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Uncertainty and the effectiveness of fiscal policy

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Abstract

During the Great Recession of 2007-2009 uncertainty in the United States reached historically high levels. This paper analyzes the effectiveness of fiscal policy under different uncertainty regimes in the U.S. High uncertainty is known to make economic agents postpone their decisions on consumption and investment (real-options channel), making economic policy less effective. We use several uncertainty measures in a threshold vector autoregressive model (TVAR) to endogenously estimate different uncertainty regimes. Then we analyze the effectiveness of different fiscal policy shocks in each uncertainty regime. We measure uncertainty using S&P 100 volatility index (VXO) and Baa corporate bond yield relative to yield on 10-year treasury constant maturity (Baa10ym). Our benchmark model consists of aggregate government spending, taxes, uncertainty, and GDP. In addition to the benchmark model, we estimate three extensions. First, we differentiate between government consumption, investment, and defense expenditures. Second, we check the robustness using two different measures of uncertainty – VXO and Baa10ym. Third, we compute impulse responses of GDP aggregates: consumption and investment. Nonlinear impulse response functions differentiate between positive and negative fiscal shocks, as well as between small and big fiscal shocks. Confidence intervals are obtained by bootstrapping in order to determine the statistical significance of impulse responses. This paper has five important findings. (1) We find that fiscal policy shocks have a much larger effect on the economy during periods of high uncertainty. (2) We also find that during periods of average or low uncertainty government spending shocks tend to crowd out private sector investment spending, but during periods of high uncertainty, after a one-year delay, government spending shocks "crowd-in" private sector investment expenditures. (3) We find large shocks typically do not have the same dollar for dollar effect on GDP as small shocks. That is, 2SD shocks tend to have only a 33-50% larger effect than 1SD shocks. (4) We find that expansionary tax shocks are not as powerful as contractionary tax shocks. And finally and perhaps most importantly (5) we find that government investment spending shocks are far more potent that government consumption and government defense spending shocks. This last result suggests that infrastructure investment expenditures are a much better way to stimulate the economy than other types of government spending.

Key words
uncertainty, fiscal policy, threshold, VAR model

JEL classification
C32, D81, E62, H30

Introduction

Uncertainty increased dramatically after the Great recession in 2007 affecting the economic performance of most world economies as well as economic policies implemented by many governments. In most economies the financial sector suffered from increased uncertainty, turmoil on stock markets and higher risk aversion. Meanwhile, the real sector experienced lower investment because of increased caution and the resulting increase in the difficulty of financing new projects. Policymakers also faced new challenges in implementing both monetary and fiscal policy because of the zero lower bound on interest rates and the introduction of many unconventional monetary policy measures designed to stabilize both the U.S. and international financial systems. The recovery was slow and painful, and some authors present evidence that supports the notion that a relatively high level of uncertainty is a reasonable explanation for the sluggish recovery (Bloom 2009, Cover 2011). This raises the basic question addressed by this paper: What is the best way to fight a recession which is accompanied by a historically high level of uncertainty? In particular, we examine whether the effects of fiscal policy are different under conditions of high uncertainty than they are under average and relatively low levels of uncertainty.

This paper addresses this issue by developing an empirical model that allows one to examine the effectiveness of the U.S. fiscal policy in different uncertainty regimes. We estimate a threshold structural vector autoregressive model (SVAR) with high and low uncertainty regimes. We use two measures of uncertainty, the CBOE S&P 100 volatility index (VXO) and Baa corporate bond yield relative to yield on 10-year treasury constant maturity (*Baa10ym*). We identify the structural tax and government spending shocks using the SVAR framework of Blanchard and Perotti (2002) and look at the response of GDP and GDP components to these identified shocks. Generalized impulse response functions (GIRFs) are calculated with initial values from 2008, 1987, and 2005 which represent high, medium and low uncertainty, respectively. Given the nonlinear nature of the model, we distinguish between positive and negative fiscal shocks, as well as between big and small shocks in search for whether the response of the economy to fiscal policy depends on the initial level of uncertainty. This is a contribution to the literature on the effectiveness of fiscal policy because the extent to which the effectiveness of fiscal policy depends on uncertainty has not been considered in the literature as yet. The paper uses threshold SVAR model with bootstrapped confidence intervals which is a simple and very convenient approach to handle a problem of uncertainty dependence.

There is a literature that examines whether uncertainty is an important cause of economic fluctuations, but most of this research focuses on measuring uncertainty and on effects of high uncertainty on a real sector (see Bloom 2014 for a summary of the related literature). How (or whether) the level of uncertainty affects the way monetary and fiscal policy work is an issue that has received very little attention in the literature. Focusing specifically on fiscal policy, we don't know whether the size of fiscal multipliers differ during periods of high and low uncertainty, and we don't know whether the set of tools the government can efficiently use depends on the level of uncertainty. Economic theory and partial empirical research give ambiguous results, and our paper contributes to that end.

It can be shown that the level of uncertainty affects economic behavior. The most straightforward approach is to examine the behavior of a producer with market power. As uncertainty increases, such a producer tends to set its price higher[1] implying a lower level of output. This

[1] Let p be price, the demand curve be $q = (\beta+\varepsilon)p^{-\alpha}$, and profits $\pi = p \cdot q - q^2$, where $\beta>0$ and $\alpha>1$ are known constants and ε is a mean zero symmetrically distributed random variable such that $|\varepsilon| < \beta$, and has known

establishes that economic behavior is different under high uncertainty than under low uncertainty. It can also be shown that as uncertainty increases economic agents become more cautious and therefore tend to postpone their decisions on the consumption of durable goods, investment, and hiring. This channel is known as the real options channel because such decisions are costly and involve substantial sunk costs[2], so economic agents engage in *wait-and-see* behavior. *Wait-and-see* behavior makes economic agents less responsive to changes in the economic environment. In particular firms tend to be less responsive to changes in prices, demand, and economic policy (see Bloom et al. 2012 and Aastveit et al. 2013). Households have a wider area of inaction when faced with increased uncertainty, and their actions are more volatile and less predictable (Bertola et al. 2005). In sum, wait-and-see behavior postpones decision making, widens the area of inaction and makes economic policy less effective. Indeed, Aastveit et al. (2013) show that monetary policy is less effective when uncertainty is high, but there is no research which analyzes the effectiveness of fiscal policy.

On the other hand, Auerbach and Gorodnichenko (2012a and 2012b) showed that fiscal multipliers for government spending are bigger during a recession than during an expansion and this appears to contradict the real options channel.[3] They estimate a state dependent model which distinguishes between high and low GDP regimes and find that government spending is more effective during a recession, which is a standard Keynesian prediction. They focus almost completely on government spending, and taxes are not considered in more detail. Riera-Crichton et al. (2015) report similar findings regarding government spending for a sample of OECD countries: recessionary multipliers are bigger, and the biggest multipliers are observed in extreme recessions. But there is no general agreement upon empirical method for measuring fiscal policy multipliers. Hence, Ramey and Zubiary (2014) show that the way of measuring fiscal multipliers can influence the results. They do not find convincing evidence that properly computed multipliers depend on the amount of the slack in the economy.

Although uncertainty tends to be highly countercyclical, the economy is not necessarily in a recession when the level of uncertainty is high. A state-dependent model which distinguishes between recessions and expansions is not the same as an uncertainty dependent model which recognizes high and low uncertainty regimes. Some recessions are followed by a lower level of uncertainty, and sometimes uncertainty is high even though GDP growth is non-negative.

Many different approaches have been used to identify fiscal policy shocks within a linear SVAR model.[4] This paper follows the approach of Blanchard and Perotti (2002) who assume that changes in GDP cannot affect discretionary fiscal policy within a quarter, but only automatic fiscal policy responses. They identify the structural shock to government spending as a shock that is orthogonal to both taxes and GDP, and identify the structural shock to taxes by using institutional data on the elasticity of tax revenue with respect to GDP. More specifically, based on their estimates of these elasticities, they assume that elasticity of tax revenue with respect to real GDP is 2.08. Using

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variance σ^2. If the firm is risk neutral and maximizes expected profits, then $p = \left(\frac{2\alpha(\beta^2+\sigma^2)}{\alpha-1}\right)^{\frac{1}{\alpha+1}}$. The greater the value of σ, the higher the value of p, implying a lower planned level of output.

[2] Adjustment costs of selling already installed equipment for firms could be up to 50% of its value (Ramey and Shapiro 2001 and Cooper and Haltiwanger 2006). Adjustment cost of hiring and firing new employees could be 10% to 20% of annual salary (Bloom 2009).

[3] Uncertainty is highly countercyclical which makes it high in recessions. However, as argued below, recession does not have to be followed by a high uncertainty level, which should have in mind when considering results of Auerbach and Gorodnichenko (2012a and 2012b).

[4] Ramey (2016) summarizes the literature on fiscal policy shocks focusing on linear models, but she also discusses the most important results of a state dependent models (recession vs. expansion).

this identification scheme they report that a positive government spending shock causes an increase in GDP and an increase in consumption expenditures. Similarly, they find that a positive tax shock has the opposite effects. Interestingly, they find that investment tends to decrease following positive shocks to either government spending or taxes.

Regardless of different identification schemes, linear SVAR and accompanying DSGE models do not provide enough flexibility to tackle the issue of effectiveness of fiscal policy in different uncertainty regimes. High uncertainty might be an important outlier in our understanding of fiscal policy and a part of *dark corners* of the economy (Blanchard 2014) for which we need more flexible nonlinear models.

In this paper, we estimate a threshold SVAR with fiscal shocks identified by restrictions in the spirit of those employed by Blanchard and Perotti (2002). Our analysis is focused on the generalized impulse responses of GDP and its components (consumption and investment) to government spending and tax shocks.

The main results of the paper show that both tax and government spending shocks have a stronger impact on GDP during a high uncertainty regime than under regimes with either medium or low uncertainty. A probable explanation is that in high uncertainty regime government spending shocks tend to increase or crowd-in private sector investment after a one-year delay. Private consumption expenditures also react strongly to government spending shocks uncertainty is high. On the other hand, in medium and low uncertainty regimes, government spending shocks show standard crowding out effects of private investment followed by a moderate response of consumption expenditures.

Next, we find that shocks to government investment expenditures have a much more powerful effect on GDP than do shocks to government defense or consumption expenditures. Shocks to government defense spending initially have a bigger effect on GDP than shocks to government consumption expenditures, but the difference tends to decline over time. The importance of our results for the components of government spending is illustrated by Figure 1 which presents a plot of 4-quarter moving averages of the growth rates of total government investment spending, consumption spending and defense spending. The last recession began during the fourth quarter of 2007, while the figure shows that the moving average of the growth rate of government investment spending began to decline after 2008:3, while that for government defense spending began to decline right after 2008:4, and government consumption spending began to decline after the 2009:2. All three of these declines last until at least the end of 2012. If, as our results imply, government investment expenditures provide a greater degree of stimulus than other components of government spending, then Figure 1 shows that, as far as government spending is concerned, the economic recovery act 2009 did not provide the United States economy with much stimulus.

Unlike previous research, our results do not show much difference between the per dollar effect on GDP of big and small government spending shocks as well as between positive and negative government spending shocks. However, we do find important differences in the per dollar effects of relatively large and small tax shocks. A tax cut that is twice as large does not provide twice as much stimulus to real GDP. Also, we find that expansionary tax shocks are not as powerful as contractionary tax shocks. The main policy recommendation that our results support is that during a recession with a relatively high level of uncertainty the most effective form of countercyclical fiscal policy is for the government to increase its investment expenditures, along with relatively modest tax cuts.

The paper is structured as follows. Section 2 describes the empirical methodology and the data. Section 3 presents results for different model specifications and robustness checks, while Section 4 offers some conclusions.

Data

The model consists of four variables: taxes, government spending, uncertainty, and GDP. Additionally, we add the GDP components – personal consumption expenditures and gross private domestic investment – as fifth variables for robustness check. Quarterly data used spans from 1947:1 to 2015:4. We use two fiscal variables in the baseline model – the growth rate of real net taxes and the growth rate of government consumption expenditures and gross investment. As one of the extensions of the baseline model, we change the definition of government spending and use its components. Therefore, separate models are estimated using government consumption expenditures, government gross investment, and government national defense consumption and investment expenditures. Fiscal data are from the Bureau of Economic Analysis database. We use growth rates of real GDP and its components, real personal consumption expenditures, and real gross private domestic investment. GDP and GDP components are from Federal Reserve Bank of St. Louis FRED database.

The baseline model uses VXO index as a measure of uncertainty. VXO is CBOE S&P100 options volatility index from Chicago Board Options Exchange. This is an old version of VIX index which is based on S&P500. However, VXO data is available for a longer time period starting from 1986 to the present. The data on VXO prior to 1986 is taken from Bloom (2009). Three other measures of uncertainty also are considered. Baa10ym is Moody's seasoned Baa corporate bond yield minus the 10-year constant maturity yield on US Treasury bonds. BaaFF is Moody's seasoned Baa corporate bond minus federal funds rate. Both measures are downloaded from FRED database. We also consider the quarterly growth rate of the S&P 500 stock market index.

Methodology

Linear Version of the Model

Consider the following structural time series model written in autoregressive form:

$$\sum_{L=0}^{L=N} \boldsymbol{B}(\boldsymbol{L})\boldsymbol{X}_{\boldsymbol{t-L}} = \boldsymbol{\varepsilon}_t, \tag{1}$$

where each $\boldsymbol{B(L)}$ is a 4-by-4 matrix of coefficients, $\boldsymbol{\varepsilon_t}$ is a vector of serially-uncorrelated, mean zero, random structural disturbances which may be mutually correlated, and $\boldsymbol{X_t}$ is a vector of endogenous variables such that $\boldsymbol{X_t} = [\tau_t, G_t, vx_t, y_t]$, where τ_t is the growth rate of net taxes, G_t is the growth rate of government purchases of goods and services, vx_t is a measure of uncertainty in levels, and y_t is the growth rate of real GDP, all during period t. Assume that multiplying $\boldsymbol{\varepsilon_t}$ by the 4x4 matrix $\boldsymbol{C^{-1}}$ yields a vector of mutually uncorrelated disturbances, $\boldsymbol{v_t}$. Since $\boldsymbol{\varepsilon_t} = \boldsymbol{Cv_t}$, this allows equation (1) to be rewritten as:

$$\boldsymbol{B(0)X_t} = \sum_{L=1}^{L=N} \boldsymbol{B}(\boldsymbol{L})\boldsymbol{X}_{\boldsymbol{t-L}} + \boldsymbol{Cv_t}\,. \tag{2}$$

Multiplying both sides of (2) by $\boldsymbol{B(0)^{-1}}$ yields:

$$\boldsymbol{X_t} = \boldsymbol{A(L)X_t} + \boldsymbol{Dv_t}, \tag{3}$$

where $\boldsymbol{A(L)} = \sum_{L=1}^{L=N} \boldsymbol{B}(\mathbf{0})^{-\mathbf{1}}\boldsymbol{B}(L)\boldsymbol{X}_{t-L}$ and $\boldsymbol{D} = \boldsymbol{B(0)}^{-1}\boldsymbol{C}$. Without loss of generality we assume that the parameters in the matrix $\boldsymbol{D}$ are chosen so that $\boldsymbol{v_t}$ is a vector of unit variance, mutually and serially independent, structural shocks.

We estimated equation (3) with lag lengths from 1 to 8 to determine the optimal lag length in $\boldsymbol{A(L)}$ for each of the following uncertainty variables: The CBOE S&P 100 volatility index (known as *VXO*), the growth rate of the S&P 500 stock market index (*gsp*),[5] the spread between the Moody's Baa bond rate and the federal funds rate (*BaaFF*), and the Baa corporate bond yield relative to the 10-year treasury constant maturity yield (*Baa10ym*). For each uncertainty variable, two lags minimized the Akaike Information Criterion (AIC), while 1 lag minimized the Bayesian Information Criterion (BIC). Generally, according to a multivariate version of the Ljung-Box Q test, it takes only 2 lags in equation (3) to remove any serial correlation up to an order of 7, but 3 lags to remove serial correlation up to order 12. We estimated our baseline model with 2, 3 and 4 lags but are only reporting results obtained from using 3 lags for the following two reasons: (1) The use of 4 lags caused a large increase in standard errors suggesting too much multi-collinearity, and (2) the results obtained using of only 2 lags were not robust to changes in the uncertainty variable.[6]

The Threshold VAR Model

The threshold model is based on the linear model as depicted in equation (3). Now assume that the values of the coefficients in $\boldsymbol{A(L)}$ depend upon whether vx_{t-d} is above or below a threshold value, vx^*. This assumption changes (3) into the following threshold VAR:

$$\boldsymbol{X_t} = \lambda_t \boldsymbol{A^U(L)X_t} + (1-\lambda_t)\boldsymbol{A^L(L)X_t} + \boldsymbol{Dv_t}, \quad (4)$$

where $\lambda_t = 1$ if $vx_{t-d} > vx^*$, and $\boldsymbol{A^U}$ and $\boldsymbol{A^L}$ represent coefficient matrices in upper and lower regime, respectively. In (4) it is assumed that whether vx_{t-d} is above or below the threshold value vx^*, affects the conditional mean of $\boldsymbol{X_t}$, but not variance-covariance matrix of unexpected changes in $\boldsymbol{X_t}$.

Now rewrite (4) in the following form:

$$\boldsymbol{X^*_t} = \lambda_t\{\boldsymbol{A^{U*}(L)X_t} + V^U(L)vx_t\} + (1-\lambda_t)\{\boldsymbol{A^{L*}(L)X_t} + V^L(L)vx_t\} + \boldsymbol{Dv_t}, \quad (5)$$

where $\lambda_t = 1$ if $vx_{t-d} > vx^*$, where $\boldsymbol{X^*_t} = [\tau_t, G_t, y_t]$. Hence, equation (5) differs from (4) only in its treatment of vx_t. In (4) vx_t is an endogenous variable, while in (5) it is an exogenous variable.

In searching for the best threshold variable and its threshold value, we proceed in two steps. First we search for an optimal threshold variable treating each candidate uncertainty variable as exogenous, then in the second step we estimate a threshold value treating the selected uncertainty variable, *vx*, as an endogenous variable. In the first step, we are only interested in how the movement of vx_t across its threshold value affects the conditional means of the members of $\boldsymbol{X^*_t} = [\tau_t, G_t, y_t]$, and we are not interested in explaining the variation of the threshold variable. Therefore, we use a grid search of (5) to choose the threshold variable (chosen from *VXO*, *dsp*, *BAAff*, and *Baa10ym*), its delay (*d* periods), and its threshold value, vx^*. This was done by calculating the likelihood of the system (5) for all possible combinations of the threshold variable, delays from 1 to 4 periods, the possible values of vx^* between the 0.15 and 0.85 percentiles of the candidate uncertainty variable. We used the

[5] This variable was found by Cover and Lee (2015) to contain more information about the future growth rates of employment and industrial production than other measures of uncertainty.

[6] We also find that when using only two lags the results obtained when we replace total government spending with its various components are not logically consistent with one another.

sample period, 1956:1-2016:4. We found that the use of *VXO* with a delay of three maximized the likelihood function of system (5). In the second step, having chosen *VXO* as the uncertainty variable and a delay of 3, we performed a grid search of system (4), which considers vx_t as an endogenous variable, using *VXO* as the uncertainty variable for all possible combinations of delays from 1 to 4 and values of vx^* between the 0.15 and 0.85 percentiles of the values of *VXO* within the sample period. We found the value of vx^* to be 23.06 and once again the optimal delay to be three.

The Structural VAR and TVAR

Equation (3) becomes a structural VAR and equation (4) a structural TVAR model with the addition of assumptions sufficient to identify the parameters that make up matrices ***B(0)*** and ***C*** (and therefore the components of ***D***). As is discussed in the next few paragraphs, the parameters in ***B(0)*** represents the contemporaneous interactions between the variables in $\boldsymbol{X_t}$, while the parameters in ***C*** represent the tendency for structural shocks to taxes and government spending to occur simultaneously.

This paper uses an identification strategy similar to that employed by Blanchard and Perotti (2002). Ignoring for the time being the lagged values of $\boldsymbol{X_t}$ on the RHS of (3) and letting b_{ii} and c_{ii} be unknown parameters consider the following model[7]:

$$\begin{bmatrix} 1 & 0 & 0 & -b_{14} \\ 0 & 1 & 0 & 0 \\ -b_{31} & -b_{32} & 1 & (-b_{34}=0) \\ -b_{41} & -b_{42} & -b_{43} & 1 \end{bmatrix} \begin{bmatrix} \tau_t \\ G \\ vx_t \\ y_t \end{bmatrix} = \begin{bmatrix} 1 & c_{12} & 0 & 0 \\ c_{21} & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} v_t^{\tau} \\ v_t^{G} \\ v_t^{vx} \\ v_t^{y} \end{bmatrix} \qquad (6)$$

The 4×4 matrix on the LHS of (6) is ***B(0)***, while that on the RHS is ***C***. The first row of (6) is a structural equation for net taxes (τ_t) in which τ_t increases with GDP (y_t), but no other contemporaneous variable. τ_t also depends on the structural shocks to government spending, v_t^G, and net taxes, v_t^{τ}. There are two ideas behind this equation. The first is that once the effect of GDP on taxes is taken into account, then no other variables have a contemporaneous effect on taxes. The second is that it is possible that legislation that causes a structural shock to government spending could also include a provision that changes taxes (implying $c_{12} \neq 0$). The second row of (6) states that government spending (G_t) does not depend on any other current variables and is affected only by its own structural shock, v_t^G, and possibly (if $c_{21}>0$) the structural shock to net taxes, v_t^{τ}. This follows from the use of quarterly data. As Blanchard and Perotti (2002) point out, changes in government spending and taxes could be a result of two different mechanisms: (1) automatic responses to economic activity under existing fiscal policy rules and (2) discretionary adjustments which change fiscal policy rules. The use of quarterly data eliminates second channel, because it takes longer than one quarter to implement discretionary adjustments to fiscal policy. If $c_{21} \neq 0$, it implies that a structural shock to taxes includes provisions to either increase or decrease government spending. To the extent that the structural shocks to government spending and net taxes are the result of automatic responses, clearly c_{21} and c_{12} are measuring the same thing. It is therefore necessary to assume that either c_{21} or c_{12} is zero in order to identify this model. Because the correlation between the unexpected changes[8] in government spending and taxes is relatively low, which of these two parameters is set to zero has little effect on our results, so we just report results for the assumption $c_{21} = 0$.

[7] Removing the third row and third column of the matrices in (4) yields an equation equivalent to equations (2)-(4) in Blanchard and Perotti (2002) once they set their parameter b1 equal to zero.

[8] Throughout this paper the phrase "the unexpected change of" any variable, say z_t, refers to $z_t - E(z_t|I_{t-1})$, where $E(z_t|I_{t-1})$ is the mathematical expectation of z_t conditional on information available during period *t-1*.

The third row of (6) states that vx_t depends on both current taxes and government spending as well as its own structural shock. In principle vx_t can also depend on the current value of y_t, but, for reasons discussed below, we present results only for the case in which it is assumed that $b_{34} = 0$, implying no contemporaneous effect of y_t on vx_t. The fourth row of (6) states that y_t depends contemporaneously on τ_t, y_t, and vx_t, as well as its own structural shock. Although we are assuming that vx_t has a contemporaneous effect on y_t, we could have just as well assumed that y_t has a contemporaneous effect on vx_t ($b_{43} = 0$ with $b_{34} \neq 0$). This, however, has no effect on how the structural shocks to taxes and government spending affect real GDP, since it does not affect the first two columns of $\boldsymbol{D} = \boldsymbol{B(0)^{-1}C}$. Furthermore, this does not mean that the structural shock to GDP has no contemporaneous effect on vx_t. Rather, because current GDP affects current net taxes, and current net taxes affect current vx_t, the structural shock to GDP has an indirect contemporaneous effect on vx_t through its effect on net taxes.

The assumptions that $c_{21} = b_{34} = 0$ are not quite enough to identify the structural model. One additional assumption is necessary. Because c_{12} cannot be zero if c_{21} is, following Blanchard and Perotti (2002), we identify the model by assuming a fixed value for b_{14}. Blanchard and Perotti estimate b_{14} (their coefficient a_1) by inferring how a 1% increase in the tax base affects net taxes from four categories of taxes: indirect taxes, corporate income taxes, social security taxes and personal income taxes. Following Giorno et al. (1995) they use institutional data sources to indirectly estimate the elasticity of tax revenue with respect to GDP, which is coefficient b_{14} in our model. For the sample period studied by Blanchard and Perotti the average value of this parameter is 2.08. The value of the parameter is not fixed over time, but it varies. However, many following studies build on Blanchard and Perotti's (2002) estimate of 2.08 to identify tax shocks (see Ramey 2016 for the literature review and a discussion on identification of tax shocks).

In our baseline model we assume $b_{14} = 2.08$ for the following reasons. First, and very importantly, the value of b_{14} does not affect how the structural shock to government spending affects the other variables, that is, it does not affect the second column of $\boldsymbol{D} = \boldsymbol{B(0)^{-1}C}$. Second, if b_{14} is too low the impact effect of a positive tax shock on GDP is positive. For our baseline model, b_{14} must be at least 1.5 in order for the impact effect of a positive tax shock on GDP to be negative. Hence we must assume $b_{14} > 1.5$. Third, as b_{14} rises above 1.5 (in our baseline model), the impact effect of a positive tax shock on GDP becomes larger, so that eventually the impact of 1% increase in taxes on real GDP becomes unrealistically large. For example, if we assume $b_{14} = 3.0$, a 1% unexpected increase in taxes causes real GDP to decrease by 0.41%, which implies an impact tax multiplier of about –2.0, which in our opinion is too large. But if we assume $b_{14} = 2.0$, a 1% unexpected increase in taxes causes real GDP to decrease on impact by only 0.09%, which implies an impact tax multiplier of only –0.45, which is more reasonable, but may still be too large. Since we must have $b_{14} > 1.5$, and values of b_{14} greater than 2.08 are going to yield impact multipliers of tax shocks that clearly are too large, we conclude that it is reasonable to follow Blanchard and Perotti and use $b_{14} = 2.08$.

Impulse Response Functions and Confidence Intervals

The baseline model was estimated for a sample period 1950:1-2016:1 and the best threshold value of vxo_{t-3} was found to be vx^*=23.06. Figure 2 presents a plot of vxo and its threshold value. For 51 out of the 265 observations in our sample the value of vxo_{t-3} is above the threshold value.

Because the model is nonlinear in principle the shapes of its impulse response functions (IRF) depend on the conditions under which the shocks occur, as well as the probability that the value of vx_{t-3} will cross its threshold value. We therefore obtained generalized impulse response functions (GIRF) using three sets of initial conditions: (1) Those that prevailed during 2008:4, a quarter with a very high level of uncertainty; (2) those that prevail during 1987:3, a quarter with a level of uncertainty approximately equal to the threshold value, 23.06 (medium uncertainty); and (3) those that prevailed during 2005:3, a quarter with a relatively low level of uncertainty. To estimate the model's GIRF's we used the following bootstrap procedure.

First we took random draws (with replacement) of the VAR residuals and added these to the fitted values of the estimated model to obtain a set of resampled data and re-estimated the model using the resampled data. We then obtained an estimate of the GIRF's for each of the re-estimated model's structural shocks by forecasting the model. Because random shocks can cause the economy to cross from one regime to another, the forecasts were performed with random shocks added to each period's forecasted values. This was done by assuming that the re-estimated model's residuals are normally distributed with a VCV matrix equal to that of the VCV of the residuals obtained from the re-estimated model, which we denote here as Σ^*. The re-estimated model was used to forecast the model's variables using each of the above initial conditions and with shocks randomly drawn from a multivariate normal distribution with VCV = Σ^* added to each period's forecasted values. Next, the shocks for the first period of the simulation were changed in a manner that made them consistent with the value of the first structural shock being equal to one standard deviation. The model was then simulated again using the same random shocks as before. The difference between the first and second set of forecasts is one realization of the possible GIRFs to the structural shock being examined. This process was repeated 500 times and the average of the realizations of the estimated GIRFs was chosen as our estimate of the GIRF for the shock being studied for this particular re-estimated model.

We then took another random draw (with replacement) of the VAR residuals and added these to the fitted values of the estimated model to obtain a second set of resampled data and estimated the model with this second new data set. We then obtained a second estimate of the model's set of GIRFs. This procedure was performed 1,000 times to obtain standard error bands for the GIRFs as well as their median values.

Results

The Baseline Model

Figures 3a, 3b, and 3c presents the set of accumulated GIRF's to the set of one standard deviation (1SD) structural shocks assuming the initial conditions respectively are those that prevailed during 2008:4, 1987:3, and 2005:3. In each figure the first column denotes the response to a 1SD shock to net taxes, the second column the responses to a 1SD shock to government spending, the third column the responses to a 1SD shock to uncertainty and the fourth column the responses to a 1SD shock to real GDP.

The first column of Figures 3a-3c show that a 1SD shock to taxes represents a permanent increase in taxes that initially causes a decrease in real GDP. This decrease in real GDP is temporary, remaining significant for only a few quarters in Figures 2b and 2c with medium and low uncertainty. In contrast the effect of the tax shock in high uncertainty in Figure 3a grows gradually for at least seven quarters and has a permanent effect that slightly more than twice the size of its initial impact. These results imply that tax changes have a larger and more long-lasting effect on real GDP during periods of relatively high uncertainty.

The second column of Figures 3a-3c shows that a 1SD shock to government spending is initially about a 1% increase in government spending. In Figures 3b and 3c with medium and low uncertainty the increase in government spending gradually grows becoming about a 2.5% increase in government spending after 7 quarters, but in high uncertainty in Figure 3a after one quarter it jumps to about 2% and more or less remains there. In each figure the shock to government spending causes an increase in real GDP, but in Figure 3a the response of real GDP begins growing after 3 quarters and reaches it maximium value four quarters later. The response of real GDP to a 1SD shock to government spending is smallest in Figure 3c (low level of uncertainty) and highest in Figure 3a (high level of uncertainty), suggesting that the effectiveness of expansionary government spending increases as the level of uncertainty in the economy increases.

Hence Figures 3a-3c show that the effects of the structural shocks to taxes and government spending on real GDP are sensitive to initial conditions, and in particular they show that fiscal policy shocks have their most powerful effect on the economy during periods of relatively high uncertainty. Figure 4 presents the effects of each of the four structural shocks on real GDP in a manner that allows one to better see how a change in initial conditions affects the GIRFs. It also includes the responses obtained from a linear model. The shaded region in the first column in Figure 4 denotes the 68% confidence interval obtained for the GIRFs based on the initial conditions that prevailed during 2008:4, while the shaded region in the second and third columns respectively represents the confidence intervals obtained using the 1987:3 and 2005:3 initial conditions. Finally, the shaded area in the fourth column represents the confidence intervals obtained with a linear model.

The graph in the first row and column of Figure 4 presents the impulse responses of real GDP to a 1SD shock to taxes for all three sets of initial conditions plus that obtained from the linear model. The shaded region is the 68% confidence interval obtained when the initial conditions are those that prevailed in 2008:4. Notice that the IRF from the linear model as well as the GIRF for the conditions in 2005:3 both are always within the 2008:4 confidence interval, while the GIRF for 1987:3 lies above it. Notice also that the response of GDP to a 1SD tax shock is a much larger negative response under conditions in 2008:4 (high uncertainty) than under the other two conditions and under the linear model. This illustrates the above conclusion that if initial conditions are such that uncertainty is high, the effect of a tax increase on real GDP is relatively large. Moving from left to right in the first row of Figure 3, one sees that the GIRF for the 2008:4 starting values is always below the 1987:3 confidence interval and right on the bottom edge of the 2005:3 confidence interval. Also notice that the IRF from the linear model lies between the GIRF under conditions in 2008:4 (high uncertainty) and the other two GIRF's.

Similarly, the first entry in the second row of Figure 4 shows the responses of real GDP to a 1SD shock to government spending along with the confidence interval for the 2008:4 GIRF. Notice that the responses obtained from the linear model and the 2005:3 (low uncertainty) starting values are very similar and lie above the 2008:4 confidence interval beginning about 4 quarters after the shock. Moving to the right one sees that the 2008:4 GIRF lies at the uppower edge of the 1987 confidence interval and well above the confidence intervals for the 2005:3 GIRF and the linear IRF. According to this row, the response of real GDP to a 1SD shock to government spending is clearly more powerful when there is an higher level of uncertainty.

The first two rows of Figure 4, therefore, clearly illustrate that the GIRF's obtained using 2008:4 starting values imply that a high level of uncertainty increases the effect of changes in fiscal policy. Our model implies that fiscal policy is more effective when there is a higher level of uncertainty in the economy.

The responses of other variables also make economic sense. Column 3 of Figures 3a-3c shows that an increase in uncertainty causes both real GDP and tax revenue to decline, though the decline in real GDP when the level of uncertainty is high (Figure 3a) is smaller than under average or below average uncertainty. Even though the shock to uncertainty is temporary the declines in real GDP and tax revenue are permanent (Figures 3b and 3c) except when uncertainty is already high (Figure 3a). Column 4 of these figures show that a 1SD shock to real GDP has little effect on uncertainty when uncertainty is initially low or average (Figures 3b and 3c), but causes a decrease in uncertainty when uncertainty is already relatively high (Figure 3a). Finally, the figures in the fourth column of Figures 3a-3c show that the shock to GDP causes permanent increases in both real GDP and taxes. We mention these GIRFs simply because they are reasonable a priori and therefore provide some support for our structural specification.

The last two graphs of row 2 of Figure 3a show that there is a very little response of government spending to the structural shocks to uncertainty and real GDP when uncertainty is initially high. But Figures 3b and 3c show that with the conditions that prevailed during 1987:3 (medium uncertainty) and 2005:3 (low uncertainty) the shock to real GDP gradually causes the level of government spending to increase, while the shock to uncertainty continues to have little or no effect on government spending. Since an increase in the level of real GDP is likely to lead to an increase in government spending (assuming government spending is a normal good), these results are also reasonable, though the failure of government spending to increase in response to the GDP shock in Figure 3a suggests that when uncertainty is relatively high, the US government has been reluctant to increase its spending on goods and services (see also Figure 1 above).

As mentioned above, we compute GIRF's functions because in a TVAR during the response to a shock the threshold variable may cross its threshold value. Figure 5 presents the median response of GDP to tax and government spending shocks for four different cases: ± 1 SD and ± 2 SD. There are two important findings presented in Figure 5. The first is that whether the shock is positive or negative, the response of a 2SD shock generally is not twice the size of the response to 1SD shock, *particularly when uncertainty is high*. The second is that expansionary tax shocks are not as potent as contractionary tax shocks.

In regard to the first point, the top graph in the first column of Figure 5 shows that the response of real GDP to a +2SD shock to taxes 2 to 3 quarters later is not much different from the response to a +1SD shock. Furthermore, once 10 quarters have passed, the decrease in output from a +2SD increase in taxes is only about 50% greater than (rather than twice as large as) the decrease in output from a +1SD shock to taxes. The bottom graph in the first column of Figure 5 shows something similar for decreases in government spending. There is very little or no difference between the effects of –2SD and –1SD shocks to government spending during the second through the fourth quarter after the shock at which point the –2SD shock begins to have a larger effect. But 10 quarters after the decrease in government spending, the effect of a –2SD shock to government spending is only 33% larger than that of the –1SD shock to government spending (rather than twice as large). Similar points can be made for negative shocks to taxes and positive shocks to government spending.

To see the second point consider the first graph in the first row of Figure 5 (2008 initial conditions). Notice that the response of GDP to the –2SD shock to taxes reaches a local peak the second quarter after the shock and at this point the increase in real GDP is about 0.42%. After a brief decline real GDP begins to grow slowly, but the increase in GDP never reaches 0.6%. In contrast the response of GDP to the +2SD shock to taxes reaches a decline of about 0.4% the second quarter after the shock but in the third quarter after the shock it continues to decrease and reaches a decline slightly more than 0.6% the 5th quarter after the quarter of the shock. Hence a positive tax shock is more powerful by about 20% during the 3rd through 6th quarters after the shock. Similarly, the middle graph in the first row of Figure 5 (average uncertainty case) clearly shows that the decline in output after a +2SD shock to taxes is much larger than the increase in output after a –2SD shock, particularly the 3rd through 7th quarters after the shock.

Adding GDP components into the baseline model

Following the procedure of Blanchard and Perotti (2002) we examine how fiscal policy shocks affect consumption and investment expenditures by adding these variables in turn to the model as a fifth variable. For consistency the structure of SVAR model remains the same as in equation (4) with the addition of the fifth variable which is modeled in a recursive scheme. We also use the same number of lags and same delay as in our baseline model. Results are presented in Figures 6a and 6b showing responses to a +1SD shock to government spending and taxes, respectively.

In Figure 6a we see that the response of consumption to a +1SD shock to government spending is very similar to the response of GDP for when the starting conditions are those in 2005 (low uncertainty case) and 1987 (medium uncertainty case). However, the response of investment expenditures in these two cases indicates that increases in government spending tend to crowd out investment expenditures. For 1987 starting conditions (medium uncertainty) the decline in investment expenditures quickly reaches 2%, while for the 2005 starting conditions (low uncertainty) it quickly reaches –1.4%. Things are different, however, when the starting conditions are those of 2008, the high uncertainty case. These responses are shown in the top row of Figure 6a. First, response of consumption is much stronger in comparison to medium and low uncertainty regime. Notice also that although initially investment expenditures are crowded out by a +1SD shock to government spending, after 5 quarters investment expenditures have increased. Hence in the high uncertainty case we find less crowding out from an increase in government spending and possibly "crowding in".

In Figure 6b we see that the response of consumption expenditures is very similar to the response of GDP in all three cases, but the response of investment expenditures depends on initial conditions. Since there is clearly crowding out in response to increases in the government spending in the low and medium uncertainty cases (2005 and 1987), we might expect that an increase in taxes might not cause much of a decline in investment expenditures for these two cases. We do observe this in Figure 6b for the medium uncertainty case (1987), but not for the low uncertainty case (2005) where investment expenditure declines by about 1%. In the high uncertainty case (starting conditions those in 2008), the +1SD increase in taxes initially causes a decrease in investment expenditures, but after seven quarters the accumulated response of investment expenditures becomes practically zero.

Robustness Check: Changing the Definition of Government Spending

We check the robustness of the above results obtained from our baseline model in several ways. First, we change the definition of government spending from total government spending to: 1) government defense and nondefense investment expenditures; (2) government defense and nondefense consumption expenditures; and (3) government consumption and investment defense expenditures. Again, we use the same number of lags and same delay as in the baseline model.

Figure 7 presents the responses of real GDP to 1SD shocks to the various types of government spending shocks. The first row presents the responses to a 1SD shock to total government spending, the second row to a 1SD shock to government investment spending, the third row to a 1SD shock to government consumption spending, and the fourth row to a 1SD shock to defense spending. In the first column, the shaded area represents the 68% confidence interval for the impulse response function obtained from using conditions in 2008 as starting values, while in the second and third columns the shaded areas respectively represent confidence intervals obtained from using conditions in 1987 and 2005 as starting values.

The first row of Figure 7 replicates results from the baseline model showing the enhanced effectiveness of government spending in a high uncertainty regime. The second row of Figure 7 shows that response of GDP to changes in government investment is positive, very strong and pronounced in comparison with other components. However, results differ depending on initial conditions. Response of GDP with 2008 initial conditions is the strongest, followed by initial conditions from 1987 and 2005. It is important to emphasize that in 2008 a response of total government spending behaves very similar to the response in government investment, which can explain a fast and strong positive reaction. Furthermore, the response of real GDP when using the 2008 and 1987 starting values remains positive and statistically significant for an indefinite period of time. On the other hand, the positive effect on real GDP of the 1SD investment spending shock when using 2005 starting values is temporary and is statistically insignificant after five quarters.

The third row of Figure 7 shows that regardless of the starting values used to obtain the GIRFs of real GDP to a shock to government consumption spending, the initial response is relatively small. However, when uncertainty is medium or low such as in 1987 and 2005, response of GDP quickly becomes statistically insignificant. That is not the case for 2008 initial conditions with high uncertainty, because after four to five quarters response of GDP starts to increase and reaches its maximum after fifteen quarters. Although government consumption is usually considered as not very efficient, this result indicate that even consumption expenditures are efficient in high uncertainty environment. The fourth row of Figure 7 shows that the response of real GDP to a 1SD shock to government defense spending is initially positive and statistically significant but only remains positive for a substantial period of time if one uses the 2008 starting values.

The results presented in Figure 7 confirm that 1SD structural shocks to all components of government spending cause a substantial increase in real GDP under conditions that existed in 2008:4, but not under conditions that prevailed during 2005:3, or even 1987. These results support our findings from the baseline model that fiscal policy is more efficient in high uncertainty regime, and we continue to find evidence of a threshold effect because the starting conditions have a meaningful effect on the GIRFs.

Robustness Check: Using a Different Measure of Uncertainty

For a robustness check, we change the uncertainty variable from the *VXO* to the spread between Moody's BAA corporate bond rate and the 10-year constant maturity US Treasury bond rate, which we denote by *Baa10ym*. Because the 10-year constant maturity treasury rate is only available beginning in April 1953, the sample period for these robustness tests begins in 1955:1. The uncertainty measured by Baa10ym and the estimated threshold value are shown in Figure 1b.

Figure 8 presents the results from using *Baa10ym* as the uncertainty variable. The first row of Figure 8 presents the GIRF's for the structural shock to taxes and shows that a 1SD shock to taxes causes a substantial and permanent decline in real GDP. The shaded area in the first column is the 68% confidence interval based on conditions that existed in 2008:4. Notice that the GIRFs based on the other starting conditions all lie outside the confidence interval for 2008:4 conditions. Hence when using *vx=Baa10ym*, we continue to find that the effect of a 1SD shock to taxes is more powerful during periods of high uncertainty than periods of relatively low and normal uncertainty.

The second row of Figure 8 shows the GIRF's for the 1SD shocks to government spending using *Baa10ym* as a measure of uncertainty. It shows that the effect of a 1SD shock to government spending is also much larger during conditions that existed during 2008:4 than during conditions that existed during 1987:3 and 2005:3. This finding is again consistent with our previous results from the baseline model as well as for the models presented in Figure 7 for government investment, consumption, and defense spending. However, median response of GDP to government spending shock in 2008 is very strong, but confidence intervals are very wide (although significant).

Conclusion

This paper presents results obtained from a TVAR model designed to study the effects of fiscal policy on the United States economy where the switch variable is a measure of uncertainty. We use an identifying scheme similar to that of Blanchard and Perotti (2002) and the results we present illustrate that importance of analyzing the United States economy with a nonlinear model. In our baseline model we find that fiscal policy shocks—particularly government spending shocks—have a more powerful effect on GDP the higher the level of uncertainty. This is illustrated by the second row of Figure 5 that shows that the GIRF of a +1SD government spending shock in the high uncertainty regime (2008 starting conditions) lies above that for the average uncertainty regime (1987 starting conditions) which lies above that for the low uncertainty regime (2005 starting conditions). As shown in Figure 5 we find that large shocks are not as effective on a dollar-for-dollar basis as small shocks since 2SD shocks have less than double the effect of 1SD shocks. Figure 5 also shows that expansionary tax shocks have a smaller effect than contractionary tax shocks. We also find that when uncertainty is average or low there is a significant amount of crowding out of private sector investment spending, but when uncertainty is high, the short-run crowding out that occurs during the first year after the shock is reversed and followed by significant crowding in. Finally, we find that government investment spending has a more reliable and powerful effect on GDP than government consumption and defense expenditures. Hence our results imply that government infrastructure spending is a more appropriate way to stimulate the economy during a recession regardless of the level of uncertainty in the economy.

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Figures

Figure 1

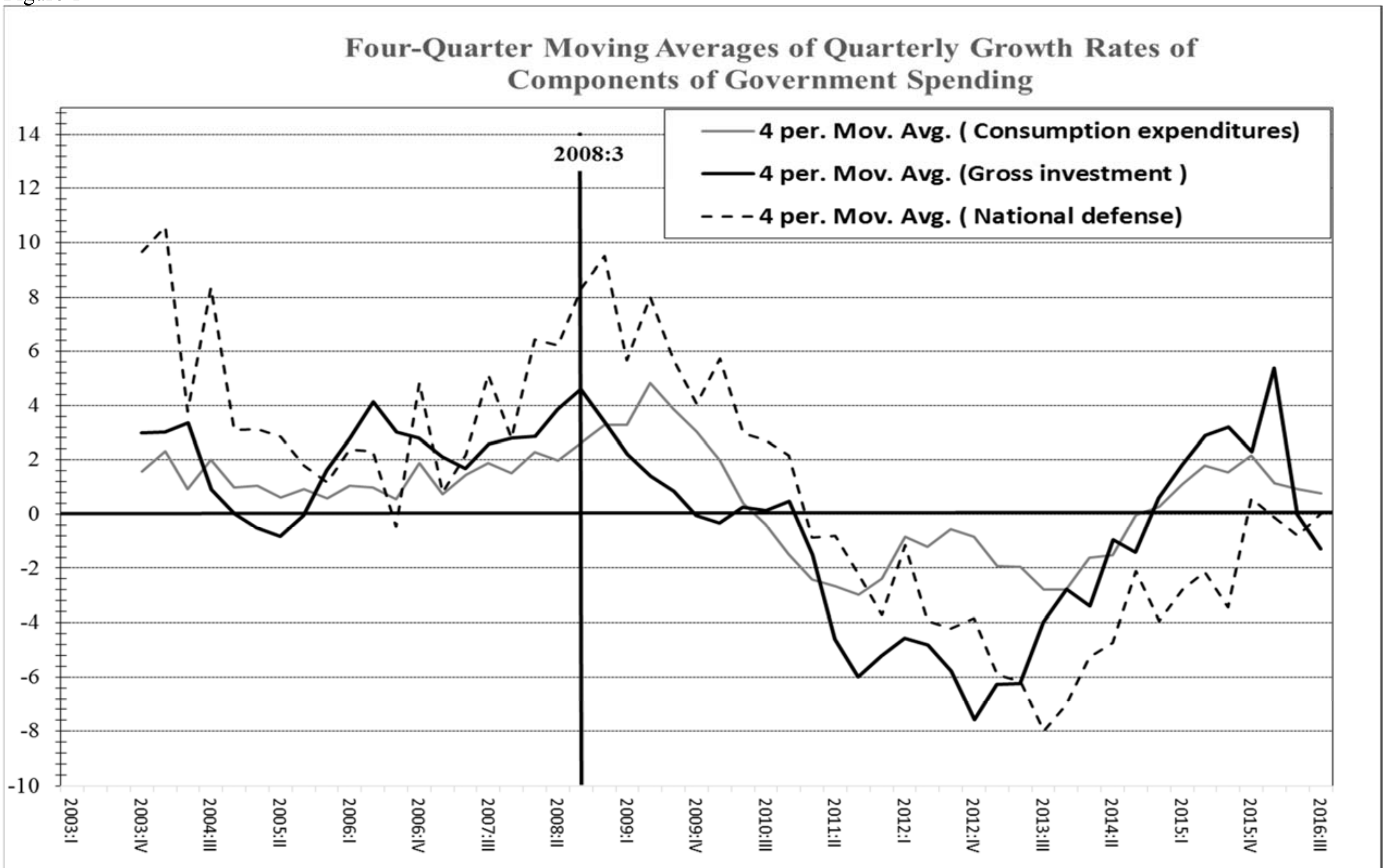


Figure 2a. VXO and its Threshold Value

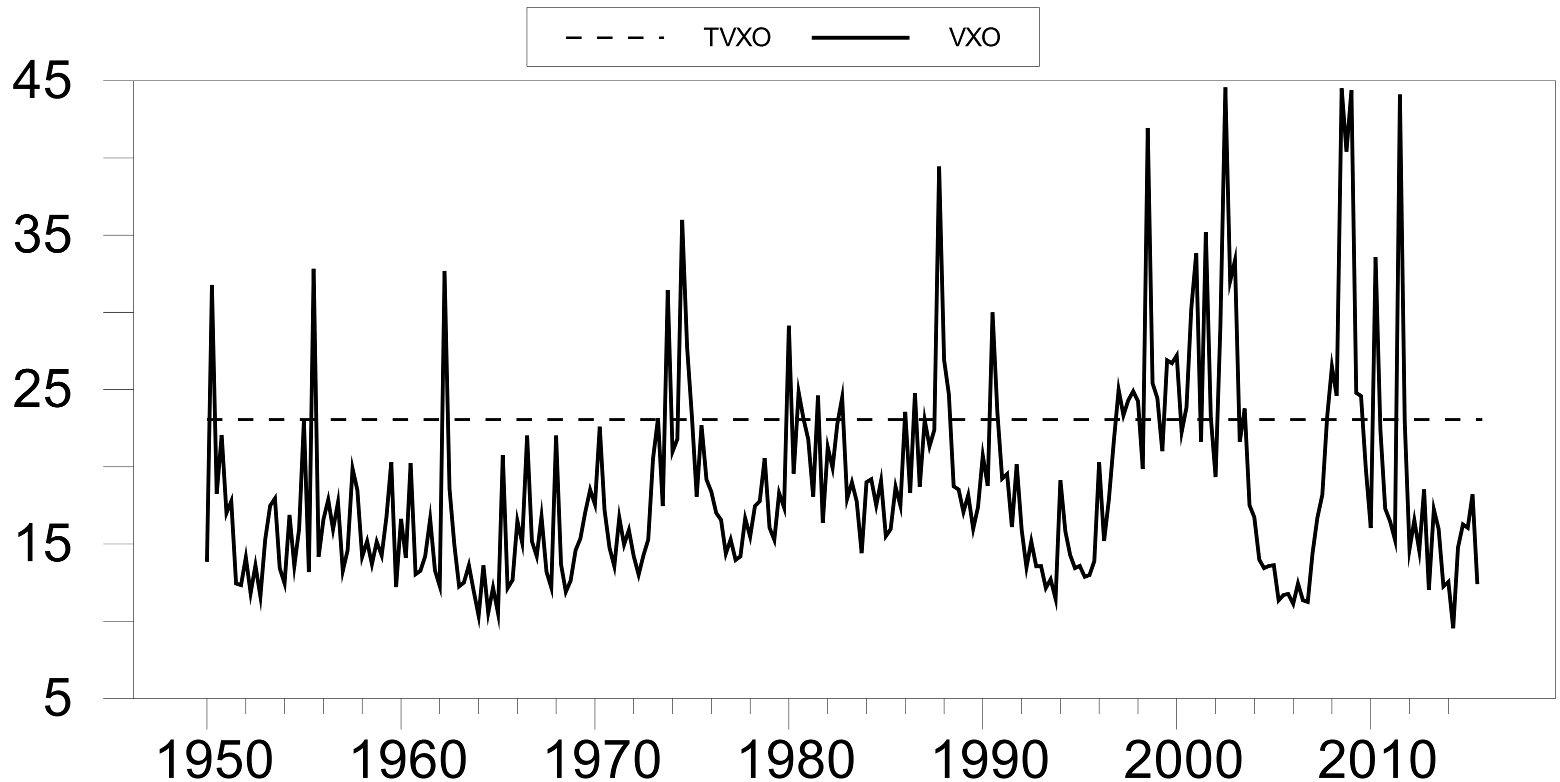


Figure 2b. Baa10ym and its Threshold Value

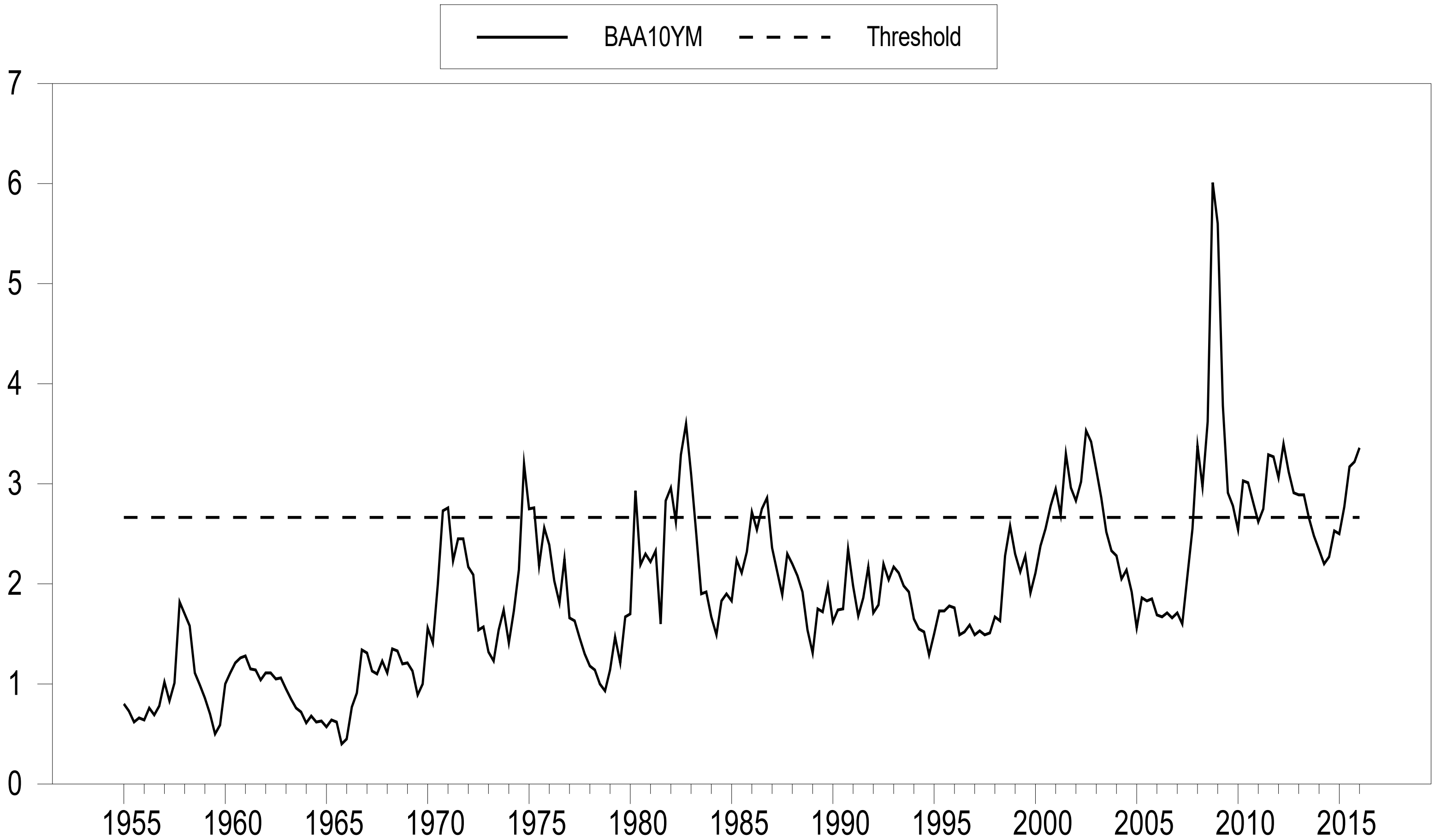


Figure 3a. Generalized Impulse Response Functions for Baseline Model using initial conditions prevailing in 2008:4

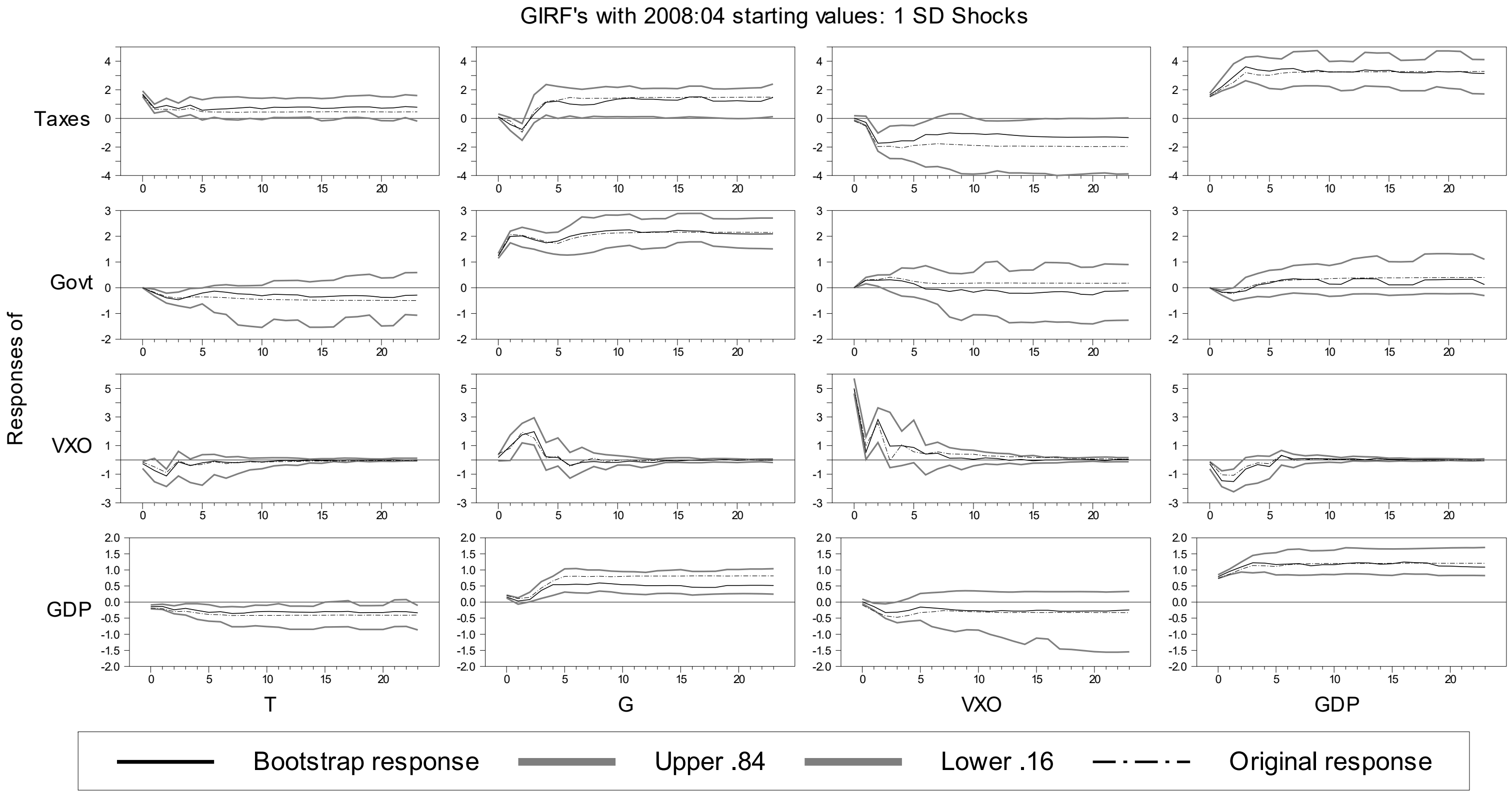


Figure 3b. Generalized Impulse Response Functions for Baseline Model using initial conditions prevailing in 1987:3

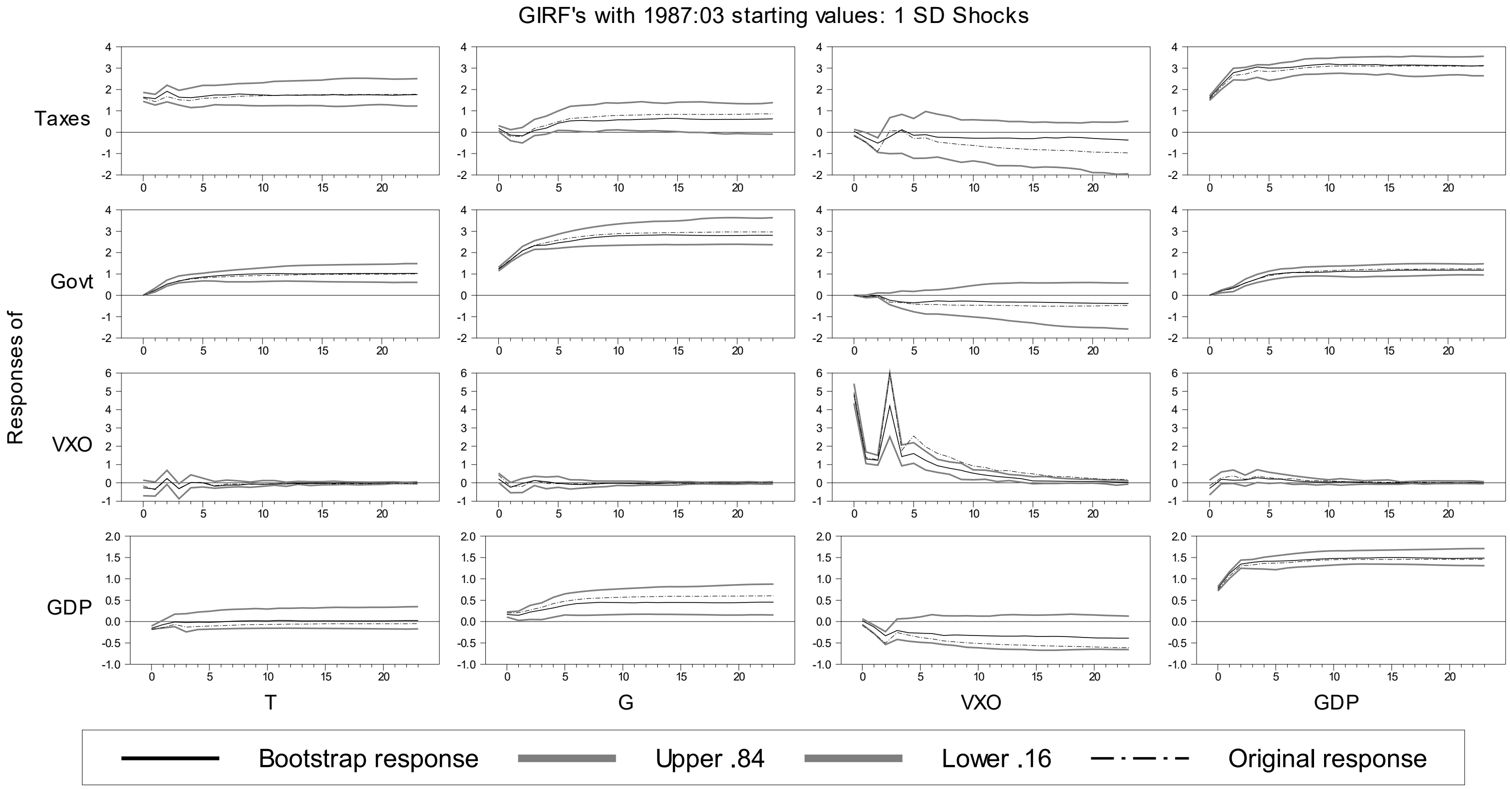


Figure 3c. Generalized Impulse Response Functions for Baseline Model using initial conditions prevailing in 2005:3

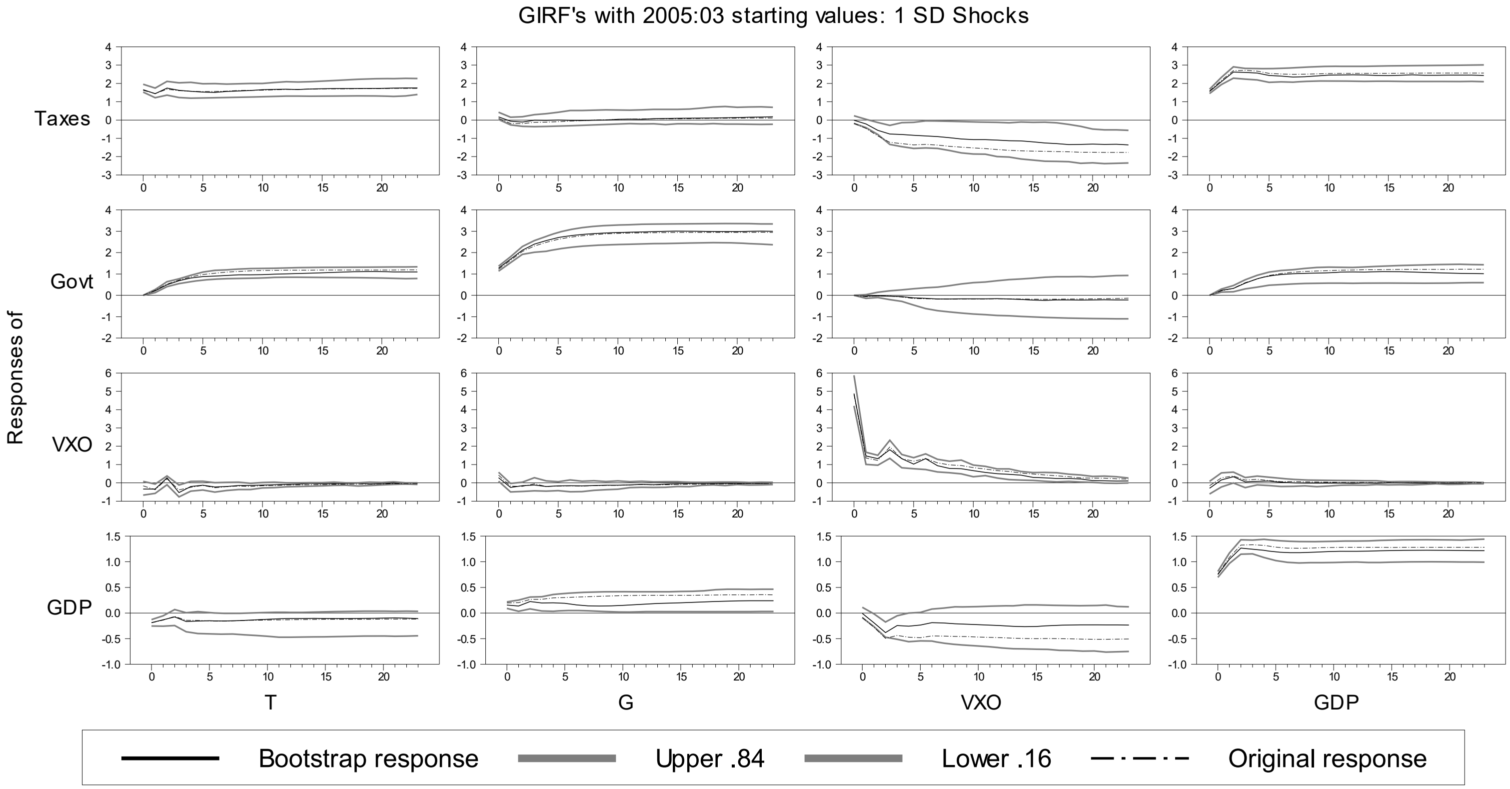
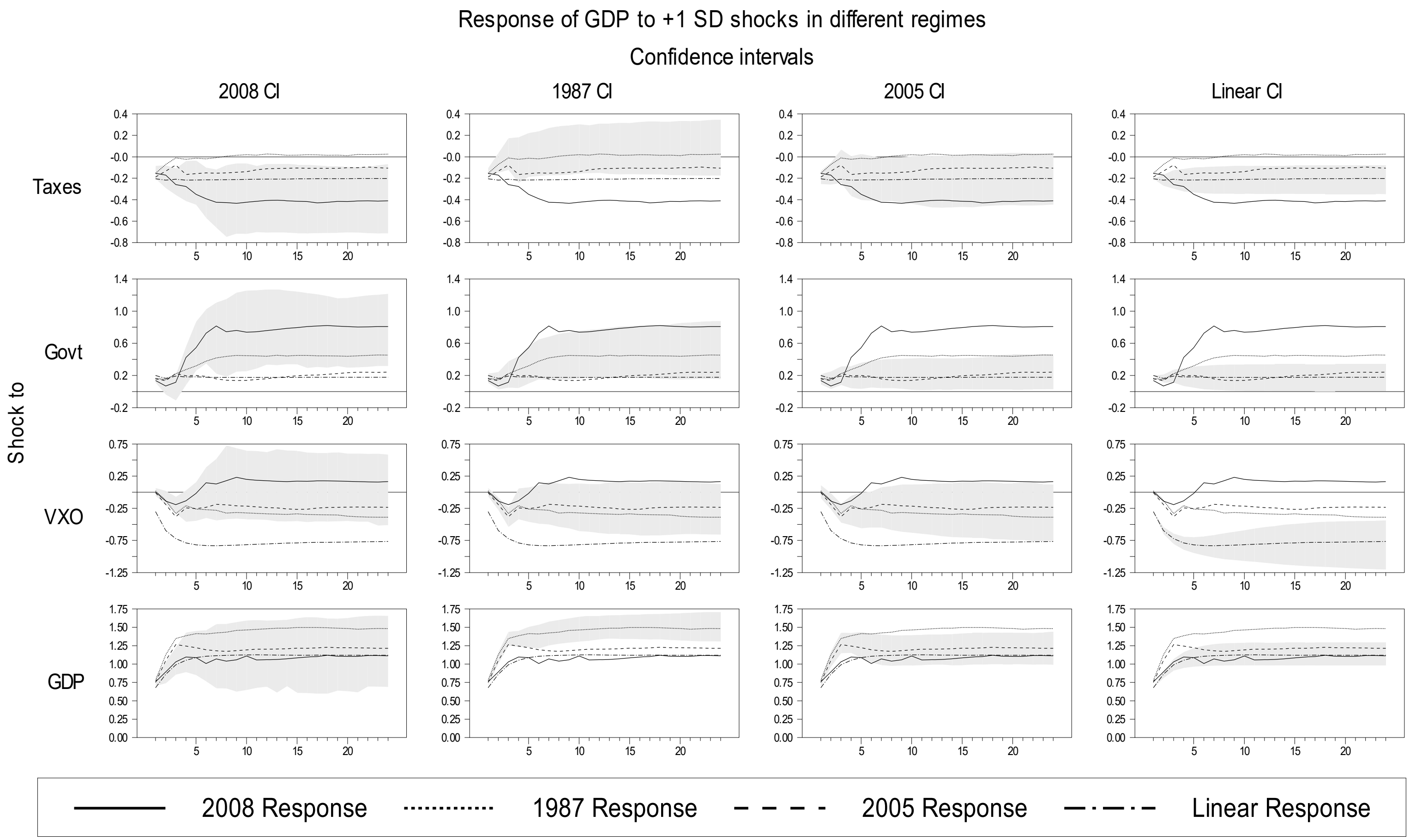
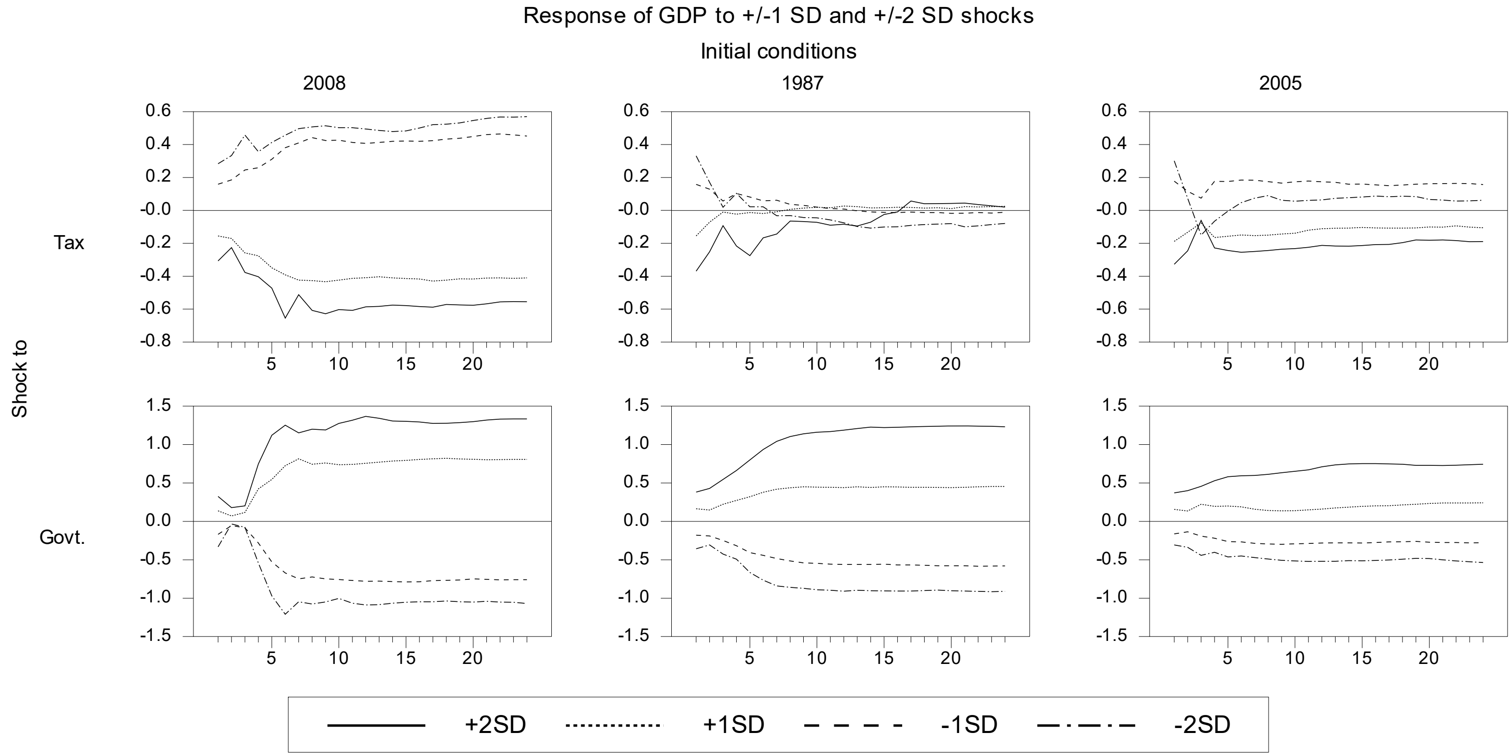


Figure 4. Comparison of the Responses of GDP to +1SD shocks in Different Regimes



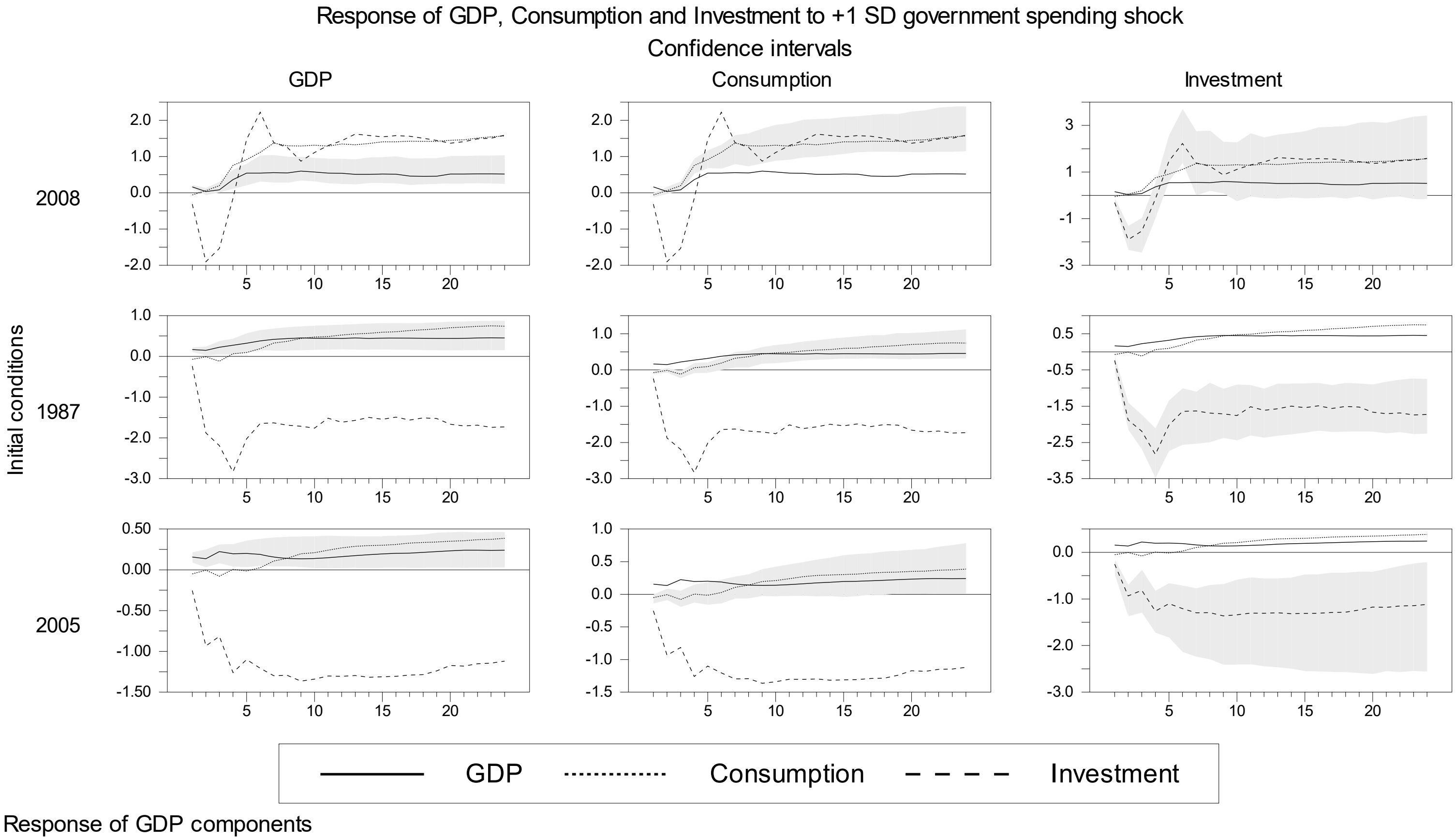
Note: Figure shows responses of GDP to shocks in taxes, government spending, VXO, and GDP (on Y axis). Shaded areas are 68% confidence intervals obtained by bootstrapping. On X axis from left to right we show confidence intervals for different initial conditions: 2008:4, 1987:3, 2005:3, and confidence intervals for a linear SVAR model.

Figure 5. Response of GDP to positive and negative, big and small shocks



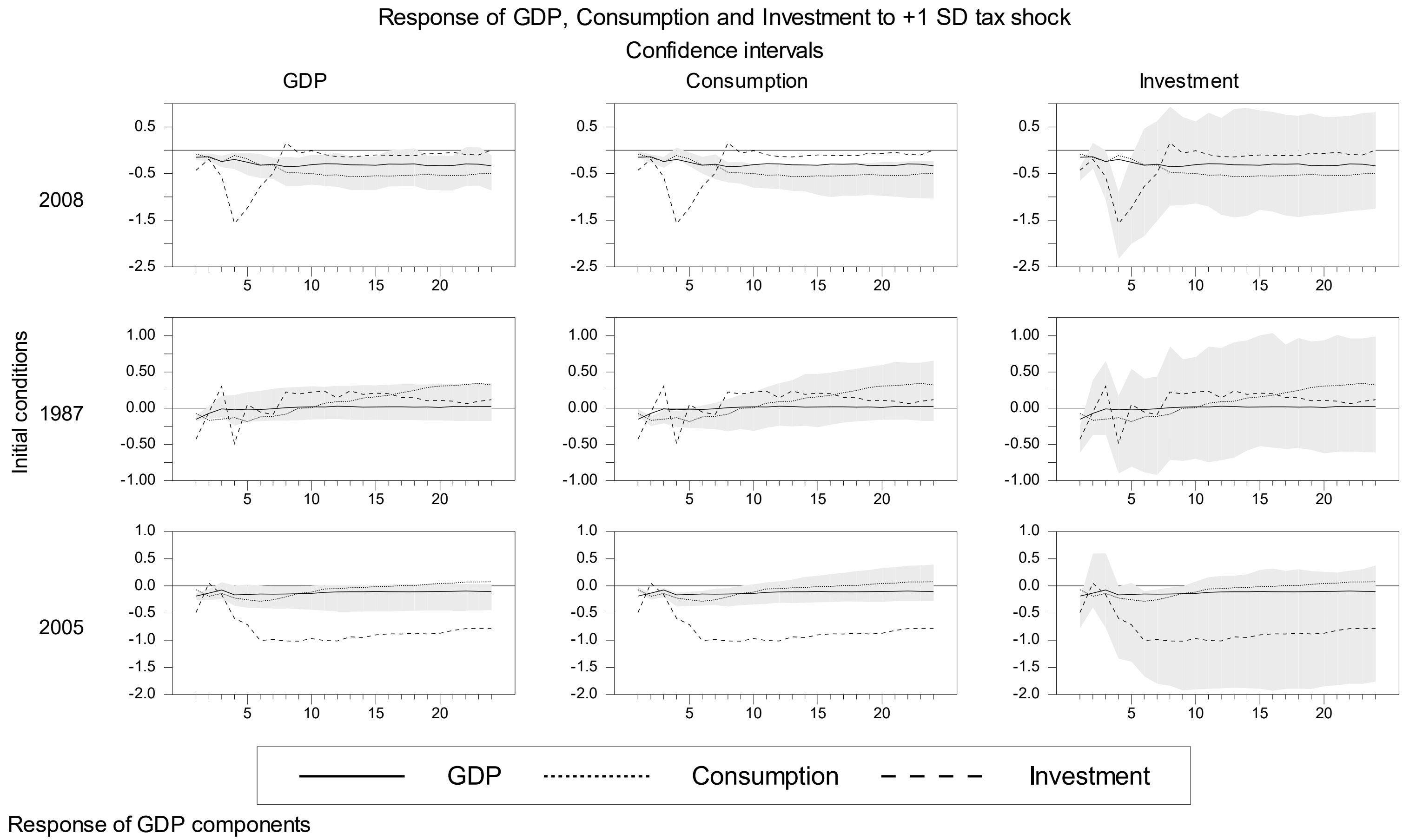
Big, small, positive, and negative shocks

Figure 6a. Comparison of Responses of GDP, Consumption and Investment to a 1SD shock to Government Spending



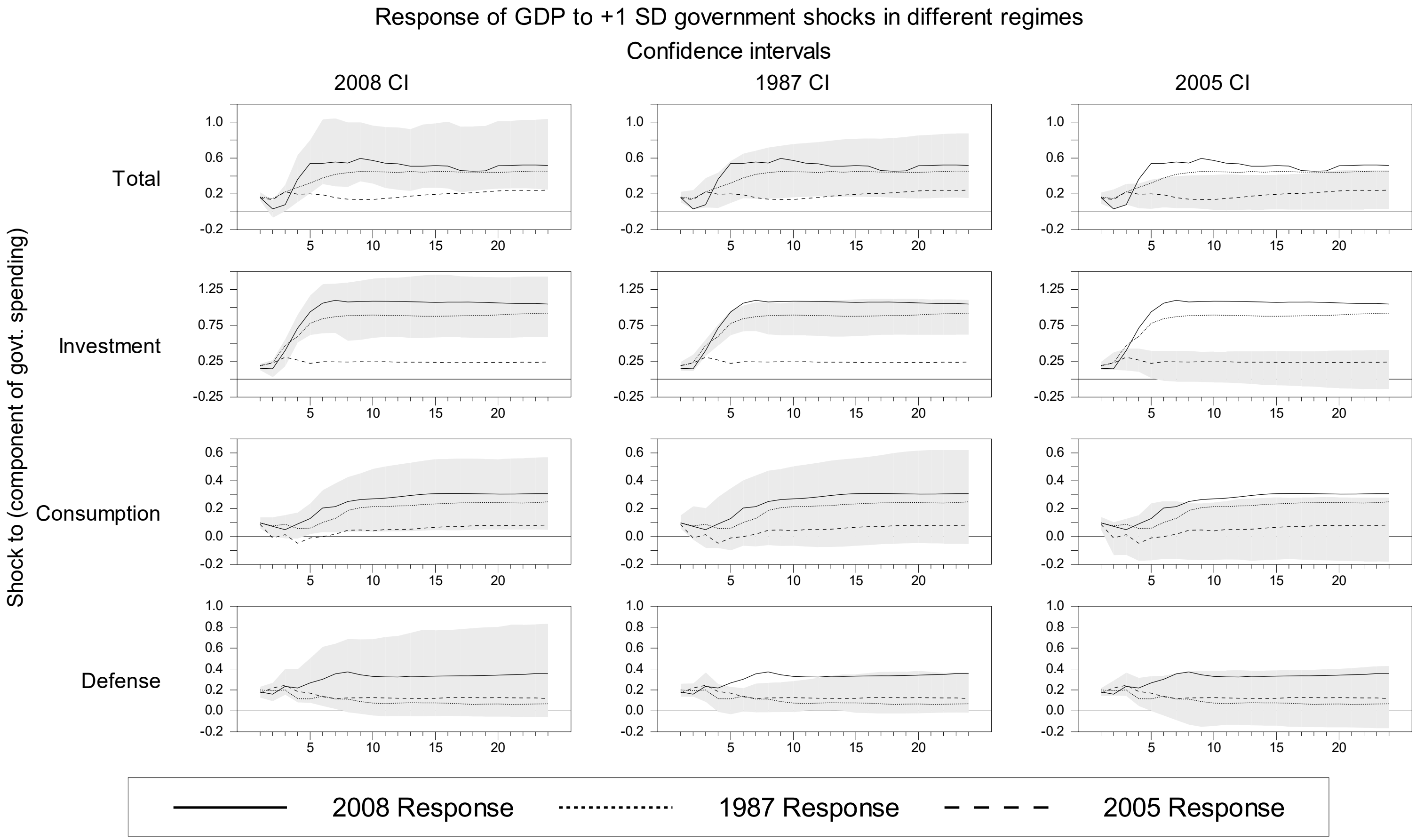
Note: Figure shows responses of GDP, consumption and investment to shock in government spending. Shaded areas are 68% confidence intervals obtained by bootstrapping. Axis Y shows different initial condition. On X axis from left to right we show confidence intervals for GDP, consumption, and investment.

Figure 6b. Comparison of Responses of GDP, Consumption and Investment to a 1SD shock to Taxes



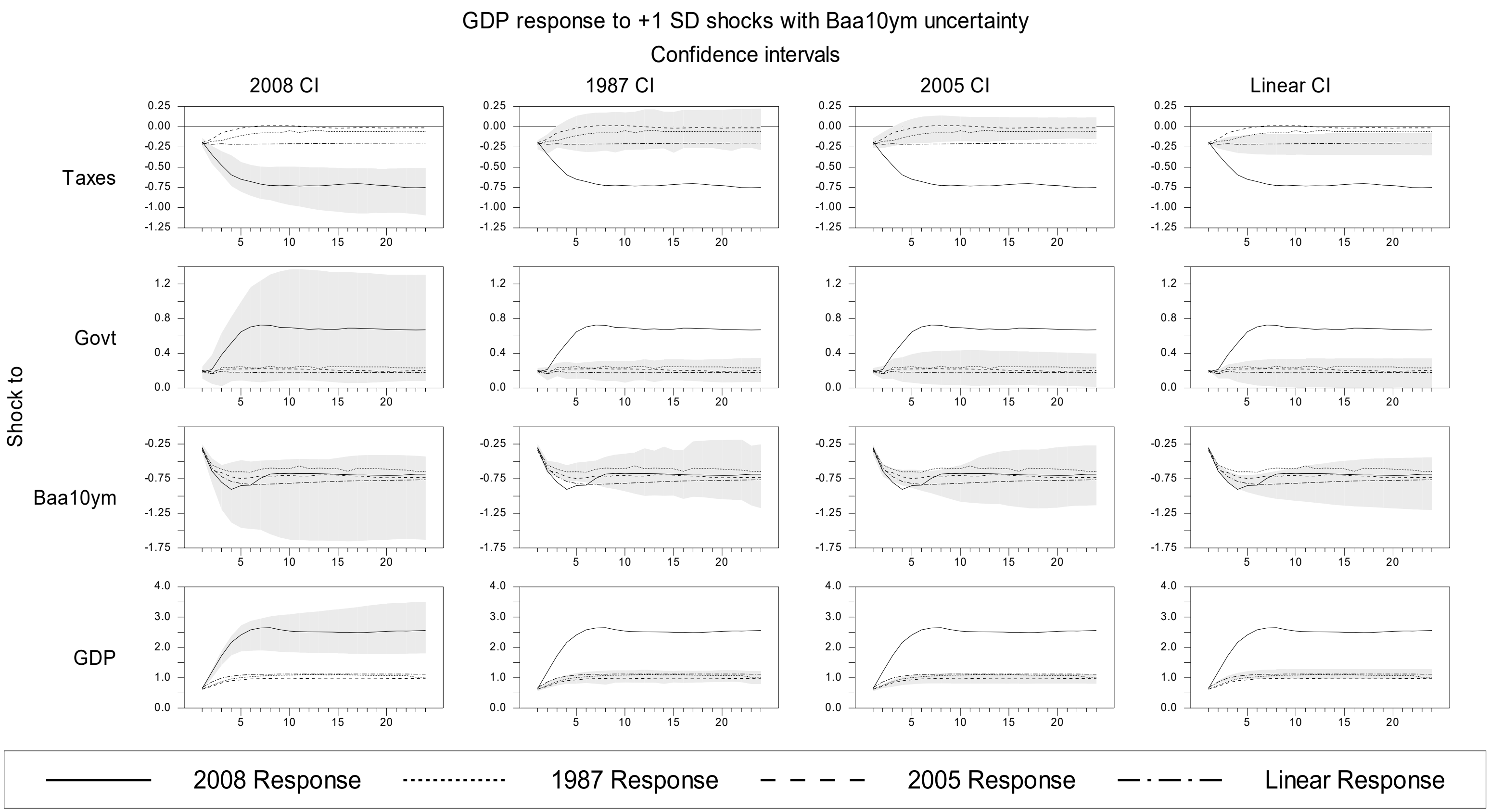
Note: Figure shows responses of GDP, consumption and investment to shock in taxes. Shaded areas are 68% confidence intervals obtained by bootstrapping. Axis Y shows different initial condition. On X axis from left to right we show confidence intervals for GDP, consumption, and investment.

Figure 7. Response of GDP to different types of Government Spending Shocks



Note: Figure shows responses of GDP to different types of government spending shocks (on Y axis). Shaded areas are 68% confidence intervals obtained by bootstrapping. On X axis from left to right we show confidence intervals for different initial conditions: 2008:4, 1987:3, and 2005:3.

Figure 8. Comparison of the Responses of GDP to +1SD shocks in Different Regimes Using Baa10ym as uncertainty variable



Note: The figure shows responses of GDP to shocks in taxes, government spending, Baa10ym, and GDP (on Y axis). Shaded areas are 68% confidence intervals obtained by bootstrapping. On X axis from left to right we show confidence intervals for different initial conditions: 2008:4, 1987:3, 2005:3, and confidence intervals for a linear SVAR model.