The Dynamic Response of the Budget Balance to Tax, Spending and Output Shocks: Does Model Specification Matter?

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February 2, 2001

Abstract

This paper estimates how the US budget responds to shocks in taxes, spending and output. In particular, we consider the dynamic adjustment of the two budget components (taxes and spending) to such shocks. The recently developed *Generalized Impulse Response Function,* which takes the historical distribution of the residuals into account, is applied. We select the 'correct' specification, estimate two VAR and two VEC models and compare the results. Our chosen specification suggests that tax, spending and output shocks generate deficits in the long run while the tax and output shocks generate a surplus in the short run. Moreover, model specification matters indeed.

JEL classification numbers: C32; C52; E62;
Keywords: Generalized impulse response function, Model specification, VAR, Budget deficit, Fiscal variables.

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1 Introduction

This paper has two purposes: (i) estimate the dynamics of the US budget balance as a response to reduced form tax, government spending and Gross National Product (*GNP*) shocks and, (ii) investigate the importance of model specification. The reason for (i) is that the US have run a deficit almost every year since the second world war. The central question is of course: 'why'? In order to shed some light on this question we will calculate the impact and dynamic effects of the budget balance to the three mentioned shocks. We are particularly interested in the issue whether or not the budget balance responds differently to tax and spending shocks, respectively. Moreover, we will also calculate the dynamic tax and spending response to tax and spending shocks. We thereby get the dynamics of the two components of the budget balance as well as the permanence of such shocks. With this information we can evaluate the relative importance of the tax and spending response to such shocks for the development of the budget deficit.

We apply the recently developed *Generalized Impulse Response Function* (*GIRF*, see Koop et al., 1996 and Pesaran and Shin, 1996, 1998) as a device to address the issues raised in the paper. The *GIRF* calculates the dynamic response to reduced form shocks in vector autoregressive (VAR) and vector error correction (VEC) models - taking the historical distribution of the residuals into account. The reasons for choosing the *GIRF* are twofold: First, the *GIRF* requires *no* identifying restrictions (apart from multivariate normality) in order to calculate impulse responses. Moreover, the *GIRF* implies (as will be shown) that all variables are endogenous and affect each other contemporaneously. This is of central importance when considering both output and fiscal variables in the same system. For example, a reduced form shock in *GNP* will affect both taxes (indirect and direct) and spending (e.g., transfers) contemporaneously due to the fact that the residuals are correlated. The *GIRF* is therefore to be distinguished from structural analysis in which we 'hold everything else constant'.[1] The second reason for applying the *GIRF* is that it has not yet been applied to any work on fiscal analysis.

The second purpose of the paper is, as mentioned, to take a close look at the importance of model specification. The main reason is that several recent empirical studies of structural fiscal analysis have applied VAR models in levels and/or first differences (see, among others, Blanchard and Perotti, 1999, Edelberg et al., 1999, Fatás and Mihov, 1999 and Rotemberg and Woodford, 1992). Hence, they neglect the fact variables might cointegrated so that a VEC model would be the appropriate choice.[2] In brief, model

[1] Identifying structural shocks can be done in a variety of ways. Choleski decomposition (Sims, 1980), long run restrictions (Blanchard and Quah, 1989) and institutional factors (Blanchard and Perotti, 1999) are some examples of identifications that have been put forward. The problem is of course that one can always question the assumptions needed for a particular identification and show that the results are not unique as they differ depending on the particular identification used.

[2] Blanchard and Perotti (1999) allow (in some specifications) taxes and government spending to cointegrate with the vector $(1\ -1)$. They do not, however, test for cointegration relationship between other

specification has not been a central issue (not an issue at all in some cases) in these papers.

We include four variables (*GNP*, government spending, taxes and private consumption) in our model based on the neoclassical framework by Becker (1997). It can shown that *if* these four variables are stochastically non-stationary (integrated of order one, I(1)), then the intertemporal budget constraints of the private sector and the government, respectively, imply two cointegrating relationships including: (i) *GNP*, taxes and private consumption: $\begin{bmatrix} 1 & -1 & -1 \end{bmatrix}$ and, (ii) government spending and taxes: $\begin{bmatrix} 1 & -1 \end{bmatrix}$. Hence, this neoclassical framework suggest that the VEC model including two theoretical cointegrating relations is the correct specification. However, there are (at least) three other possible alternatives to this specification that we will consider: (1) a VEC model with the *estimated* cointegrating relationships, (2) a VAR model in first differences if variables are found to be I(1) *but not* cointegrated and, (iii) a VAR model in level including deterministic trends if the variables are found to be deterministically non-stationary. Our model specification procedure consists of three steps. First, the cause of non-stationarity (stochastic or deterministic) is determined. Second, if the variables are found to be I(1), we test for the presence of cointegration. Finally, if cointegration exists, we test if the theoretical long run vectors of the neoclassical model are within the cointegration space. We will select the 'correct' model and compare the implied impulse responses with its' three competitors. As will be shown, the model specification is central for the results.

The rest of the paper is structured as follows: section 2 presents the *GIRF*, section 3 describes the model specification and the data, section 4 presents the results and section 5 concludes.

2 The Generalized Impulse Response Function

As the *GIRF* is recently developed and has, to the authors knowledge, never been applied in any published work on fiscal analysis, the methodology is described in some detail below. The method was invented by Koop et al. (1996) and has been extended by Pesaran and Shin (1996, 1998).

We begin to consider a VAR model:

$$\mathbf{x}_t = \sum_{i=1}^{p} \mathbf{A}_i \mathbf{x}_{t-i} + \boldsymbol{\varepsilon}_t, \tag{1}$$

where $\mathbf{x}_t$ is a $m \times 1$ vector of jointly determined dependent variables, p is the lag length, $\mathbf{A}_i$ are $m \times m$ coefficient matrices and $\boldsymbol{\varepsilon}_t$ is a $m \times 1$ vector of innovations. The standard assumptions concerning a system like (1) are (see Lütkepohl, 1993): $E(\boldsymbol{\varepsilon}_t) = 0, E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t') = \boldsymbol{\Sigma}, E(\boldsymbol{\varepsilon}_t, \boldsymbol{\varepsilon}_s) = 0$ for $t \neq s$ and the stability condition which implies that all roots of

variables included in their models.

$|\mathbf{I}_m - \Sigma_{i=1}^{p}\mathbf{A}_i z^i| = 0$ fall outside the unit circle (we will consider the VEC model below and then unit roots are allowed for, i.e. $z = 1$). In order to calculate impulse responses we need the vector moving average representation of (1) which simply is:

$$\mathbf{x}_t = \sum_{i=0}^{\infty} \mathbf{\Phi}_i \boldsymbol{\varepsilon}_{t-i}, \tag{2}$$

where the $m \times m$ coefficient matrices $\mathbf{\Phi}_i$ in (2) can be calculated recursively by using:

$$\mathbf{\Phi}_i = \sum_{j=1}^{i} \mathbf{\Phi}_{i-j}\mathbf{A}_j, \tag{3}$$

for $i = 1, 2, ...$ and $\mathbf{\Phi}_0 = \mathbf{I}_m$. The *GIRF* can formally be defined as:

$$\mathbf{GI}_{\mathbf{x}}(n, \delta_k, \quad_{t-1}) = E(\mathbf{x}_{t+n}|\varepsilon_{kt} = \delta_k, \quad_{t-1}) - E(\mathbf{x}_{t+n}| \quad_{t-1}), \tag{4}$$

where δ_k represents the shock to variable k and is hence a scalar, n is the number of periods ahead, ${}_{t-1}$ is all available information at the time of the shock. Equation (4) states that the *GIRF* for the vector $\mathbf{x}$, n periods ahead, is the difference of the expected value of $\mathbf{x}_{t+n}$ when taking the shock δ_k into account. By assuming Gaussian innovations, $\boldsymbol{\varepsilon}_t \backsim N(0, \mathbf{\Sigma})$, Koop et al. (1996) show that the conditional expectation of the shock equals:

$$E(\boldsymbol{\varepsilon}_t|\varepsilon_{kt} = \delta_k) = (\sigma_{1k}, \sigma_{2k}, ..., \sigma_{mk})'\sigma_{kk}^{-1}\delta_k = \mathbf{\Sigma}\mathbf{e}_k\sigma_{kk}^{-1}\delta_k, \tag{5}$$

where $\mathbf{e}_k$ is a selection vector with unity in the kth element and zero elsewhere. The *GIRF* of a unit shock ($\delta_k = 1$) to variable k can be found by using (5) and (2) and then applying (4):

$$\boldsymbol{\psi}_k(n) = \mathbf{\Phi}_n\mathbf{\Sigma}\mathbf{e}_k\sigma_{kk}^{-1}. \tag{6}$$

It is clear that (6) is order invariant (as opposed to Choleski decomposition) which is of central importance as our estimated systems consist of (see section 3) *GNP*, government spending, taxes and private consumption. All these variables can be considered to be endogenous and potentially affect each other contemporaneously.

It is important to note that a shock in equation k implies shocks in other equations as well due to the historical distribution of the residuals. For example, the *impact* response to a shock in the first equation equals: $\boldsymbol{\psi}_1'(0) = \begin{bmatrix} 1 & \sigma_{12}/\sigma_{11} & \sigma_{13}/\sigma_{11} & \sigma_{14}/\sigma_{11} \end{bmatrix}$, as $\mathbf{\Phi}_0$ is an identity matrix, see (6). Therefore the *GIRF* is not aimed to answer what will happen if a shock occur in one variable 'holding everything else constant'. Rather the historical distribution of the residuals (expressed in the estimated variance-covariance matrix, $\hat{\mathbf{\Sigma}}$) totally determines the impact effect of other variables. More specifically, if the residuals of variable i and j are positively correlated ($\hat{\sigma}_{ij} = \hat{\sigma}_{ji} > 0$ in $\hat{\mathbf{\Sigma}}$) then a shock to variable i (j) will have a positive *impact* effect on variable j (i) as $\mathbf{\Phi}_0$ is an identity matrix. After impact, however, the signs of the moving average parameters ($\mathbf{\Phi}_n$) will also affect the results.

To be explicit, a positive shock in the GNP equation implies a positive impact shock to the tax and spending equations as well because of the fact that the reduced form residuals of these variables are positively correlated. The obvious reason is that output, taxes and spending move closely together historically.

Note that the *GIRF* does not concern structural shocks (e.g., productivity, labor supply shocks) in which the reduced form shocks are (through identification assumptions) transformed to structural shocks. Rather, the *GIRF* concerns reduced form shocks which can be interpreted as 'average shocks' during the estimation period which, due to the historical distribution of the residuals, are correlated with each other.

As mentioned in the introduction, we believe that the VEC specification is the correct one, i.e.:

$$\Delta \mathbf{x}_t = \sum_{i=1}^{p-1} \mathbf{\Gamma}_i \Delta \mathbf{x}_{t-i} + \mathbf{\Pi} \mathbf{x}_{t-1} + \boldsymbol{\varepsilon}_t, \tag{7}$$

where $\mathbf{\Pi} \equiv (\mathbf{A}_1 + \mathbf{A}_2 + ... + \mathbf{A}_p - \mathbf{I})$ and $\mathbf{\Gamma}_i \equiv -\sum_{j=i+1}^{p} \mathbf{A}_j$. We can extract the VAR parameters ($\mathbf{A}_i$) using the following relationship:[3]

$$\left[\mathbf{A}_1 ... \mathbf{A}_p\right] = [\mathbf{\Gamma}_1 ... \mathbf{\Gamma}_{p-1}\ \mathbf{\Pi}]\mathbf{W} + \mathbf{J}.$$

The moving average matrices in levels are then calculated using:[4]

$$\mathbf{\Phi}_n = \mathbf{J}\mathbf{A}^n\mathbf{J}'. \tag{8}$$

In short, we estimate (7) and calculate the VMA representation in (8). Then we use (6) to calculate the *GIRF*.

3 Model Specification

As Becker (1997) we select our included variables on the basis of two intertemporal budget constraints emerging from the standard neoclassical framework. The first is the one of

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[3] where: $\mathbf{W} = \begin{bmatrix} \mathbf{I}_m & -\mathbf{I}_m & \mathbf{0} & ... & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{I}_m & -\mathbf{I}_m & ... & \mathbf{0} & \mathbf{0} \\ . & . & . & & . & . \\ . & . & . & & . & . \\ . & . & . & & . & . \\ \mathbf{0} & \mathbf{0} & ... & & \mathbf{I}_m & -\mathbf{I}_m \\ \mathbf{0} & \mathbf{0} & ... & & \mathbf{0} & \mathbf{I}_m \end{bmatrix}$, $\mathbf{J} = \begin{bmatrix} \mathbf{I}_m & \mathbf{0} & ... & \mathbf{0} \end{bmatrix}$.

[4] where: $\mathbf{A} = \begin{bmatrix} \mathbf{A}_1 & \mathbf{A}_2 & \mathbf{A}_3 & ... & \mathbf{A}_{p-1} & \mathbf{A}_p \\ \mathbf{I}_m & \mathbf{0} & \mathbf{0} & ... & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{I}_m & \mathbf{0} & ... & \mathbf{0} & \mathbf{0} \\ . & . & . & & . & . \\ . & . & . & & . & . \\ . & . & . & & . & . \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & ... & \mathbf{I}_m & \mathbf{0} \end{bmatrix}$.

the government which includes taxes (net of interest payments on debt, r_tD_t), NT_t, and total government spending (G_t). *If* these two variables are *stochastically* non-stationary of the first order (i.e., I(1)), they should be cointegrated with the vector: $\begin{bmatrix} 1 & -1 \end{bmatrix}$. This has been widely tested, see e.g. Hakkio and Rush (1991). The second intertemporal budget constraint is the one of the private sector. Here we have that total income (Y_t)[5], net taxes (NT_t) and private consumption (PC_t) should be cointegrated with the vector: $\begin{bmatrix} 1 & -1 & -1 \end{bmatrix}$ if the variables are I(1). Putting these two sets of variables together we get a four variable vector; $\mathbf{x}_t' = \begin{bmatrix} Y_t & G_t & NT_t & PC_t \end{bmatrix}$. Hence, if these variables are I(1), the two theoretical cointegrating vectors are: $\beta_1 = \begin{bmatrix} 0 & 1 & -1 & 0 \end{bmatrix}$ and, $\beta_2 = \begin{bmatrix} 1 & 0 & -1 & -1 \end{bmatrix}$.

However, it is also possible that *deterministic* instead of stochastic trends are present in the above mentioned variables. If this is the case, VAR models including deterministic trends are to be used instead of VEC models. Several recent studies of the effects of structural fiscal policy shocks make use of VAR models, see Blanchard and Perotti (1999), Edelberg et al. (1999), Fatás and Mihov (1999) and Rotemberg and Woodford (1992). *If*, however, the variables are I(1) *and* cointegrated, the VAR specification is incorrect, see, e.g., Johansen (1995). Before we show tests of unit roots and cointegration, the data used is described below.

3.1 Data

The US Data is taken from the National Income and Product Accounts (NIPA). We use data on the general government (federal plus state and local governments).[6] *Net taxes* (NT) include personal, corporate, indirect taxes and social security taxes *less* net interest payments. *Spending* (G) includes government consumption, investments and transfers. We use Gross National Product (GNP) as our income variable (Y_t) as this variable account for factor payments from abroad. Total private consumption is used for PC_t. All data is per capita, deflated by the GDP deflator and expressed in natural logarithms.

The period studied is 1947-1997. Quarterly data is available for all variables. However, it is impossible not to reject multivariate normality when using quarterly data (often with a sizable margin indeed!). We have tried to include dummies for the wars and 'extreme' quarters (such as the tax cut in 1975:2) as well as to estimate shorter time periods (e.g. 1969:1-1997:4) but we still clearly reject normality. As was shown in section 2 above, the $GIRF$ requires normality and yearly data is instead applied as we can not reject normality for this frequency in any of our estimations. As yearly data only provides 51 observations over the period 1947-1997, we apply tests using small sample corrections and, at times, bootstrapping methods.[7] All test are performed using the 5 % significance level.

[5] $Y_t = YL_t + r_tA_t - r_tD_t$ where YL_t = labor income, A_t = private wealth including D_t.

[6] I thank Roberto Perotti for providing some of the data.

[7] We apply the following bootstrap method concerning the asymptotic normality test in Lütkepohl

3.2 Tests of Unit Roots and Cointegration

In principle, four specifications are potentially interesting when considering the mentioned variable vector: $\mathbf{x}_t' = \begin{bmatrix} Y_t & G_t & NT_t & PC_t \end{bmatrix}$. If variables are found to have deterministic trends, a VAR model (including such trends) is appropriate. If the variables instead are found to be I(1) *but not* being cointegrated, a VAR model in first differences is the correct one. Finally, if the variables are I(1) *and* cointegrated, a VEC model (which includes estimated *or* theoretical cointegrating relations) should be applied.

Hence, the first step is to examine if the variables are deterministically or stochastically nonstationary. We have performed unit root tests following Dicky and Fuller (1979) and Phillips and Perron (1988) (critical values for $T = 50$ are applied). As shown in Table 1, we have performed the tests including both (i) a constant and (ii) a constant and a linear trend. We *can not* reject unit root in 15 of the 16 estimations in Table 1. The exception is the Phillips-Perron test of government spending (G) when only including a constant. The overall picture, however, suggest that stochastic trends are present and, as all variables contain upward trends, we follow the results when including a linear trend in the unit root estimation in which we can not reject that all variables are I(1).

VAR models (including deterministic trends) in *levels* can therefore be ruled out. However, it is still possible that the variables are I(1) but not cointegrated. In this case, VAR models in *first differences* would be appropriate. In order to discriminate between a VAR in first differences and a VEC model, we must test for cointegration among the variables.

The first step, however, in applying a VEC model is to determine the proper lag length. Here we make use of the small sample corrected Portmanteau test (see Lütkepohl, 1993). The most parsimonious model with no autocorrelation was selected; one lag in the VEC model (i.e. two lags in VAR) for $\mathbf{x}_t' = \begin{bmatrix} Y_t & G_t & NT_t & PC_t \end{bmatrix}$ and yearly data. Due to the upward trend in all included series we include a constant in the VEC model:

$$\Delta \mathbf{x}_t = \boldsymbol{\mu} + \boldsymbol{\Gamma}_1 \Delta \mathbf{x}_{t-1} + \boldsymbol{\alpha}\boldsymbol{\beta}' \mathbf{x}_{t-1} + \boldsymbol{\varepsilon}_t. \tag{9}$$

As shown in Table 2, the rank prediction of the theoretical model is correct. Both the

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(1993):

1) We estimate the VAR/VEC model to be applied and calculate the test value of the normality test in Lütkepohl (1993), save the parameters and the residuals.

2) We generate a new residual series (transformed according to the estimated covariance matrix), $\tilde{\boldsymbol{\epsilon}}_t$, by drawing randomly with replacement from the estimated residuals, $\hat{\boldsymbol{\varepsilon}}_t$. Then we calculate (in the case of the VEC model):

$$\Delta \hat{\mathbf{x}}_t^* = \hat{\boldsymbol{\mu}} + \hat{\boldsymbol{\Gamma}}_1 \Delta \mathbf{x}_{t-1}^* + ... + \hat{\boldsymbol{\Gamma}}_p \Delta \mathbf{x}_{t-p}^* + \hat{\boldsymbol{\Pi}} \mathbf{x}_{t-1}^* + \tilde{\boldsymbol{\epsilon}}_t$$

3) The VEC model is then re-estimated using $\Delta \hat{\mathbf{x}}_t^*$.

4) Re-calculate the normality test. Step 2-4 is repeated 5000 times.

5) Finally, using the percentile method (see Efron and Tibshirani, 1993) we compared the estimated value in *1)* with the empirical distribution and calculated the p-value.

Table 1: Unit root tests

	Constant + trend				
	Y	G	NT	PC	Critical value (T=50)
ADF	-2.00	-3.32	-2.81	-2.64	-3.50
PP	-2.01	-2.00	-2.61	-2.79	-3.50

	Constant				
	Y	G	NT	PC	Critical value (T=50)
ADF	-1.21	-2.83	-0.88	0.28	-2.93
PP	-1.41	-3.10	-0.89	0.28	-2.93

Note: Augmented Dicky-Fuller (ADF) and Phillips-Perron (PP) tests are shown in the table. 'Constant' and 'trend' concern the deterministic components in the ADF/PP regressions. The variables are defined in section 3-3.1. The critical values concern the 5% significance level and the case in which the number of observations is 50.

critical values of the empirical distribution of the bootstrap procedure and the asymptotic distribution clearly suggest two cointegrating vectors.[8] This result rules out the VAR model in first differences (without cointegrating relationships). The estimated long run vectors are displayed in Table 2. We can clearly reject that the theoretical vectors are within the cointegration space. Hence, *our chosen model is the VEC model with two estimated cointegrating relationships.*

3.3 Models to be Estimated

As mentioned in the introduction, one of the two purposes of the paper is to investigate the importance of model specification when estimating the dynamics of the budget balance to shocks in taxes, spending and GNP. Based on the above model specification procedure, we carry out estimations using the following four specifications:

1) VEC model with estimated cointegrating relationships: this is our chosen model based on our model selection procedure above and used by Becker (1997) in fiscal policy analysis.

2) VEC model with theoretical cointegrating relationships: although the theoretical relationships were rejected, it is interesting to see the implications of the theoretical

[8] We bootstrap the Trace statistic under four possible cointegration ranks; $r = 0, ..., 3$ (see Giersbergen, 1996, and Jacobson et al., 1998, for similar applications). The bootstrap procedure is similar to the one of the normality test, described in footnote 6. For each simulation, we calculate the Trace statistics and at the end we apply the percentile method to get the 95 % critical values for $r = 0, ..., 3$.

Table 2: Rank determination

	Critical values Trace test		
H_0	Bootstrap	Asymptotic	Test value
r=0	51.37	47.21	84.07
r□1	31.69	29.38	40.16
r□2	16.28	15.34	12.50
r□3	3.86	3.84	0.59

Estimated long-run vectors		
Beta(1)	[1 -0.232 -0.377 -0.255]	
Beta(2)	[1 3.0 -4.826 0.686]	
Normality test (p-values)		
Bootstrap	Asymptotic	
0.81	0.15	

Note: The table concerns the $x_t' = \left[\begin{array}{cccc} Y_t & G_t & NT_t & PC_t \end{array}\right]$ model, variables are defined in section 3-3.1. 'Bootstrap' shows the 95 percent critical value based on 5000 replications, procedure described in footnote 8. 'Asymptotic' shows the asymptotic 95 percent critical value (Hansen and Juselius, 1995). The asymptotic normality test presented in Lütkepohl (1993) is bootstrapped, see procedure in footnote 7.

framework compared to the estimated vectors. This specification is also used by Becker (1997).

3) VAR model in levels: used by, among others, Blanchard and Perotti (1999), Edelberg et al. (1999), Fatás and Mihov (1998) and Rotemberg and Woodford (1992) in fiscal policy analysis. Here we follow Blanchard and Perotti (1999) and include a constant, a linear and a quadratic trend.

4) VAR model in first differences: used by, among others, Blanchard and Perotti (1999) and Rotemberg and Woodford (1992).

4 Results

We begin with the tax and spending response to tax, spending and GNP shocks, respectively (section 4.1). In these estimations we can evaluate the contribution of taxes and spending to the dynamic budget balance response. In this exercise, we can spot the budget balance response ($T-G$, without confidence bands though) for the four specifications and thereby compare their different predictions. Finally, in section 4.2, we present the budget balance response (together with its' confidence bands) to tax, spending and *GNP* shocks for our *chosen* specification.

Throughout the estimations, we transform the impulse responses so that they show the dollar response of, e.g., government spending to a unit dollar shock in, e.g., taxes. We do so by evaluating the response at the mean of the series involved. Although asymptotic confidence bands are derived in Pesaran and Shin (1998), we use a bootstrap approach due to relatively few observations.[9]

4.1 Tax and Spending Response to Tax, Spending and GNP Shocks

In this section we analyze the effect of aggregate reduced form tax, spending and *GNP* shocks on taxes and spending, respectively, using the same variable vector as above: $\mathbf{x}'_t = \begin{bmatrix} Y_t & G_t & NT_t & PC_t \end{bmatrix}$.

4.1.1 Spending Shocks

To be explicit, using the VEC model with estimated long run vectors (i.e., our chosen model, model 1), a unit dollar shock in government spending (G_t, ordered as number two

[9] We make use of the 'standard normal intervals' (see Efron and Tibshirani (1993). Step *1)* to *4)* are similar to the procedure described in footnote 6 with the obvious exception that we calculate the *GIRFs* of interest in each simulation. In step *5)* we calculate the standard error of the empirical distribution of the bootstrapped *GIRFs*. 95 percent confidence bands around the estimate in step *1)* are shown in the figures.

in the system) has the following impact effects in dollars (evaluating the response at the mean of the series involved, $\frac{\bar{s}_t}{\bar{G}_t}$ below) using the historical distribution of the errors, see (6):

$$\begin{aligned}
\hat{\psi}_2^{'}(0) * \frac{\bar{s}_t}{\bar{G}_t} &= \left[\begin{array}{cccc} \hat{\sigma}_{21}/\hat{\sigma}_{22} & \hat{\sigma}_{22}/\hat{\sigma}_{22} & \hat{\sigma}_{23}/\hat{\sigma}_{22} & \hat{\sigma}_{24}/\hat{\sigma}_{22} \end{array} \right] * \frac{\bar{s}_t}{\bar{G}_t}, \\
&= \left[\begin{array}{cccc} 1.38 & 1 & 0.25 & 0.31 \end{array} \right], \qquad \bar{s}_t = \overline{GNP}_t, \bar{G}_t, \overline{NT}_t, \overline{PC}_t, \qquad (10)
\end{aligned}$$

where $\hat{\sigma}_{ij}$ comes from the estimated variance-covariance matrix, $\hat{\mathbf{\Sigma}}$. The *impact* response of output (ordered first), taxes (ordered third) and private consumption (ordered fourth) is: 1.38, 0.25 and 0.31 dollars, respectively. Hence, the impact effect on the budget balance is: $T_t - G_t = 0.25 - 1 = -0.75$ dollars.

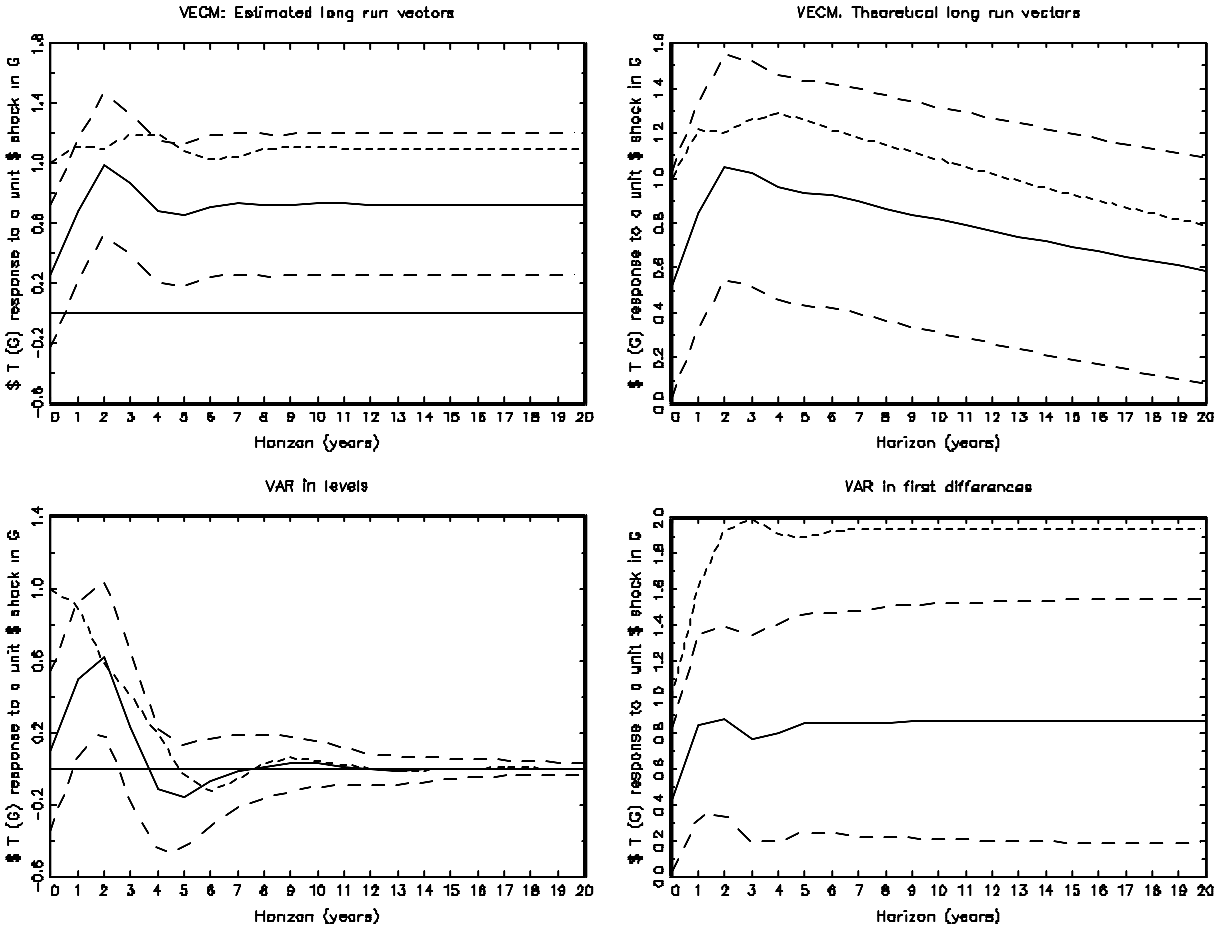
Now we turn to the *dynamic* tax and spending response to a shock in government spending. We include both the tax and the spending response to the spending shock in Figure 1 below. We present the tax and spending response in the same figure so that the budget balance response easily can be seen. The tax response (solid lines) is shown together with its' 95% bootstrapped confidence intervals (dashed lines). The small, dashed lines concern the government spending response (i.e., the permanence of the spending shock). We do not include confidence bands for the spending response to its' own shock (it is always significant) in order to get a clearer picture. (They can be received from the author on request).

First, it is worth to emphasize that all models but the VAR model in levels open up for long run effects while the long run effects in the VAR model in levels are zero by definition. However, we can compare the long run effects of model 1, 2 and 4 listed above (section 3.3) and we can also compare the short run effects of all models.

In our chosen model (model 1, VEC model with estimated long run vectors) the shock in government spending is permanent (see the small, dashed lines). The long run response (20 years) to a unit dollar shock is about 1.1 dollars. There are great differences between the permanence of the shocks of the chosen model and the two other models (models 2 and 4) that open up for long run effects. The permanence in the VEC model with *theoretical* long run vectors is about 0.8 dollars after 20 years while it continues to decrease. Even more strikingly, in the VAR model in first differences, the shock is more than permanent (2.0 dollars after 20 years).

Turning to the tax response to spending shocks, we can first note the impact effect of 0.25 dollars for our chosen model which was calculated in (10) above. The long run response is about 0.75 dollars and significant. Although the impact response of the VEC model with theoretical vectors and the VAR in first differences are much greater compared to the chosen model, the long run responses do not differ that much. It is obvious that the shock in government spending causes a budget deficit (the difference between the tax and spending response) - both in the short and the long run (20 years) in all four models. Note, also, that the budget balance response of the VEC model with *theoretical* vectors goes to zero by definition, after about 70 years (not shown in the figure).

Figure 1: Tax (solid lines together with dashed confidence bands) and government spending (small, dashed lines) response to a spending shock



In conclusion, when considering the both the tax and spending response to spending shocks in these models, the VAR model in first differences implies a much greater deficit compared to our chosen model - about -1.0 dollars in the long run compared to only about -0.4 dollars while the VEC model with theoretical vectors implies a lower deficit (about -0.20 dollars after 20 years). Common to all model specifications, however, is that the tax response is not strong enough in order to keep up with the government spending response and this fact results in budget deficits. As we shall see now, there are even greater differences between the models when we now turn to tax shocks.

4.1.2 Tax Shocks

In Figure 2, we consider the tax and spending response to tax shocks. For our chosen specification, the tax shock is not permanent. The long run effect is only about 0.3 dollars (see the small, dashed lines). As for the spending shocks above, the *permanence* of the tax shock differs substantially between the three models that open up for long run effects. This is especially the case for the VAR model in first difference where the long run effect is about 0.85 dollars. Turning to the spending response to tax shocks, we can first note that spending responds positively to tax shocks in all four models, although the VAR model in levels have several negative responses. The magnitude differs, however, between the models. For our chosen specification, the long run response is about 0.45 dollars. Hence, after the initial surplus, the government spending response catch up and become greater than the tax response which implies a deficit.

Most important, however, is that the models predict *opposite* effects of tax shocks on the budget balance. While our chosen VEC model and the VEC model with theoretical vectors predicts a budget deficit in the long run (20 years: the budget is in balance after about 70 years for the VEC model with theoretical vectors) due to the tax shock, the VAR model in levels[10] and the VAR model in first differences predict a budget *surplus*. Model specification is therefore of central importance for the results. Failing to take cointegrating relations into account when they are present is serious indeed.

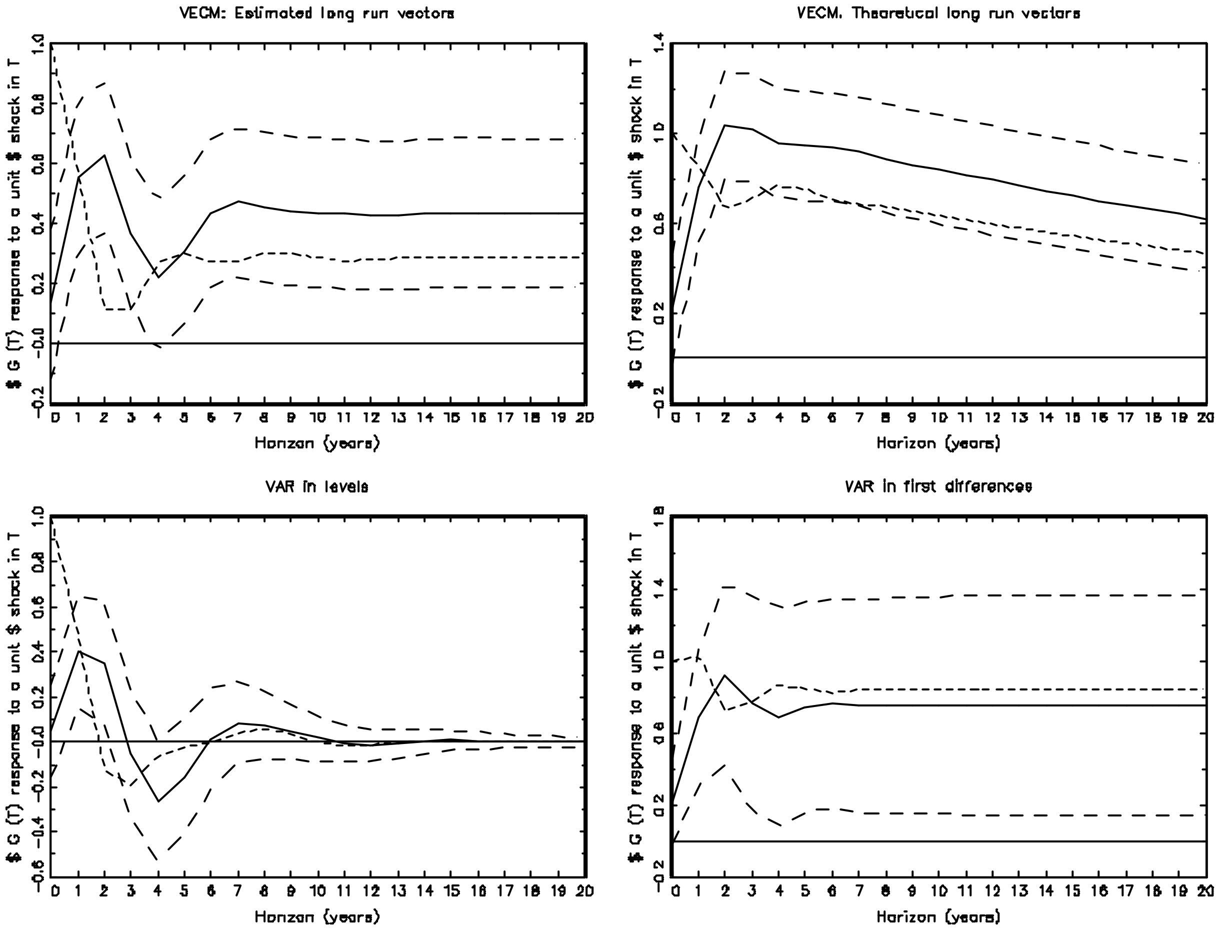
4.1.3 GNP Shocks

In order to be able to show both the tax and spending response (and thereby the budget balance response) to GNP shocks in the same figure, we have removed the confidence bands in Figure 3.[11] Confidence bands for the budget balance reponse to GNP (and tax and spending) shocks are shown in section 4.2 below). The GNP, tax and spending response is shown with small dashed, dashed and solid lines, respectively, in Figure 3.

[10] If one adds up the budget balance responses to tax shocks in the VAR model in levels this results in a budget surplus.

[11] The confidence bands can be received from the author on request.

Figure 2: Government spending (solid lines together with dashed confidence bands) and tax (small, dashed lines) response to a tax shock



A reduced form shock in GNP has positive impact effects on both taxes and government spending in all four models. This implies that GNP and tax and spending residuals, respectively, are positively correlated, see (6). The long run government spending response is similar in the three models that open up for long run effects: about $0.3 - 0.45$ dollars. The counterpart for the tax response is about $0.25 - 0.4$ dollars. In all models, the tax response is greater than the spending response in the very short run. The spending response then catch up and become greater in the two VEC models. The important difference is that the two VEC models implies a *negative* budget response from year two and onwards (the budget balance response of the VEC model with theoretical vectors goes to zero by definition, after about 70 years). The VAR model in first differences, on the other hand, predicts a *positive* budget response from impact and onwards. Again, we find that failing to take cointegrating relationships into account matters indeed.

4.2 Budget Balance Response to Tax, Spending and GNP Shocks

As we already have looked at the budget balance response ($G - T$, without confidence bands) of the three shocks above, we do want to not repeat the analysis here for all four specifications when we, in this section, include confidence bands around the budget response. Instead, we show only the confidence bands of our chosen specification concerning the three shocks, see Figure 4.[12]

Repeating some comments from above: the budget balance responds positively on impact to tax and GNP shocks while negatively on impact to government spending shocks. After impact, however, the budget balance response to tax and GNP shocks turn negative and the long run response is about -0.15 dollars. After the negative impact to the shock in government spending, the budget balance improves but deteriorates again with a long run response of about -0.40 dollars. Hence, the budget balance suffers most severely from shocks in government spending. Taxes can not keep up with the government spending shock which is permanent (see Figure 1). Government spending, on the other hand, responds to tax shocks such that the long run effect on the budget balance is negative (after a positive impact) as shown in Figure 2. The responses are in general quite close to significance. In particular, the short term responses to tax and spending shocks are significant.

[12] The confidence bands of the budget balance response of the three shocks can be received from the author on request. We can roughly say that the significance of the VEC model with theoretical vectors is about the same as for the VEC model with empirical vectors (shown in the paper). The budget balance response to a shock in government spending is always significant in the VAR model in first differences while the response to a tax shock is not significant.

Figure 3: Government spending (solid lines), tax (dashed lines) and GNP (small, dashed lines) response to a GNP shock

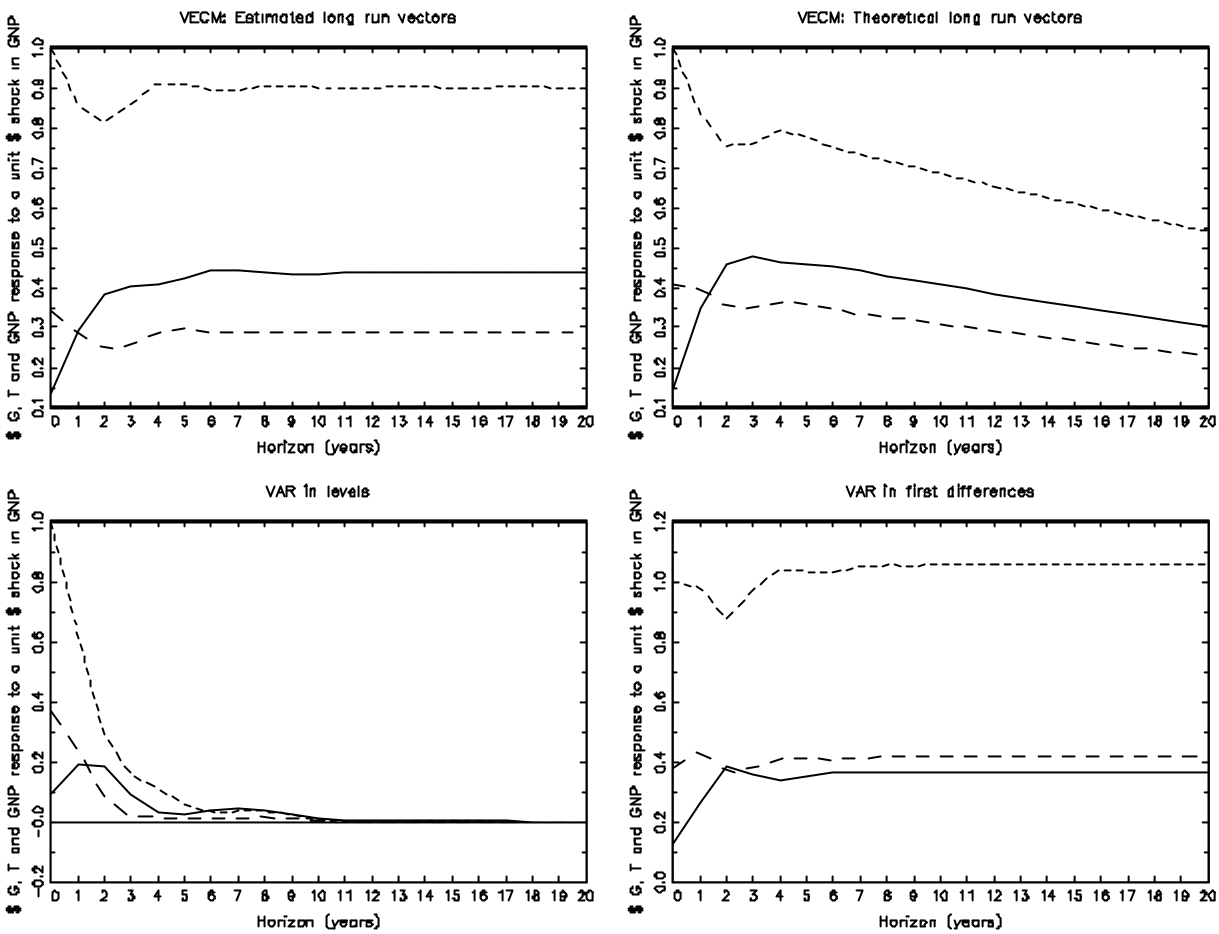
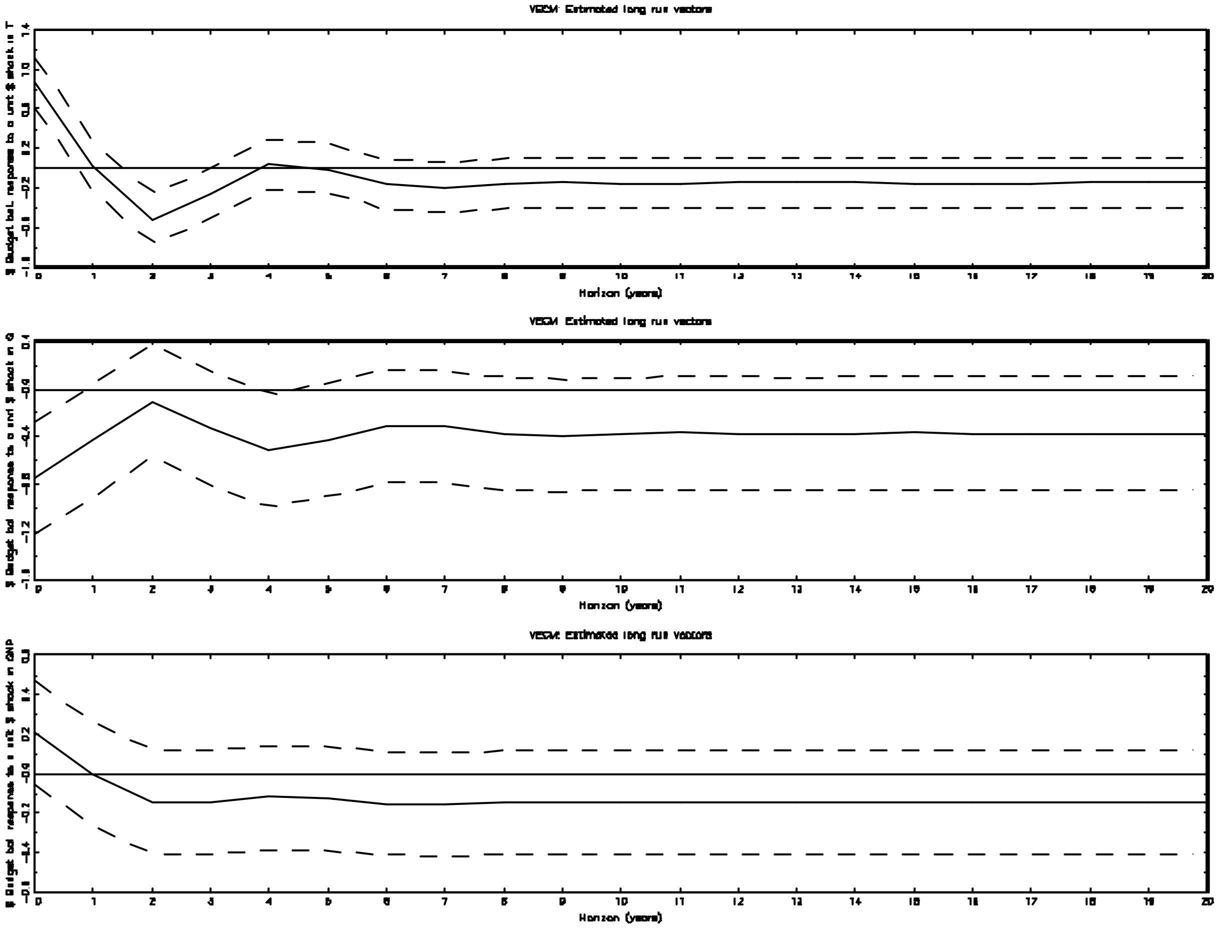


Figure 4: Budget balance response to tax (upper panel), government spending (mid panel) and GNP (lower panel) shocks



5 Conclusions

This paper considers two issues: one economic and one econometric. The former concerns the budget balance response to reduced form tax, spending and GNP shocks and the latter concerns the sensitivity of model specification for the results. The recently developed *Generalized Impulse Response Function, GIRF,* is used as a device to address these issues. The *GIRF* is reduced form based and requires no identifying assumptions concerning shocks. Instead, the *GIRF* takes the historical distribution of the residuals into account which implies that all variables are affected contemporaneously by a reduced form shock. In particular, the impact effect from a shock is solely determined by the historical distribution of the reduced form VAR/VEC residuals. E.g., a shock in GNP implies positive contemporaneous shocks in taxes and spending as their VAR/VEC residuals are positively correlated. After impact, the moving average matrices play an important role. Hence, we can trace out the dynamic effects of the budget balance due to the three mentioned shocks.

Four potential model specifications (two VAR and two VEC models) are put forward as potential candidates. Based on a neoclassical framework, we use data on *GNP*, government spending, taxes and private consumption and find that the data is best represented in a VEC model with two (estimated) cointegrating relationships. This decision is based on unit root and cointegration tests. There are two main findings in the paper:

First, model specification matters. In most of our estimations, the four different models imply different tax, spending and budget balance responses to the shocks considered in the paper. This is true for both the sign and the magnitude of the responses. In particular, if we neglect to take existing cointegrating relationships into account, we would wrongly suggest that the long run budget balance response to tax, spending and GNP shocks was positive, while our chosen model predicts a negative long run response. Thus, the results highlight the importance of model specification as well as sensitivity analysis in macroeconomics.

Second, using our chosen specification, we find that reduced form government spending shocks are permanent (1.1 dollars after 20 years). A unit dollar shock in spending results in a deficit of about 0.4 dollars after 20 years as the tax response is only about 0.7 dollars. Tax shocks, on the other hand, is not permanent: only about 0.3 dollars remain after 20 years. The government spending response is smaller than the tax response in the first couple of years (i.e., implying a budget surplus) but become greater after that and the deficit is about -0.15 dollars after 20 years. The budget balance responds positively on impact to GNP shocks while then turning negative with a long run effect of about -0.15 dollars after a unit dollar shock in GNP. In short, the US budget deficit is affected negatively in the long run by all three shocks while the short run effect differs.

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