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DEFENSE GOVERNMENT SPENDING IS CONTRACTIONARY, CIVILIAN GOVERNMENT SPENDING IS EXPANSIONARY

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ABSTRACT

Impulse responses to government spending shocks in Standard Vector Autoregressions (SVARs) typically display "expansionary" features. However, SVARs can be subject to a "non-fundamentalness" problem. "Expectations - Augmented" VARs (EVARs), which use direct measures of forecasts of defense spending, typically display "contractionary" responses to a defense news shock. I show that, when properly specified, SVARs and EVARs give virtually identical results. The reason for the widespread, opposite view is that defense shocks have "contractionary" effects while civilian government spending shocks have "expansionary" effects. Existing EVARs and SVARs, however, include only total government spending. In addition, the former are typically estimated on samples that include WWII and the Korean war, when defense shocks prevailed, while the latter are estimated mostly on post-1953 samples, when civilian shocks prevailed.

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1 Introduction

Policymakers would like to know what happens if they increase government spending by, say, 1 percent of GDP. In a strict sense, we know that this question cannot be addressed with data: the answer depends, among other things, on the type and timing of current and expected future government spending and taxation, hence it requires controlled experiments that the econometrician does not have access to. But suppose one still wanted to elicit an approximate answer from the data: what would be a reasonable methodology?

A widespread approach consists of regressing a government spending variable on past information, and tracing the dynamic effects of the residual of this regression on the variables of interest. This is the methodology embedded in the standard Vector Autoregression (SVAR) approach[1]. Contributions based on this methodology, like Blanchard and Perotti (2002), Caldara and Kamps (2008), Fatas and Mihov (2001), Galí, López-Salido, and Vallés (2007), Perotti (2007), and Auerbach and Gorodnichenko (2012), typically find that GDP increases by more than government spending, so that the private components of GDP, in particular private consumption, also increase; Ravn and Simonelli (2008) and Monacelli, Perotti and Trigari (2010) find a positive response of the real consumption and product wage, respectively. These results are consistent with some "neo-keynesian" models, where consumption and, in some versions, the real wage increase in response to a rise in government spending, and the output multiplier can be larger than 1 (see e.g. Ravn, Schmitt-Grohé and Uribe 2006, Galí, López-Salido, and Vallés 2007, Monacelli and Perotti 2008, Bilbiie 2011, and Woodford 2011). However, the distinction between "neo-keynesian" and "neo-classical" models, and the associated terminology, has become increasingly blurred. Because the contribution of the present paper is empirical, I will use the more neutral term "expansionary" to denote this type of results.

[1] The acronym "SVAR" usually stands for "Structural VAR". But as described below, in the present context this approach has nothing structural as it is usually meant by this adjective in the VAR literature: it relies on a simple Choleski decomposition. When this approach is used to study the effects of tax shocks instead of spending shocks, identification is not obtained by a simple triangularization of the variance - covariance matrix of the residuals, hence the adjective "structural".

An important criticism of the SVAR approach is that the government spending shocks estimated by the econometrician are likely to have been anticipated by the public. In these circumstances, the econometrician's information set is smaller than that of the private agents, so that the true fiscal policy shocks cannot be recovered from the estimated shocks.[2] Ramey (2011) argues that this can lead to an expansionary bias in the impulse responses from a SVAR.

When measures of the private sector forecasts of fiscal variables are available, the obvious solution is to use them directly in the VAR. For brevity, I will refer to this approach as the "expectations - augmented" VAR, or EVAR. Romer and Romer (2010) and Mertens and Ravn (2012), among others, do this with forecasts of tax changes. Ramey (2011) uses a measure of changes in the expectations of the present value of defense spending, or "defense news" for short, constructed from narrative sources. She shows that in this EVAR the response of GDP to defense news shocks in samples that include WWII and/or the Korean war is smaller than the increase in government spending, so that private GDP and in particular private consumption fall; the real wage also falls (although not in all samples). These results are largely consistent with a standard neoclassical model with lump-sum taxation like Baxter and King (1993), where "throw - in - the - ocean" government spending, that does not enter the production or utility functions, affects the economy via a pure wealth effect and raises GDP but reduces private consumption and the real wage. I will refer to this set of results as the "contractionary" effects of government spending shocks.

In this paper, I show that, contrary to a widespread perception, there is no contradiction between EVAR and SVAR studies of the effects of government spending shocks. The reason for the widespread, opposite view is that defense and civilian government spending have different effects. Existing SVARs and EVARs, however, only include total government spending in their specifications. In addition, defense news EVARs are estimated on samples that include WWII and/or the Korean War, when shocks to defense spending predominate. On the other hand, most existing SVARs are estimated on samples that start in 1954 or later, when shocks to civilian government spending predominate. I show that if

[2] Under certain assumptions, such as perfect foresight by the private sector, the MA representation is non-invertible, or non-fundamental for the variables used in the VAR.

one allows explicitly for different effects of the two types of government spending, defense spending shocks in a SVAR generate "contractionary" responses that are virtually identical to those of a defense news EVAR estimated on the same sample. In contrast, civilian government spending shocks generate large "expansionary" responses, that are highly statistically significant and significantly different from the responses to both EVAR defense news shocks and SVAR defense spending shocks. The fact that, when properly specified and when comparison is made between the appropriate shocks and on the same sample, EVARs and SVARs give the same answer also casts doubt on the empirical relevance of the anticipation (or non-fundamentalness) problem of SVARs.

I also show that EVARs suffer from significant robustness problems. If one excludes WWII - which involved a number of factors whose effects are virtually impossible to assess, like price controls, production controls, rationing, the draft, and patriotism - the evidence from the defense news EVAR depends heavily on one observation during the Korean War when, unrelated to the war, new Fed regulation discouraging the purchase of durables was introduced.

The outline of the paper is as follows. Section 2 presents the SVAR and EVAR approaches using a simple model as a guide. Section 3 presents the evidence from a defense news EVAR estimated over the WWII sample 1939:1-2008:4 and the Korean War sample 1947:1 - 2008, that does not allow for different effects of defense and civilian government spending, and shows that it displays very similar contractionary responses to a SVAR with the same variables and over the same samples. Section 4 shows that these seeming contradictions with standard interpretations of the literature can be reconciled by allowing for different effects of defense and civilian government spending. Section 5 shows that this is indeed the case empirically: the former has contractionary effects, the latter large expansionary effects. Section 6 studies the predictability of the SVAR residuals. Section 7 discusses an alternative decomposition of total government spending on goods and services, into government spending on purchases of goods and on employment. Section 8 discusses the instrumental variable interpretation of SVARs and EVARs. Section 9 concludes.

2 A simple model and its VARs

2.1 A simple neoclassical growth model

Because it is important to use a model that can be solved analytically, I will study a very simple neoclassical growth model with inelastic labor supply, similar to that used by Leeper, Walker and Yang (2008) and Mertens and Ravn (2010) to study non-fundamental tax shocks. I show that the model generates a simple bivariate VAR; thus, commonly used alternative identification strategies in fiscal policy VARs can be mapped into alternative assumptions about variables and parameters of the model. This is only a toy model, which I will use to understand the main econometric issues involved.

Most of the empirical VAR literature does not distinguish between different types of government spending on goods and services, and uses *total* government spending on goods and services as its government spending variable. This is the case for instance of Blanchard and Perotti (2002) and Ramey (2011), and numerous other papers. Initially, I will follow the same approach. A representative agent maximizes

$$U = E_0 \sum_{t=0}^{\infty} \frac{C_t^{1-\sigma}}{1-\sigma}; \qquad \sigma > 0, \tag{1}$$

$$\text{s.t. } C_t + G_t + K_t = Z_t K_{t-1}^{\alpha}$$

where C_t is private consumption, G_t is government spending on goods and services, K_t is capital and Z_t is an exogenous technological shock, whose logarithm is white noise. For simplicity capital depreciates entirely each period.

The representative agent takes the path of G_t as given. Let a small letter denote a log deviation from the steady state. I assume a process for g_t of the form

$$g_t = \rho g_{t-1} + a_{t/t-1} + a_{t/t} + \eta z_t \qquad 0 \leq \rho < 1 \tag{2}$$

where $a_{t/t-j}$ is the change in government spending announced at time $t-j$ for time t, as a share of government spending. Thus, this specification allows for anticipated changes in government spending ($a_{t/t-1}$) as well as unanticipated changes ($a_{t/t}$). $a_{t/t}$ and $a_{t+1/t}$ are exogenous. I will use the term "fiscal foresight" to refer to the case of a strictly positive variance of $a_{t+1/t}$.

Appendix A shows that the solution of the model can be characterized by two dynamic equations, one for g_t and the other for any of the endogenous variables y_t, k_t, c_t, or private GDP q_t.[3] For presentation purposes, I will focus on private consumption. The reason is that in this simple model total GDP is predetermined, hence unanticipated changes to different types of government spending cannot have different effects on private GDP. In contrast, private consumption can decline or increase on impact; the latter case occurs if private consumption and government spending are strong complements (see below).

Let θ_k be the root inside the unit circle of the characteristic equation for k_t, and let $\overline{x}$ denote the steady state share of variable X to GDP. The bivariate VAR consists of equation (2) and

$$c_t = \phi_c c_{t-1} + \phi_g g_{t-1} + \phi_{g1} a_{t/t-1} + \phi_{g2} a_{t/t} + \phi_{g3} a_{t+1/t} + \phi_z z_t \tag{3}$$

$$\phi_c > 0; \quad \phi_g < 0; \quad \phi_{gi} < 0, \quad i = 1, 2, 3$$

(the precise expressions for all these coefficients are given in Appendix A).

Thus, the impact effect on private consumption (as a share of GDP) of an unanticipated change in government spending equal to one percentage point of GDP, i.e. of a unit realization of $\overline{g}a_{t/t}$, is

$$\frac{\partial(\overline{c}c_t)}{\partial(\overline{g}a_{t/t})} = \frac{\overline{c}}{\overline{g}}\phi_{g2} \tag{4}$$

and similarly for $a_{t/t-1}$ and $a_{t+1/t}$. All these effects are negative, from the wealth effect of a change in government spending.

[3] Private GDP is defined as the difference between GDP and government spending. Private GDP is often considered a compact measure of the "expansionary" or "contractionary" effects of a government spending shock: in the former case, private GDP increases, in the latter it falls.

2.2 G-SVARs

The "standard" VAR approach to identification, or "SVAR", is based on two assumptions (see e.g. Blanchard and Perotti 2002):

(i) because of decision and implementation lags, there is no contemporaneous feedback from output or its components to g_t: $\eta = 0$;

(ii) there are no anticipated changes to future government spending: $a_{t+1/t} = 0$.

Under these assumptions the estimated reduced form model is

$$g_t = \rho g_{t-1} + u_{g,t}^{GS} \tag{5}$$

$$c_t = \phi_c c_{t-1} + \phi_g g_{t-1} + u_{c,t}^{GS} \tag{6}$$

where

$$u_{g,t}^{GS} = a_{t/t}; \qquad u_{c,t}^{GS} = \phi_{g2} a_{t/t} + \phi_z z_t \tag{7}$$

When, like here, the government spending variable is total government spending on goods and services, I call this specification a "G-SVAR", hence the superscript "GS".

It is easy to see that under the joint assumptions above, a Choleski decomposition where g_t comes first delivers a consistent estimate of the impulse responses to $a_{t/t}$. In fact, a Choleski decomposition is equivalent to estimating ϕ_{g2} by regressing $\widehat{u}_{c,t}^{GS}$ on $\widehat{u}_{g,t}^{GS}$ (where a "hat" denotes an estimate).

Obviously if SVAR assumption (i) fails, i.e. if $u_{g,t}^{GS}$ includes z_t, such a regression gives a biased estimate of ϕ_{g2}. The same occurs if assumption (ii) fails, i.e. if there is fiscal foresight. In this case the G-SVAR reduced form residuals are not those given in expression (7), but

$$u_{g,t}^{GS} = a_{t/t-1} + a_{t/t}; \qquad u_{c,t}^{GS} = \phi_{g1} a_{t/t-1} + \phi_{g2} a_{t/t} + \phi_{g3} a_{t+1/t} + \phi_z z_t; \tag{8}$$

As a consequence, the estimate of ϕ_{g2} has a positive, or "expansionary", bias, for two reasons. First, $\widehat{u}_{g,t}^{GS}$ now includes $a_{t/t-1}$, which has a less negative coefficient than $a_{t/t}$ in the c equation ($\phi_{g1} > \phi_{g2}$). Second, the coefficient of $a_{t+1/t}$ in the c equation, ϕ_{g3}, is negative. Hence, if there is fiscal foresight, in a G-SVAR the coefficient of c_{t-1} in the c equation, ϕ_c, picks up the effect of $a_{t/t-1}$, which is included in the residual $u_{c,t}^{GS}$.[4]

2.3 G-EVARs

Suppose the two SVAR assumptions fail, and the econometrician has data on the anticipated change $a_{t+1/t}$. She can estimate consistently the following reduced form

$$g_t = \rho g_{t-1} + a_{t/t-1} + u_{g,t}^{GE} \tag{9}$$

$$c_t = \phi_c c_{t-1} + \phi_g g_{t-1} + \phi_{g1} a_{t/t-1} + \phi_{g3} a_{t+1/t} + u_{c,t}^{GE} \tag{10}$$

where

$$u_{g,t}^{GE} = a_{t/t} + \eta z_t; \qquad u_{c,t}^{GE} = \phi_{g2} a_{t/t} + \phi_z z_t \tag{11}$$

I call this specification the "Expectations-Augmented" VAR, or EVAR. When the government spending variable is *total* government spending on goods and services, I call this specification a "G-EVAR", hence the superscript "GE".

Without need for further identifying assumptions (in particular, one does not need SVAR assumption (i), $\eta = 0$), one can then estimate consistently the impulse response to $a_{t+1/t}$ directly from the reduced form equations (9) and (10).

However, in practice we do not have measures of the entire anticipated government spending change $a_{t+1/t}$, but only of one component of it. This causes a bias in the estimate of a G-EVAR too. Let D_t and V_t be defense and civilian government spending on goods and services, with $D_t + V_t = G_t$. The "defense news" variable of Ramey (2011) is defined as the the revision in the expectation of the present value of future changes in discretionary defense spending as a share of output. Applying this definition to the model used here, the defense news variable

[4] Because $a_{t/t-1}$ has a negative effect on both c_t and c_{t-1}, from the omitted variable formula ϕ_c is biased upward. As a consequence, $\widehat{u}_{c,t}^{GS}$ contains c_{t-1} with a negative coefficient. Thus, in the regression of $\widehat{u}_{c,t}^{GS}$ on $\widehat{u}_{g,t}^{GS}$, there is an extra positive term which is a function of the negative covariance between c_{t-1} and $a_{t/t-1}$, multiplied by the negative coefficient of c_{t-1} in the estimate of $\widehat{u}_{c,t}^{GS}$. Note that the upward bias in the estimation of the coefficient of c_{t-1} will also cause a downward bias, *ceteris paribus,* in the dynamic response of c to $a_{t/t}$.

is:[5]

$$R_{d,t} = \overline{d}\sum_{i=1}^{\infty}\beta^i E_t(d_{t+i} - d_{t+i-1}) \tag{12}$$

where $\overline{d}$ is the steady state ratio of defense spending to GDP. Assume for simplicity the same process for d_t and v_t

$$d_t = \rho d_{t-1} + a_{d,t/t-1} + a_{d,t/t}; \qquad v_t = \rho v_{t-1} + a_{v,t/t-1} + a_{v,t/t} \tag{13}$$

where $a_{d,t/t-j}$ and $a_{v,t/t-j}$, $j = 0, 1$, are defense and civilian spending shocks, expressed as shares of steady state defense and civilian spending, respectively. Again for simplicity, assume also that these shocks are independent of each other at all leads and lags. Expression (12) becomes

$$R_{d,t} = \frac{\beta\overline{d}a_{d,t+1/t}}{1-\beta\rho} \tag{14}$$

As $R_{d,t}$ is just a multiplicative function of $a_{d,t+1/t}$, I will use the term "defense news variable" to refer to $a_{d,t+1/t}$. Given $\overline{g}g_t = \overline{d}d_t + \overline{v}v_t$, the estimated reduced form G-EVAR becomes

$$g_t = \rho g_{t-1} + a_{d,t/t-1} + u^{EG}_{g,t} \tag{15}$$

$$c_t = \phi_c c_{t-1} + \phi_g g_{t-1} + \phi_{d1} a_{d,t/t-1} + \phi_{d3} a_{d,t+1/t} + u^{EG}_{c,t} \tag{16}$$

where

$$u^{GE}_{g,t} = a_{v,t/t-1} + a_{t/t}; \quad u^{GE}_{c,t} = \phi_{v1} a_{v,t/t-1} + \phi_{g2} a_{t/t} + \phi_{v3} a_{v,t+1/t} + \phi_z z_t \tag{17}$$

and

$$\phi_{di} = \frac{\overline{d}}{\overline{g}}\phi_{gi}; \qquad \phi_{vi} = \frac{\overline{v}}{\overline{g}}\phi_{gi} \quad i = 1, 2, 3 \tag{18}$$

Thus, the effect on private consumption (as a share of GDP) of unanticipated

[5] The inessential difference is that Ramey (2011) divides each quarter's revision of the nominal value of future expected defense spending by the previous period's nominal GDP, while here it is divided by steady-state GDP.

changes in d_t and v_t equal to one percentage point of steady - state GDP are:

$$\frac{\overline{c}}{\overline{d}}\phi_{d2} = \frac{\overline{c}}{\overline{v}}\phi_{v2} = \frac{\overline{c}}{\overline{g}}\phi_{g2} \tag{19}$$

and similarly for $a_{j,t/t-1}$ and $a_{j,t+1/t}$, $j = 1, 2$. These obviously are the same effects that were found in section 2.1 (see expression 4).

However, because ϕ_{v3} is negative, here too the omission of $a_{v,t/t-1}$ and $a_{v,t+1/t}$ will cause a positive bias in the estimation of ϕ_c. Importantly, however, and unlike in a G-SVAR, even in this case the *impact* coefficient ϕ_{d3} of $a_{d,t+1/t}$ will be estimated without bias, because $a_{d,t+1/t}$ is uncorrelated with all the other variables in the system.

In practice, one can estimate the trivariate VAR

$$a_{d,t+1/t} = \xi_c c_{t-1} + \xi_g g_{t-1} + \xi_1 a_{d,t/t-1} + \widetilde{u}_{a,t}^{GE} \tag{20}$$

$$g_t = \rho g_{t-1} + q_{t-1} + a_{d,t/t-1} + \widetilde{u}_{g,t}^{GE} \tag{21}$$

$$c_t = \phi_c c_{t-1} + \phi_g g_{t-1} + \phi_{d1} a_{d,t/t-1} + \widetilde{u}_{c,t}^{GE} \tag{22}$$

and do a Choleski decomposition where $a_{d,t+1/t}$ comes first. This approach is equivalent to estimating the GVAR (15) - (16) because, if $a_{d,t+1/t}$ is indeed unpredictable, all the coefficients of (20) are 0, and the residual of this equation is $a_{d,t+1/t}$ itself.[6]

To summarize: First, the responses to both unanticipated and anticipated changes to government spending are negative. Second, if there is fiscal foresight the estimated G-SVAR response to $a_{t/t}$ has an "expansionary" bias. Third, the G-EVAR dynamics will also be estimated with a bias, but the impact response to an unanticipated shock will be estimated without bias.

[6] Of course, in pratice this is not the case. As Swanson (2006) points out, it is not clear how to interpret the shock to $a_{d,t+1/t}$ in this specification, and it is even more difficult to interpret the impulse response to such a shock.

3 G-EVARs and G-SVARs in practice

3.1 WWII

I start from the same data,[7] the same sample 1939:1 - 2008:4, and the same specification of the G-SVAR and the G-EVAR as Ramey (2011). Initially, the vector of endogenous variables X_t includes $a_{d,t+1/t}$, the log of real per capita government spending on goods and services g_t, the log of real per capita GDP y_t, the three-month T-bill rate i_t, the Barro-Redlick average marginal income tax rate τ_t, and the log of total hours h_t. The specification is the six-variables version of the G-EVAR (20) - (22) which, as we have seen, under the null is exactly equivalent to (15) - (16). Each equation includes four lags of the endogenous variables, a constant, and linear and quadratic time trends.

Column 1 of Figure 1 displays the median responses of government spending, GDP, private GDP, the tax rate and the interest rate to a shock to the defense news variable in a G-EVAR. This column replicates Figure X of Ramey (2011), except that here and in what follows the responses of national income account variables (like government spending, private consumption, private GDP etc.) are expressed as percentage points of GDP by multiplying the log response by the average ratio of that variable to GDP.[8] The response of interest rate is expressed in basis points (a change by 50 is a change in the interst rate by .5 percentage points) and the response of the tax rate is expressed in percentage points.

Column 2 displays the responses of the same variables to a shock to total government spending on goods and services in a G-SVAR, from a Choleski decomposition in which total government spending is ordered first. In both columns, the initial shock (to defense news in the G-EVAR and to total government spending in the G-SVAR) is normalized so that the maximum response of total government spending is one percentage point of GDP. 95 percent confidence bands are also displayed.[9]

[7] See the data Appendix. Unless otherwise noted, all variables were donwloaded from Valerie Ramey's website.

[8] In this sample these ratios vary very little over time, hence this transformation is entirely innocuous. In any case, when computing an impulse response from a different sample, the average shares are recomputed over that sample.

[9] Standard errors are computed by bootstrapping, sampling with replacement the errors of

In the G-EVAR, total government spending peaks after 6 quarters; at about the same time, GDP increases by slightly less than 1 percent; the response of private GDP is positive but insignificantly different from 0. In the G-SVAR, government spending jumps on impact instead of increasing gradually. GDP increases gradually, and its peak is about half the G-EVAR peak; consequently, private GDP now falls, and significantly so. This difference cannot be explained by different behaviors of taxes or the interest rate (rows 4 and 5).

Column 3 displays the median difference, with 95 percent confidence bands, between the G-EVAR and the G-SVAR responses. These differences are always statistically insignificant, except for the private GDP response in the first quarter, which is significantly *smaller* in the G-SVAR.

Figure 2 displays the responses of the various components of private consumption, of total investment, of total hours, and of the real product wage in manufacturing.[10] All GDP components, except the consumption of services, fall, both in the G-EVAR and in the G-SVAR; in fact, the two sets of responses are very similar, both numerically and statistically (see column 3).[11] Hours increase in the G-EVAR, and fall in the G-SVAR;[12] the real wage increases in both.

Thus, both G-EVARs and G-SVARs responses display "contractionary" features. When the two differ, G-SVAR responses are more "contractionary" than G-EVAR responses.

Instead of treating $a_{d,t+1/t}$ as an endogenous variable, one could estimate directly the five-variables version of the G-EVAR specification (15) and (16). One could also estimate a G-SVAR by applying a Choleski decomposition to the re-

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the reduced form. Given a new set of reduced form errors, I estimate the G-EVAR and the G-SVAR, and then compute the response, at each horizon, of the two specifications and of their difference. At each horizon, the responses and their differences are lined up from the smallest to the largest. The figure displays the 500th, the 25th, and the 975th of these responses, and of their differences, at each horizon.

[10] Each response in this figure is obtained from a specification where the variable in question replaces the variable "hours" in the G-EVAR or G-SVAR. Here too all responses of components of GDP are expressed as percentage points of GDP by multiplying the log response by the average ratio of the variable to GDP.

[11] Note an initial positive blip (although not statistically significant) in durables consumption in the G-EVAR. As noted by Ramey (2011), this is likely due to the panic purchase of durables at the beginning of the war.

[12] Here and in all the rest of the paper the responses of civilian employment are very similar to those of total hours, hence they will not be shown.

siduals of the G-EVAR specification (15) and (16). If there is fiscal foresight, this reduces the bias in estimating ϕ_{g2}, because it leaves only the anticipated civilian change in the residual. In both cases, the resulting impulse responses (not shown) are virtually identical to those of Figures 1 and 2.

3.2 Was WWII exceptional?

WWII involved by far the largest change in defense spending of the sample, and as such it is potentially highly informative: the expectation of the present value of defense spending rose by 74.5 percent of GDP in 1941:1, by 42.5 percent of GDP in 1942:3, and by similarly large numbers in numerous other quarters of the war. But many researchers would be wary of using WWII to make inferences about the effects of government spending shocks in "normal" times. WWII involved factors like price controls, production controls, rationing, the draft, and patriotism: to disentangle their role on variables like labor supply, the real wage, private consumption, and private investment is virtually impossible. To cite two recent examples, Hall (2009) argues that the combined effect of these factors on GDP and labor supply is likely to be negative; in contrast, Barro and Redlick (2011) argue that it is likely to be positive. However, these authors also openly recognize that these are just conjectures based purely on intuition.

On private consumption and investment we do have a few hints on the possible effects of these factors. Durables and non-durables consumption were subject to rationing and production controls; we have seen in Figure 2 that both variables decline in both the G-EVAR and the G-SVAR; in contrast, services, which were not rationed, increase in both specifications (see row 3 of Figure 2). In addition, as Gordon and Krenn (2010, p. 11) argue, the war and its preparation mechanically reduced private consumption of non durables, as recorded in the national income accounts, "since it excludes the food and clothing provided to the 10 percent of the population that served in the military, as these were counted as government rather than consumption expenditures."

Similar accounting issues arise with private investment, another variable that falls in both the G-EVAR and the G-SVAR responses (see row 4 of Figure 2): "Yet much of this new investment in plant and equipment was not counted as investment in the national accounts.[....] [T]he ongoing attempt to double plant capacity was being financed by the government, not by the company's own funds [...] Since investment in war-related plant expansion was counted as government spending rather than private investment in the national accounts, the surge of war-related investment during 1941 occurred simultaneously with a decline in measured private investment in the last half of 1941" (Gordon and Krenn 2010, p. 11).[13]

3.3 Korea

Those who are skeptical about the information contained in WWII may want to use a post-WWII sample. An additional advantage of starting the sample in 1947:1 is that official quarterly national income data were first collected on this date; earlier data have to be interpolated from annual figures.

The first two columns of Figure 3 replicate the first two columns and the first three rows of Figure 1, but on the Korean war sample starting in 1947:1. The results are qualitatively similar to those of the longer sample, although they are weaker and with larger standard errors. In fact, very few responses are significant (this holds also for the other variables, not shown); this was not apparent in Ramey (2011) because, for this sample, she does not display standard errors. If one abstracts from the large standard errors, there is still evidence of contractionary effects, and again more so in the case of G-SVAR responses (again with the exception of the real wage).

[13] Importantly, as Gordon and Krenn emphasize, these effects started well before Pearl Harbour. And they are not just the manifestation of the classical crowding out effect of government spending on private spending, as in the wealth effect of the neoclassical model. Although formal rationing of durable goods started in January 1942, by mid-1941 exceptional non-market constraints on production for civilian consumption and investment had been put in place for the war preparation effort. As the Director of the Office of Price Administration wrote: "Civilian supplies of all kinds are being requisitioned for military needs so as to force the cutting down of production for civilian use . . . When [aluminum supply] is cut off suddenly, as has happened recently, businessmen face bankruptcy and whole communities lose the payroll lifeblood of their existence . . . Auto production is being limited and faces almost complete extinction. Can anyone estimate, at this time, the far-reaching dislocations of stoppage?" (Leon Henderson, "We Only Have Months," *Fortune*, July 1941, p. 68, cited in Gordon and Krenn 2010, p. 19).

3.4 Robustness

We have just seen that if one excludes WWII, the effects of shocks to the defense news variable can be estimated only imprecisely. In 1950:3 and 1950:4 the expectation of the present value of future defense spending rose by 63 and 41 percent of GDP, respectively; the next largest revision in the post-WWII sample is 6.4 percent of GDP, in 1980:1; the next largest revisions during the Korean war were even smaller: -2.02 percent of GDP in 1953:1 and -3.06 percent in 1953:3.

1950:3 turns out to be indeed crucial in the post-WWII sample. The last two columns of Figure 3 replicate the first two columns but exclude 1950:3[14]: this is enough for the defense news G-EVAR to lose any statistical informativeness. The standard error bands are now extremely wide, so that nothing is even remotely significant. The G-SVAR appears to be more robust: when 1950:3 is excluded, the standard errors increase slightly, but the response of private GDP remains significant at the trough.

As always in these cases, one could argue that there is no reason to discard any useful information. At the same time, it is important to be aware of the key role played by a single quarter. And there are specific reasons why one might want to check the robustness of the results when 1950:3 is excluded. In 1950:3 and in 1950:4 there were two well-identified, exceptional factors that were entirely unrelated to the war but that substantially affected the response of durable consumption and of investment.

Although there was no formal rationing, in the first two quarters of the Korean War important restrictions on the purchase of durables were introduced; both were motivated by developments preceding the war. On September 18, 1950, the Federal Reserve introduced Regulation W, setting higher downpayments than those prevailing in the market for the purchase of durable goods, and reducing the maturities of the loans; the rules were further tightened on October 16 1950. The *Survey of Current Business*, November 1950, calculates that Regulation W might have decreased the purchase of durables by about \$2.5 to \$3 billion annually, or about 10 percent of total durable purchases and about 1 percent of 1950 GDP. In addition, Regulation X, also introduced in the fall of 1950, restricted the terms

[14] This is done by adding a dummy variable for each quarter from 1950:3 to 1951:3.

of mortgages; by mid-1951, it had caused a decline in homebuilding, which in turn was reflected in a decline in the purchases of durables and semi-durables like furniture and household equipment.[15]

4 The composition of government spending shocks

4.1 Reconciling two contradictions

A large G-SVAR literature, including among others Blanchard and Perotti (2002), Caldara and Kamps (2008), Fatas and Mihov (2001), Galí, López-Salido, and Vallés (2007), finds economically and statistically significant expansionary effects of $a_{t/t}$. Ramey (2011) finds contractionary responses to $a_{d,t+1/t}$ in a G-EVAR, and attributes the expansionary effects estimated in the G-SVAR literature to the expansionary bias from the presence of fiscal foresight. In contrast to both sets of results, I find that G-SVARs display contractionary effects, and indeed more contractionary than G-EVARs.

How does one reconcile these two seeming contradictions of my results with the existing literature? The expansionary G-SVAR studies cited above start in 1954 or later.[16] Defense spending shocks were much larger in the sample up to the Korean War than afterwards. This suggests that the composition of total government spending shocks - civilian vs. defense spending shocks - might be important.

Consider a slight modification of the model used so far. Now the representative agent maximizes

[15] Regulation W should be seen against a steady increase in installment credit at the end of the forties: by 1950, less than half of the durables purchased were paid cash; and in 1949 one every four new cars was purchased by households with less than \$3,000 of income, against one in eight the year before. See the *Survey of Current Business*, November 1950, pp. 11 and 12. See the *Survey of Current Business*, November 1951, p. 7, for a description of Regulation X.

[16] Another difference is that most SVAR studies - including Blanchard and Perotti (2002) - use 68 percent confidence bands, thus often giving a misleading impression of statistical significance.

$$U = E_0 \sum_{t=0}^{\infty} \frac{\left(C_t V_t^{\delta}\right)^{1-\sigma}}{1-\sigma}; \qquad \sigma > 0, \quad \delta > 0 \tag{23}$$

$$\text{s.t.} \quad C_t + D_t + V_t + K_t = Z_t K_{t-1}^{\alpha}$$

where D_t and V_t are defense and civilian government spending respectively. The processes for d_t and v_t are as in (13). Appendix B solves this model with the method of undetermined coefficients. The solution for c_t is

$$\begin{aligned} c_t \;=\; & \psi_c c_{t-1} + \psi_d d_{t-1} + \psi_{d1} a_{d,t/t-1} + \psi_{d2} a_{d,t/t} + \psi_{d3} a_{d,t+1/t} + \\ & + \psi_{v1} a_{v,t/t-1} + \psi_{v2} a_{v,t/t} + \psi_{v3} a_{v,t+1/t} + \psi_z z_t \end{aligned} \tag{24}$$

where the expressions for the coefficients ψ are given in Appendix B.

When $\delta > 0$ the effects of civilian spending and of defense spending are different. Defense spending shocks have exactly the same contractionary effects as in the previous model. If $\sigma < 1$ private consumption and civilian government spending are Edgeworth complements, and shocks to civilian spending are less contractionary than shocks to defense spending ($\psi_{v2} > \phi_{v2}$, $\psi_{v3} > \phi_{v3}$). If in addition δ is sufficiently large, shocks to civilian spending can even be expansionary ($\psi_{v2} > 0$, $\psi_{v3} > 0$). Thus, this is a simple way of rationalizing a positive effect of government spending on private consumption without having to resort to a much more complicated model with price rigidities. From now on, I will assume $\sigma < 1$ and $\delta > 0$.

4.2 DC-SVAR

Under the two SVAR assumptions that there is no fiscal foresight and $\eta = 0$, the reduced form SVAR is:

$$d_t = \rho d_{t-1} + u_{d,t}^{DCS} \tag{25}$$

$$v_t = \rho v_{t-1} + u_{v,t}^{DCS} \tag{26}$$

$$c_t = \psi_c c_{t-1} + \psi_d d_{t-1} + \psi_v v_{t-1} + u_{c,t}^{DCS} \tag{27}$$

where

$$u_{d,t}^{DCS} = a_{d,t/t}; \quad u_{v,t}^{DCS} = a_{v,t/t}; \quad u_{c,t}^{DCS} = \psi_{d2} a_{d,t/t} + \psi_{v2} a_{v,t/t} + \psi_z z_t \tag{28}$$

To indicate that the government spending variables include both defense and civilian government spending, I call this specification a "DC-SVAR", hence the superscript "DCS". Under the usual SVAR assumptions, this approach estimates separate impulse responses to unanticipated changes in civilian and defense spending, $a_{v,t/t}$ and $a_{d,t/t}$. [17]

What happens if the SVAR assumptions are satisfied but the econometrician incorrectly assumes that $\delta = 0$, hence she estimates a G-SVAR like (5) and (6), with g_t as the only government spending variable? Intuitively, the estimated impulse response to a unit shock to $\overline{g} g_t$ will be in between the responses to $\overline{d} a_{d,t/t}$ and to $\overline{v} a_{v,t/t}$.

4.3 DC-EVAR

Now suppose that the first SVAR assumption fails, and there is fiscal foresight. The reduced form EVAR is:

$$d_t = \rho d_{t-1} + a_{d,t/t-1} + u_{d,t}^{DCS} \tag{29}$$

$$v_t = \rho v_{t-1} + v_{v,t/t-1} + u_{v,t}^{DCS} \tag{30}$$

$$c_t = \psi_c c_{t-1} + \psi_d d_{t-1} + \psi_v v_{t-1} + \psi_{d1} a_{d,t/t-1} + \psi_{d3} a_{d,t+1/t} + u_{c,t}^{DCE} \tag{31}$$

[17] In the model, $a_{v,t/t}$ and $a_{d,t/t}$ are uncorrelated, hence it makes no difference which of the two variables comes first in the Choleski decomposition. In practice, they might not be uncorrelated; but as shown below, their correlation is low enough that their order makes no appreciable difference.

where

$$u_{d,t}^{DCE} = a_{d,t/t} + a_{d,t/t-1}; \quad u_{v,t}^{DCE} = a_{v,t/t} + a_{v,t/t-1} \tag{32}$$

$$u_{c,t}^{DCE} = \psi_{d2} a_{d,t/t} + \psi_{v1} a_{v,t/t-1} + \psi_{v2} a_{v,t/t} + \psi_{v3} a_{v,t+1/t} + \psi_z z_t \tag{33}$$

I will call this specification a "DC-EVAR", hence the superscript "DCE".

What happens if the econometrician incorrectly assumes that $\delta = 0$, thus estimating a G-EVAR like (9) and (10)? Once again, there will be a bias in the estimate of the c equation. But there is a fundamental reason why one should expect a smaller difference between a G-EVAR and a DC-EVAR than between a G-SVAR and a DC-SVAR: unlike in a DC-SVAR, in a DC-EVAR the impact effect of a defense news shock, ψ_{d3}, is still estimated correctly even if $\delta > 0$, since $a_{d,t+1/t}$ is independent of all other variables in the reduced form equation (as in a G-EVAR).

I show below that indeed the difference between the G-EVAR and DC-EVAR responses to defense shocks is minimal; in contrast the two DC-SVAR impulse responses, to civilian and defense spending shocks, are very different from each other - one positive and one negative -, with the G-SVAR impulse response lying in between them. As explained above, this is precisely what one would expect if $\sigma < 1$ and δ is sufficiently large.

5 DC-EVARs and DC-SVARs in practice

I will now compare the responses to a defense news shock in a DC-EVAR and the two responses - to a civilian and defense spending shocks - in a DC-SVAR.[18] The specifications of the DC-EVAR and of the DC-SVAR are the same as the specifications of the G-EVAR and G-SVAR, respectively, except that the vector of endogenous variables includes d_t and v_t instead of g_t.

In the DC-EVAR the defense news variable is still first in the Choleski decomposition. In the DC-SVAR, d_t and v_t still precede all other variables in the

[18] I construct the civilian government spending series using chain-linked series on total government spending on goods and services and on defense spending on goods and services, and applying Whelan (2002)'s method to subtract two chain-linked series.

Choleski decomposition. There is no theoretical guidance on the order of these two variables; however, because the residuals of the two reduced form equations for d_t and v_t have a correlation of only -.09, the order turns out to be immaterial to the results. As a convention, I will show results when defense spending is ordered first and civilian spending second, but, as mentioned, the reverse ordering produces exactly the same impulse responses.

The sample starts in 1947:1, so as to include the Korean War while avoiding the problems discussed regarding WWII. Figures 4 and 5 display DC-EVAR responses to a defense news shock (column 1), DC-SVAR responses to a defense spending shock (column 2) and DC-SVAR responses to a civilian spending shock (column 3). The responses in the first two columns are very close to each other and similar to the G-EVAR and G-SVAR responses in columns 1 and 2 of Figure 3, but now the standard error bands are much tighter. These responses display clear contractionary features:GDP falls (DC-EVAR) or is flat (DC-SVAR); private GDP declines (Figure 4); consumption of durables and private investment decline significantly, while nondurables and services are flat (Figure 5). The only case in which the DC-EVAR and the DC-SVAR responses to a defense spending shock differ is that of the real wage, which falls in the DC-EVAR and increases in the DC-SVAR.

In contrast, DC-SVAR responses to a civilian spending shock, in column 3 of the same Figures 4 to 5, display all the typical expansionary features: peak GDP and private GDP responses of about 2 percent after about two years, significant at the 95 percent level; positive responses of durables (.5 percentage points of GDP at peak), non durables (.2 percentage points), and of private investment (1 percent of GDP), all significant except for non-durables; hours and the real wage increase significantly. Except for the real wage, all these responses have the opposite signs to the responses in columns 1 and 2 of the same figures.

Rows 5 and 6 in Figure 4 suggest that these expansionary features of civilian spending shocks cannot be explained by differences in the accompanying monetary or tax policies: both the federal funds rate and the Barro-Redlick tax rate increase in the medium to long run in response to a civilian spending shocks (column 3) while they decline (after a small initial increase in the case of taxes) in response to a defense news shock or a defense spending shock (columns 1 and 2).

To save space, I do not display the differences between these responses. But the results can be easily summarized. The difference between the DC-EVAR responses and DC-SVAR responses to a defense spending shock are always very small and insignificant. The DC-SVAR responses to a civilian spending shock are always larger than the other two, and nearly always significantly different from them at the 5 percent level.

Figure 6 displays the DC-SVAR responses to a civilian and a defense spending shock, respectively, from the three samples. Defense spending shocks are contractionary in all three samples. Civilian spending shocks are expansionary in all three samples.

Another indicator of the effects of government spending shocks is the cumulative total government spending output multiplier, defined as the ratio of the cumulated response of GDP at the numerator and the cumulated response of government spending at the denominator, each using a discount factor of .99 per quarter. Table 1 displays median cumulative multipliers at 8 quarters, from the Korean war and the post-1953 samples.

Table 1: **Multipliers at 8 quarters.**

		1947-2008	1954-2008
1	DC-EVAR	**.18**	**-.60**
2	DC-SVAR, def. shock	**.31**	**.15**
3	DC-SVAR, civ. shock	**1.09**	**1.12**

The multiplier is computed as the ratio of the cumulated response of GDP at 8 quarters to the cumulated response of total government spending at 8 quarters (calculated by multiplying the cumulated log response by the average share of government spending in GDP in each sample, using a discount factor of .99 per quarter.

The DC-EVAR multipliers and the defense spending DC-SVAR multipliers are always close to 0 or negative. The civilian spending DC-SVAR multiplier is above 1 in both samples.

6 Interpreting the SVAR residuals

As Ramey (2011) notes in the context of a G-SVAR, the DC-SVAR residuals of the defense spending equation are predictable by the Ramey-Shapiro military buildup variable (see row 1 of Table 2).

Table 2: **Granger causality, defense spending shocks.**

	Sample	F-stat	p-value
1	1947:1 - 2008:4	4.06	.003
2	excluding 1950:3	1.34	.257
3	1954:1-2008:4	1.24	.296

Regression of the residual of the defense government spending equation from the DC-SVAR on 4 lags of the Ramey - Shapiro dummy variable. The F-statistics refers to the exclusion of 4 lags of the Ramey - Shapiro dummy variable.

However, once again all of the predictive power of the Ramey-Shapiro dummy variable comes from Korea, and from 1950:3 in particular. In fact, if one excludes 1950:3 (row 2), or if the sample starts in 1954:1 (row 3), then the military buildup dummy no longer Granger causes the DC-SVAR residual of the defense spending equation. Yet, as mentioned above, even in the post-1953 sample DC-SVAR defense spending shocks still lead to responses that are statistically significant.

What about the civilian government spending shocks from a DC-SVAR? Not surprisingly, they cannot be predicted by the Ramey-Shapiro military dummy (see row 1 of Table 3). It could be argued that civilian government spending on goods and services is easily predictable because it is determined by long-run factors like population dynamics, that affect the need for several types of civilian spending, like transportation infrastructure and schools. These dynamics should largely be captured by the linear and quadratic trends of the DC-SVAR. Still, row 2 of Table 3 shows that, when the civilian spending shock is regressed on lags 1 to 12 of the log of population, the latter are jointly insignificant.

Table 3: **Granger causality, civilian spending shocks.**

	Sample	Predictor	F-stat	p-value
1	1947:1 - 2008:4	war dummies	.78	.542
2	1947:1 - 2008:4	war dummies, tot. pop.	1.31	.193

Regression of the structural civilian government spending shock (the residual of the regression of the residual of the civilian spending equation on the residual of the defense spending equation) from the DC-SVAR on 4 lags of the Ramey - Shapiro dummy variable (row 1) and 4 lags of the Ramey - Shapiro dummy variable and 12 lags of the log of total population (row 2). The F-statistics refers to the exclusion of all lags of the right-hand side variables.

7 An alternative decomposition

What explains the difference in the effects of civilian and defense spending shocks? A complete explanation is beyond the scope of this paper. But one plausible hypothesis is that spending on government employment and the remaining component of government spending (mostly purchases of goods) have different effects, and that defense and civilian spending shocks simply differ in the intensities of these two components.

This hypothesis is unfortunately difficult to test in the existing sample. The problem is illustrated in Figure 7, which displays responses from a SVAR with four government spending variables: civilian government employment, civilian purchases of goods, defense employment, and defense purchases of goods. Each column displays the response to shocks of each of these variables. When displaying the responses to the two defense spending shocks, defense purchases of goods and the defense employment come first, in this order; when displaying the responses to the two civilian spending shocks, civilian purchases of goods and civilian government employment come first, in this order.[19] As usual, all responses are normalized so that the response of total government spending (the sum of the four government spending variables) is one percent of GDP at peak.

[19] As usual, the responses of the four government spending variables are expressed as shares of GDP by multiplying the original response by the average share of that variable in GDP. This implicitly assumes that government wages do not change when a shock to government employment occurs. Results using the defense and civilian government wage bills instead of employment are very similar.

Only a shock to civilian purchases of goods (column 1) generates a clean experiment, in the sense that the responses of the other government spending variables are very small. In response to this shock, private GDP increases. A shock to civilian government employment generates a less clean experiment; the maximum increase in civilian government employment itself is worth just .4 percent of GDP; the remaining .6 percent of GDP at peak is made up from the other three components of government spending. Still, in this experiment private GDP increases substantially, by 2 percent of GDP at peak.

The two defense spending shocks are difficult to distinguish from each other because they generate similar responses of the government spending variables: in both cases defense employment spending increases by .5 percent of GDP, and civilian purchases of goods fall considerably. The difference between the two experiments is that defense purchases of goods increase more in response to a shock to defense purchases of goods. In this case, private GDP initially increases, then falls below 0 for a prolonged period of time; it is flat when defense employment spending is shocked.

Overall, a pairwise comparison of shocks to civilian and defense goods purchases, and of shocks to civilian and defense government employment, shows that in each pair the first component has expansionary effects, and the second has weaker, or even negative, effects.

8 An instrumental variable interpretation

One could interpret a G-SVAR and a G-EVAR as two approaches that estimate the same object using two different instruments for g_t: the residual of the reduced form g_t equation in the former case, and the defense news variable in the latter. The latter instrument has the advantage that it does not require the two SVAR hypotheses to hold. To best understand this instrumental variable interpretation, it is useful to start from the equation for c_t, which, assuming initially $\delta = 0$, can be written as (see equation A. 28 in Appendix A):

$$c_t = \phi_c c_{t-1} + \phi_{g_2} g_t + (\phi_g - \rho\phi_{g_2}) g_{t-1} + (\phi_{g1} - \phi_{g2}) a_{t/t-1} + \phi_{g3} a_{t+1/t} + (\phi_z - \phi_{g_2}\eta) z_t \quad (34)$$

With a slight abuse of terminology, I will call this equation "the structural equation for c_t". If the two SVAR assumptions hold, the above equation becomes

$$c_t = \phi_c c_{t-1} + \phi_{g_2} g_t + (\phi_g - \rho\phi_{g_2}) g_{t-1} + u_{c,t}^{GS}; \qquad u_{c,t}^{GS} = \phi_z z_t \tag{35}$$

The Choleski decomposition in a G-SVAR can be interpreted as an instrumental variable estimation, in which the residual $u_{g,t}^{GS}$ of (5), which is nothing but $a_{t/t}$, is used to instrument for g_t in (35). In the language of Stock and Watson (2012), $u_{g,t}^{GS}$ is an "internal" instrument. Now suppose the two SVAR assumptions fail. Instead of (34), one can write the c_t equation as (see again equation A. 28 in Appendix A):

$$c_t = \phi_c c_{t-1} + \phi_{g_1} g_t + (\phi_g - \rho\phi_{g_1}) g_{t-1} + \phi_{g3} \frac{\overline{d}}{\overline{g}} a_{t+1/t}^{d} + u_{c,t}^{GE}; \tag{36}$$

$$u_{c,t}^{GE} = (\phi_{g2} - \phi_{g1}) a_{t/t} + \phi_{g3} \frac{\overline{v}}{\overline{g}} a_{v,t+1/t} + (\phi_z - \phi_{g_2}\eta) z_t \tag{37}$$

Because $\eta \neq 0$, $u_{g,t}^{GS}$ is no longer a legitimate instrument for g_t. The G-EVAR approach can be interpreted as estimating the equation using $a_{d,t/t-1}$ as an instrument for g_t. In the language of Stock and Watson (2012) this is an "external instrument": a *component* of the structural shock of the g_t equation that is not correlated with the structural shock of (36).

All this is indeed correct when $\delta = 0$. But when $\delta > 0$, both the G-EVAR and the G-SVAR are misspecified, regardless of whether the two SVAR assumptions hold or not. The coefficients of d_t and its lags are different from those of v_t and its lags. As a consequence, in a G-SVAR, the estimated effect of total government spending will be a mixture of the effects of civilian and defense spending. In a G-EVAR total government spending instrumented with the defense news variable reflects mostly variation in defense spending; hence the G-EVAR response will be very similar to the DC-EVAR response to defense spending shocks. This is indeed what we have seen in the previous section.

9 Conclusions

In this paper, I have shown that defense spending shocks in SVARs and defense news shocks in EVARs have contractionary effects; civilian spending shocks in SVARs have expansionary effects. Hence, generalizing from results on defense spending shocks to often-heard statements like "government spending has zero or negative effects on private economic activity" is unwarranted.

In addition, defense spending shocks in a DC-SVAR and defense news shocks in a DC-EVAR have virtually identical effects. This suggests that anticipation effects are not important, and that the key distinction is in the type of shock - defense vs. civilian. Of course, ideally one would also have data on civilian spending "news". But the fact that responses to SVAR defense shocks and EVAR defense news shocks are virtually identical suggests (without demonstrating) that SVARs, if properly specified, are a good enough tool to investigate the effects of government spending shocks. These results are consistent with those of Chahrour, Schmitt-Grohė and Uribe (2010), who generate the data from a DSGE model in which part of the shocks (to taxation) are anticipated, and show that a SVAR displays minimal bias.

The conclusions of this paper appear to contradict the widespread notion that EVARs and SVARs deliver sharply different answers. The reason for this mistaken notion is that the literature does not allow for different effects of defense and civilian government spending, and defense news EVARs are estimated on samples including WWII and Korea, when defense spending shocks prevailed, while SVARs are typically estimated on samples starting in 1954 or later, when civilian spending shocks prevailed. Hence, the two methodologies essentially capture two different types of shocks - defense spending shocks the former, and civilian spending shocks the latter.

One might argue that studying the effects of civilian spending shocks is not interesting because, if they are not purely of the "throw-in-the-ocean" type, they cannot discriminate between neoclassical and neokeynesian models. However, from an empirical and policy viewpoint estimating the effects of civilian spending shocks is as interesting as estimating the effects of defense spending shocks; in fact, one could argue that in peacetime it is *more* interesting.

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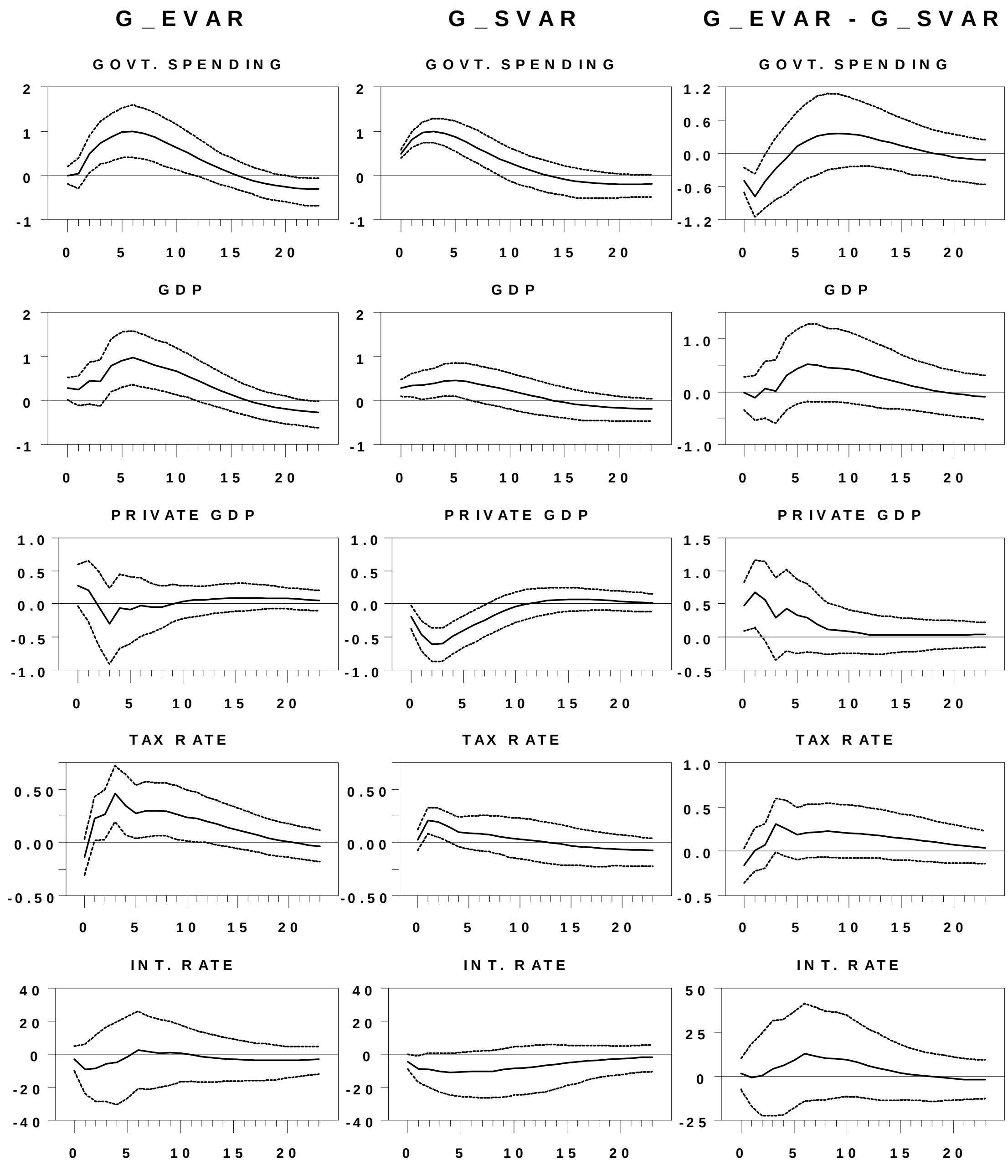

Figure 1: G-EVAR and G-SVAR, 1939-2008, I

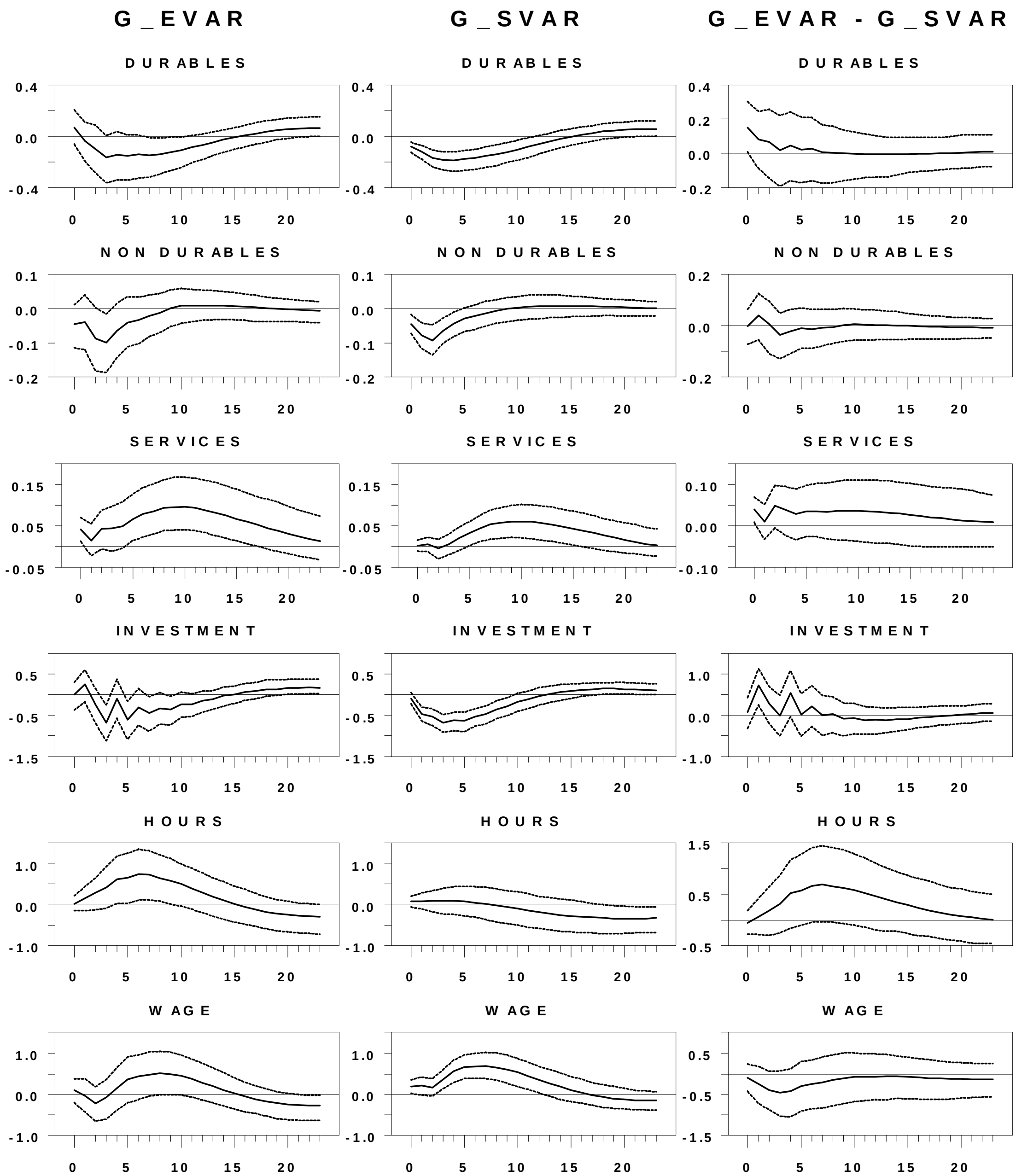

Figure 2: G-EVAR and G-SVAR, 1939-2008, II

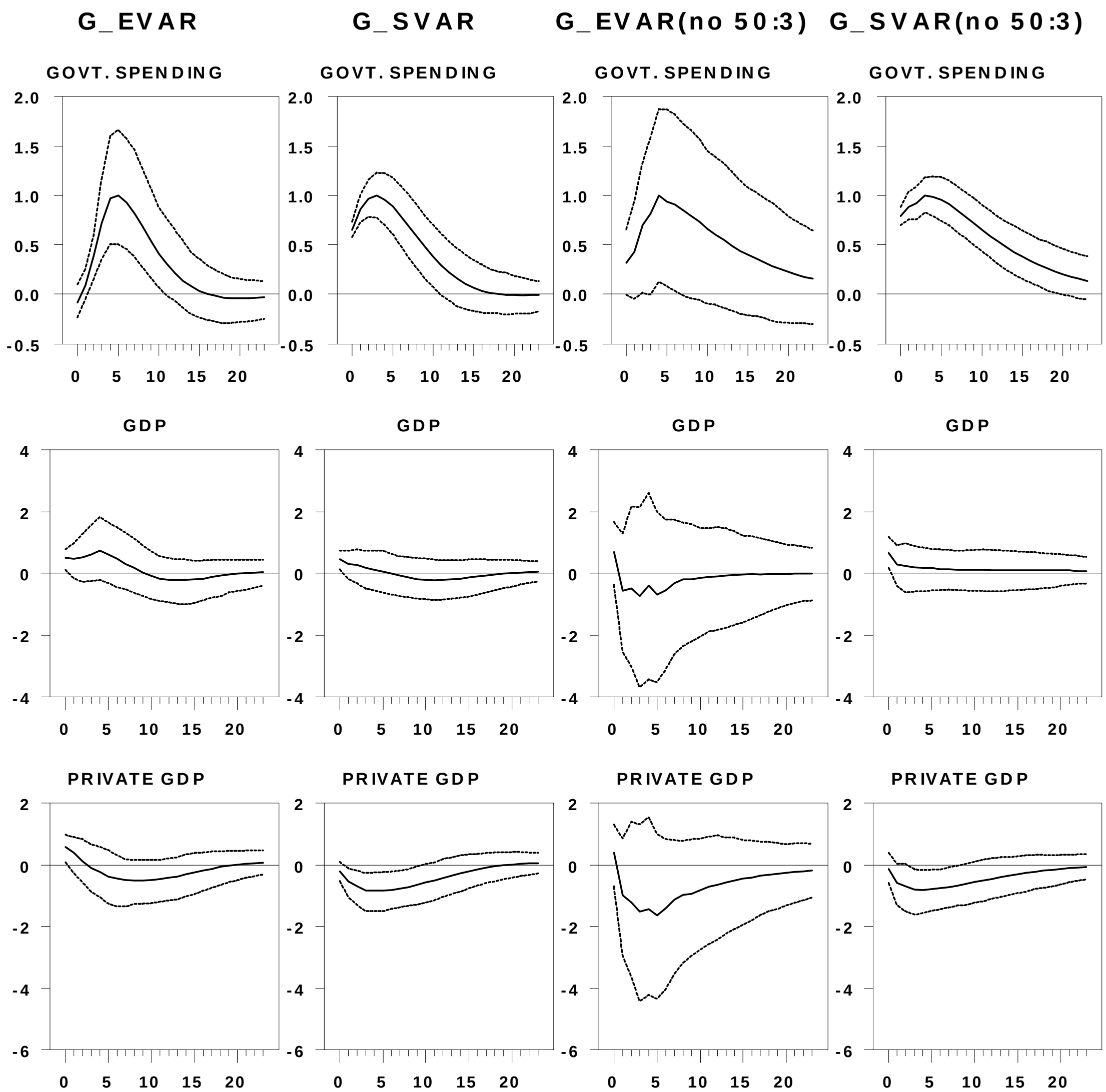

Figure 3: G-EVAR and G-SVAR, 1947-2008

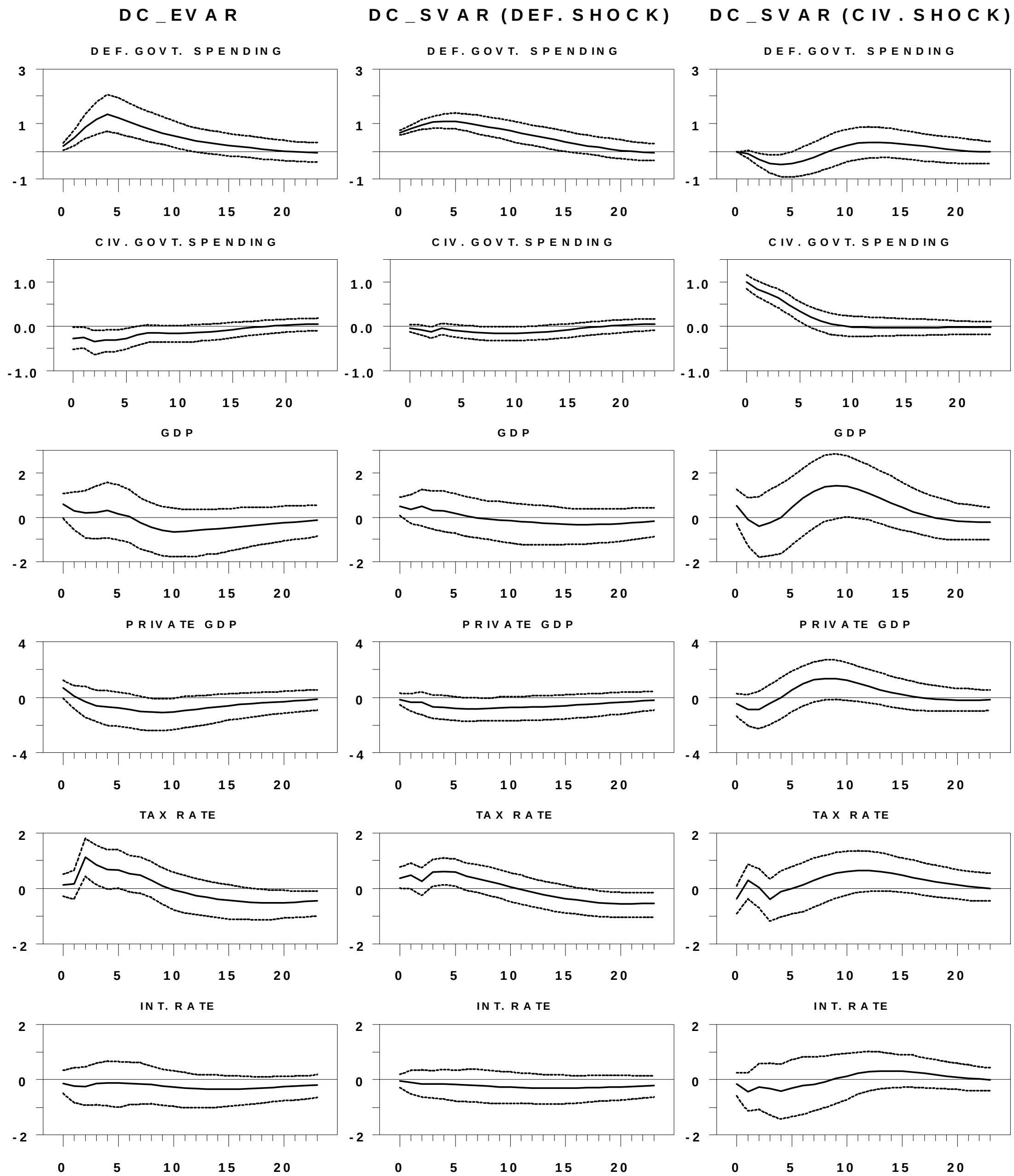

Figure 4: DC-EVAR and DC-SVAR, 1947-2008, I

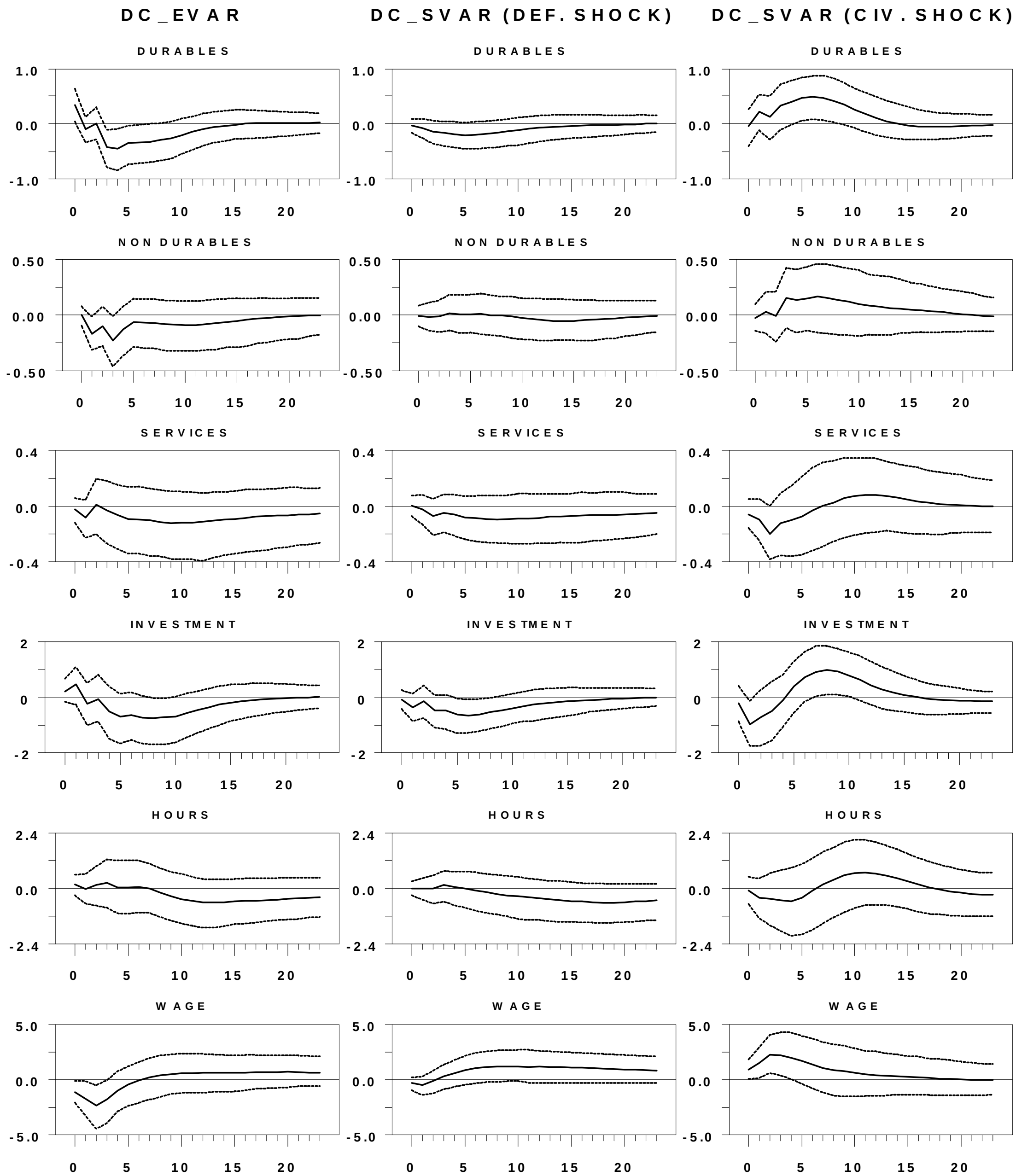

Figure 5: DC-EVAR and DC-SVAR, 1947-2008, II

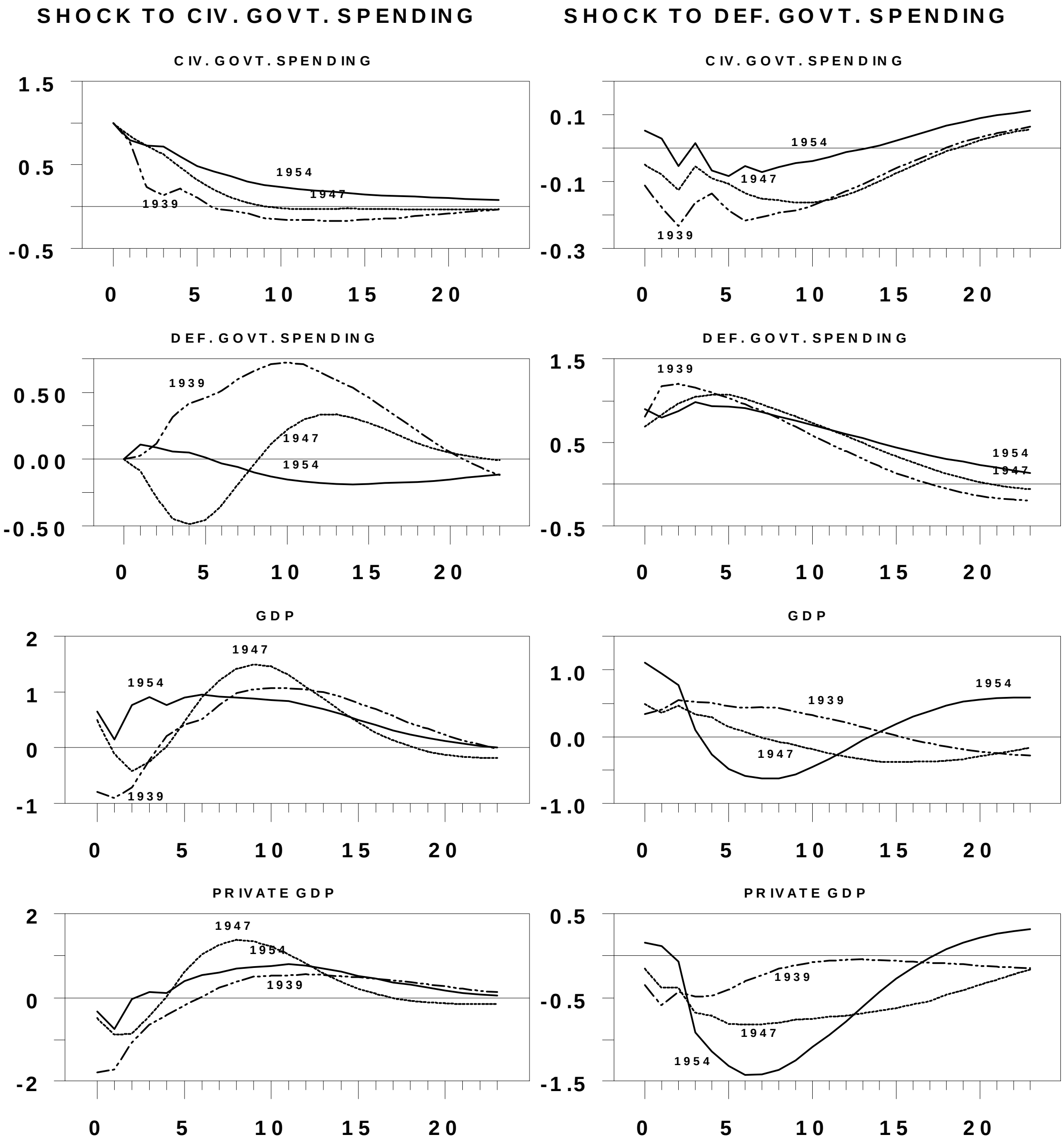

Figure 6: DC-SVAR, 1939-2008, 1947-2008, and 1954-2008

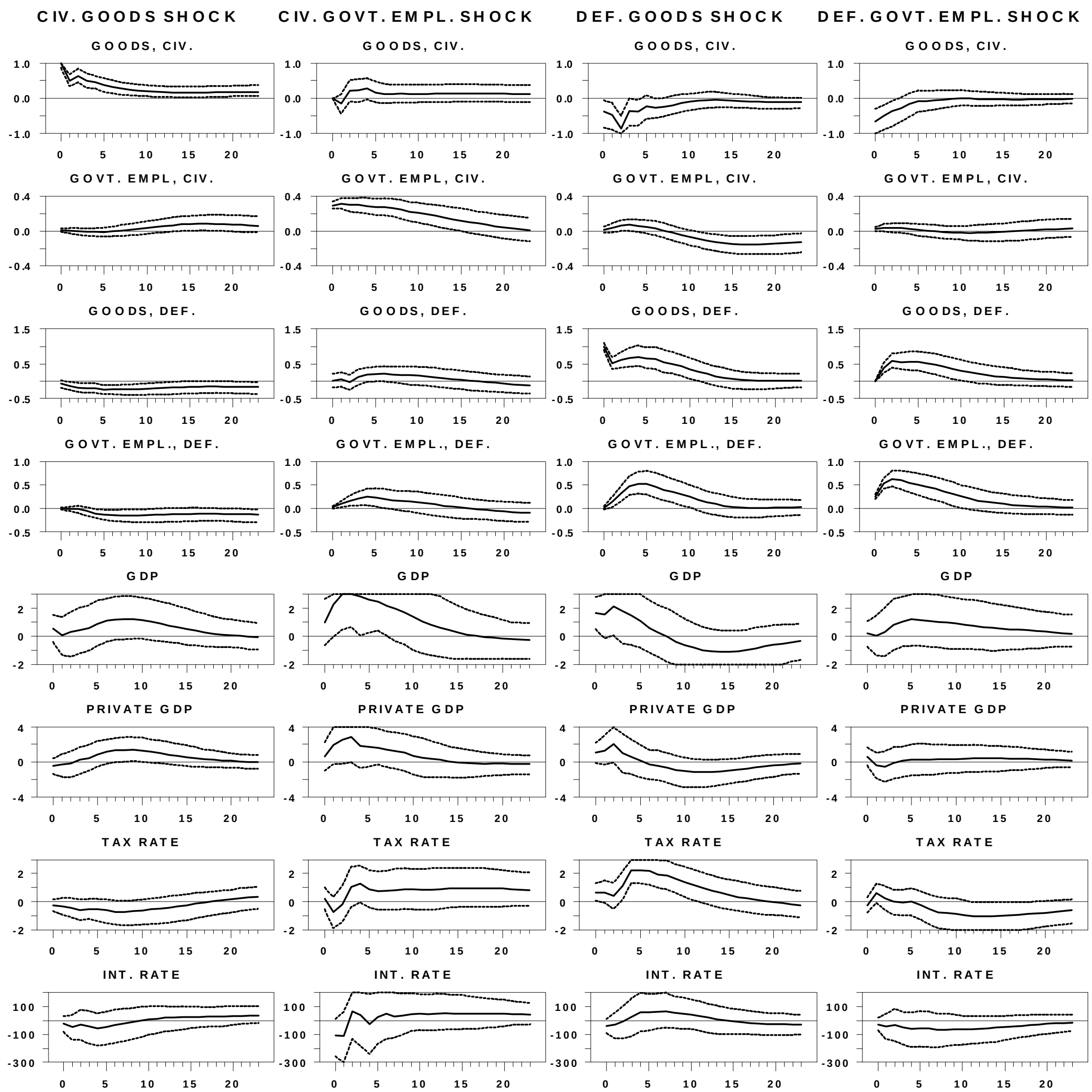

Figure 7: Shocks to government purchases of goods and employment, 1947-2008

Appendix A

Let $\overline{c} = C/Y$ be the steady state value of consumption, as a share of steady-state GDP, and similarly for $\overline{g}$ and $\overline{k}$. Loglinearization of the resource constraint of the economy gives

$$\overline{c}c_t = \alpha k_{t-1} - \overline{g}g_t - \overline{k}k_t + z_t \tag{A. 1}$$

The two loglinearized first order conditions are:

$$r_t = (\alpha - 1)k_{t-1} + z_t \tag{A. 2}$$

$$\sigma c_t = \sigma E_t c_{t+1} + (1 - \alpha)k_t \tag{A. 3}$$

where r_t is the difference between the interest rate and the rate of time preference $1/\beta - 1$. Assume a process for g_t of the form

$$g_t = \rho g_{t-1} + a_{t/t-1} + a_{t/t} + \eta z_t \tag{A. 4}$$

where $a_{t/t}$ and $a_{t/t-1}$ are expressed as shares of steady state government spending and z_t is white noise. To apply the method of undetermined coefficients, I assume the following process for k_t

$$k_t = \theta_k k_{t-1} + \theta_g g_{t-1} + \theta_{g1} a_{t/t-1} + \theta_{g2} a_{t/t} + \theta_{g3} a_{t+1/t} + \theta_z z_t \tag{A. 5}$$

In steady state

$$aK^{\alpha-1} = \frac{1}{\beta} \tag{A. 6}$$

(note that in steady state $Z_t = 1$), hence

$$\overline{k} = \alpha\beta \tag{A. 7}$$

From (A. 1), (A. 3) and (A. 4):

$$\frac{\sigma}{\overline{c}}(\alpha k_{t-1} - \overline{g}g_t - \overline{k}k_t + z_t) - \frac{\sigma}{\overline{c}}(\alpha k_t - \rho\overline{g}g_t - \overline{g}a_{t+1/t} - \overline{k}E_t k_{t+1}) - (1-\alpha)k_t = 0 \tag{A. 8}$$

Multiplying through by $\bar{c}\sigma^{-1}$, and using (A. 5)

$$\begin{aligned}&(\alpha k_{t-1} - \bar{g}g_t - \bar{k}k_t + z_t) - (\alpha k_t - \rho\bar{g}g_t - \bar{g}a_{t+1/t}) - \\ &-\bar{c}\sigma^{-1}(1-\alpha)k_t + \bar{k}(\theta_k k_t + \theta_g g_t + \theta_{g1}a_{t+1/t}) = 0\end{aligned} \tag{A. 9}$$

Define

$$\gamma \equiv \bar{k} + \alpha + \pi > 0 \tag{A. 10}$$

where

$$\pi \equiv \bar{c}\sigma^{-1}(1-\alpha) \tag{A. 11}$$

and collect all terms in the same variables

$$\alpha k_{t-1} + (\bar{g} + \bar{k}\theta_{g1})a_{t+1/t} + \left[\bar{k}\theta_g - (1-\rho)\bar{g}\right] g_t + (\bar{k}\theta_k - \gamma)k_t + z_t = 0 \tag{A. 12}$$

Now use again (A. 5) to replace k_t and (A. 4) to replace g_t

$$\begin{aligned}&\alpha k_{t-1} + (\bar{g} + \bar{k}\theta_{g1})a_{t+1/t} + \left[\bar{k}\theta_g - (1-\rho)\bar{g}\right] (\rho g_{t-1} + a_{t/t-1} + a_{t/t} + \eta z_t) + \\ &+(\bar{k}\theta_k - \gamma)(\theta_k k_{t-1} + \theta_g g_{t-1} + \theta_{g1}a_{t/t-1} + \theta_{g2}a_{t/t} + \theta_{g3}a_{t+1/t} + \theta_z z_t) + z_t = 0\end{aligned} \tag{A. 13}$$

and collecting terms

$$\begin{aligned}&\left[\alpha + (\bar{k}\theta_k - \gamma)\theta_k\right] k_{t-1} + \\ &\left[\bar{k}\theta_g\rho - (1-\rho)\bar{g}\rho + (\bar{k}\theta_k - \gamma)\theta_g\right] g_{t-1} + \\ &\left[\bar{k}\theta_g - (1-\rho)\bar{g} + (\bar{k}\theta_k - \gamma)\theta_{g1}\right] a_{t/t-1} + \\ &\left[\bar{k}\theta_g - (1-\rho)\bar{g} + (\bar{k}\theta_k - \gamma)\theta_{g2}\right] a_{t/t} + \\ &\left[\bar{g} + \bar{k}\theta_{g1} + (\bar{k}\theta_k - \gamma)\theta_{g3}\right] a_{t+1/t} + \\ &\left[1 + (\bar{k}\theta_k - \gamma)\theta_z + (\bar{k}\theta_g - (1-\rho)\bar{g})\eta\right] z_t\end{aligned} \tag{A. 14}$$

Thus from the first line of (A. 14) we have

$$\left(\bar{k}\theta_k - \gamma\right)\theta_k + \alpha = 0 \tag{A. 15}$$

i.e.

$$\overline{k}\theta_k^2 - \gamma\theta_k + \alpha = 0 \tag{A. 16}$$

This gives

$$\theta_k = \frac{\gamma \pm \sqrt{\gamma^2 - 4\alpha\overline{k}}}{2\overline{k}} \tag{A. 17}$$

The smaller root is smaller than 1 if

$$\gamma - \sqrt{\gamma^2 - 4\alpha\overline{k}} < 2\overline{k} \tag{A. 18}$$

This reducs to

$$\pi > 0 \tag{A. 19}$$

which is obviously true. Also we have

$$\theta_g = -\frac{\rho(1-\rho)\overline{g}}{\gamma - \overline{k}\theta_k - \overline{k}\rho} < 0; \quad \theta_{g1} = \theta_{g2} = -\frac{(1-\rho)\overline{g}}{\gamma - \overline{k}\theta_k - \overline{k}\rho} < 0; \quad \theta_{g3} = \frac{\overline{g} + \overline{k}\theta_{g1}}{\gamma - \overline{k}\theta_k} > 0 \tag{A. 20}$$

From (A. 15)

$$\gamma - \overline{k}\theta_k = \theta_k^{-1}\alpha \tag{A. 21}$$

hence, using also $\overline{k} = \alpha\beta$

$$\begin{aligned} \theta_g &= -\frac{\alpha^{-1}\theta_k\overline{g}\rho(1-\rho)}{1-\theta_k\beta\rho} < 0; \quad \theta_{g1} = \theta_{g2} = -\frac{\alpha^{-1}\theta_k\overline{g}(1-\rho)}{1-\theta_k\beta\rho} < 0; \\ \theta_{g3} &= \overline{g}\theta_k\alpha^{-1}\left[\frac{1-\theta_k\beta}{1-\theta_k\beta\rho}\right] > 0; \qquad \theta_z = \alpha^{-1}\theta_k + \theta_{g1}\eta \end{aligned} \tag{A. 22}$$

To get the law of motion of private GDP q_t, multiply (A. 5) by α and add and subtract z_{t+1} and $\theta_k z_t$. This gives:

$$\begin{aligned} ak_t + z_{t+1} &= \theta_k(\alpha k_{t-1} + z_t) + \alpha\theta_{g1}g_t + \alpha\theta_{g3}a_{t+1/t} \\ &\quad + (\alpha\theta_z - \theta_k - \alpha\theta_{g1}\eta)z_t + z_{t+1} \end{aligned} \tag{A. 23}$$

From the definition of θ_z in (A. 22)

$$\alpha\theta_z - \theta_k - \alpha\theta_1\eta = 0 \tag{A. 24}$$

Therefore, (A. 23) becomes (also shifting by one period)

$$y_t = \theta_k y_{t-1} + \alpha\theta_{g1} g_{t-1} + \alpha\theta_{g3} a_{t/t-1} + z_t \tag{A. 25}$$

Now subtract $\overline{g} g_t$ and $\theta_k \overline{g} g_{t-1}$ from both sides of (A. 25) to get the law of motion of private GDP

$$q_t = \mu_q q_{t-1} + \mu_g g_{t-1} + \mu_{g1} a_{t/t-1} + \mu_{g2} a_{t/t} + \mu_{g3} a_{t+1/t} + \mu_z z_t \tag{A. 26}$$

where

$$\begin{aligned}
\mu_q &= \theta_k; \quad \mu_g = \overline{g}\left[\theta_k - \rho - \frac{\theta_k(1-\rho)}{\alpha - \theta_k \overline{k}\rho}\right]; \qquad\qquad (\text{A. } 27) \\
\mu_{g1} &= -\overline{g}\theta_k \left[\frac{\overline{g}(1-\rho)+\pi}{\alpha - \theta_k \overline{k}\rho}\right] < 0; \quad \mu_{g2} = -\overline{g}; \quad \mu_{g3} = 0; \quad \mu_z = 1 - \overline{g}\eta
\end{aligned}$$

To get the law of motion of private consumption, subtract $\overline{k} k_t - \theta_k \overline{k} k_{t-1}$ from both sides of (A. 26). This gives:

$$c_t = \phi_c c_{t-1} + \phi_g g_{t-1} + \phi_{g1} a_{t/t-1} + \phi_{g2} a_{t/t} + \phi_{g3} a_{t+1/t} + \phi_z z_t \tag{A. 28}$$

where

$$\begin{aligned}
\phi_c &= \theta_k; \quad \phi_g = -\alpha^{-1}\rho\overline{g}\theta_k \frac{\pi}{1-\theta_k\beta\rho} < 0; \qquad\qquad (\text{A. } 29) \\
\phi_{g1} &= -\alpha^{-1}\overline{g}\theta_k \frac{\pi}{1-\theta_k\beta\rho} < 0; \quad \phi_{g2} = -\overline{g}\frac{1-\theta_k\beta}{1-\theta_k\beta\rho} < 0 \\
\phi_{g3} &= -\alpha^{-1}\overline{g}\theta_k\beta\frac{1-\theta_k\beta}{1-\theta_k\beta\rho} < 0; \quad \phi_z = 1 - \theta_k\beta - \alpha^{-1}\eta\overline{g}\left[\frac{1-\theta_k\beta}{1-\theta_k\beta\rho}\right]
\end{aligned}$$

Appendix B

This appendix solves the model when $\delta > 0$. The problem of the representative agent is now

$$U = E_0 \sum_{t=0}^{\infty} \frac{(C_t V_t^{\delta})^{1-\sigma}}{1-\sigma}; \qquad \sigma > 0, \quad \delta > 0 \tag{B. 1}$$

s.t.

$$C_t + D_t + V_t + K_t = \; Z_t K_{t-1}^{\alpha} \tag{B. 2}$$

Note that, given $\delta > 0$, the second cross derivative of the utility function is positive is $\sigma < 1$. Loglinearization of the resource constraint of the economy gives

$$\bar{c} c_t = \; \alpha k_{t-1} - \bar{d} d_t - \bar{v} v_t - \bar{k} k_t + z_t \tag{B. 3}$$

The log-linearized Euler equation now is:

$$\sigma c_t - \delta(1-\sigma) v_t = \sigma E_t c_{t+1} - \delta(1-\sigma) E_t v_{t+1} + (1-\alpha) k_t \tag{B. 4}$$

The second first order condition is as before:

$$r_t = (\alpha - 1) k_{t-1} + z_t \tag{B. 5}$$

Assume processes for d_t and v_t of the form[20]

$$v_t = \rho v_{t-1} + a_{v,t/t-1} + a_{v,t/t}; \quad d_t = \rho d_{t-1} + a_{d,t/t-1} + a_{d,t/t} \tag{B. 6}$$

To apply the method of undetermined coefficients, I assume the following processes for k_t

$$\begin{aligned} k_t \;&=\; \theta_k' k_{t-1} + \theta_d d_{t-1} + \theta_v v_{t-1} + \theta_{d1} a_{d,t/t-1} + \theta_{d2} a_{d,t/t} + \theta_{d3} a_{d,t+1/t} \\ &\quad + \theta_{v1} a_{v,t/t-1} + \theta_{v2} a_{v,t/t} + \theta_{v3} a_{v,t+1/t} + \theta_z' z_t \end{aligned} \tag{B. 7}$$

[20] For simplicity, I assume that v_t and d_t do not depend on z_t, i.e. $\eta = 0$. The case of $\eta \neq 0$ was illustrated in Appendix A.

Like before, in steady state

$$aZK^{\alpha-1} = \frac{1}{\beta} \tag{B. 8}$$

hence

$$\overline{k} = \alpha\beta \tag{B. 9}$$

From (B. 4) and (B. 6)

$$\sigma c_t - \delta(1-\sigma)[v_t(1-\rho) - a_{v,t+1/t}] - \sigma E_t c_{t+1} - (1-\alpha)k_t = 0 \tag{B. 10}$$

Multiplying through by $\overline{c}\sigma^{-1}$, and using (B. 3)

$$\begin{aligned}(\alpha k_{t-1} - \overline{d}d_t - \overline{v}v_t - \overline{k}k_t + z_t) - \overline{c}\sigma^{-1}\delta(1-\sigma)(1-\rho)v_t + \overline{c}\sigma^{-1}\delta(1-\sigma)a_{v,t+1/t} - \\ - (\alpha k_t - \rho\overline{d}d_t - \overline{d}a_{d,t+1/t} - \rho\overline{v}v_t - \overline{v}a_{v,t+1/t} - \overline{k}E_t k_{t+1}) - \overline{c}\sigma^{-1}(1-\alpha)k_t = 0\end{aligned} \tag{B. 11}$$

and using expression (B. 7) to replace $E_t k_{t+1}$

$$\begin{aligned}&(\alpha k_{t-1} - \overline{d}d_t - \overline{v}v_t - \overline{k}k_t + z_t) - \overline{c}\sigma^{-1}\delta(1-\sigma)(1-\rho)v_t - \\ &-(\alpha k_t - \rho\overline{d}d_t - \overline{d}a_{d,t+1/t} - \rho\overline{v}v_t - \overline{v}a_{v,t+1/t}) + \overline{c}\sigma^{-1}\delta(1-\sigma)a_{v,t+1/t} - \\ &-\overline{c}\sigma^{-1}(1-\alpha)k_t + \overline{k}(\theta'_k k_t + \theta_d d_t + \theta_{d1}a_{d,t+1/t} + \theta_v v_t + \theta_{v1v,t+1/t}) = 0\end{aligned} \tag{B. 12}$$

collecting terms

$$\begin{aligned}&\left[-\overline{d} + \overline{d}\rho + \overline{k}\theta_d\right] d_t + \\ &+ \left[-\overline{v} - \overline{c}\sigma^{-1}\delta(1-\sigma)(1-\rho) + \rho\overline{v} + \overline{k}\theta_v\right] v_t + \\ &+ \left[-\overline{k} - \alpha - \overline{c}\sigma^{-1}(1-\alpha) + \overline{k}\theta'_k\right] k_t + \alpha k_{t-1} + \\ &+ \left[\overline{d} + \overline{k}\theta_{d1}\right] a_{d,t+1/t} + \left[(\overline{v} + \overline{k}\theta_{v1}) + \overline{c}\sigma^{-1}\delta(1-\sigma)\right] a_{v,t+1/t} + z_t = 0\end{aligned} \tag{B. 13}$$

Now define

$$\gamma \equiv \overline{k} + \alpha + \overline{c}\sigma^{-1}(1-\alpha) \tag{B. 14}$$

and

$$\chi \equiv \bar{c}\sigma^{-1}\delta(1-\sigma) \tag{B. 15}$$

and replace k_t, v_t and d_t with their expressions from (B. 6) and (B. 7):

$$\begin{aligned}
&\left[-(1-\rho)\bar{d}+\bar{k}\theta_d\right](\rho d_{t-1}+a_{d,t/t}+a_{d,t/t-1})+ \\
&+\left[-(\bar{v}+\chi)(1-\rho)+\bar{k}\theta_v\right](\rho v_{t-1}+a_{v,t/t}+a_{v,t/t-1})+ \\
&+\left[-\gamma+\bar{k}\theta_k'\right]*[\theta_k' k_{t-1}+\theta_d d_{t-1}+\theta_v v_{t-1}+\theta_{d1}a_{d,t/t-1}+\theta_{d2}a_{d,t/t}+\theta_{d3}a_{d,t+1/t}] \\
&+\left[-\gamma+\bar{k}\theta_k'\right]*\left[\theta_{v1}a_{v,t/t-1}+\theta_{v2}a_{v,t/t}+\theta_{v3}a_{v,t+1/t}+\theta_z' z_t\right] \\
&+\alpha k_{t-1}+\left[\bar{d}+\bar{k}\theta_{d1}\right]a_{d,t+1/t}+\left[\bar{v}+\bar{k}\theta_{v1}+\chi\right]a_{v,t+1/t}+z_t=0
\end{aligned} \tag{B. 16}$$

Collecting terms:

$$\begin{aligned}
&\left\{\left[-\gamma+\bar{k}\theta_k\right]\theta_k'+\alpha\right\}k_{t-1}+ \\
&+\left\{\left[-(1-\rho)\bar{d}+\bar{k}\theta_d\right]\rho-\left[\gamma-\bar{k}\theta_k'\right]\theta_d\right\}d_{t-1}+ \\
&+\left\{\left[-(\bar{v}+\chi)(1-\rho)+\bar{k}\theta_v\right]\rho-\left[\gamma-\bar{k}\theta_k'\right]\theta_v\right\}v_{t-1}+ \\
&+\left\{\left[-(1-\rho)\bar{d}+\bar{k}\theta_d\right]-\left[\gamma-\bar{k}\theta_k'\right]\theta_{d1}\right\}a_{d,t/t-1}+ \\
&+\left\{\left[-(1-\rho)\bar{d}+\bar{k}\theta_d\right]-\left[\gamma-\bar{k}\theta_k'\right]\theta_{d2}\right\}a_{d,t/t}+ \\
&+\left\{\left[-\gamma+\bar{k}\theta_k'\right]\theta_{d3}+(\bar{d}+\bar{k}\theta_{d1})\right\}a_{d,t+1/t}+ \\
&+\left\{\left[-(\bar{v}+\chi)(1-\rho)+\bar{k}\theta_v\right]-\left[\gamma-\bar{k}\theta_k'\right]\theta_{v1}\right\}a_{v,t/t-1}+ \\
&+\left\{\left[-(\bar{v}+\chi)(1-\rho)+\bar{k}\theta_v\right]-\left[\gamma-\bar{k}\theta_k'\right]\theta_{v2}\right\}a_{v,t/t}+ \\
&+\left\{\left[-\gamma+\bar{k}\theta_k'\right]\theta_{v3}+(\bar{v}+\bar{k}\theta_{v1})+\chi\right\}a_{v,t+1/t}+ \\
&+\left\{\left[-\gamma+\bar{k}\theta_k'\right]\theta_z'+1\right\}z_t=0
\end{aligned} \tag{B. 17}$$

From the first line of (B. 17) we have

$$(\bar{k}\theta_k'-\gamma)\theta_k'+\alpha=0 \tag{B. 18}$$

which implies

$$\theta_k'=\theta_k \tag{B. 19}$$

Equating to 0 the expressions in braces gives

$$\begin{aligned}\theta_d &= \frac{\overline{d}}{\overline{g}}\theta_g < 0; \quad \theta_{di} = \frac{\overline{d}}{\overline{g}}\theta_{gi} < 0; \quad \theta_v = \frac{\overline{v}+\chi}{\overline{g}}\theta_g; \\ \theta_{vi} &= \frac{\overline{v}+\chi}{\overline{g}}\theta_{gi} < 0; \quad \theta_z' = \theta_z; \quad i = 1,2,3\end{aligned} \tag{B. 20}$$

Now multiply (B. 7) by α, subtract z_{t+1} from both sides and use $\theta_z = \frac{1}{\alpha}\theta_k$

$$\begin{aligned}ak_t + z_{t+1} &= \theta_k(\alpha k_{t-1} + z_t) + \theta_d \alpha d_{t-1} + \theta_v \alpha v_{t-1} + \theta_{d1}\alpha a_{d,t/t-1} + \\ &+\theta_{d2}\alpha a_{d,t/t} + \theta_{d3}\alpha a_{d,t+1/t} + \theta_{v1}\alpha a_{v,t/t-1} + \theta_{v2}\alpha a_{v,t/t} + \theta_{v3}\alpha a_{v,t+1/t} + z_{t+1}\end{aligned} \tag{B. 21}$$

Hence, using $\theta_d = \rho\theta_{d1}$; $\theta_{d1} = \theta_{d2}$, and similarly for civilian spending

$$y_{t+1} = \theta_k y_t + \alpha\theta_d d_t + \alpha\theta_v v_t + \alpha\theta_{d3} a_{d,t+1/t} + \alpha\theta_{v6} a_{v,t+1/t} + z_{t+1} \tag{B. 22}$$

To find the law of motion of private GDP q_t, let

$$\begin{aligned}q_t &= \mu_q' q_{t-1} + \mu_d d_{t-1} + \mu_v v_{t-1} + \mu_{d1} a_{d,t/t-1} + \mu_{v1} a_{v,t/t-1} \\ &+\mu_{d2} a_{d,t/t} + \mu_{v2} a_{v,t/t} + \mu_{d3} a_{d,t+1/t} + \mu_{v3} a_{v,t+1/t} + \mu_z' z_t\end{aligned} \tag{B. 23}$$

To find the coefficients μ's, lag (B. 22) by one period and subtract $\overline{g}g_t$ and $\theta_k\overline{g}g_{t-1}$ from both sides:

$$q_t = \theta_k q_{t-1} + (\theta_k\overline{d} + \alpha\theta_{d1})d_{t-1} + (\theta_k\overline{v} + \alpha\theta_{v1})v_{t-1} + \alpha\theta_{d3} a_{d,t/t-1} + \alpha\theta_{v3} a_{v,t/t-1} - \overline{g}g_t + z_t \tag{B. 24}$$

hence

$$\begin{aligned}q_t &= \theta_k q_{t-1} + (\theta_k\overline{d} + \alpha\theta_{d1} - \rho\overline{d})d_{t-1} + (\theta_k\overline{v} + \alpha\theta_{v1} - \rho\overline{v})v_{t-1} + \\ &+(\alpha\theta_{d3} - \overline{d})a_{d,t/t-1} + (\alpha\theta_{v3} - \overline{v})a_{v,t/t-1} - \overline{d}a_{d,t/t} - \overline{v}a_{v,t/t} + z_t\end{aligned} \tag{B. 25}$$

Therefore:

$$\mu_q' = \ \theta_k; \quad \mu_d = \frac{\overline{d}}{g}\mu_g < 0; \qquad \mu_{d1} = \frac{\overline{d}}{g}\mu_{g1} < 0; \quad \mu_{d2} = \frac{\overline{d}}{g}\mu_{g2} < 0; \quad \mu_{d3} = 0; \tag{B. 26}$$

$$\mu_v = \frac{\overline{v}}{g}\mu_g + \frac{\alpha}{g}\chi\theta_g; \quad \mu_{v1} = \frac{\overline{v}}{g}\mu_{g1} + \frac{\alpha}{g}\chi\theta_{g1}; \qquad \mu_{v2} = \frac{\overline{v}}{g}\mu_{g2} < 0; \qquad \mu_{v3} = 0 \tag{B. 27}$$

Because y_t is predetermined, equal increases in $\overline{d}d_t$ or $\overline{v}v_t$ have the same effects on q_t: they reduce it one to one. If private and public consumption are complements ($\sigma < 1$), c_t falls less on impact in response to $\overline{v}v_t$, or it can even increase. In this case, however, capital next period will be lower, hence private GDP will be lower (μ_v is a decreasing function if χ).

To find the law of motion of c_t, define:

$$\begin{aligned} c_t &= \psi_c c_{t-1} + \psi_d d_{t-1} + \psi_{d1} a_{d,t/t-1} + \psi_{d2} a_{d,t/t} + \psi_{d3} a_{d,t+1/t} + \\ &\quad + \psi_{v1} a_{v,t/t-1} + \psi_{v2} a_{v,t/t} + \psi_{v3} a_{v,t+1/t} + \psi_z z_t \end{aligned} \tag{B. 28}$$

Now subtract $\overline{k}k_t - \theta_k \overline{k}k_{t-1}$ from both sides of (B. 25), to obtain:

$$\begin{aligned} \psi_c &= \theta_c \\ \psi_d &= \frac{\overline{d}}{g}\phi_g; \qquad \psi_{di} = \frac{\overline{d}}{g}\phi_{gi} < 0; \qquad i = 1,2,3 \\ \psi_v &= \frac{\overline{v}}{g}\phi_g + \alpha(1-\beta)\frac{\chi}{g}\theta_g < 0; \\ \psi_{v1} &= \frac{\overline{v}}{g}\phi_{g1} + \alpha(1-\beta)\frac{\chi}{g}\theta_{g1} < 0; \\ \psi_{v2} &= \frac{\overline{v}}{g}\phi_{g2} - \alpha\beta\frac{\chi}{g}\theta_{g2} \lesseqgtr 0; \\ \psi_{v3} &= \frac{\overline{v}}{g}\phi_{g3} - \alpha\beta\frac{\chi}{g}\theta_{g3} \lesseqgtr 0; \end{aligned} \tag{B. 29}$$

Appendix C: The data

The series name and the Table number refers to the Bureau of Economic Analysis dataset

Real GDP: series B191RA3, Table 1.1.3 and Ramey (2011)'s dataset
Total government spending: series B822RA3, Table 1.1.3, Table 3.9.3 and Ramey (2011)'s dataset
Defense government spending: series B824RA3, Table 1.1.3, Table 3.9.3 and Ramey (2011)'s dataset
Civilian government spending: constructed from the series B822RA3, and B824RA3, using Whelan (2002)'s formula
Defense government spending on purchases of goods: W087RA3, Table 3.10.3
Civilian government spending on purchases of goods: constructed from the series W131RA3 ("Intermediate goods and services purchased, nondefense, Federal") and W140RA3 ("Intermediate goods and services purchased, State and Local"), using Whelan (2002)'s formula
Defense government employment: series militemp, Ramey (2011)'s dataset
Civilian government employment: series civgovemp+emergwrk, Ramey (2011)'s dataset
Interest rate: Interets rate in three-month government bonds, series tb3, Ramey (2011)'s dataset
Tax rate: Barro-Redlick average marginal tax rate and Ramey (2011)'s dataset
Personal consumption of durables: series DDURRA3 Table 1.1.3 and Ramey (2011)'s dataset
Personal consumption of non-durables: series DNDGRA3 Table 1.1.3 and Ramey (2011)'s dataset
Personal consumption of services: series DSERRA3 Table 1.1.3 and Ramey (2011)'s dataset
Gross private domestic investment: B006RA3 Table 1.1.3 and Ramey (2011)'s dataset
Hours: series tothours, Ramey (2011)'s dataset
Defense news: series pdvmily, Ramey (2011)'s dataset
Total population: series totpop, Ramey (2011)'s dataset