)	1.0324	(0.9522)	1.7572	(0.9529)	6.6859	(0.7664)	1.2330	(0.8954)	1.2821	(0.9984)
fed.inv.exp	4.3572	(0.9693)	0.8000	(0.9928)	1.4212	(0.9917)	2.5260	(1.0000)	0.5754	(1.0000)	1.0984	(1.0000)
fed.def.exp	1.3084	(1.0000)	0.3354	(1.0000)	0.6496	(1.0000)	2.6108	(1.0000)	0.6329	(1.0000)	1.1891	(0.9999)
fed.non.exp	5.7323	(0.8698)	1.3001	(0.8734)	2.0469	(0.8982)	5.3024	(0.9084)	1.5980	(0.7652)	2.6954	(0.7371)
fed.sur.def	5.2423	(0.9133)	1.6000	(0.7644)	3.0506	(0.6424)	3.9108	(0.9858)	1.5412	(0.7867)	2.9150	(0.6784)
stl.tot.rec	7.3565	(0.6850)	1.8982	(0.6507)	2.4108	(0.8117)	2.8370	(0.9997)	0.6660	(0.9999)	1.1650	(1.0000)
stl.cur.tax	11.3773	(0.2562)	2.8785	(0.3364)	3.0954	(0.6306)	2.4432	(1.0000)	0.6453	(1.0000)	1.2460	(0.9992)
stl.per.tax.	1.1555	(1.0000)	0.2440	(1.0000)	0.4732	(1.0000)	1.4235	(1.0000)	0.4413	(1.0000)	0.8608	(1.0000)
stl.pro.tax	3.7543	(0.9898)	0.7135	(0.9989)	1.3026	(0.9978)	1.2685	(1.0000)	0.2859	(1.0000)	0.5498	(1.0000)
stl.cor.tax	3.5535	(0.9938)	0.6951	(0.9995)	1.2068	(0.9998)	2.1726	(1.0000)	0.5280	(1.0000)	0.9489	(1.0000)
stl.cur.tra	4.0669	(0.9809)	1.1044	(0.9337)	2.1496	(0.8753)	2.5392	(1.0000)	0.6009	(1.0000)	1.1094	(1.0000)
stl.tot.exp	3.2288	(0.9978)	0.6450	(1.0000)	1.1940	(0.9999)	4.3080	(0.9715)	0.8107	(0.9917)	1.3322	(0.9966)
stl.cur.exp	2.1365	(1.0000)	0.4470	(1.0000)	0.8506	(1.0000)	1.1580	(1.0000)	0.3278	(1.0000)	0.6441	(1.0000)
stl.inv.exp.	2.9690	(0.9993)	0.4454	(1.0000)	0.7940	(1.0000)	3.2065	(0.9980)	0.9298	(0.9741)	1.6834	(0.9640)
stl.sur.def	4.4729	(0.9638)	1.1119	(0.9316)	1.8026	(0.9454)	3.4985	(0.9947)	0.7313	(0.9981)	1.3772	(0.9944)

15 percent symmetric trimming; Test sample: 1963:1-1998:4; Null hypothesis: no structural breaks in the fiscal variables; Hansen (1997) asymptotic p-values.

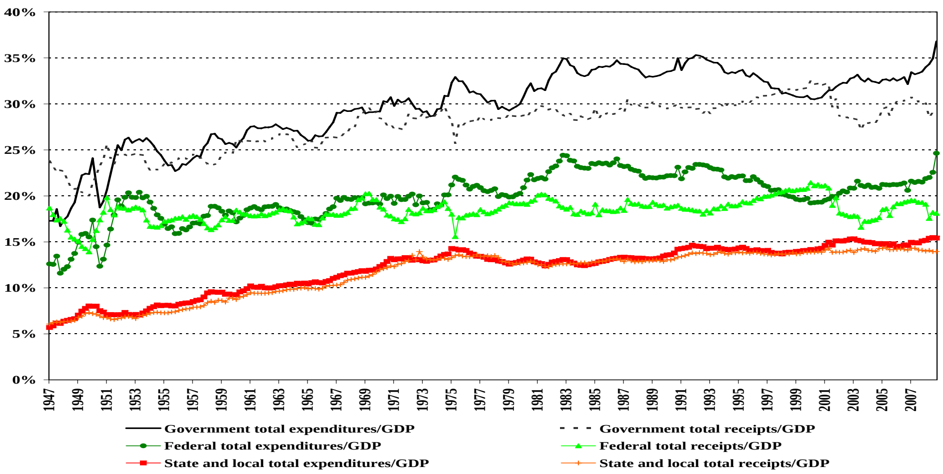
Table 3.7: Tests for structural breaks.

Output growth equation				Inflation equation			
RMSE	Fiscal variable	RMSE	Fiscal variable	RMSE	Fiscal variable	RMSE	Fiscal variable
3.1586	gov.pro.tax	3.2498	stl.cor.tax	1.0977	gov.pro.tax	1.1257	gov.cor.tax
3.1740	stl.pro.tax	3.2563	gov.cur.tax	1.1032	fed.pro.tax	1.1264	stl.sur.def
3.1748	fed.non.exp	3.2585	fed.def.exp	1.1034	gov.sur.def	1.1266	stl.tot.rec
3.1913	fed.soc.con	3.2597	fed.inv.exp	1.1137	fed.sur.def	1.1272	fed.soc.con
3.1994	gov.soc.con	3.2625	fed.sur.def	1.1139	stl.pro.tax	1.1290	stl.cur.tra
3.2000	stl.sur.def	3.2631	stl.tot.exp	1.1150	fed.cur.exp	1.1314	gov.tot.exp
3.2090	gov.sur.def	3.2634	fed.cur.tax	1.1153	fed.inv.exp	1.1317	gov.soc.con
3.2163	stl.inv.exp.	3.2646	fed.per.tax	1.1164	stl.inv.exp.	1.1323	stl.cor.tax
3.2216	stl.tot.rec	3.2653	gov.per.tax	1.1174	stl.tot.exp	1.1333	gov.per.tax
3.2255	fed.pro.tax	3.2659	fed.cor.tax	1.1175	fed.tot.exp	1.1336	gov.cur.tax
3.2291	stl.cur.tax	3.2691	gov.cor.tax	1.1191	gov.cur.exp	1.1341	fed.tot.rec
3.2325	gov.inv.exp	3.2709	stl.cur.exp	1.1199	stl.cur.tax	1.1353	fed.cur.tax
3.2378	gov.cur.exp	3.2727	fed.tot.exp	1.1201	gov.inv.exp	1.1367	stl.cur.exp
3.2470	stl.per.tax.	3.2735	stl.cur.tra	1.1211	stl.per.tax.	1.1368	fed.non.exp
3.2471	fed.cur.exp	3.2778	gov.tot.exp	1.1241	fed.cor.tax	1.1369	fed.per.tax
3.2483	fed.tot.rec			1.1249	fed.def.exp		

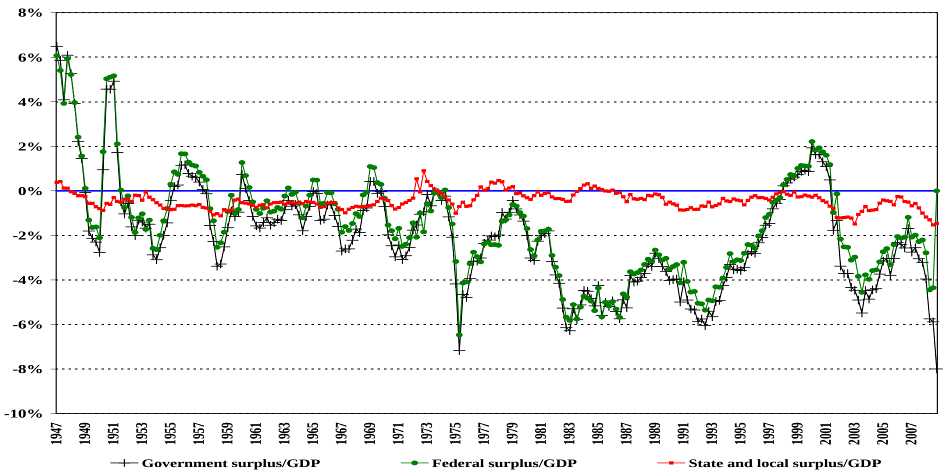
Table 3.8: Root mean squared errors of recursive residuals (RMSE).



(a) Government expenditures less transfers.



(b) Government total expenditures and receipts.



(c) Government surpluses or deficits.

Figure 3.1: US government expenditures and receipts as fractions of GDP (Source: our computations using BEA data).

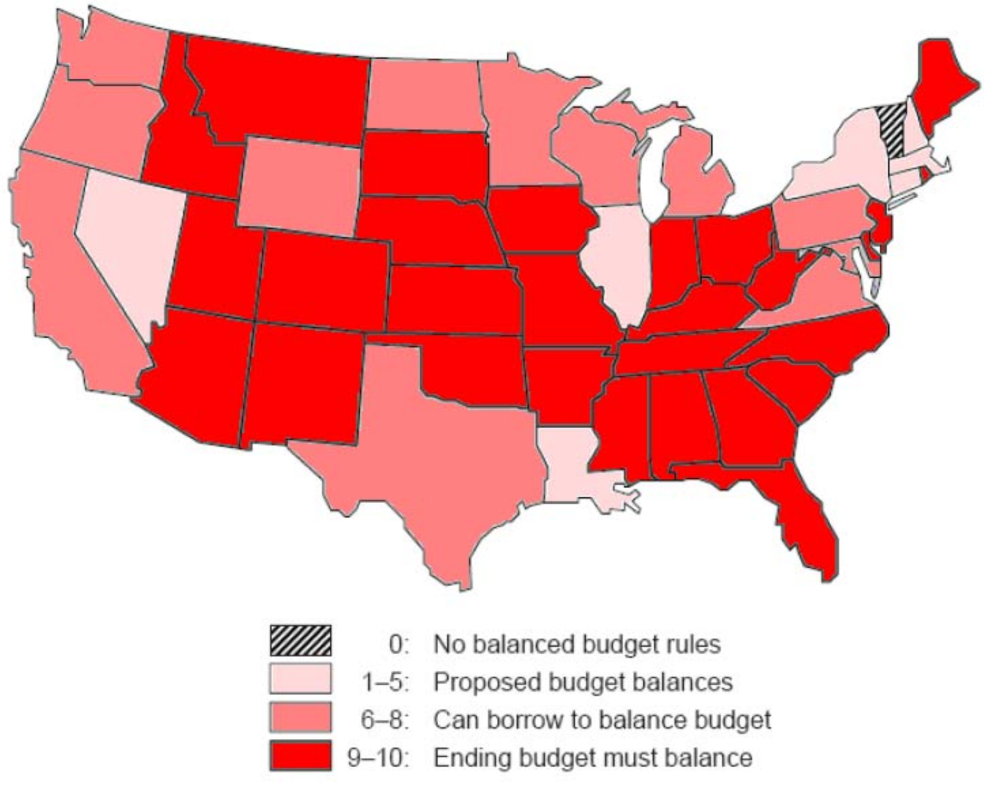
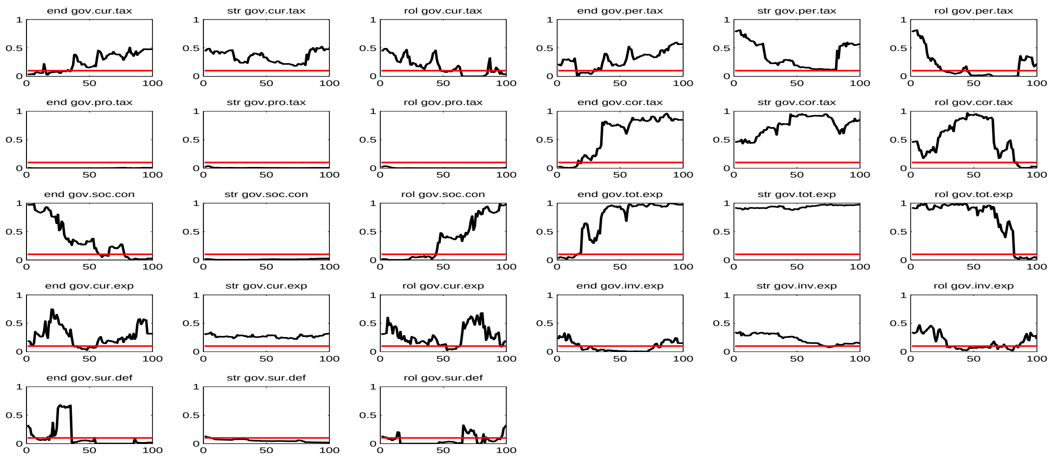
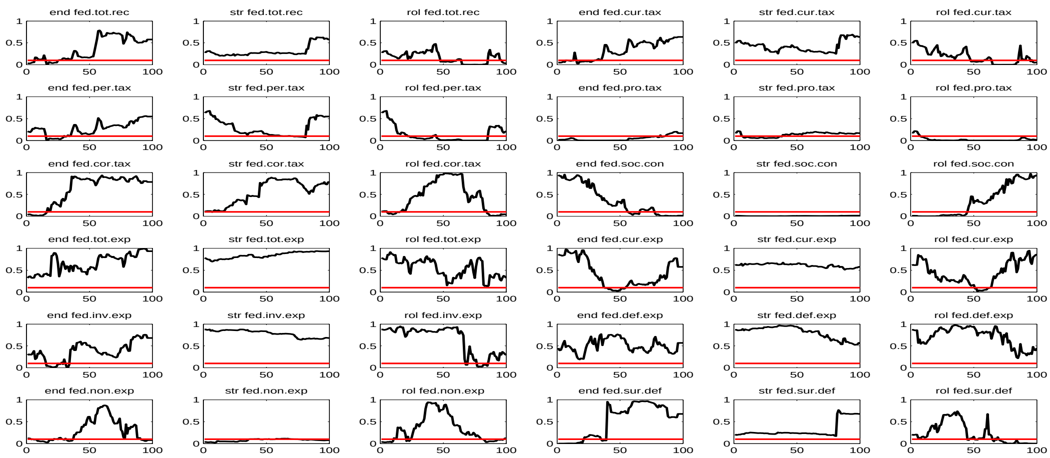


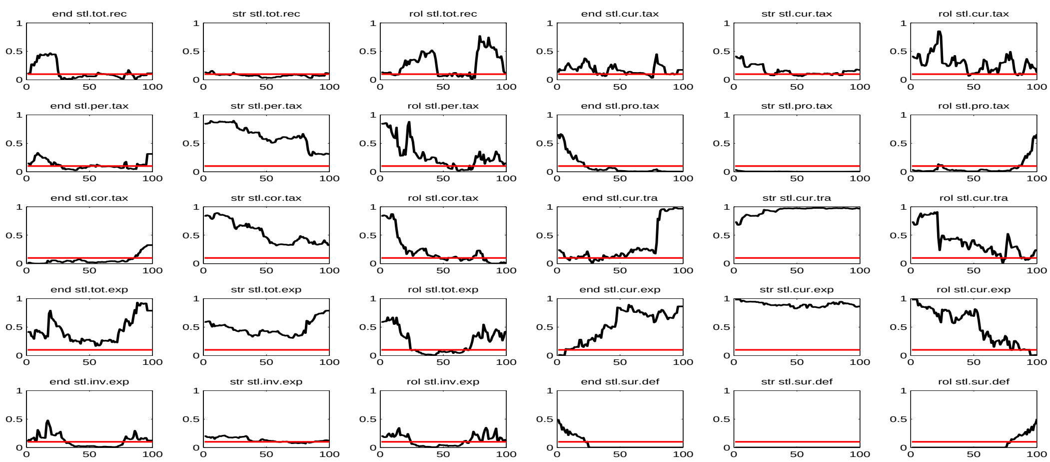
Figure 3.2: Balanced budget requirements in the US (Source: AICR, 1987).



(a) Government current receipts and expenditures.

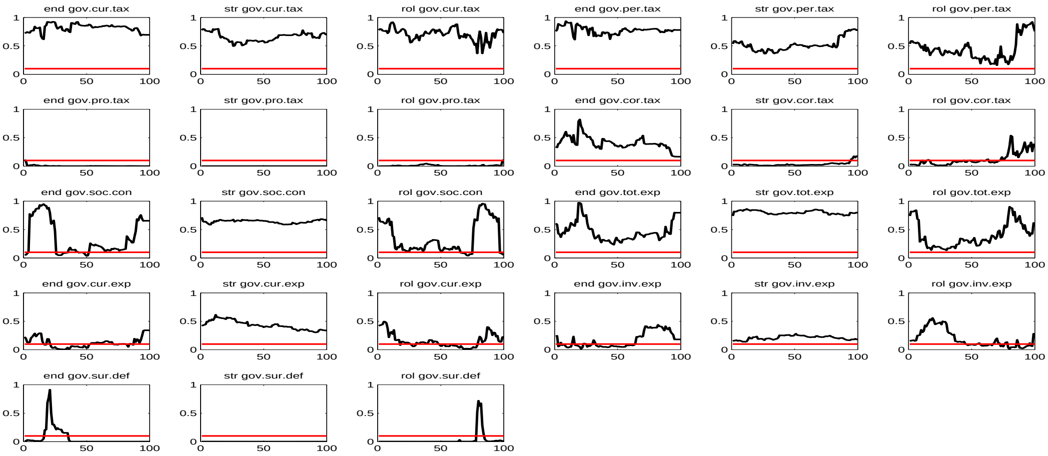


(b) Federal government current receipts and expenditures.

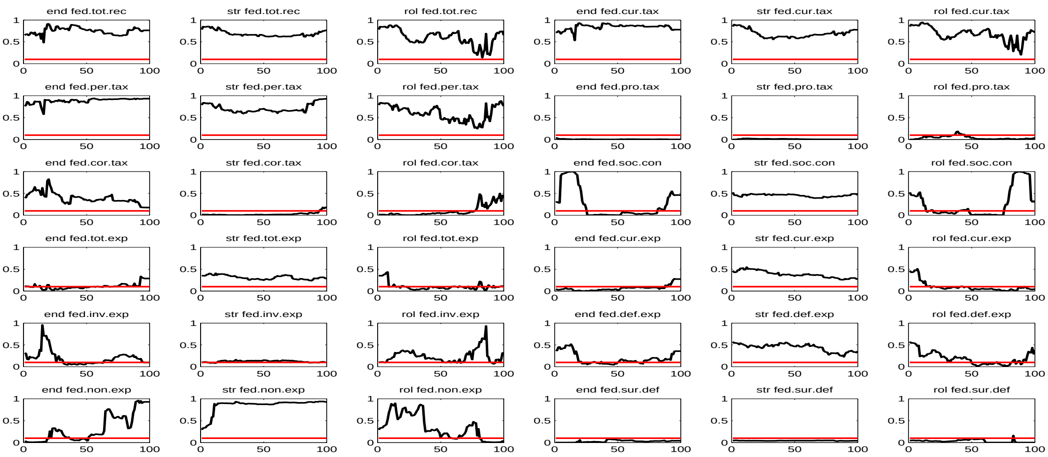


(c) state-local government current receipts and expenditures.

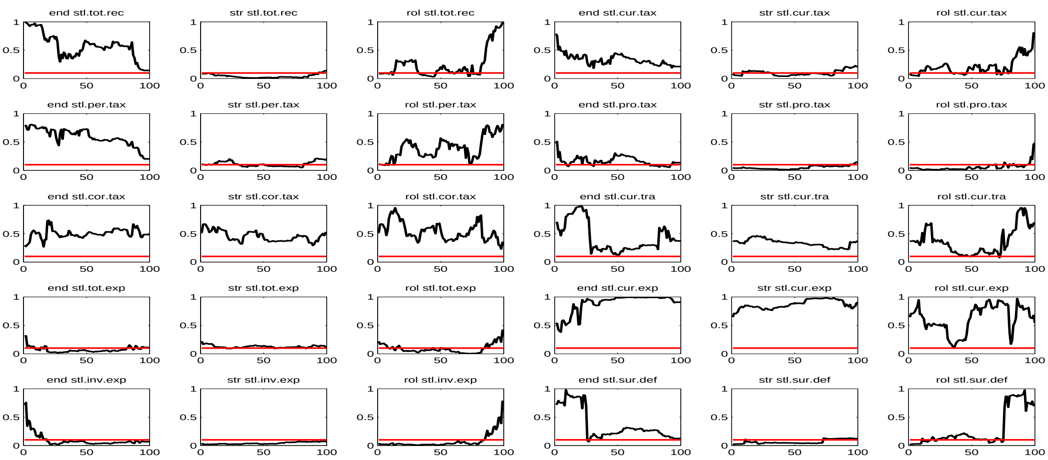
Figure 3.3: Recursive p-values of Granger non-causality tests on fiscal indicators in the output growth equation.



(a) Government current receipts and expenditures.



(b) Federal government current receipts and expenditures.



(c) state-local government current receipts and expenditures.

Figure 3.4: Recursive p-values of Granger non-causality tests on fiscal indicators in the inflation equation.

Bibliography

Andrews, D. (1993): "Tests for Parameter Instability and Structural Change With Unknown Change Point," *Econometrica*, 61(4), 821–856.

Andrews, D., and W. Ploberger (1994): "Optimal tests when a nuisance parameter is present only under the alternative," *Econometrica*, 62, 1383–1414.

Bahl, R., and J. Martinez-Vazquez (1990): "Inflation and the Real Growth of State and Local Government Expenditures," *American Economic Review*, 80(2), 166–70.

Barro, R. (1981): "Output effects of government purchases," *The Journal of Political Economy*, pp. 1086–1121.

Baxter, M., and R. King (1993): "Fiscal policy in general equilibrium," *The American Economic Review*, pp. 315–334.

Blanchard, O., and R. Perotti (2002): "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output," *Quarterly Journal of Economics*, 117(4), 1329–1368.

Burnside, C., M. Eichenbaum, and J. Fisher (2000): "Assessing the effects of fiscal shocks," *NBER Working Papers*, 7459.

——— (2004): "Fiscal Shocks and their Consequences," *Journal of Economic Theory*, 115, 89–117.

Caldara, D., and C. Kamps (2008): "What are the effects of fiscal shocks? A VAR-based comparative analysis," *ECB Working Paper Series*, 877.

Calvo, G. (1983): "Staggered prices in a utility-maximizing framework," *Journal of Monetary Economics*, 12(3), 383–98.

Campbell, J., and N. Mankiw (1989): "Consumption, income, and interest rates: reinterpreting the time series evidence," *NBER macroeconomics annual*, pp. 185–216.

Darroch, J., S. Lauritzen, and T. Speed (1980): "Markov fields and log-linear interaction models for contingency tables," *The Annals of Statistics*, pp. 522–539.

Dempster, A. (1972): "Covariance selection," *Biometrics*, 28(1), 157–175.

Edelberg, W., M. Eichenbaum, and J. Fisher (1999): "Understanding the Effects of a Shock to Government Purchases," *Review of Economics Dynamics*, pp. 166–206.

Eichenbaum, M., and J. D. M. Fisher (2005): "Fiscal Policy in the Aftermath of 9/11," *Journal of Money, Credit and Banking*, 37(1), 1–22.

Fats, A., and I. Mihov (2001): "The effects of fiscal policy on consumption and employment: theory and evidence," *CEPR Discussion Papers*, 2760.

Fats, A., and I. Mihov (2006): "The macroeconomic effects of fiscal rules in the US states," *Journal of Public Economics*, 90(1-2), 101 – 117.

Francis, N., and V. Ramey (2005): "Measures of per capita hours and their implications for the technology-hours debate," *NBER working paper*.

Friedman, B., and K. Kuttner (1992): "Money, income, prices, and interest rates," *American Economic Review*, 82(3), 472–492.

Galí, J., J. López-Salido, and J. Vallés (2004): "Rule-of-Thumb Consumers and the Design of Interest Rate Rules.," *Journal of Money, Credit & Banking*, 36(4), 739–764.

Galí, J., J. López-Salido, and J. Valles (2007): "Understanding the effects of government spending on consumption," *Journal of the European Economic Association*, 5(1), 227–270.

Granger, C. (1969): "Investigating causal relations by econometric methods and cross-spectral methods," *Econometrica*, 34(4), 424–438.

Granger, C., and N. Swanson (1997): "Impulse response functions based on a casual approach to residual orthogonalization in vector autoregressions," *Journal of the American Statistical Association*, 92(1), 357–367.

Greene, W. (2003): *Econometric analysis*. Prentice Hall Upper Saddle River, NJ.

Hall, P. (1992): *The Bootstrap and Edgeworth Expansion*. Springer-Verlag: New York.

Hamilton, J. (1985): "Historical causes of postwar oil shocks and recessions," *The Energy Journal*, 97–116.

Hansen, B. (1997): "Approximate Asymptotic P Values for Structural-Change Tests," *Journal of Business and Economic Statistics*, 15, 60–67.

King, R., C. Plosser, and S. Rebelo (1988): "Production, growth and business cycles: The basic neoclassical model," *Journal of Monetary Economics*, 21(2/3), 195–232.

Lauritzen, S., and D. Spiegelhalter (1988): "Local computations with probabilities on graphical structures and their application to expert systems," *Journal of the Royal Statistical Society. Series B (Methodological)*, pp. 157–224.

Leeper, E. M., C. A. Sims, and T. Zha (1996): "What Does Monetary Policy Do?," *Brookings Papers on Economic Activity*, 27, 1–78.

Linneman, L. (2006): "The Effect of Government Spending on Private Consumption: A Puzzle?," *Journal of Money Credit and Banking*, 38(7), 1715–1736.

Lütkephol, H. (2005): *New Introduction to Multiple Time Series Analysis.* Springer-Verlag: Berlin Heidelberg.

Mountford, A., and H. Uhlig (2008): "What are the effects of fiscal policy shocks?," *NBER Working Papers*, 14551.

Oxley, L., G. Wilson, and M. Reale (2009): "Constructing structural VAR models with Conditional Independence Graphs," *Mathematics and Computers in Simulations*, 79, 2916–2916.

Perotti, R. (2005): "Estimating the effects of fiscal policy in OECD countries," *Proceedings of the Federal Bank of San Francisco.*

——— (2007): "In Search of the Transmission Mechanism of Fiscal Policy," *NBER Macroeconomics Annual*, 22, 169–226.

Poterba, J. (1996): "Budget institutions and fiscal policy in the US states," *The American Economic Review*, pp. 395–400.

Poterba, J., and K. Rueben (1999): *Fiscal Rules and State Borrowing Costs: Evidence from California and Other States.* Public Policy Institute of CA.

Ramey, V., and M. Shapiro (1998): "Costly capital reallocation and the effects of government spending," *Carnegie-Rochester Confer. Series on Public Policy*, 48, 145–194.

Ramey, V. A. (2008): "Identifying government spending shocks: it's all in the timing," *University of California at San Diego.*

Ravn, M., S. Schmitt-Grohe, and M. Uribe (2006): "Deep Habits," *Review of Economic Studies*, 73, 195–218.

Reale, M., and G. Wilson (2001): "Identification of vector AR models with recursive structural errors using conditional independence graphs," *Statistical Methods and Applications*, 10(1), 49–65.

Romer, C., and P. Romer (1989): "Does monetary policy matter: a new test in the spirit of Friedman and Schwartz," *NBER Macroeconomics Annual*, pp. 63–129.

Sims, C. (1972): "Money, income and causality," *American Economic Review*, 62(4), 540–552.

Sørensen, B., L. Wu, and O. Yosha (2001): "Output fluctuations and fiscal policy: US state and local governments 1978–1994," *European Economic Review*, 45(7), 1271–1310.

Sørensen, B., and O. Yosha (2001): "Is state fiscal policy asymmetric over the business cycle?," *Economic Review - Federal Reserve Bank of Kansas City*, 86(3), 43–64.

Stock, J., and M. Watson (2003): "Forecasting output and inflation: the role of asset prices," *Journal of Economic Literature*, 41, 788–829.

Uhlig, H. (2005): "What are the effects of monetary policy on output? Results from an agnostic identification procedure," *Journal of Monetary Economics*, 52(2), 381–419.

Wilson, G., and M. Reale (2008): "The sampling properties of conditional independence graphs for I (1) structural VAR models," *Journal of Time Series Analysis*, 29(5), 802–810.