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INSTITUT DE HAUTES ETUDES
INTERNATIONALES ET DU DÉVELOPPEMENT

GRADUATE INSTITUTE OF INTERNATIONAL
AND DEVELOPMENT STUDIES

Graduate Institute of
International and Development Studies Working Paper
No: 06/2013

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This paper conducts an empirical investigation of the effects of temporary versus persistent fiscal policy shocks. Using data from the US I show that short lived fiscal expansions have a positive effect on output and consumption; while persistent fiscal shocks generate negative effects on consumption and - to a lesser extent – on output. Persistent fiscal expansions are associated with an increase in precautionary savings, collapse in consumers' confidence and an increase the yield curve's term premium. Consistently with consumption smoothing, short-lived fiscal expansions generate a temporary deficit in the current account, while persistent fiscal shocks leave the external balance unaffected. I find evidence of non-linearity in the effects of temporary and persistent fiscal shocks according to (i) the level of public debt and (ii) the state of the business cycle. Persistent fiscal shocks have larger negative effects on consumption and output if they take place at high levels of public debt, possibly due to the higher costs of fiscal stabilization. The state of the business cycle is also very relevant. Persistent fiscal shocks generate negative multipliers in times of economic boom, but these negative multipliers disappear in periods of recession when credit constraints are more likely to bind. On the other hand, temporary fiscal shocks have positive effects both in times of expansion and in times of recession, but with the multipliers being way larger in the latter case. Differently with what hypothesized by the earlier literature on \non-Keynesian" _scale effects, I find little evidence that these effects are asymmetric depending on the size of the shocks.

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First draft: June 2011
This draft: June 2012

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Keywords: Fiscal Policy; Public Debt; Fiscal Multipliers; Non-Keynesian Effects; Business Cycle.

JEL Classification Numbers: C10, E43, F42, F62, H68.

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1 Introduction

Facing the prospects of a dire and prolonged recession, during 2008 and 2009 many governments around the world have discussed and implemented several stimulus packages in the hope that this would serve to spur economic activity and absorb mounting unemployment. The size of the packages has been remarkable, ranging from around 2% of GDP in Europe to about 6% in the US and 13% of GDP in China. The political debate around the implementation of such important measures was reflected in the revival of the academic research on the effectiveness of fiscal policy interventions. Although the debate took place under unusual circumstances - i.e. the sharpest economic decline since the Great Depression - the arguments advanced by the opposing factions are hardly new. Concerns about fiscal sustainability have led some economists to insist on a relatively short-lived fiscal stimulus, while the rapid increase in unemployment caused by the free-falling private demand has induced others to support a more prolonged intervention.

The proponents of a rather short-lived fiscal stimulus challenge the standard view of a positive effect of deficit spending on aggregate demand. From a theoretical point of view this is justified by the idea that a persistent fiscal stimulus, because it is accompanied by the accumulation of a large stock of public debt, can raise concerns about fiscal sustainability and/or the future tax bill. This can in turn translate into a reduction of aggregate demand if forward looking agents discount the higher burden of future taxes. Under these circumstances fiscal policy expansions can have contractionary effects (Sutherland 1997, Bertola and Drazen 1993).

On the other side of the spectrum there are those who share the views of the standard Keynesian models, which suggest that the larger government's intervention the larger the increase in aggregate demand. For this reason they are in favor of a more long-lasting fiscal intervention.

The possibility that temporary and persistent fiscal expansions have different effects on the aggregate demand has been tested by some earlier literature which was looking for the so called "non-Keynesian" effects of fiscal policy, which is: the possibility that fiscal expansions can have contractionary effects. This prediction has found some empirical support in some studies which analyzed the effect of large and persistent fiscal consolidations (Giavazzi and Pagano 1990 and Alesina and Perotti 1997 among others), suggesting that fiscal policy expansions should be rather limited as the costs of persistent fiscal expansions can outweigh their benefits. The empirical evidence is however not conclusive. Part of the problem is related to the fact that different studies employ different methodologies and identification strategies but - and maybe more importantly - it is also due to the difficulty of empirically distinguishing persistent and temporary fiscal expansions.

Most of the works which intended to test these two different theories (Alesina and Perotti 1995, Givazzi et al. 1999, 2000, Giavazzi et al 2005, among others) adopted a "narrative approach" to identify the fiscal policy shocks. As a result, they confined their attention to those movements of the budget balance which were "large and persistent" according to some pre-specified threshold. This identification strategy confuses two theoretically different aspects of the policy shocks: persistence and magnitude. Besides, the small number of shocks which are identified using the narrative approach does not allow drawing robust inference on these two distinct characteristics. The usual argument in defense of the narrative identification scheme is that researchers should only focus on large shocks because they are both more likely to capture discretionary variations in the fiscal policy stance and are the only ones which are likely to change agents' perception about the future path of fiscal variables. This however ignores the fact that even small shocks can influence agents' expectations, provided that the fiscal authority adopts is credible enough.

Building on the weaknesses of previous empirical studies, in this paper I propose a novel identification strategy to analyze the effects of persistent and temporary fiscal policy shocks, while at the same time taking into consideration agents' expectations about the future path of fiscal policy variables. By employing non-linear specifications I also test whether temporary and persistent fiscal expansions have different effects depending on: (i) the reaction of monetary authority, (ii) the level of public debt, (iii) the state of the business cycle and (iv) the size of the shocks. I show that there exist marked differences in the effects of short-lived and persistent fiscal policy shocks. Short-lived fiscal expansions generate positive effect on output, consumption and investments, while persistent deficit spending shocks are associated with slightly negative multipliers on private consumption and - to a lesser extent on output. By employing a counterfactual analysis as in Bachman and Sims (2012) I show that these results are not related to the different reaction of the monetary policy authority.

Consistently with the hypothesis that agents react to the higher burden of future taxes, persistent fiscal policy shocks are also associated with a significant increase in private savings, a decrease in consumers' confidence and an increase in the yield curve's term premium. On the other hand, after a temporary fiscal expansion private savings do not increase - and instead decrease slightly in the medium run - consumers' confidence increases and the term premium does not react.

I then extend the literature on the time varying effects of fiscal policy and on "non-Keynesian" effects of fiscal policy by analyzing the impact of temporary and persistent fiscal shocks both at different levels of public debt and in different states of the business cycle. To tackle the first issue I embed the same identification scheme into a VAR augmented with an interaction term with the level of public debt. The results show that at high levels of public debt persistent fiscal policy shocks have a stronger negative effect on consumption and output. This confirms the results of some earlier literature on the "non-Keynesian" effects of fiscal policy (Blanchard 1990 and Sutherland 1997) and shows that, because concerns about fiscal sustainability are worse at high levels of public debt, they worsen the negative effects of persistent fiscal policy shocks. To answer the second question, instead, I follow Amisano et al. (2009) and Auerbach and Gorodnichenko (2010) and estimate a non linear model (Smooth Transition VAR) to allow the effects to differ according to the state of the business cycle. Consistently with the predictions of models with credit constrained agents (Gali et al 2007), I show that persistent fiscal policy shocks have negative effects in times of economic boom and mildly positive effects during recessions. On the other hand, temporary fiscal shocks have positive effects both in times of expansion and in times of recession, but with the multiplier being about 10 times as large in the latter case.

Finally, I assess whether besides the persistence of the fiscal shocks, their size also matters. Extending the framework proposed by Ravn and Sola (2004) I adopt a two-step estimation and identify the effects of small and large temporary and persistent shocks. I find that there is no evidence of asymmetry between small and large temporary shocks. On the other hand, some mild asymmetry exists between the effects of large and small persistent shocks in that large persistent shocks seem to have a smaller contractionary effect on output, pointing towards the presence of two counteracting forces: a "non-Keynesian" force and a "Keynesian" force, with the former prevailing on the latter.

The paper is organized as follows: Section 2 discusses in more details the results and the contributions of the existing literature; Section 3 presents the empirical framework and discusses the identification strategy; Section 4 presents the data used; Section 5 discusses the main results and Section 6 concludes. Further methodological details are contained in the Appendices.

2 Literature Review

In the debate about the necessity of a fiscal stimulus, the critical voices which raised concerns about the need of a government intervention find their theoretical justification in the standard neoclassical models of fiscal policy (Aiyagari, Christiano, and Eichenbaum 1992 and Baxter and King 1993). This class of models has cast severe doubts about the standard presumption that fiscal policy shocks are always associated with expansionary effects. In particular, they predict the effects of fiscal policy shocks to depend on their persistence. And precisely: if fiscal policy shocks are financed by lump sum taxes, while temporary shocks determine an increase in both output and consumption, permanent fiscal shocks trigger a negative wealth effect which translates into lower consumption because associated to a downward revision of lifetime income.

In the past, the experience of countries like Denmark, Sweden and Ireland which, after embarking into fiscal consolidation plans, experienced output growth and reduction in unemployment, contributed to support these ideas and created a line of research which has focused on the analysis of these "perverse" or "non-Keynesian" effects of fiscal policy.

This line of research raised doubts against the standard Keynesian arguments according to which persistent fiscal policy shocks are preferable to temporary, as the larger government's intervention the larger the economic expansion. If consumption is a function of disposable income alone, and there are no concerns about the profile of future taxes, then deficit spending ensures "bang for the buck" and carries no side effects. This type of dynamics is embedded in theoretical models such as the one by Romer and Bernstein (2009). According to the "neoclassical" perspective, instead, short-lived fiscal policy expansions should be preferable given that persistent fiscal shocks can raise concerns about fiscal sustainability and future tax liabilities. Moreover, they can also induce agents to believe into a future regime characterized by larger spending, larger accumulation of public debt and higher taxes. These expectations can trigger a strong counter-reaction which determines a contraction in the real economy (Sutherland 1997, Bertola and Drazen 1993 and Berben and Brosen 2007).

In their seminal article Giavazzi and Pagano (1990) argued that because agents react to the present value of future taxes persistent fiscal policy shocks translate into a downward revision of their permanent income. Symmetrically, persistent consolidations might have expansionary effects - the so called “expansionary contractions”. They show evidence that that large and persistent fiscal consolidations are in general associated with an increase in private consumption. Barry and Devereux (1995) analyze the possibility of expansionary contractions in the context of a two periods neoclassical model. Their model supports the predictions of Giavazzi and Pagano (1990), but they find employment is to be adversely affected by both temporary and persistent consolidations.

Blanchard (1990) and Bertola and Drazen (1993) have advanced the hypothesis that persistent fiscal expansions can have perverse effects because they are accompanied by “delayed stabilizations”, as opposed to temporary fiscal expansions for which stabilizations occur in the “near future”. Blanchard (1990) in his commentary on the article by Giavazzi and Pagano argued that in the latter case a fiscal adjustment removes fear of harsher future stabilizations plan. It can stabilize expectations, increase consumers’ expected disposable income, and increase confidence of investors and therefore stimulates aggregate demand. The same confidence effect has been highlighted by other papers such as Alesina and Ardagna (1998 and 2010). In short, by committing to fiscal consolidation in the near future, the government eliminates the need for a larger and possibly more disruptive consolidation later on and this can have expansionary effects. The only assumption required for this mechanism to work is that the longer the government waits to consolidate, the higher will be the required tax increase when it will have to embark in it; and with distortionary taxes higher tax rates reduce output. The higher the tax rate required by fiscal consolidation, the higher the permanent distortions will be. Hence, if the consolidation takes place in the near future it removes expectations of lower output and this can have a positive effect on confidence, which induces agents to decrease precautionary savings. At the same time it decreases the “option value of waiting” for consumers, therefore stimulating durable consumption and private investments. Following this line of argument we could expect short lived fiscal expansion to be more effective in boosting the economy with respect to persistent fiscal expansion which instead can have negative effects by postponing fiscal stabilization far away in the future.

This so called “German view of fiscal policy” has found some empirical support for example in the studies by Giavazzi and Pagano (1990), Giavazzi Jappelli and Pagano (1996, 2000) and Alesina and Perotti (1997) among others. These results, mostly drawn using a sample of OECD countries, show that a non-monotonic response between fiscal shocks and demand is more likely to arise when fiscal impulses are large and persistent. In their studies, these “large and persistent” fiscal impulses are identified as those in which the full employment surplus, as a percent of potential output, changes by at least 1.5 percentage points per year over a two-year period. More recently, Giavazzi et al. (2005), using the same definition of fiscal shocks, confirm the evidence of non-Keynesian effects of large and persistent fiscal policy shocks and show that, on the other hand, fiscal impulses that are “relatively small” tend to be associated with standard Keynesian effects.

An obvious limitation of these studies is that they use a narrative approach and focus on "large and persistent movements" in the structural budget balance to identify fiscal shocks. The number of episodes under analysis is therefore relatively limited and the particular identification scheme risks confusing the size of the shock with its time path. The usual argument in defense of the identification scheme is that only by looking at sizeable shocks can the researcher be sure to capture instances where the fiscal shocks are accompanied by a revision in agents' expectations about the future path of fiscal policy variables. This argument, however, stems from the idea that only large shocks can be perceived as "credible" while the fiscal authority could well influence agents' expectations by committing to a time certain path for taxes or spending which is independent form the size of the original shock. It is therefore important to adopt an identification scheme which takes into account the persistence of fiscal shocks without making further assumption on their size and that, at the same time, accounts for agents' expectations about the future path of fiscal variables. The identification scheme proposed in this paper starts from this consideration, and uses expectations about future fiscal policy to identify temporary and persistent fiscal policy innovations.

The literature not only suggests that the response of aggregate demand to fiscal policy shocks depends on the nature of the shock but also provides good reasons to suspect that this reaction will not be linear and its magnitude will depend on the level of public debt and on the state of the business cycle

First, at high level of public debt consumers are more likely to question the sustainability of public finances. As a consequence they would attach higher probability of a large and painful fiscal consolidation after a persistent fiscal policy shocks. With distortionary taxes this might therefore cause a larger negative effect of a persistent fiscal expansion. The reverse of the reasoning would also hold: persistent fiscal consolidations might trigger positive real effects as agents react to the news of lower future taxes (see Bertola and Drazen 1993 and Perotti 1999). At low level of public debt, instead, consumers will be less worried about the tax bill associated with large fiscal expansions and therefore less likely to modify their consumption and savings decisions as a consequence of persistent fiscal policy shocks. Some empirical evidence in this respect has been provided by Berben and Brosens (2007). These authors show that public debt has a non-linear negative effect on private consumption meaning that fiscal policy expansions at high levels of public debt are partly crowded out by a decrease in private consumption and increase of private savings.

Second, recent studies have highlighted that fiscal policy multipliers can be different over the business cycle (Tagkalakis 2008; Baldacci et al. 2010; Auerbach and Gorodnichenko 2010, 2011). Gali et al (2007) have shown that this can be due to the presence of a fraction of credit constrained agents in the economy which varies in recessions and expansions. Because credit constraints become tighter in recessions, one would expect fiscal policy multipliers to be stronger in those cases. Tagkalakis (2008) and Auerbach and Gorodnichenko (2010, 2011) show that indeed increases in public spending have a much larger multiplier when it takes place during recessions.

Because of this evidence, one could argue that protracted fiscal expansions could be possibly more beneficial in times of recession when the standard Keynesian argument is more likely to hold. However, it is also true that during recession, with the primary deficit already soaring due to lower tax revenues, further accumulation of debt can increase the probability of fiscal consolidation and therefore increase even more the savings of the fraction of consumers that is not credit constrained. This other force would work in the opposite direction, making persistent fiscal expansion less powerful in stimulating the economy. On the contrary, temporary fiscal expansion would not trigger such a counter reaction and would therefore be more likely associated with a strong expansion in output and consumption.

Finally, a related line of inquiry has linked the effects of fiscal policy shocks to the reaction of the monetary authority. Historically, the analysis of the relationship between fiscal and monetary policy can be traced back to Sargent and Wallace's (1981) analysis of "fiscal and monetary dominance". A glance at the aggregate intertemporal budget constraint of the government provides a very good intuition behind their argument. To avoid bankruptcy, governments' stock of public debt must be backed by the present value of future surpluses, or by the real stock of money. The presence of both fiscal surpluses and money in the budget constraint of the government introduce an element of strategic interaction between the fiscal and monetary authority. In cases where the monetary authority is "dominated" by the government, if future surpluses are not sufficient to cover the governments' financing needs then the Central Bank will step in and monetize part of the debt stock. Vice versa, if it is the government to be "dominated" then the Central Bank will not move and the government will have to generate adequate surpluses. Davig and Leeper (2011) have more recently shown that in the American history there indeed exist alternating phases of "fiscal and monetary dominance".[1]

From a theoretical point of view this is equivalent to having a time-varying reaction function of the monetary authority which becomes at times more or less permissive of large fiscal deficits and high stocks of debt. Differences in the effects of persistent or temporary fiscal policy shocks might therefore also be due to the different reaction of monetary authority. Persistent fiscal expansions, because associated with accumulation of public debt, can arm-twist the Central Bank and induce it to lower interest rates to accommodate the expansion (Davig and Leeper 2011). In *Section 5.1* I will show that the reaction of the monetary authority counts very little in the explanation of the effects of persistent and temporary fiscal shocks.

3 Methodology

To analyze the effects of the fiscal policy shocks I employ VAR analysis and I use an identification procedure which allows me to distinguish between two different types of fiscal shocks: (i) short-lived fiscal expansions - which revert to zero relatively fast and (ii) persistent expansions - which revert to zero only slowly over time. The identification is

[1]Starting from this intuition the so called "fiscal theory of price level" maintains that there exists in fact a third way in which the intertemporal budget constraint of the government can be satisfied, which is through an endogenous adjustment in the price levels. The theory was developed primarily by Eric M. Leeper (1991), Christopher A. Sims (1994), and Woodford (1994, 1995, 2001). It has been criticized by Narayana Kocherlakota and Christopher Phelan, Willem Buiter (2002), Bennett T. McCallum (1999, 2001, 2003), Oscar Arce, and Dirk Niepelt.

obtained using data on the expected stock of future debt. In fact, if agents are rational and use all of their available information to form expectations about the future, it is very likely that a fiscal expansion which is accompanied by an increase in expected future debt will turn out to be persistent. On the other hand, temporary fiscal expansions will either cause the expected future debt to decline or leave it unaffected.

The baseline specification of the VAR includes five variables: the cyclically adjusted budget deficit, the forecasts for the level of public debt, output, consumption and the federal fund rate. As I will discuss in more details in the next section, the first two variables are used to identify the two fiscal policy shocks, while the federal fund rate is included to assess whether the reaction of the monetary policy is different for persistent or temporary fiscal shocks. To check the robustness of the results and deepen the understanding of the transmission mechanisms of the two fiscal policy shocks, I then re-estimate the baseline specification including a set of control variables *(Section 5.1.1)*. I then use the same identification framework in two non-linear VARs to investigate whether the effects of persistent and temporary fiscal policy shocks are "state-dependent". Following the insights from existing literature, I analyze whether their effects depend on the level of public debt and on the state of the business cycle. Because with non-linear models the number of parameters to estimate becomes very large, I will limit the analysis to the baseline specification only.

Finally, following Ravn and Sola (2004) I use the baseline specification to assess whether the differences between the effects of persistent and temporary fiscal shocks depend on the size of the shocks.

3.1 Identification

When tackling the issue of identification the literature has followed three different paths. Some studies (Perotti 2005; Auerbach and Gorodnichenko 2010) have followed the Structural VAR methodology proposed by Blanchard and Perotti (2002). Using information about the size of tax elasticities, this approach isolates discretionary fiscal shocks by taking into account the automatic reaction of the budget deficit to the business cycle. Some others (Ramey and Shapiro 1998, Edelberg et al 1999, Romer and Romer 2010, Ramey 2011) have followed the so called "narrative approach", which consists of constructing a time series of discretionary fiscal shocks. Originally (Ramey and Shapiro 1998) it consisted simply of estimating the effects on output and consumption of war episodes, arguing that those were the only instances of strong exogenous increase in government outlays. This approach has been recently refined by Ramey (2011) who constructed a series of "defense news shocks" using information about the changes in the defense budget taken from the press. A third strategy is to employ sign restrictions - or "shape restrictions" (Canova and Pappa 2007, Mountford and Uhlig 2009, Dungey and Fry 2009). In this case the identification of fiscal policy shocks is obtained by imposing some theory-driven restrictions on the responses of the variables. Exogeneity with respect to the business cycle is obtained by further identifying a business cycle shock which is by construction orthogonal to the fiscal policy shocks.

Here I follow the third path. In particular, I use sign restriction to identify two different fiscal shocks: persistent and temporary. This is obtained by introducing in the VAR also the 5 years ahead forecasts of the level of public debt published by the Congressional Budget Office (CBO) and restricting its co-movement with the cyclically adjusted budget deficit. In particular, because public debt is nothing else than the "stock side" of budget deficits, persistent fiscal policy shocks - or fiscal shocks that are perceived as being persistent - will be characterized by an increase in the budget deficit and a contemporaneous increase in the forecasts on public debt. On the other hand, fiscal shocks that are perceived as temporary will be those accompanied by expectations of counter-reaction by the fiscal authority meaning that agents will expect the burden of debt to be reabsorbed in the near future.[2]

Both the cyclically adjusted deficit and the projections on the Government Debt are published by the Congressional Budget Office (CBO). Following Laubach (2009) I use the forecasts for the baseline scenario and I consider the 5 years ahead forecasts to minimize the possibility that they are driven by considerations on the state of the business cycle. However, to minimize the possibility that the results are driven by some spurious correlation with the business cycle, I also identify a business cycle shock.[3] Following Mountford and Uhlig (2009) I identify a business cycle shock as s co-movement between output and consumption.[4]

I use the structurally adjusted budget balance to be consistent with the tradition of the literature on "Non-Keynesian effects", much of which used the cyclically adjusted budget balance when analyzing the effects of "large and persistent fiscal policy shocks" (see Afonso 2001 for a review of the literature). This choice will also prove to be very handy when - as explained in *Section 3.2.3* - I will use the first equation of the VAR to estimate a fiscal reaction function to assess whether the effects of temporary and persistent fiscal shocks change depending on their size.

In sum, the identification of the shocks is obtained imposing the following set of restrictions:

Identificaton	Budget Deficit	Expected Debt	Y	C	FFR[5]
Business Cycle Shock			>0	>0	
Temporary Fiscal Shock	>0	≤ 0			
Peristent Fiscal Shock	>0	>0			

Following Jarocinski (2010), the sign restrictions are obtained using a matrix R which is inserted in the upper left block of an identity matrix. This operation defines a block diagonal matrix V:

$$V = \begin{bmatrix} R & 0 \\ 0 & I \end{bmatrix}$$

which has the property of being orthonormal ($VV' = I$). The identifying restrictions are then imposed on the matrix Φ obtained by multiplying the Choleski factorization of the variance covariance matrix of the error term by the

[2]Moreover, because the expected future debt is expressed in real terms, a temporary increase in budget deficit at time t can be accompanied by a reduction in the expected future debt due to the simple effect of inflation.

[3]Repeating the analysis identifying only the two fiscal policy shocks does not affect the results. Results are available upon request.

[4]In their specification Mountford and Uhlig (2009)have both spending and taxes in the VAR and therefore identify also a business cycle shock as a co-movement between output, consumption and tax revenue. In this case, because we use the cyclically adjusted primary balance I only impose restrictions on output and consumption.

matrix V. Because the matrix R is a sub-matrix of V this implies that the "rotated" matrix Φ will preserve a lower triangular block of the same size as the size of matrix I. Hence, this particular structure allows us also to identify a monetary policy shock. The lower triangular structure is in fact equivalent to impose that the interest rate - which is the variable ordered last - can respond contemporaneously to all the other variables in the VAR while, on the contrary, the other variables respond to innovations to the interest rate only with a lag. Because this is the standard assumption behind the identification of monetary policy shocks (see Stock and Watson 2001), we can interpret the shock to the last equation as a monetary policy shock.

Except for this set of identifying restrictions, the response of all the other variables is left completely unrestricted, including also the response of the federal fund rate. This will yield important insights on the behavior of monetary policy when facing fiscal shocks with different temporal profiles. Ideally we would expect the monetary authority to follow a standard Taylor rule, and therefore to respond positively to economic expansions which can jeopardize price stability. In principle, however, the monetary authority could also respond to the accumulation of large stocks of public debt by adopting a more restrictive or a more lax policy depending on whether it operates in a regime of "passive" or "active" monetary policy (see Davig and Leeper 2011).

To gauge the importance of the reaction of monetary policy in the transmission of the two fiscal shocks, I conduct a counterfactual experiment as that presented by Bachmann and Sims (2012). The experiment consists of analyzing impulse responses for the two fiscal shocks while forcing the response of the monetary policy rate to be fixed at zero. This therefore allows us to understand how much of the reaction of output and consumption to the fiscal policy shocks is due to the endogenous reaction of monetary policy. More details about the construction of this counterfactual experiment are found in *Appendix A*.

3.2 Non-Linear Effects

As mentioned in *Section 2*, much of the existing literature has pointed out how the negative consequences of persistent fiscal shocks can be aggravated by the presence of a large stock of public debt. More recent works, instead, have underlined the importance of credit market imperfections, therefore implying that the effects of persistent and temporary fiscal shocks can be different over the business cycle. Finally, the older literature on "Non-Keynesian" effects has greatly emphasized the importance of the size of the shocks together with their persistence. I therefore extend the analysis of the effects of temporary and persistent shocks to non-linear econometric models to assess all these different claims.

From a theoretical point of view, the level of public debt can influence the effects of fiscal policy shocks by affecting agents' perceptions about the state and sustainability of public finances and the likelihood of fiscal consolidation following a fiscal shock. In fact, at high levels of debt it is more likely that a fiscal shock jeopardizes fiscal sustainability making fiscal consolidation inevitable. Moreover, in presence of dstortionary taxes, the higher level of

public debt will disproportionally increase the cost of fiscal consolidation. If this is incorporated by private agents, it might translate into large negative responses of consumption and also of output.
In theory the level of debt could influence the effects of temporary and persistent shocks also through another channel: the reaction function of the monetary authority. In fact, if a fiscal expansion which takes place at high levels of public debt leads to a violation of the government budget constraint, the monetary authority could decide to step in and monetize the deficit, therefore ensuring solvency. The injection of liquidity will cause interest rates to fall and - everything else equal - lead to an expansion in real activity.

Because the differences in the effects of temporary and persistent shocks hinge on the possibility that consumers react to changes in their lifetime income, it is natural to wonder what happens if we allow the fiscal multipliers to be different over the business cycle. As pointed out by Gali et al. (2007), in recessions the share of credit constrained agents increases. Hence there will be relatively more agents that react to fiscal shocks in a standard Keynesian fashion given that, without access to capital markets, their consumption depends only on disposable income. As a consequence, both types of fiscal shocks will display larger multipliers in recession than in expansions. However, because even in recessions there is a fraction of agents that is not credit constrained, the multipliers generated by temporary fiscal shocks should always be larger than those generated by persistent fiscal shocks.
Also in this case it can be instructive to analyze the responses of the monetary authority. In general in a recession the monetary authority is less concerned with the inflationary consequences of a fiscal policy expansion and is therefore less likely to raise interest rates to react to an increase in budget deficit (Christiano et al. 2009, Erceg and Linde 2010, Woodford 2010). This would further increase the fiscal policy multipliers in periods of recessions but contribute to generate differences in the effects of persistent and temporary shocks in case the reaction of the central bank is not exactly similar in the two cases.

Finally, it is interesting to assess whether there exist differences in the effects of small and large temporary and persistent fiscal policy shocks. The issue of the size of the fiscal shocks has raised particular interest especially in the earlier studies which investigated non-Keynesian effects of fiscal policy. The issue of the size was however always intertwined with that of the persistence of the shock. Especially in the literature assessing the presence of "expansionary contractions" the line of argument was that, in order to generate economic expansion, a fiscal consolidation needs to be protracted over time and consistent in size so to convince agents that a credible change in the fiscal policy regime is underway. Moreover, even in the cases in which the issue of the size of the shock was intended to be kept separate from that of persistence, many of the empirical analyses adopted an identification scheme which ended up confusing these two aspects (see *Section 2*). Having an identification scheme which isolates the aspect of persistency of the shocks, I can add a layer of complexity and disentangle the effect of size, therefore identifying four different types of shocks: small and large temporary shocks and small and large persistent shocks.

So far the investigation of the non-linear effects of fiscal policy shocks has been mainly conducted using standard panel techniques (Giavazzi, Jappelli and Pagano 2005, Tagkalakis 2008, Beber and Brosens 2007 among others). Here I follow some more recent literature and estimate non-linear VARs. In particular, to assess the effect of the level of public debt I adapt the framework proposed by Sa et al. (2011) and Towbin and Weber (2011) and include an interaction term in an otherwise standard VAR. Instead, to gauge the asymmetric effects over the business cycle I adapt the Smooth Transition VAR (ST-VAR) originally by Amisano et al. (2009) and then further developed by Auerbach and Gorodnichenko (2010). Finally, to identify the effect of the size of the shocks I adopt a two-step estimation along the lines of what proposed by Ravn and sola (2004).

3.2.1 VAR with Interaction term

To allow the effects of fiscal policy shocks to vary with the level of public debt I re-estimate the baseline specification of the VAR introducing an interaction term. The VAR takes the form:

$$Y_t = A\left(L\right)Y_{t-1} + B\left(L\right)Y_{t-1}X_{t-1} + E_t \tag{1}$$

where the variable X contains the log of the debt to GDP ratio. This formulation can in theory allow all the elements of the vector Y to be interacted with the variable X in each equation of the VAR. However, for parsimony, in each equation of the VAR I allow an interaction term only with the lags of the structurally adjusted budget deficit and of the federal fund rate. In practice this is equivalent to assuming that the non linear effects of public debt derive from the reaction functions of the government and of the central bank. In particular, level of primary deficit and of public debt will jointly determine the central bank's decision on the interest rate and the level of the interest rate and the level of public debt will determine the decision of the government about the budget deficit. Like with standard linear specifications, also in this case consistent estimates can be obtained by standard OLS equation by equation, given that even with the interaction term each equation of the VAR has the same elements. As with standard interaction terms, however, once I obtain the coefficients $\widehat{A}\left(L\right)$ and $\widehat{B}\left(L\right)$ I need to set a value for the variable X to be able to evaluate the effect of shocks on the variables included in Y. I choose values of the variable X which correspond to the top and bottom quartile of the distribution of the debt to GDP ratio, which in the sample are equivalent to 34% and 45% respectively (call them X^{low} and X^{high}. Historically, the low debt regime roughly corresponds to the first years at the beginning of the sample and the years 2000 to 2003 after President Clinton's fiscal consolidation. Periods of very high public debt, instead correspond to the last years of the sample and to the years between 1991 and 1995, the last years of the G. H. W. Bush administration and the first years of the Clinton's administration.

After having assigned values to the variable X the estimated VAR reduces to:

$$Y_t^{high} = \widehat{C_1}(L) + E_t$$
$$Y_t^{low} = \widehat{C_2}(L) + E_t$$

where $\widehat{C_1}(L) = \widehat{A}(L) + \widehat{B}(L)X^{high}$ and $\widehat{C_2}(L) = \widehat{A}(L) + \widehat{B}(L)X^{low}$. These are standard reduced form VAR models, and therefore there is no further complication to use the restrictions discussed above to identify temporary and persistent shocks and analyze their effects respectively at high and low levels of debt.

3.2.2 ST-VAR

To study the asymmetric effects of the shocks over the business cycle I follow Amisano et al. (2009) and Auerbach and Gorodnichenko (2010) and use a Smooth Transition VAR model (ST-VAR). Differently from the case discussed above, this model is particularly indicated to study the behavior of a system which "oscillates" between two extreme cases - in our case "expansions" and "recessions". The speed of transition between the two states is considered unknown and is estimated from the data. If the transition happens instantaneously, then the model collapses to a VAR augmented with dummy variables which take value 1 for one state and zero otherwise. The ST-VAR formulation not only has the desirable property of allowing the speed of transition to be estimated, but also gives the two different states a probabilistic interpretation. In our case, states of recession/expansion will therefore be identified as those states which prevail if the probability of contraction/expansion of real GDP tends to 1. The model is specified by the following set of equations:

$$Y_t = \left(1 - F\left(z_{t-1}\right)\right) A\left(L\right) Y_{t-1} + F\left(z_{t-1}\right) B\left(L\right) Y_{t-1} + E_t \tag{2}$$
$$\Sigma_t = \left(1 - F\left(z_{t-1}\right)\right) \Sigma^E + F\left(z_{t-1}\right) \Sigma^R \tag{3}$$
$$F\left(z_t\right) = \frac{\exp\left(-\lambda z_t\right)}{1 + \exp\left(-\lambda z_t\right)} \tag{4}$$

where Y_t is the vector of endogenous variables; $A\left(L\right)$ and $B\left(L\right)$ are coefficients in the lag operator and $F\left(z_t\right)$ are weights between zero and one, which are modeled to be the result of a logistic function in z_t.

To give the two states the interpretation of "recessions" and "expansions" I define the variable z_t to be the seven quarter moving average of real output growth.[6] Hence $F\left(z_t\right)$ will take values close to 1 whenever the economy is in a state of recession, while it will take values close to zero during economic expansion. Centering the logistic function around zero is very intuitive and makes economic sense. This and the characteristics discussed above are the main reasons for which I prefer this non-linear specification to assess the asymmetry of temporary and persistent fiscal

[6]As in Auerbach and Gorodnichenko (2010).

policy shocks over the business cycle.

Moreover, as discussed in Auerbach and Gorodnichenko (2010), there are also a series of reasons for which this approach is preferable to the inclusion of simple dummy variables for recession dates. First of all it makes use of all the observations in the sample to estimate the coefficients $A(L)$ and $B(L)$, which is particularly useful when there are not so many observations in one of the two states. Moreover, it allows the transition between the expansion and the recession states to happen gradually. The speed of transition between the two states is governed by the parameter λ. For values of $\lambda \to \infty$ the transition takes place with an instantaneous jump, similar to that obtained by using dummy variables instead of the logistic weights $F(z_t)$. For values of $\lambda \to 0$, instead, the transition takes place gradually.

It is important to notice that the equation (2)would be linear in the parameters $A(L)$ and $B(L)$if the coefficient λ was known. However, estimating (2) by OLS conditional on an appropriate value of λwould not allow the variance covariance matrix of the error term to be time varying. Here, following Auerbach and Gorodnichenko (2010) I assume the variance covariance matrix to be a time varying function of two matrices Σ^E and Σ^R which are respectively the variance covariance matrices of the error terms during expansions and recessions. The time variation in the variance covariance matrix Σ_t is given by the logistic weights $F(z_{t-1})$ and $(1 - F(z_{t-1}))$. Having this time varying error structure, although more realistic, introduces some complications in terms of the estimation of the model. In fact, the matrices Σ^E and Σ^R are unobservable and therefore their estimation requires a Maximum Likelihood method. In theory, conditional on the set of parameters $\{A(L), B(L)\}$ the likelihood function can be maximized for $\{\Sigma^E, \Sigma^R\}$ thus providing some consistent estimates for the two variance covariance matrices. Then, conditional on the Maximum Likelihood estimates $\left\{\widehat{\Sigma}^E, \widehat{\Sigma}^R\right\}_{ML}$, the parameters $\{A(L), B(L)\}$ can be re-estimated through Weighted OLS. Here I use a multiple step estimation, iterating the maximization of the likelihood and the weighted OLS estimation until the likelihood function reaches convergence. Moreover, differently from Amisano et al. (2009) and Auerbach and Gorodnichenko (2010) I do not calibrate the parameter λ a priori, but I estimate it together with the two variance covariance matrices. More details on the estimation procedure are provided in *Appendix A*.

Once the parameters of the model are estimated I can derive impulse response functions for the two extreme states of the economy. Impulse response functions for states of recessions are obtained as the limit for $F(z_{t-1}) \to 1$ and impulse response functions for states of expansions are obtained as the limit for $F(z_{t-1}) \to 0$. The identification of the temporary and persistent fiscal shocks in the two regimes is obtained implementing the same set of restrictions discussed in *Section 3.1*. The confidence bands are then obtained by Monte Carlo simulation.

3.2.3 Small and Big Shocks

Because of the nature of the problem, the estimation procedure needed to distinguish the effects of small and large temporary and persistent fiscal shocks is slightly more convoluted than estimating a simple VAR and it involves several steps. First we need to estimate two exogenous series of fiscal shocks, which somehow reflect the identifying restrictions of *Section 3.1.* Second, we have to distinguish into "small" and "large" according to a pre-specified cutoff value; and finally we can use those shocks as exogenous variables in a VAR and analyze their effects on the variable of interest.

In theory, exogenous fiscal shocks can be estimated as the residuals of a fiscal reaction function which, in this case is nothing else than the first equation of the VAR. In fact, in the first equation of the VAR I regress the structurally adjusted budget balance on its own lags and on the lags of expected debt, output, consumption and interest rates. This is very similar for to the fiscal reaction function hypothesized in many DSGE models (see for instance Corsetti et al. 2010). Moreover, because I use the cyclically adjusted budget deficit as a measure of fiscal stance, I can estimate the fiscal reaction function with standard OLS. If the deficit was not cyclically adjusted the estimation of such equation would suffer from endogeneity coming from the fact that, because of automatic stabilizers, movements in output affect budget deficit within the same time period.

The estimation of the fiscal reaction function is however complicated by the fact that the shocks we are interested in have to generate a given response of the budget deficit to be first classified as "temporary" or "persistent" before being split according to their size. The difference between temporary and persistent shocks are embedded in the reaction function of the budget deficit to fiscal shocks (top left panel of *Figure 1*). Hence, to be sure that the estimated shocks respect these restrictions we need to translate the coefficients of those response functions into restrictions on the coefficients of the fiscal reaction function. Such a mapping exists and it allows to take the coefficients from the response functions of deficit to temporary and persistent fiscal shocks and transform them into the coefficients on the lags of the deficit of the fiscal reaction function. Once we have retrieved those two sets of coefficients we can then plug them back into the fiscal reaction function and estimate two restricted reaction functions: one which uses the coefficients derived from the response to temporary shocks and one which uses those derived from the response to persistent shocks. The residuals of those two regressions will be series of estimated temporary and persistent fiscal policy shocks.

After having estimated the shocks I then proceed into splitting them into "large" and "small" according to whether they are larger or smaller than twice the sample standard deviation of each series. This yields 4 series of shocks which I then use as exogenous variables in a VAR which contains all the other $N-1$ variables: expected debt, output, consumption and the federal fund rate. Now, because the estimated fiscal shocks are exogenous drawing impulse responses does not entail any further identification restriction. Calling X_t the vector of variables which contains the $N-1$ set of variables of interest, I estimate:

$$X_t = F(L)X_t + G_1\widehat{\varepsilon}_t^{LP} + H_1\widehat{\varepsilon}_t^{SP} + G_2\widehat{\varepsilon}_t^{LT} + H_2\widehat{\varepsilon}_t^{ST} + u_t \tag{5}$$

where the labels LP, SP, LT, ST stand for "large and persistent", "small and persistent", "large and temporary", "small and temporary". The impulse response functions are then computed as: $[I-F(L)]^{-1}G_1$, $[I-F(L)]^{-1}H_1$, $[I-F(L)]^{-1}G_2$ and $[I-F(L)]^{-1}H_2$.

4 Data

The estimation is performed for the US for the period 1981Q4 to 2008Q4. The length of the sample and the choice of the country are dictated by the availability of data. In fact, the Congressional Budget Office is the only institution that publishes regular forecasts for the government's budget over a long time horizon and the data prior to 1981 are only available at yearly frequency. As pointed out by Leeper (2009), the main advantage of using CBO forecasts is that they are widely known to the public. Hence they should be a good proxy of agents' expectations about the future path of fiscal policy. In general the CBO forecasts are released only twice a year, and therefore the data were interpolated to obtain forecasts at a quarterly frequency. The forecasts are then transformed to real terms using the CBO's forecasts for core inflation over the same horizon. The CBO is also the source for the data on the structural deficit. This is computed by eliminating the impact of automatic stabilizers from the primary deficit. Output and private consumption are taken from the NIPA tables. The federal fund rate is taken from the historical series published by the New York Fed. Besides the 5 variables used in the baseline specification I also employ a battery of other variables to gain further insights in the results. These variables are: private savings, consumers' confidence, investments, stock prices, the term premium and the current account balance.

Savings and current account balance are taken from the FRED database and they correspond respectively to the voices: "Gross Private Savings" and "Balance on the Current Account". Following Mountford and Uhlig (2009), I measure investments using "Private Non-Residential Investment". This is constructed from the NIPA tables subtracting "Private Residential Investments" - NIPA Table I.1, row 11 - from "Nominal Gross Private Domestic Investments" - NIPA Table I.1, row 6. As an indicator of consumers' confidence I follow Cimadomo et al. (2011) and Bachmann and Sims (2012) and use the "University of Michigan Consumers' Confidence Index". Stock prices are measured using the historical series of the S&P500, published by Robert Shiller[7]. Finally, to proxy the term premium I use the difference between the yields of the 10 year and the 5 year benchmark zero coupon bonds. The macroeconomic variables are converted to real terms using the GDP deflator and expressed in logs, while interest rates are expressed in percentage points. The confidence index and the S&P500 prices are simply expressed in logs.[8]

5 Results

The discussion of the results is divided into two sections. Section 5.1 presents the results of the linear specification, while Section 5.2 discusses the results coming from the non-linear estimations.

[7] http://www.econ.yale.edu/ shiller/data.htm

[8] For the cyclically adjusted deficit and the current account balance, because they have negative values, the adjustment to logs is done following Levy Yeyati, Panizza and Stein (2007). The adjusted variable is therefore defined as:

$$\widetilde{X}_t = sign(X_t)\log(1+|X_t|)$$

5.1 Linear VAR

The baseline model consists of estimating a linear VAR which contains: the structurally adjusted deficit, the 5 years ahead forecasts on public debt, output, consumption and the federal fund rate. The VAR is estimated in levels with a constant term and two lags of the endogenous variables, as suggested by the Schwarz and the Hannan and Quinn information criteria *(Table 1)*. The shape restrictions are imposed for 1 quarter for the structural deficit and for 1 quarter for expected debt. The business cycle shock is instead identified as a co-movement between output and consumption for 4 consecutive quarters. The choice of the timing of the restrictions is driven by the scope of the exercise: I want to isolate fiscal shocks with different future path, therefore I do not restrict the deficit to be positive for more than one quarter, and at the same time I constrain the path of expected future debt for the same period. This should allow me to capture both persistent fiscal shocks and fiscal shocks that die out within a couple of quarters.

The identification strategy indeed isolates two fiscal policy shocks with a very distinct time path (*Figure 1*): the temporary shock reverts back to zero after around 2 quarters, before becoming slightly negative - but not statistically so; the persistent shock instead declines more slowly reverting to zero only after about 16 quarters. For ease of comparison the impulse responses are normalized so that they both represent the responses to a unitary shock.

As embedded in the identifying restrictions, the path of the expected debt is a reflection of the profile of the fiscal shocks. When the fiscal policy shock is persistent, the response of the expected debt is hump shaped: it responds positively on impact and then it increases for about four quarters before converging back to zero. The shape of this response indicates that the presence of a budget deficit increases the stock of future debt up to the point where agents start expecting a fiscal stabilization. On the other hand when the fiscal shock is temporary, the response of expected future debt is mildly negative, showing that the fiscal expansion is expected to be short lived. Note, however, that the path of the expected future debt represents what agents expect about the future fiscal policy, and therefore a priori it needs not to be entirely consistent with the path of the fiscal shocks. However, the results show that in general agents' expectations are consistent with the actual behavior of the budget deficit.

More importantly, the responses of the real variables are markedly different across the two types of fiscal shocks *Figure 1*). While temporary shocks have a standard Keynesian effect, persistent shocks display negative output and consumption multipliers. This suggests that as long as fiscal sustainability is not put in jeopardy by an unsustainable increase in public debt, agents react by increasing consumption and output. If however, the fiscal expansion is accompanied by an excessive accumulation of debt, the negative wealth effect of the future tax burden induces agents to compress consumption and hence income. The accumulation of public debt can also increase agents' uncertainty about the timing of the fiscal consolidation. However, because the size of fiscal consolidations increases as these are postponed in the future, this uncertainty might induce households and firms to increase their precautionary savings. Increase in savings will therefore drag down consumption and output (Minsky 1986). The next section will show that indeed private savings react consistently with this hypothesis.

Negative output and consumption multipliers, however, can be possible only with a sufficiently large share of "Ricardian agents". If in fact credit market imperfections restricted consumption and investments to the disposable income and cash flow, agents would not optimize over their lifetime wealth and therefore would respond positively to any type of fiscal policy shock (Gali et al. 2007). However, as pointed out among others by Biilbie et al. (2008), financial innovation and financial market deepening are likely to have greatly reduced the incidence of credit constraints in the US over the last 20-30 years. Section 4.2 will show that indeed, during recessions as the share of credit constrained agents increases, the negative multipliers disappear.

The size of the multipliers is however relatively small. With an average deficit to GDP ratio of around 2% over the sample, an elasticity of 0.005 translates into a multiplier of about 0.25, which is very close to that obtained by Biilbie et al. (2008).

The reaction of the monetary authority (bottom panel of*Figure 1*) is consistent with a standard Taylor rule. The Central Bank, in fact, increases the interest rates when output and consumption increase and cuts them in the other case.

Because there is correlation between impulse responses for persistent and temporary shocks, only looking at the confidence bands yields a distorted impression about the statistical significance of their difference. Hence, to assess more formally the statistical difference of the impulse responses, I build a test using the impulse responses produced by the Monte Carlo simulation. For every iteration of the Monte Carlo algorithm I save the response of all the variables to a persistent and a temporary shock and compute their differences.[9] This provides us with an empirical distribution of the difference of the responses. We can then assess whether for each of the variables contained in the VAR those distributions contain the zero for given levels of confidence. The results are reported in *Figure (2)* with the two shaded areas representing the 84% and the 95% confidence intervals respectively. We can see that the differences in the response of consumption and output tend to be statistically significant. Interestingly, however, the differences are larger for the consumption than output. According to standard neoclassical models that is exactly where the differences are supposed to be. A fiscal expansion which affects the perception of households' lifetime income increases labor supply and compresses consumption while still having a positive effect on output. The negative response of output could be due to the presence of distortionary taxes which imply the presence of a Laffer curve in the economy. In this case, a persistent fiscal shock can generate accumulation of debt and expectations of a fiscal consolidation whose costs depend on the stock of accumulated debt. If taxes are distortionary this can generate a contraction in output. If this is the case, however, one would expect the negative effect of persistent fiscal shocks to be increasing in the stock of existing debt. Later in this section I will show that this is indeed the case.

Figure (3) and *Figure (4)* show the impulse response functions to the other identified shocks: the business cycle shock and the monetary policy shock. After a business cycle shock (*Figure 3*) consumption and output increase - as imposed by the restrictions - and this induces the monetary authority to increase interest rates to prevent an

[9]This is computed by saving all the bootstrapped impulse response functions for temporary and persistent shocks and computing: $IRF^j_{test} = IRF^j_{Temp} - IRF^j_{Pers}$ where j stands for the j^{th} replication of the bootstrap. Using the 200 bootstrap replication replications I construct the empirical distribution of IRF_{test} and report its 68% and 95% confidence interval.

overheating of the economy. Interestingly, also the cyclically adjusted budget deficit reacts sightly indicating that probably not all the cyclical components of the deficit are adequately taken care of by the CBO's adjustment. The expected future debt first increases slightly on impact and then fluctuates around zero indicating that, as suggested by Laubach (2009) the five years ahead forecasts of future debt are broadly neutral to business cycle fluctuations. The monetary policy shock (*Figure 4*) is associated to an increase in the federal fund rate which then creates a contraction in both consumption and output. The structurally adjusted deficit decreases slightly perhaps reflecting the fact that the cost of financing is now higher for the government and this translates into a slightly negative reaction of the expected debt.

The bottom left panel of *Figure (1)* has shown that the monetary reaction function tends to follow a "Taylor-type" rule with increases in interest rates that follow the increases in output and consumption and decreases otherwise. It is therefore interesting to check how much does this endogenous response of the interest rate contributes to the results. Following Bachmann and Sims (2012) I therefore construct a counterfactual experiment where I constrain the interest rate to be fixed at zero after the fiscal shocks. The results from this experiment show that the contribution of monetary policy is indeed very tiny *(Figure 5)*. In the case of temporary fiscal shocks if the monetary authority had not increased the interest rate the expansion in output and consumption would have been just slightly larger and more persistent. More interestingly, in the case of a persistent fiscal policy shock the cut in the interest rates does not manage to reduce the contraction in aggregate demand. This is an indication that indeed the contraction in aggregate demand has much to do with expectations of future tax burdens, which induces agents to increase precautionary savings. In this setting a cut in interest rates does not contribute to stimulating the demand and - if anything - further increases the desired stock of savings.

5.1.1 Robustness Checks

To validate these empirical results, the first issue to tackle is the possibility that the identified fiscal policy shocks are anticipated by economic agents. Because of the implementation lags typical of fiscal policy decisions, in fact, it is possible that agents anticipate with their actions the actual increase in the budget deficit, reacting to the fiscal policy shock when this is still discussed by the government. The literature on fiscal policy refers to this issue with the term of *"Fiscal Foresight"*. From an empirical point of view the presence of anticipation effects imply that the residuals of a standard VAR are not unanticipated shocks and mapping the reaction of variables to those residuals will give a biased view about the true effects of fiscal policy.

Leeper et al. (2008) show that when fiscal policy shocks are anticipated, it is impossible to recover structural shocks from the moving average representation of the VAR and the identified shocks will be a combination of anticipated and unanticipated innovations. In theory, however, this problem can be solved if the information set spanned by the variables included in the VAR contained also the "news" about future fiscal policy. Hence, I re-estimate the linear VAR including the one year ahead forecasts on budget deficit published by the CBO among the variables. As for the forecasts on future debt, also these data are released only semi-annually and therefore I had to interpolate the missing observation to obtain quarterly frequency.

The results from this specification are reported in *Figure (6)* and *Figure (7)*. The profiles of the fiscal shocks look very similar to the baseline case, and the responses of the other variables are qualitatively and quantitatively very similar. The path of the expected deficit (bottom left panel of *Figure 6*) reflects very closely the path of the actual deficit. When testing for the difference in the impulse response functions we can see that, as for the baseline case (*Figure 1*) the differences in the response of consumption are larger than those of the response of output.

Another possible problem in the estimation is the relatively short time period which could cause estimates to be inefficient due to the relatively small number of degrees of freedom. To assess whether this is indeed a problem I repeat the estimates of the baseline specification using Bayesian estimation. Because all the variables are expressed in levels I can use the standard Litterman prior and shrink the longer lags of the variables to zero. Following Doan and Litterman (1981) I set the value of the shrinkage parameter to 2 and I estimate the VAR with 6 lags. The results (*Figure 8* and *Figure 9*) indeed confirm those obtained with standard OLS estimation.

As a second set of robustness checks I re-estimate the baseline specification adding a set of control variables. To avoid running out of degrees of freedom, however, I include them one at the time following the approach in Ramey (2011). This exercise not only serves the purpose of validating the results, but allows us to investigate more closely the possible channels of transmission of the two fiscal shocks.

One way temporary and persistent fiscal shocks can affect the real economy is through their impact on precautionary savings. If agents are worried about the costs of future debt servicing, they will more likely respond with an increase in savings to persistent fiscal shocks given that these are accompanied by a consistent increase in the stock of public debt. This form of precautionary savings would contribute to the collapse in consumption and would make fiscal policy incapable of stimulating the economy (Kimball 1990; Deaton 1991; Carroll 1992, 1997). The results (*Figure 10*) show that indeed private savings increase in response to persistent fiscal expansions, while they do not respond when the shock is temporary. Although the direction of the response of private savings to temporary and persistent shocks is consistent with economic theory, their difference is statistically significant only at 68% (*Figure 11*). The response of the other variables is very similar to the previous specifications and the larger statistical difference between the responses of consumption then those of output is also confirmed. If the reaction in private savings is a consequence of the worsening of agents' expectations about the macroeconomic environment, then we should expect it to be reflected also in indicators of consumers' confidence. Following Bachmann and Sims (2012), I therefore repeat the estimation including the "University of Michigan consumers' sentiment index". As expected, the index increases slightly in response to temporary fiscal expansions and decreases markedly after the persistent ones (*Figure 12*). As for the response of savings, however, the difference between the response of consumers' confidence is significant only at the 68% confidence level (*Figure 13*).

The deterioration of agents' perceptions about the macroeconomic environment can also be reflected in the response of private non residential investments. When I add it as additional control (*Figure 14*), I find that indeed investments react negatively to persistent fiscal expansions and positively to temporary ones, but their difference is not statistically significant (*Figure 15*). This is driven by the fact that investments react very little to temporary fiscal expansions. In principle, if investments react to agents' confidence we would expect the response to temporary fiscal expansions to be positive and significant. This apparent contradiction can be explained if we allow the "confidence effect" to be counterbalanced by the presence of a distortion which operates in the opposite direction. Alesina et al. (2002) have shown that in presence of distortionary taxes on labor, fiscal shocks by increasing labor costs reduce profits and investments. It is therefore possible that after a temporary fiscal shock the increase in confidence and the decrease in profits offset each other, generating a response of investments which is only slightly positive on impact. If instead the fiscal expansion is persistent the reduction in profits and the reaction of confidence operate in the same direction, therefore generating a negative response of investments. To assess this claim I introduce as a control variable the Standard and Poor 500 stock prices. Insofar as stock prices are a good proxy for the present discounted value of future profits we would expect it to decline in response of both a temporary and a persistent fiscal policy shock. The results (*Figure 16* and *Figure 17*) show that indeed after both fiscal shocks stock prices decline by the same magnitude.

Because of the large accumulation of public debt, persistent fiscal shocks can be also accompanied by an increase in long-term interest rates. The increase in long-term interest rate, in turn, can contribute to the fall in investments and consumption, together with the worsening of consumers' confidence if it reflects larger risk premia. I therefore include in the VAR an indicator of term premium, computed as the the difference between the ten and the five years yield on government bonds. *Figure (18)* and *Figure (19)* show the results of this exercise. Indeed the term premium responds positively to persistent fiscal expansions, while becomes slightly negative on impact after a temporary shock. The difference between these two responses is significant at the 68% level for the first three quarters.

As a final check I analyze the response of the current account balance. Short-lived fiscal expansions generate a temporary current account deficit, while persistent fiscal policy shocks have no impact on the current account and these differences are strongly significantly different from zero (*Figure 20* and *Figure 21*). This is consistent with the idea that consumers want to smooth consumption over time. In presence of a fiscal expansion which is thought to be temporary, agents will not cut on consumption and therefore the budget deficit will have to be financed by borrowing from abroad.[10] On the other hand, if the fiscal policy shock is assumed to be persistent (or permanent), then the negative wealth effect will induce agents to increase savings and cut consumption therefore leaving the external balance unaffected.

The results so far give already a very neat picture of the effects of temporary and persistent fiscal policy shocks and they seem robust and internally consistent. Temporary fiscal shocks generate an increase in output, consumption and - to a certain extent - consumers' confidence and investments. The responses of precautionary savings and of the term premium are not statistically different from zero, and the response of stock prices is instead negative and significant. On the contrary, if the shock is persistent the response is slightly negative, with larger differences from

[10] Obstfeld and Rogoff 1995.

the case of temporary shocks for the response of consumption. The contraction in consumption is accompanied by an increase in precautionary savings, which can be caused by deterioration in agents' confidence. This "confidence effect" is reflected by the negative response of the "University of Michigan consumers' confidence index" and by the positive repsonse of the term premium of the yield curve. Stock prices also respond negatively possibly indicating both a collapse in confidence and a decrease in future profits.

Theoretically these results hinge on the presence of intertemporally optimizing agents who are able to smooth consumption over time and who react to the accumulation of a large stock of public debt and to the expectations of larger future taxes. The response of the current account balance is indeed proof that in the economy agents behave in a "Ricardian fashion". If this is true we would expect the effects of temporary and persistent shocks to be different both at different levels of public debt and at different stages of the business cycle. With high stocks of public debt, in fact, tax distortions associated with a persistent fiscal expansion are likely to become more important, therefore generating a stronger negative effect on output. On the other hand, during recessions the negative effects of persistent fiscal policy shocks are likely to disappear because binding credit constraints do not allow agents to optimize intertemporally. The next section assesses the empirical validity of these claims.

5.2 Non-linear Specifications

I now turn to the results from the non-linear specifications. As mentioned in Section 2.2 I analyze whether there exist differences in the propagation of temporary and persistent shocks depending on the level of public debt and on the state of the business cycle. To preserve degrees of freedom I re-estimate only the baseline specification (Section 4.1) and I identify the two types of shocks using exactly the same sign restrictions as before.

Figure (22) and *Figure (23)* report the results obtained from the VAR with the interaction term. With respect to the standard linear specification, we can see that when public debt is within the lower 25% of its distribution (corresponding to a debt to GDP ratio of 34%) temporary fiscal policy shocks have a slightly larger positive effects, while persistent fiscal shocks have smaller negative effects which - on top of that - are almost never statistically significant. On the other hand, when the level of public debt is included in the highest quartile of its distribution (corresponding to a debt to GDP ratio of 45%), persistent fiscal policy shocks have larger negative effects, while the effect of temporary fiscal shocks hardly changes. This evidence indicates that the accumulation of public debt associated with persistent fiscal policy expansions becomes a major cause of concern for private agents when public debt is above a given threshold. These results suggest that the level of public debt is indeed relevant for the presence of negative multipliers. The reason could be that, as hypothesized by previous literature (Blanchard 1990, Bertola and Drazen 1993 and Perotti 1999) the level of public debt increases disproportionately the costs of fiscal consolidation. Hence, a persistent fiscal expansion, because linked to an increase in the expected future debt burden, makes fiscal consolidation inevitable and very painful when the stock of debt is already relatively high. As we saw in the previous section, the drop in private consumption can potentially be explained by the increase in private savings or - although to a lesser extent - the decrease in consumers' confidence. These are all variables which we expect to respond to expectations of future a higher tax burden. As for the response of output, it is also very different for persistent fiscal shocks at low and high levels of debt. This can be explained by the presence of distortionary taxes, which generate a Laffer Curve in the economy. When the stabilization needed to bring the financial house in order is large (i.e. the stock of existing debt is large) and, on top of that, a persistent fiscal shock further increases the likelihood of a large stabilization, the associated distortions can decrease aggregate output. If this is the case we would expect the negative response of output to persistent fiscal shocks to disappear (or nearly disappear) when the stock of existing debt is small which is indeed what we see in *Figure (22)*.

Comparing the reactions of the monetary policy authority in the two cases (bottom left panel of *Figure 22* and *Figure 23*) is also instructive. If persistent fiscal policy shocks take place at low levels of public debt, the central bank lowers the federal fund rate for about three quarters to counterbalance the small contraction in output. If instead persistent fiscal policy shocks take place at high levels of public debt, the central bank lowers interest rates for a longer period of time. This accommodating behaviour, however, cannot be fully interpreted as an instance of "Fiscal Dominance" given that the cut of the interest rates seems to be relatively low compared with the large contraction in economic activity.

The ST-VAR framework is instead employed to investigate asymmetries over the business cycle. The transition function $F(z_t)$ (*Figure 24*) shows that the estimation method effectively captures recession episodes which correspond roughly to the NBER recession dates, and the estimates show that the transition from expansions recessions happens very fast. This evidence is consistent with what found by other studies (Auerbach and Gorodnichenko 2010). Given that the transition variable z_t has been standardized to take values between zero and one, a value of λ of 4.63 means that a one standard deviation shock to the transition variable translates into a 99% increases in the probability of switching regime within the same period.

The analysis of the impulse response functions points towards some important asymmetries in the propagation of temporary and persistent fiscal policy shocks in recessions and expansions. From comparing *Figure (25)* with *Figure (26)* we can notice that persistent fiscal expansions have a negative effect on output and consumption only when the economy is booming. During recessions, instead, the reaction of consumption and output to persistent fiscal expansions is basically zero. This can be explained by the fact that, during recessions, due to the higher incidence of credit constraints the fraction of agents that can respond with higher savings to a persistent fiscal policy shock decreases, therefore eliminating the negative fiscal multipliers. The opposite is true when the economy is in expansion. Temporary fiscal policy shocks, instead, have positive effects on output and consumption both in expansions and in recessions. In the latter case, however, the effect is about 10 to 20 times stronger with a multiplier of about 4, very similar to that calibrated by Christiano et al. (2009). The reaction of the federal fund rate shows that during expansions the central bank reacts to persistent fiscal policy shocks by tightening the monetary policy stance, while it is accommodating for transitory fiscal shocks. During periods of recessions, instead, it slightly lowers interest rates after persistent fiscal expansions, while considerably tightening them when fiscal policy shocks are short-lived. This result, although counter-intuitive, can be explained by the large expansionary effects of the fiscal shock.

5.3 Small vs. big shocks

As discussed in *Section 2*, an interesting exercise that the proposed identification scheme allows us to do is studying the effects of the size of the shocks. By using expectations to identify the two types of shocks, in fact, I already account for the "credibility" aspect of the fiscal expansion and therefore I am able to assess the effect of shocks' size alone. In some sense, requiring expectations to move in one direction or another is like focusing on the sub-set of persistent and temporary fiscal shocks whose nature is correctly anticipated by agents.

As for temporary shocks, we can see that the response of output is very similar irrespective of the size (top right panel of *Figure 28*), while the response of consumption is more persistent in the case of small shocks. Because for both cases the response of monetary policy is very similar, the reason of the difference must lie elsewhere. Again, the present discounted value of future tax liabilities can help us understand the asymmetry. Despite being temporary, if the shock is very large it can be that agents discount more heavily the larger future taxes, and this works against the expansionary effect. However, because the shock is still "temporary" in nature it does not cause the typical protracted build up of public debt which, in the case of persistent shocks, is responsible for the negative response of output. When the shocks are persistent, on the contrary, we can see that they appear to be more contractionary when they are relatively small. This might be the result of two forces: a "non-Keynesian" one, which tends to depress consumption and output and a "Keynesian" one which operates in the opposite direction. The boost coming from the size of the shock limits the contractionary effects, despite the fact that the monetary authority responds by slightly increasing the interest rate. On the contrary, when the shock is small, the consequences "non-Keynesian" channels strongly dominates therefore creating a larger contraction in consumption. Similarly, in presence of a less powerful "Keynesian" channel also the contraction of output will be larger (top right panel of *Figure 28*).

6 Concluding remarks

Since the onset of the "Great Recession", economists have been fiercely arguing on columns of blogs and in academic publications about the pros and cons of government intervention. Concerns about fiscal sustainability and about the possibility of "Ricardian" reactions of the private sector have led some to insist on a "short lived-if any" fiscal intervention. Others, instead, decisively support a more prolonged involvement of the Governments, arguing that standard Keynesian effects are likely to prevail over sustainability concerns: and the more so the larger the share of credit constrained agents or the larger slack in aggregate demand.

This paper contributes to this lively debate by introducing an empirical framework that allows to compare the real effects of temporary versus persistent fiscal expansions. I estimate a VAR using US data and, by means of sign restrictions, I identify two different fiscal policy shocks which differ by their temporal path. I show that fiscal expansions which are short-lived - and therefore not accompanied by large build-ups of public debt - generate positive effect on output, consumption and investments, while persistent deficit spending shocks are associated with slightly negative multipliers on private consumption and - to a lesser extent - on output. By employing a counterfactual analysis as in Bachman and Sims (2012) I show that these results are not related to the different reaction of the monetary policy authority. Consistently with the hypothesis that agents react to the higher burden of future taxes, persistent fiscal policy shocks are also associated with a significant increase in private savings, a decrease in consumers' confidence and an increase in the yield curve's term premium. On the other hand, after a temporary fiscal expansion private savings do not increase - and instead decrease slightly in the medium run - consumers' confidence increases and the term premium does not react. As conjectured by "*fiscal hawks*", the negative effects of persistent fiscal expansions increase with the level of public debt. Moreover, despite the fact that these negative multipliers disappear in periods of economic downturns, way larger "bang for the buck" is obtained by implementing temporary fiscal expansions. Finally, when analyzing the differences between positive and negative persistent and temporary shocks, I find that some mild asymmetry exists between the effects of large and small persistent shocks in that large persistent shocks seem to have a smaller contractionary effect on output, pointing towards the presence of two counteracting forces: a "non-Keynesian" force and a "Keynesian" force, with the former prevailing on the latter.

These results provide some guidelines for the design of a successful stimulus package. They suggest that persistent fiscal policy shocks, because they are accompanied by a large increase in expected future debt, fail to stimulate the economy. Temporary fiscal expansions, instead, have positive effects as they do not trigger any "Ricardian" reaction. These positive effects are particularly pronounced in times of recession, when the share of credit constrained agents increases.

It is however possible, as pointed out by De Grauwe (2009), that there are some "abnormal recessions" where the combination of private sector de-leveraging and deflationary spirals ensures that persistent fiscal policy shocks have large and long lasting real effects. The size of the multipliers of fiscal shocks in "balance sheet" recessions is an issue that I leave for future research.

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7 APPENDIX A

7.1 Estimation of the ST-VAR

The version of the ST-VAR presented in this paper closely follows that presented by Auerbach and Gorodnichenko (2010). The structural model can be described as:

$$\begin{aligned} Y_t &= (1 - F(z_{t-1}))\, A(L)\, Y_{t-1} + F(z_{t-1})\, B(L)\, Y_{t-1} + E_t \\ \Sigma_t &= (1 - F(z_{t-1}))\, \Sigma^E + F(z_{t-1})\, \Sigma^R \\ F(z_t) &= \frac{\exp(-\lambda z_t)}{1 + \exp(-\lambda z_t)} \end{aligned}$$

Although highly non-linear, it can easily be estimated by iterating a maximum likelihood estimation and weighted least squares. Let's first rewrite the VAR in compact notation, stacking the coefficients $A(L)$ and $B(L)$ into a matrix Γ,and let's call X_t the matrix that contains the regressors weighted by the transition function $F(z_{t-1})$:

$$X_t = \begin{bmatrix} (1 - F(z_{t-1}))\, Y_{t-1} \;\; (1 - F(z_{t-1}))\, Y_{t-2} ... (1 - F(z_{t-1}))\, Y_{t-p}; \\ F(z_{t-1})\, Y_{t-1} \;\; F(z_{t-1})\, Y_{t-2} ... F(z_{t-1})\, Y_{t-p} \end{bmatrix}$$

The VAR model can therefore be written in compact form as:

$$Y_t = X_t \Gamma + E_t$$

So that the log likelihood function of the regression model can be writen as:

$$\mathcal{L} = c - \frac{1}{2} \log(|\Sigma_t|) - \frac{1}{2} \sum_{t=1}^{T} (Y_t - X_t\Gamma)' \, \Sigma_t^{-1} (Y_t - X_t\Gamma)$$

which can then be rewritten in terms of trace:

$$\mathcal{L} = c - \frac{1}{2} \log(|\Sigma_t|) - \frac{1}{2} tr\left[(Y_t - X_t\Gamma)(Y_t - X_t\Gamma)' \, \Sigma_t^{-1}\right]$$

Now, because Σ_t is a function of $\{\Sigma^E, \Sigma^R, \lambda\}$, we can rewrite the likelihood making this demendence explicit:

$$\mathcal{L} = c - \frac{1}{2} \log\left(\left|\Sigma\left(\Sigma^E, \Sigma^R, \lambda\right)_t\right|\right) - \frac{1}{2} tr\left[(Y_t - X_t\Gamma)(Y_t - X_t\Gamma)' \, \Sigma\left(\Sigma^E, \Sigma^R, \lambda\right)_t^{-1}\right] \tag{6}$$

Conditional on estimates of Γ, the likelihood can be maximized for $\{\Sigma^E, \Sigma^R, \lambda\}$, given some starting values $\{\Sigma^{E(0)}, \Sigma^{R(0)}, \lambda^{(0)}\}$.

Once we have the ML estimates $\left\{\widehat{\Sigma}^E, \widehat{\Sigma}^R, \widehat{\lambda}\right\}_{ML}$, the parameters in of the VAR can be efficientily estimated by weighted least squares with the weight given by $\widehat{\Sigma}_t = \left(1 - F\left(z_{t-1}, \widehat{\lambda}\right)\right) \widehat{\Sigma}^E + F\left(z_{t-1}, \widehat{\lambda}\right) \widehat{\Sigma}^R$. The GLS estimation of the parameters Γ is given by:

$$vec\left(\widehat{\Gamma}\right) = \left[\sum_{t=1}^{T}\left(\widehat{\Sigma}_t^{-1} \otimes X_t^{'}X_t\right)\right]^{-1} vec\left(\sum_{t=1}^{T} X_t^{'}Y_t\widehat{\Sigma}_t^{-1}\right) \tag{7}$$

Then the maximization can iterate between (6) and (7) until the likelihood converges. I adopted a stopping criterion for the likelihood function defined as:

$$\frac{\left|\mathcal{L}^{(j)} - \mathcal{L}^{(j-1)}\right|}{\overline{\mathcal{L}^{(j,\, j-1)}}} < 1e-4$$

where $\mathcal{L}^{(j)}$ is the log likelihood function at iteration (j) and $\overline{\mathcal{L}^{(j,\, j-1)}} = \frac{\left|\mathcal{L}^{(j)}+\mathcal{L}^{(j-1)}\right|}{2}$. The stopping criterion is from "Numerical Recipes" (2007), p. 423.

7.2 Counterfactual analysis - Bachmann and Sims (2012)

In this section I explain in more details the construction of a counterfactual experiment. The analysis is very general and serves the purpose of answering the following question: *"What would happen to the response of variable y after a shock to variable x if variable k did not react to the shock at any lags?"*. Hence scope of the exercise is to derive a "counterfactual" response function.

Following Bachman and Sims (2012) I obtain the counterfactual impulse response by creating a series of *"fictional shocks"* ${\varepsilon^k}_{h=1}^H$ which, if added to the response of variable k to a shock to variable x, make it equal to zero for all the H periods.

To see how this can be implemented in practice, let's consider the case of a trivariate VAR in which the structure of the contemporaneous correlation of the reduced form shocks is given by matrix B_0 and the elements ε_t are the structural shocks:

$$\begin{bmatrix} x_t \\ k_t \\ z_t \end{bmatrix} = \begin{bmatrix} a_{11}(L) & a_{12}(L) & a_{13}(L) \\ a_{21}(L) & a_{22}(L) & a_{23}(L) \\ a_{31}(L) & a_{32}(L) & a_{33}(L) \end{bmatrix} \begin{bmatrix} x_t \\ k_t \\ z_t \end{bmatrix} + \underbrace{\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}}_{B_0} \begin{bmatrix} \varepsilon_t^X \\ \varepsilon_t^K \\ \varepsilon_t^Z \end{bmatrix}$$

Let's denote the impulse response of variable i to shock q at horizon h: $\Phi_{i,q,h}$. Hence, if for our counterfactual example we want variable k not to respond to shocks to variable x, we have to compute a series of "fictional shocks" that satisfy the following set of restrictions: $\Phi_{k,x,h} = 0$, $\forall h = 1, ..., H$. Without loss of generality, suppose that the shock takes place at time $t = 1$. The restriction for the firstperiod is then satisfied if ε_1^K is such that:

$$\widetilde{\Phi}_{k,x,1} \equiv \Phi_{k,x,1} + \Phi_{k,k,1}\varepsilon_1^K = 0$$

which, in the case of the trivariate VAR above takes the form:

$$\widetilde{\Phi}_{k,x,1} \equiv b_{21} + b_{22}\varepsilon_1^K = 0$$

which, in turn, implies:

$$\varepsilon_1^K = -\frac{b_{12}}{b_{22}}$$

In the following period, the same restriction is required to hold, but there will be another effect to be considered: the one coming from the shock ε_1^K which will impact the variable k with a coefficient of $\Phi_{k,k,2}$. The restriction therefore will take the form:

$$\widetilde{\Phi}_{k,x,2} \equiv \Phi_{k,x,2} + \Phi_{k,k,2}\varepsilon_1^K + \Phi_{k,k,1}\varepsilon_2^K = 0$$

which implies that the shock at time $t = 2$ can computed recursively as:

$$\varepsilon_2^K = -\frac{\Phi_{k,x,2} + \Phi_{k,k,2}\varepsilon_1^K}{b_{22}}$$

For a generic horizon $h \in \{2, ..., H\}$ the expression for the fictitious shocks is:

$$\varepsilon_h^K = -\frac{\Phi_{k,x,h} + \sum_{j=1}^{h-1}\Phi_{k,k,h-j+1}\varepsilon_j^K}{b_{22}}$$

After having computed the complete series of the shocks, we can then retrieve the counterfactual impulse response building on the fact that, by construction, the shocks constrain the response of variable k to a shock to variable x to be zero. Hence the counterfactual impulse response will be given by:

$$\widetilde{\Phi}_{i,x,h} = \Phi_{i,x,h} + \sum_{j=1}^{h}\Phi_{i,x,h-j+1}\varepsilon_j^K$$

7.3 Derivation of the Constrained Fiscal Reaction Function

In this section I explain in greater details how to estimate the impulse response functions of small and large persistent and temporary fiscal shocks. As discussed in *Section 3.2.3*, the estimation proceeds in steps. First, I estimate the structural persistent and temporary shocks from a fiscal reaction function with some restrictions on the parameters. Second, the structural shocks are used as exogenous variables in a VAR which contains the same variables as the baseline specification except for the first variable - the structural budget deficit - which has been used to estimate the fiscal reaction function.

Let's first see how a VAR where the shocks are allowed to have different effects depending on their size would differ from a standard linear VAR. In the linear case a general vector Y_t under stationarity always allows a $MA(\infty)$

representation: $Y_t = A(L)e_t$. The filter $A(L)$ can be estimated by inverting the $MA(\infty)$ representation and casting it in VAR(p)[11]: $A(L)^{-1}Y_t = e_t$. e_t are the reduced form shocks. Structural inference can be done by mapping the structural shocks ε_t into the endogenous variables contained in Y_t. This is obtained by imposing a set of restrictions which then yield: $A(L)^{-1}Y_t = e_t = B^*\varepsilon_t$, with $E(\varepsilon_t\varepsilon_t') = I$. The impulse response functions of the structural shocks are then obtained from: $Y_t = A(L)B^*\varepsilon_t$.

If instead the data generating process is such that large (L) and small (S) shocks have a different effect on the endogenous variables in Y_t, the $MA(\infty)$ representation is such that:

$$Y_t = C(L)\varepsilon_t^L + D(L)\varepsilon_t^S$$

While the coefficients on the $MA(\infty)$ representation of a standard structural VAR can be estimated inverting the process, in this case it is not possible. The model could in theory be estimated from:

$$Y_t = F(L)Y_t + G\varepsilon_t^L + H\varepsilon_t^S + \nu_t \tag{8}$$

with the structural shocks included as additional regressors. In our case, because we want to identify the effects of both temporary and persistent fiscal shocks, we will have to retrieve four series of shocks and estimate two equations like (8): one for the temporary and one for the persistent fiscal shocks. Because the ε_t are structural fiscal shocks, they can in principle be estimated as residuals from a fiscal reaction function.

Given that in its structural form, the first equation of our baseline VAR[12] expresses the structurally adjusted deficit in terms of its own lags and contemporaneous values and lags of macroeconomic variables, I consider it a fiscal reaction fucntion. That equation is:

$$D_t = \sum_{s=1}^{p} \rho_s D_{t-s} + \sum_{j=1}^{N-1}\sum_{s=0}^{p} b_{js}X_{j,t-s} + \varepsilon_t \tag{9}$$

where the variable D_t is the structurally adjusted deficit and the X_{jt} are the other $N-1$ variables of the VAR. Consistent estimates of the parameters in (9) can be obtained by standard OLS. Unfortunately the estimated residuals from equation (9) are not useful to our analysis, as they are neither "temporary" nor "persistent". Temporary and persistent structural fiscal shocks will be shocks estimated from (9) which respect the identifying restrictions imposed in the original VAR of *Section 3.1*. Because a shock is classified as "temporary" or "persistent" depending on how fast the response of the deficit D_t reverts back to zero after a fiscal shock, I can calibrate two sets of parameters ρ_s - $\{\rho_s^T\}_{s=1}^p$ and $\{\rho_s^P\}_{s=1}^p$ - in (9) so that the path of D_t after an innovation in ε_t mirrors the blue and the red lines reported in the top left panel of *Figure (1)*.

Let's call γ_h the coefficients of the impulse response functions in the top left panel of *Figure (1)*. Given that we

[11] with p finite
[12] See *Section 3.1*

have two structural fiscal shocks - persistent and temporary - I denote them as:

$$\begin{aligned}\frac{\partial D_{t+h}}{\partial \varepsilon_t^P} &= \gamma_h^P \\ \frac{\partial D_{t+h}}{\partial \varepsilon_t^T} &= \gamma_h^T\end{aligned}$$

where the superscripts P and T stand for *"temporary"* and *"persistent"*. The values of γ_h are known, hence all we need is to map their values into the coefficients $\{\rho_s^T\}_{s=1}^p$ and $\{\rho_s^P\}_{s=1}^p$ of the reaction function (9). To understand how to do this let's first rewrite the reaction function (9) in companion form:

$$\mathcal{D}_t = R\mathcal{D}_{t-1} + B(L)X_t + \mathcal{E}_t \tag{10}$$

In the case of $p = 2$ the matrix R is simply given by:

$$R = \begin{bmatrix} \rho_1 & \rho_2 \\ 1 & 0 \end{bmatrix}$$

and the vactor $\mathcal{E}_t$ is:

$$\mathcal{E}_t = \begin{bmatrix} \varepsilon_t \\ 0 \end{bmatrix}$$

The equation (10) can be easily be inverted to find the impulse response function for a fiscal policy shock:

$$\mathcal{D}_t = [I - R(L)]^{-1} \mathcal{E}_t$$

which can be computed as:

$$\frac{\partial D_{t+h}}{\partial u_t} = JR^h J'$$

where the matrix J[13] allows us to isolate the top left element of the matrix R^h. It is easy to see that for the first two periods the impulse response to the deficit shock is equal to:

$$\begin{aligned}\frac{\partial D_{t+1}}{\partial \varepsilon_t} &= \rho_1 \\ \frac{\partial D_{t+2}}{\partial \varepsilon_t} &= \rho_1^2 + \rho_2\end{aligned}$$

Hence, for the case of $p = 2$, we can equate the impulse responses found by estimating the VAR with those implied by the fiscal reaction function and we have a system in two equations two unknowns which pins down the value of

[13]For a VAR(p) with N variables the matrix J is defined as: $J = [I_N | 0_{N*N(p-1)}]$

the parameters ρ_1 and ρ_2:

$$\begin{cases} \rho_1 = \gamma_1 \\ \rho_1^2 + \rho_2 = \gamma_2 \end{cases}$$

Therefore, by using the values of the parameters $\{\gamma_1^T, \gamma_2^T\}$ and $\{\gamma_1^P, \gamma_2^P\}$, I can compute $\{\rho_1^T, \rho_2^T\}$ and $\{\rho_1^P, \rho_2^P\}$ and then use them to estimate two restricted reaction functions, one whose residuals are the "persistent" fiscal shocks and another one whose residual are the "temporary" fiscal shocks. *Figure (27)* shows that indeed the responses of the cyclically adjusted deficit to these estimated shocks are very similar to those obtained from the estimated VAR (top left panel of *Figure 1*).

I can then split the two estimated series of persistent and temporary fiscal shocks $\widehat{\varepsilon_t}^P$ and $\widehat{\varepsilon_t}^T$ into two more categories depending on whether they are *larger or smaller than twice their sample standard deviation.* Let's call these shocks: $\left\{\widehat{\varepsilon_t}^{LP}, \widehat{\varepsilon_t}^{SP}, \widehat{\varepsilon_t}^{LT}, \widehat{\varepsilon_t}^{ST}\right\}_{t=1}^{T}$. Using these shocks I can then estimate a VAR with the other $N-1$ variables:[14]

$$X_t = F(L)X_t + G_1\widehat{\varepsilon_t}^{LP} + H_1\widehat{\varepsilon_t}^{SP} + G_2\widehat{\varepsilon_t}^{LT} + H_2\widehat{\varepsilon_t}^{ST} + u_t \tag{11}$$

and compute impulse response functions as: $[I - F(L)]^{-1}G_1$, $[I - F(L)]^{-1}H_1$, $[I - F(L)]^{-1}G_2$ and $[I - F(L)]^{-1}H_2$.

[14]Remember from *Section 3.1* the other $N-1$ variables in the VAR are: expected debt, output, consumption and the federal fund rate.

8 APPENDIX B - Tables

Table 1: **Lag Selection**

Lag	LR	AIC	SC	HQ
0	NA	-0.820825	-0.688939	-0.76748
1	1280.537	-14.22951	-13.43819	-13.90943
2	111.0955	-14.99626	**-13.54551***	**-14.40946***
3	52.54637	-15.12687	-13.01669	-14.27334
4	26.93522	-14.96647	-12.19686	-13.84622
5	54.15123	-15.20837	-11.77933	-13.82139
6	38.41337	-15.2715	-11.18303	-13.61779
7	26.72927	-15.19241	-10.44451	-13.27198
8	40.97493	-15.40106	-9.993734	-13.21391
9	25.93799	-15.38967	-9.322907	-12.93579
10	**44.80562***	**-15.83277***	-9.106583	-13.11217

$*$ indicates lag order selected by the criterion at 5% level
LR: sequential modified LR test statistic; AIC: Akaike information criterion;
SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

9 APPENDIX C - Linear VAR

Figure 1: **Temporary and Persistent Fiscal Shocks - Baseline**

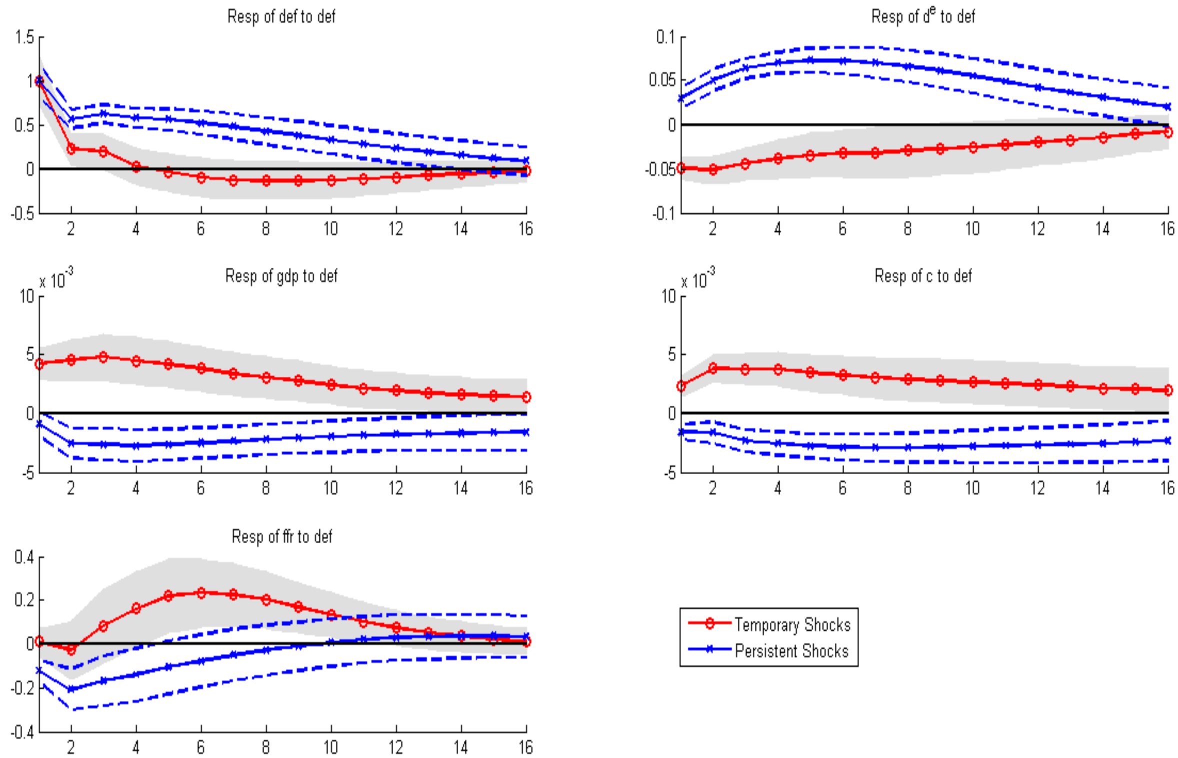


Figure 2: **Test - Baseline**

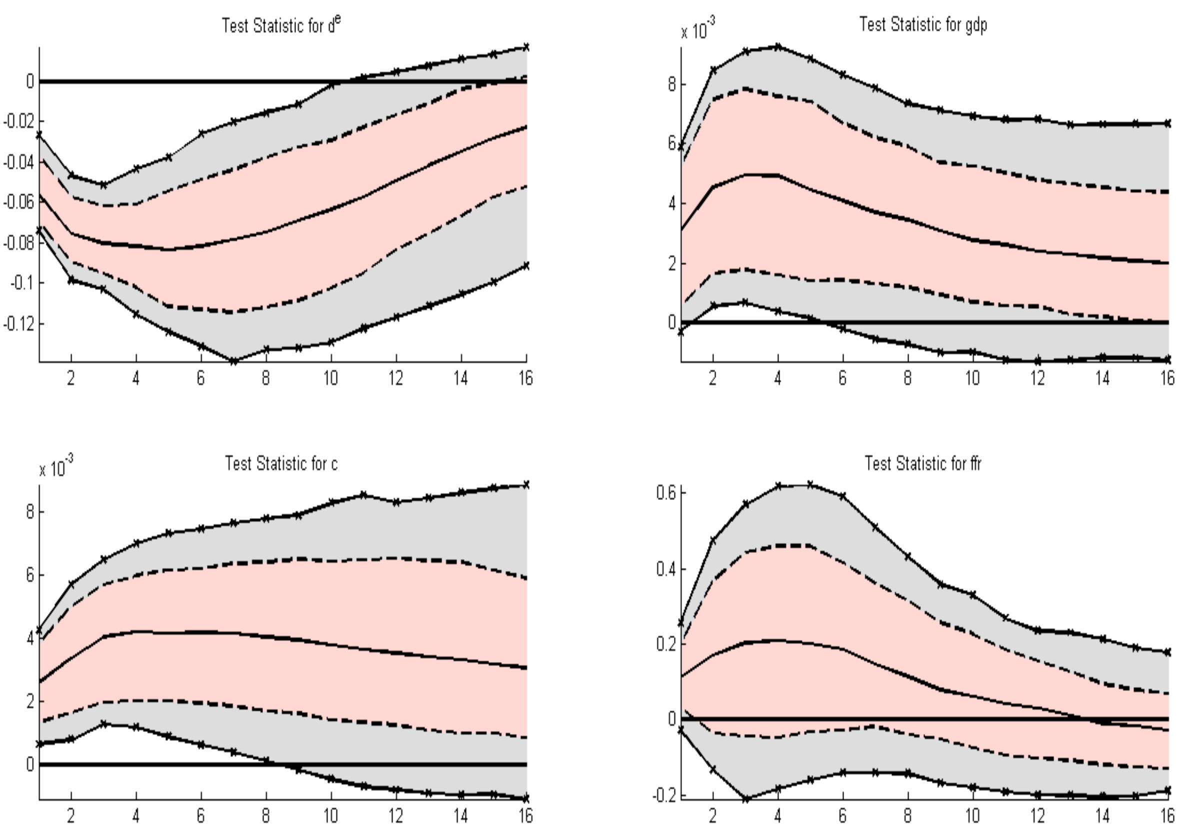


Figure 3: **Business Cycle Shock - Baseline**

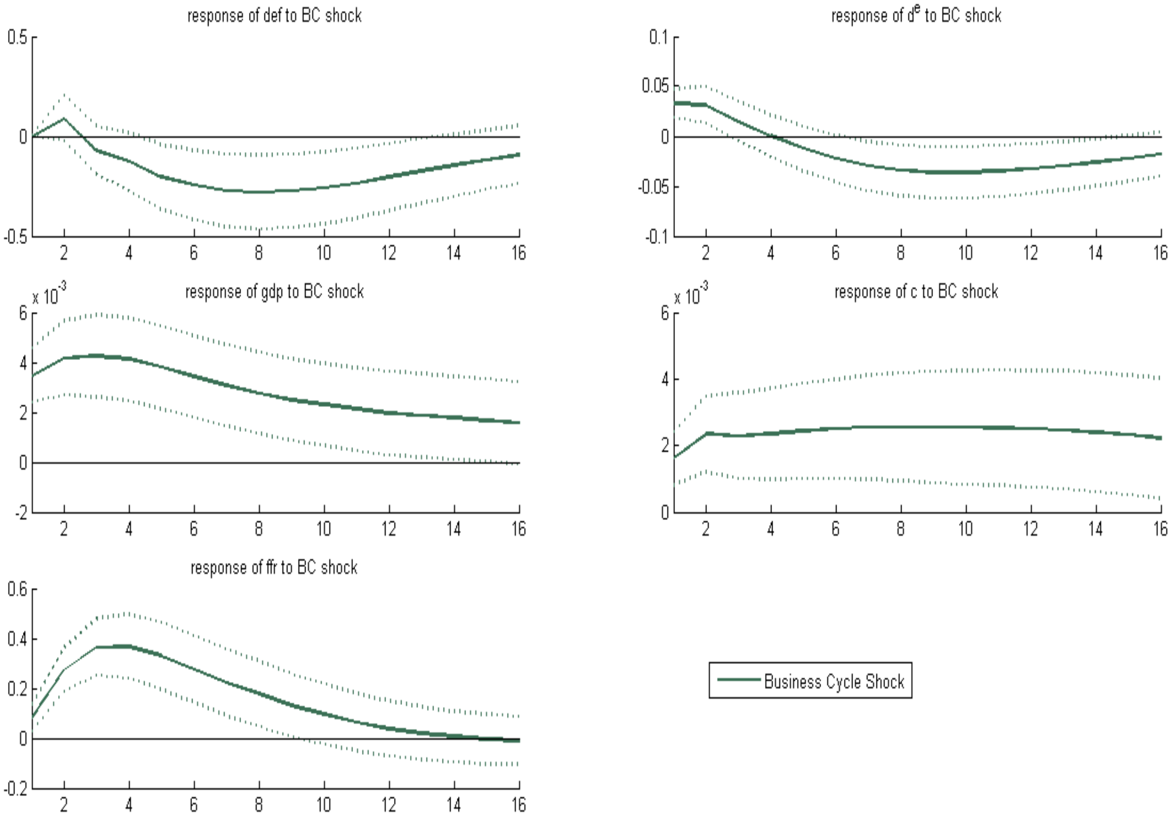


Figure 4: **Monetary Policy Shock - Baseline**

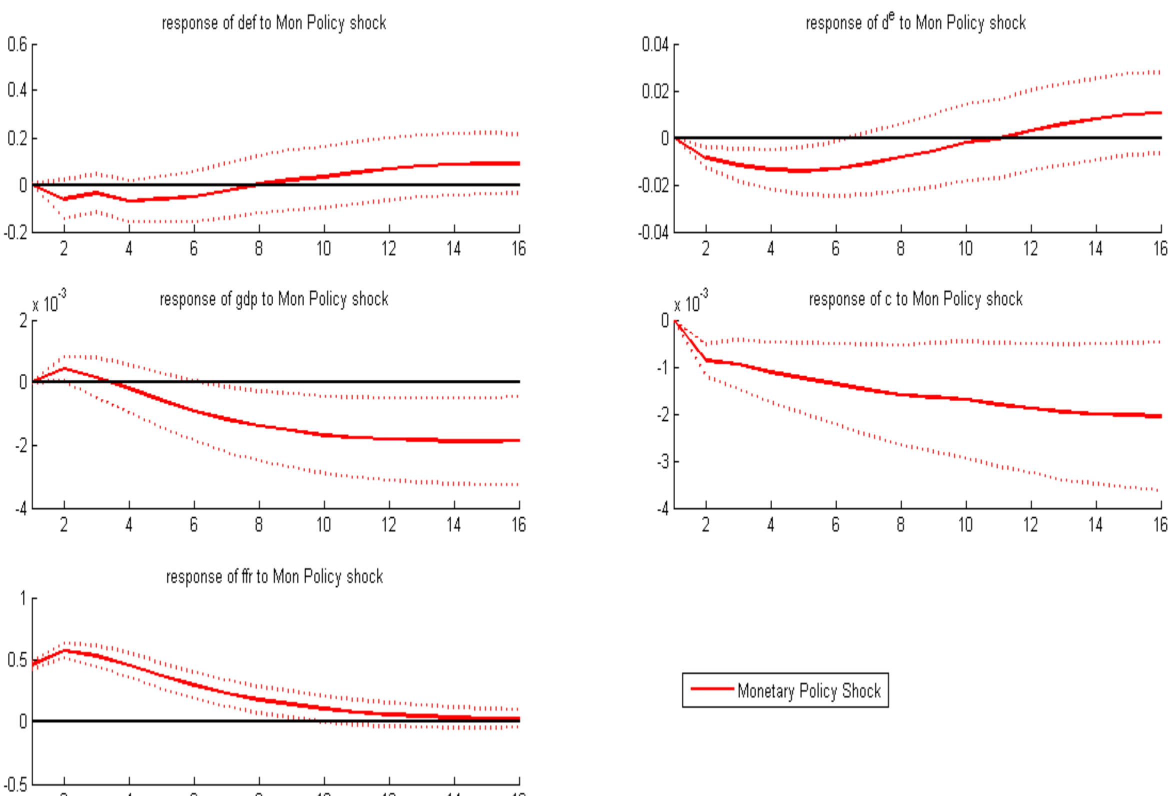


Figure 5: **Counterfactual Experiment - Baseline**

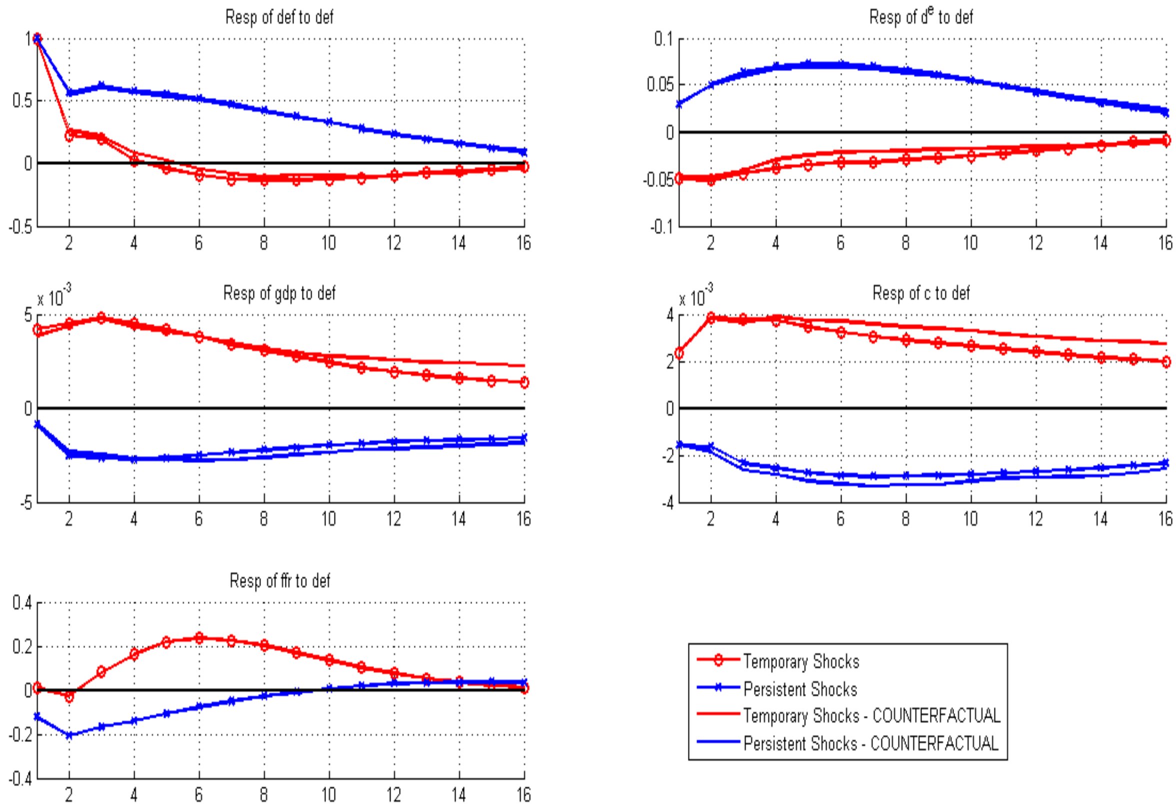


Figure 6: **Temporary and Persistent Fiscal Shocks - Expected Deficit**

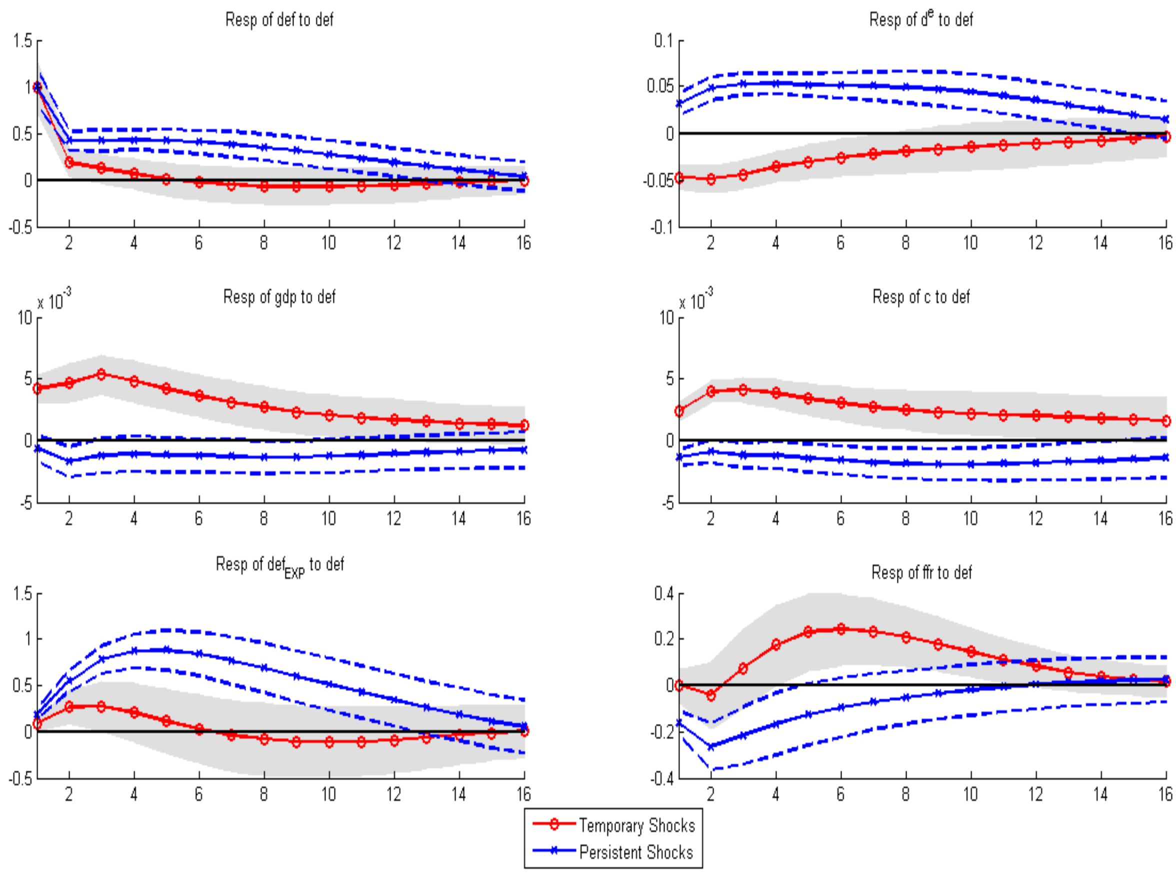


Figure 7: **Expected Deficit - Test**

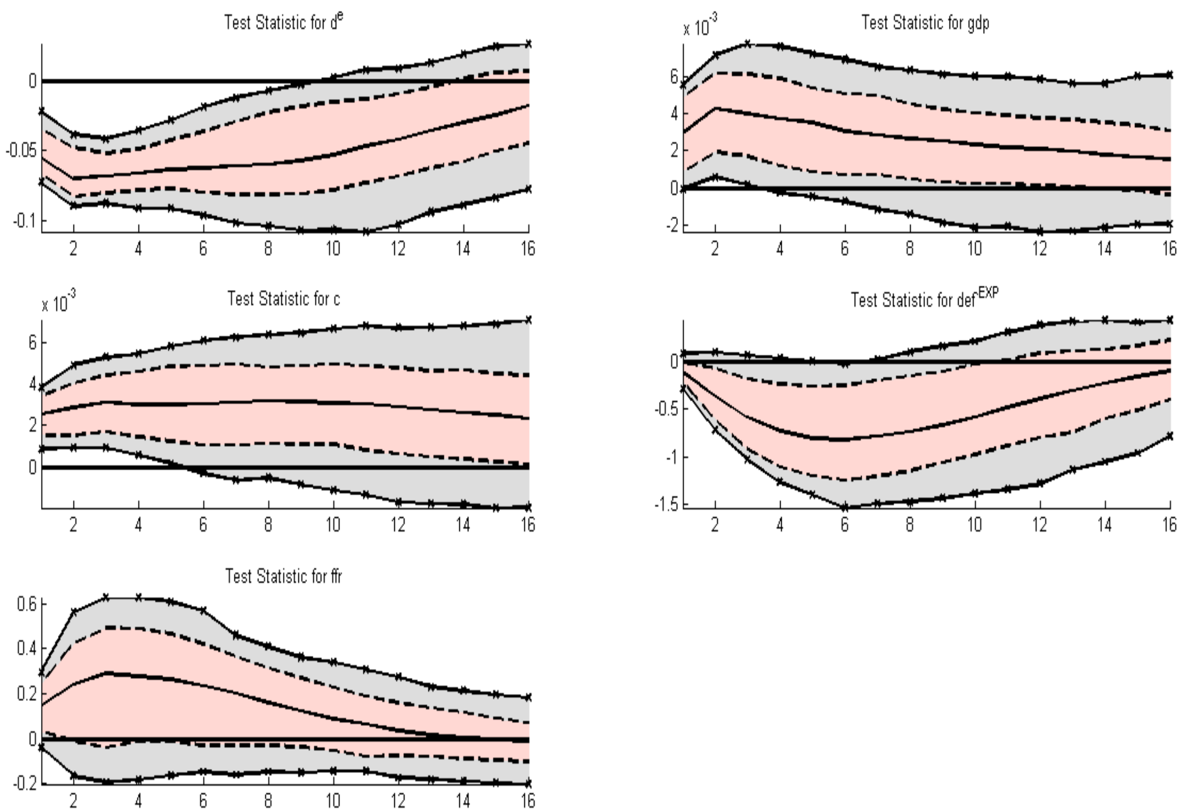


Figure 8: **Temporary and Persistent Fiscal Shocks - Bayesian**

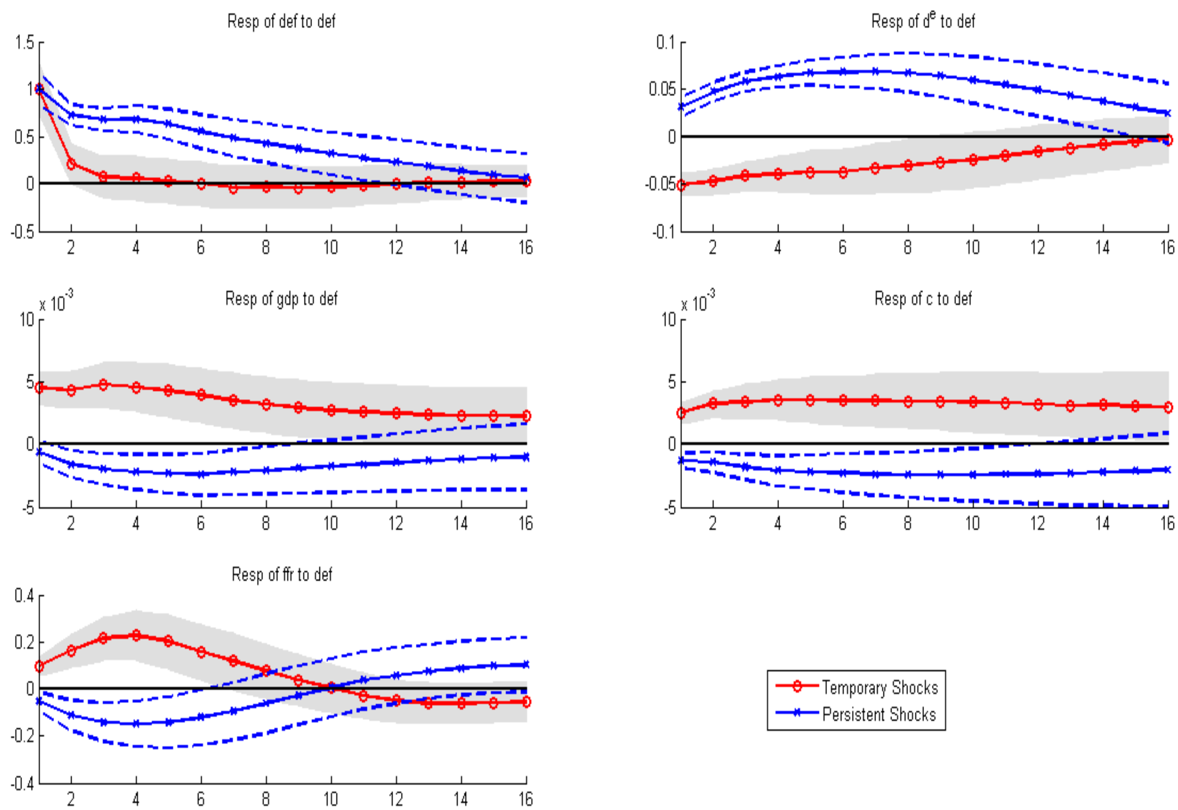


Figure 9: **Bayesian - Test**

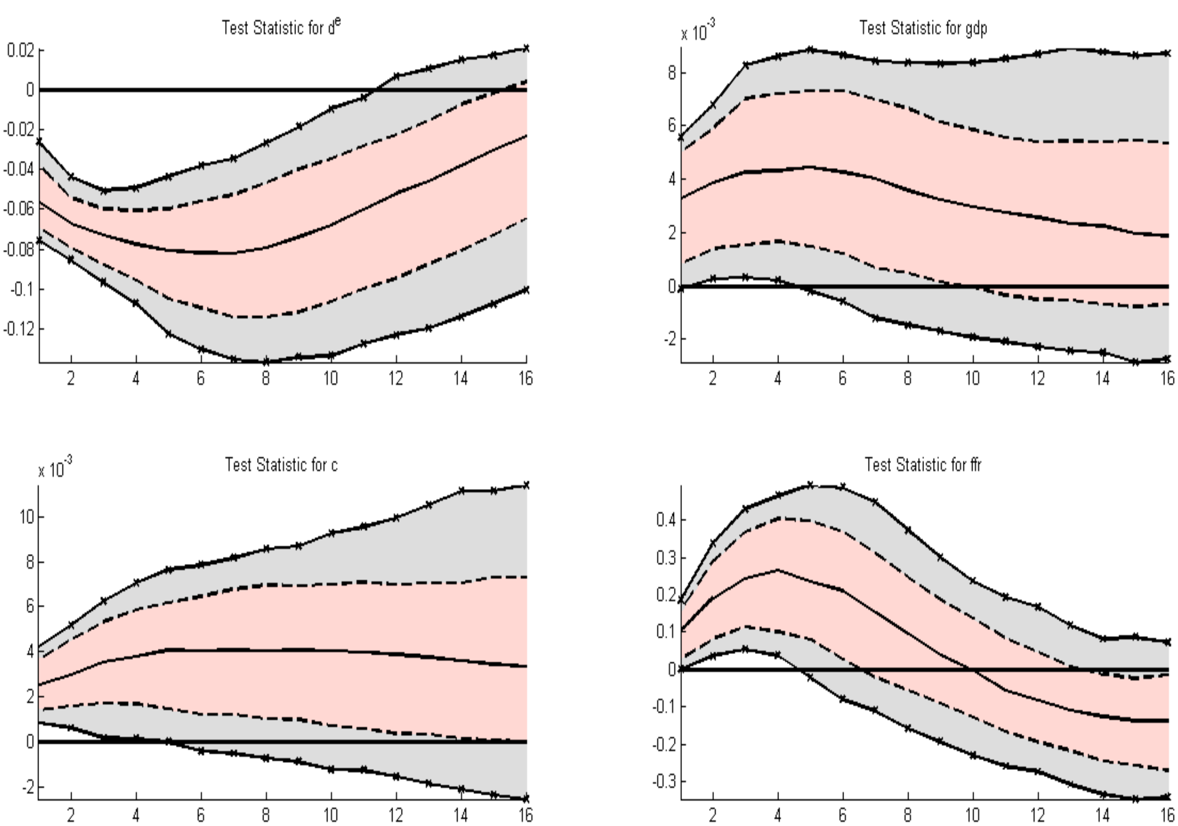


Figure 10: **Temporary and Persistent Fiscal Shocks - Savings**

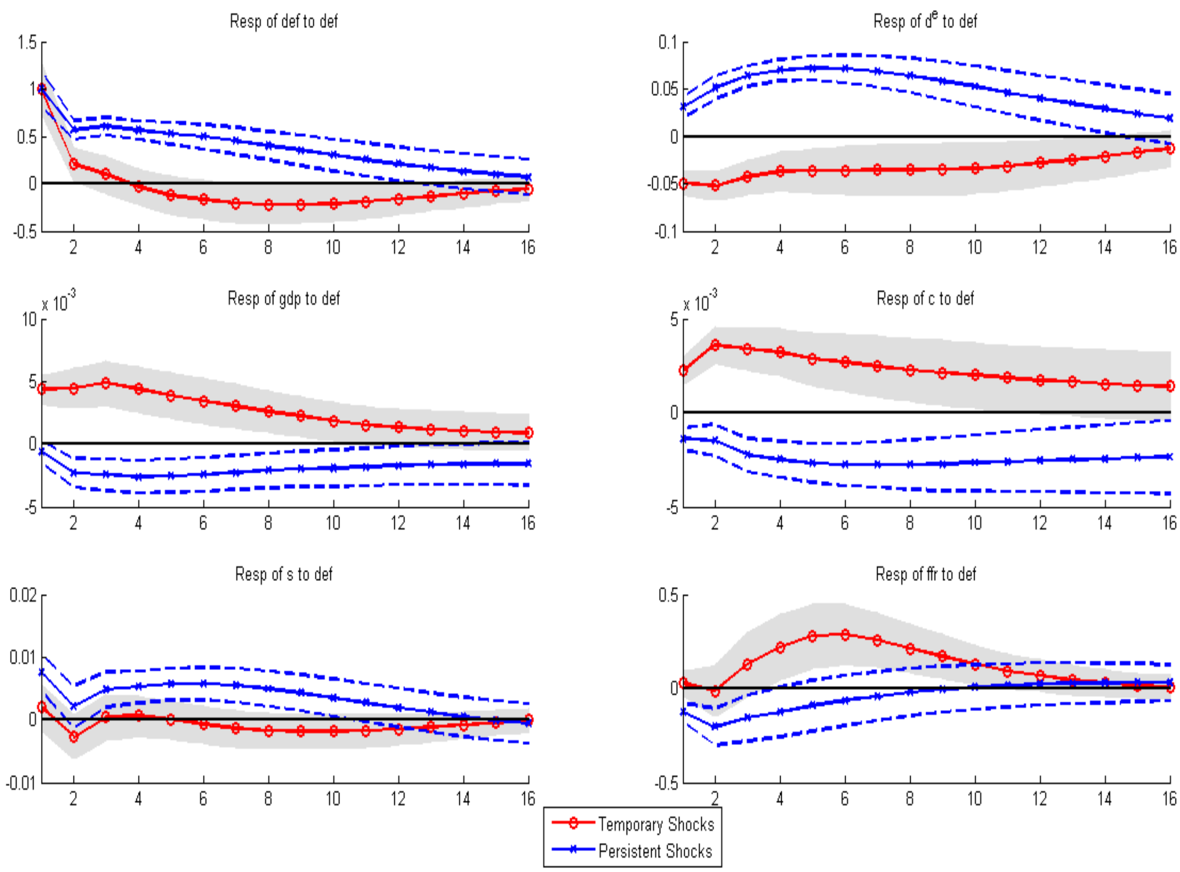


Figure 11: **Savings - Test**

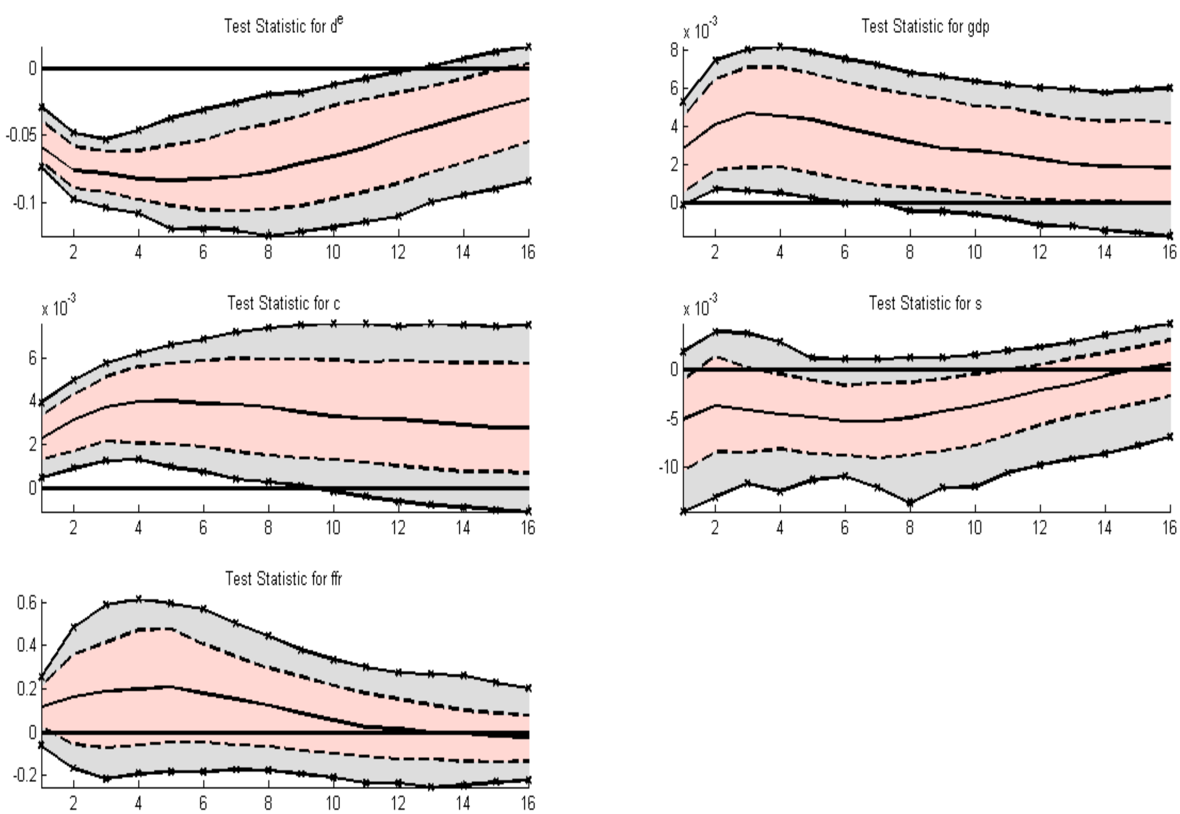


Figure 12: **Temporary and Persistent Fiscal Shocks - Confidence**

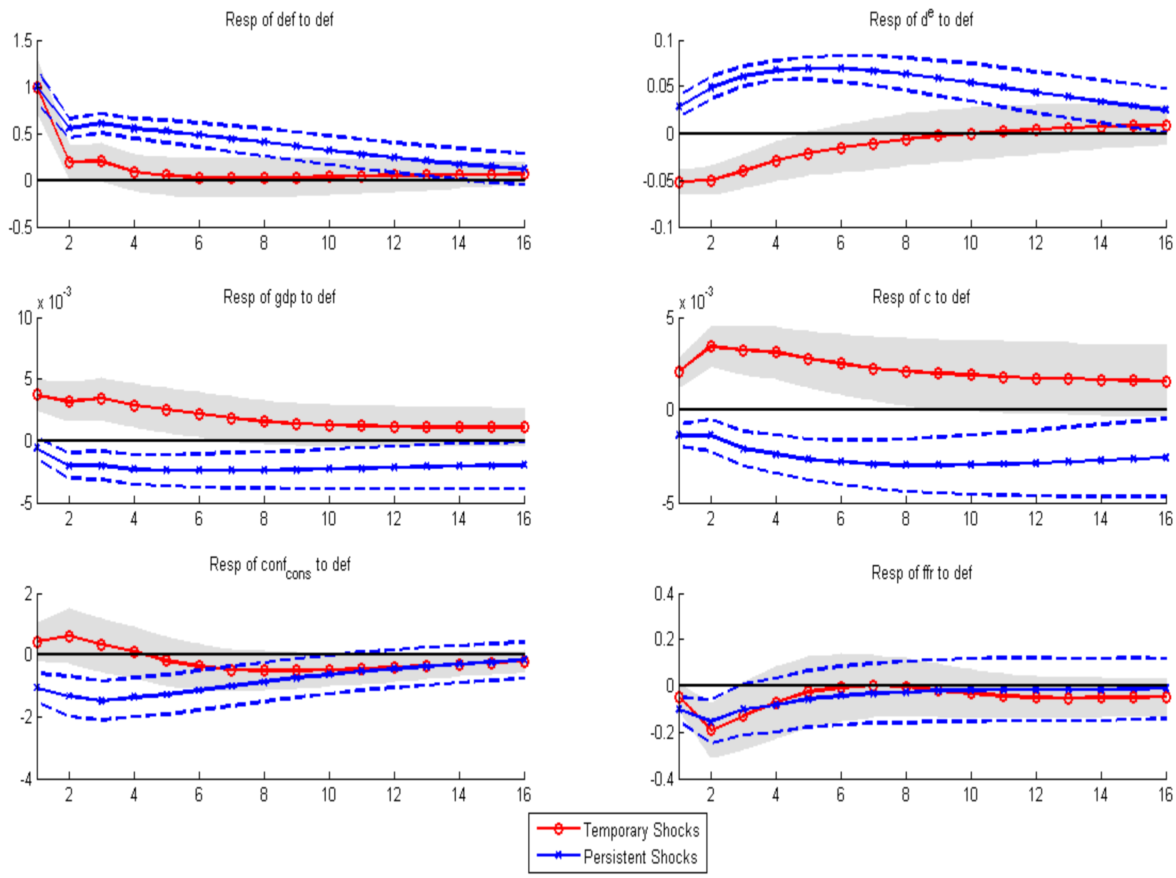


Figure 13: **Confidence - Test**

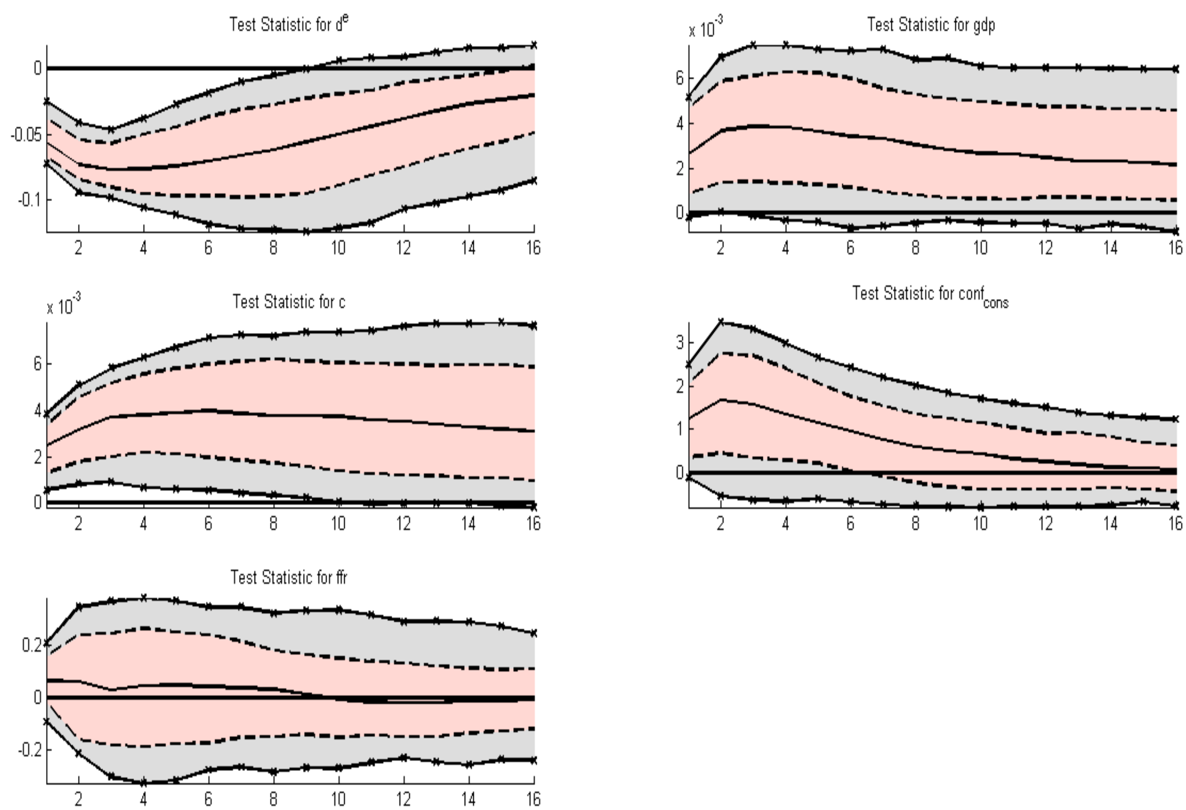


Figure 14: **Temporary and Persistent Fiscal Shocks - Investments**

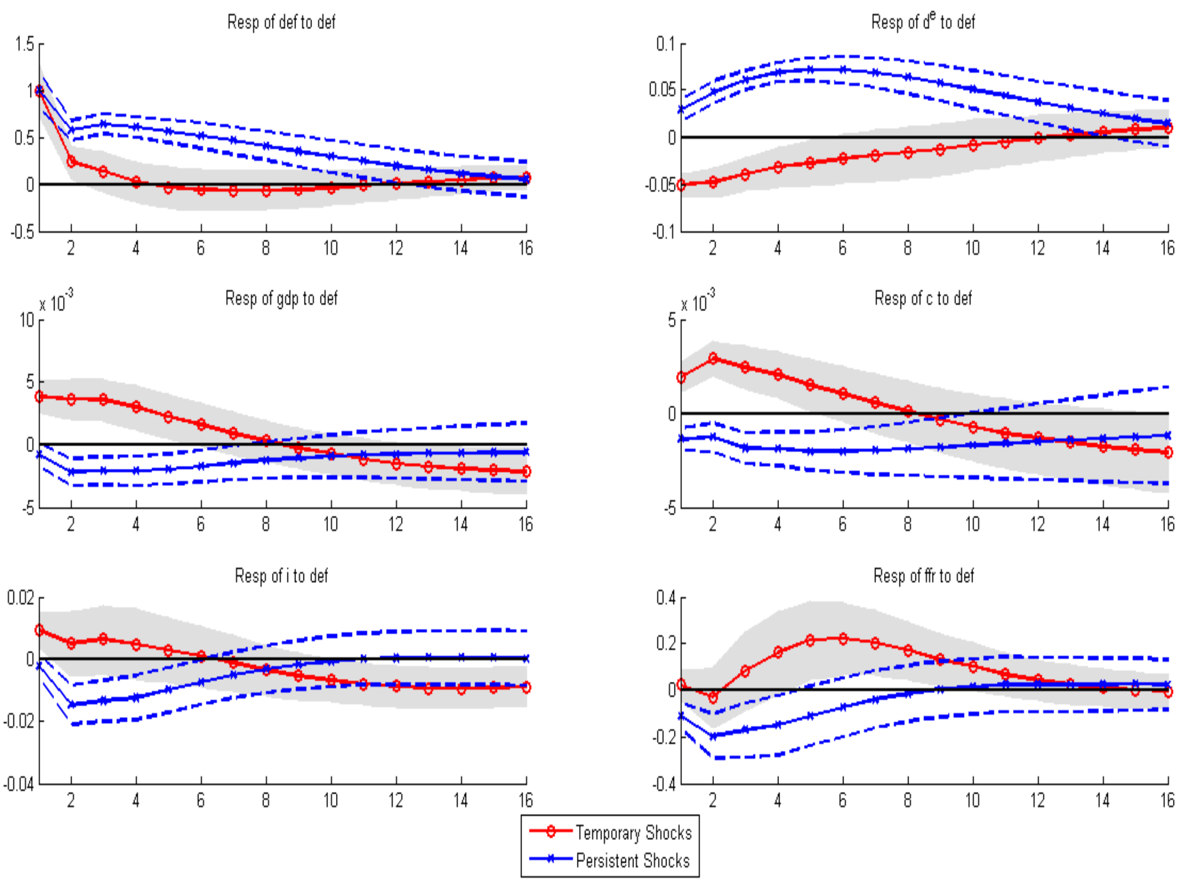


Figure 15: **Investments - Test**

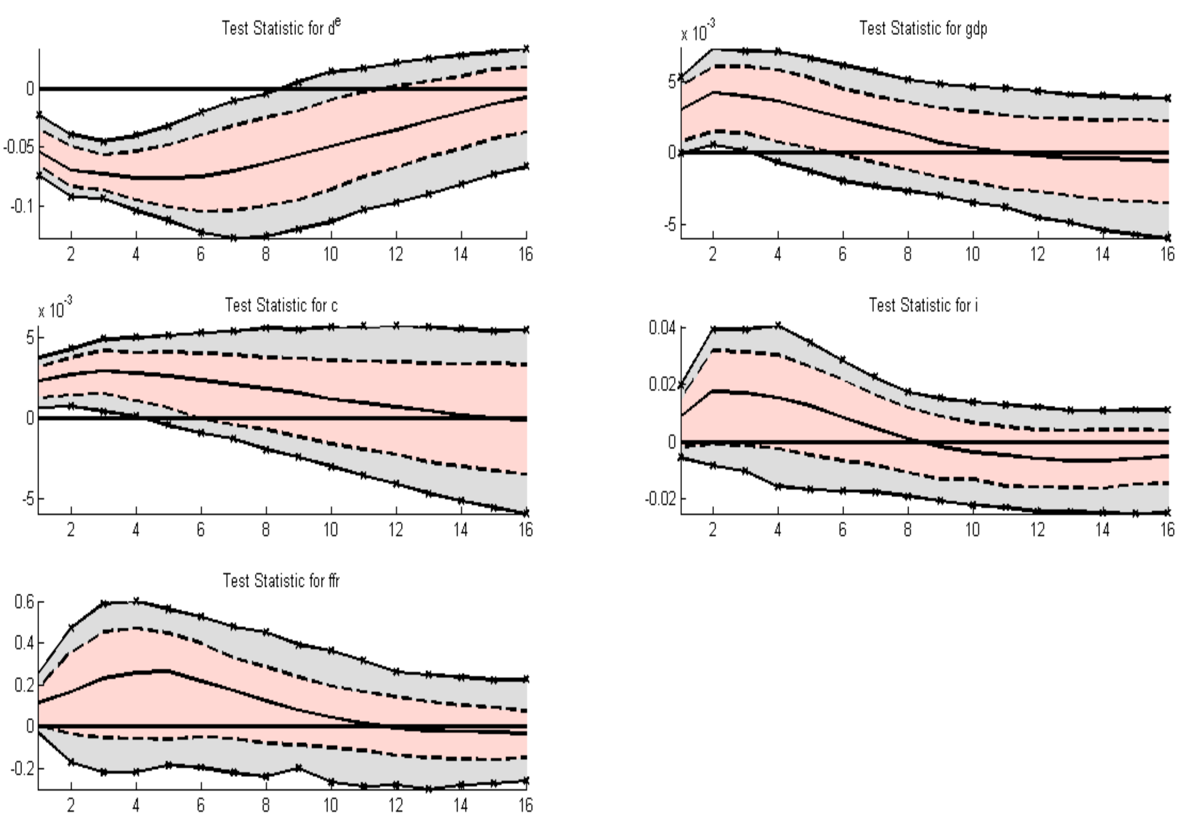


Figure 16: **Temporary and Persistent Fiscal Shocks - Stocks**

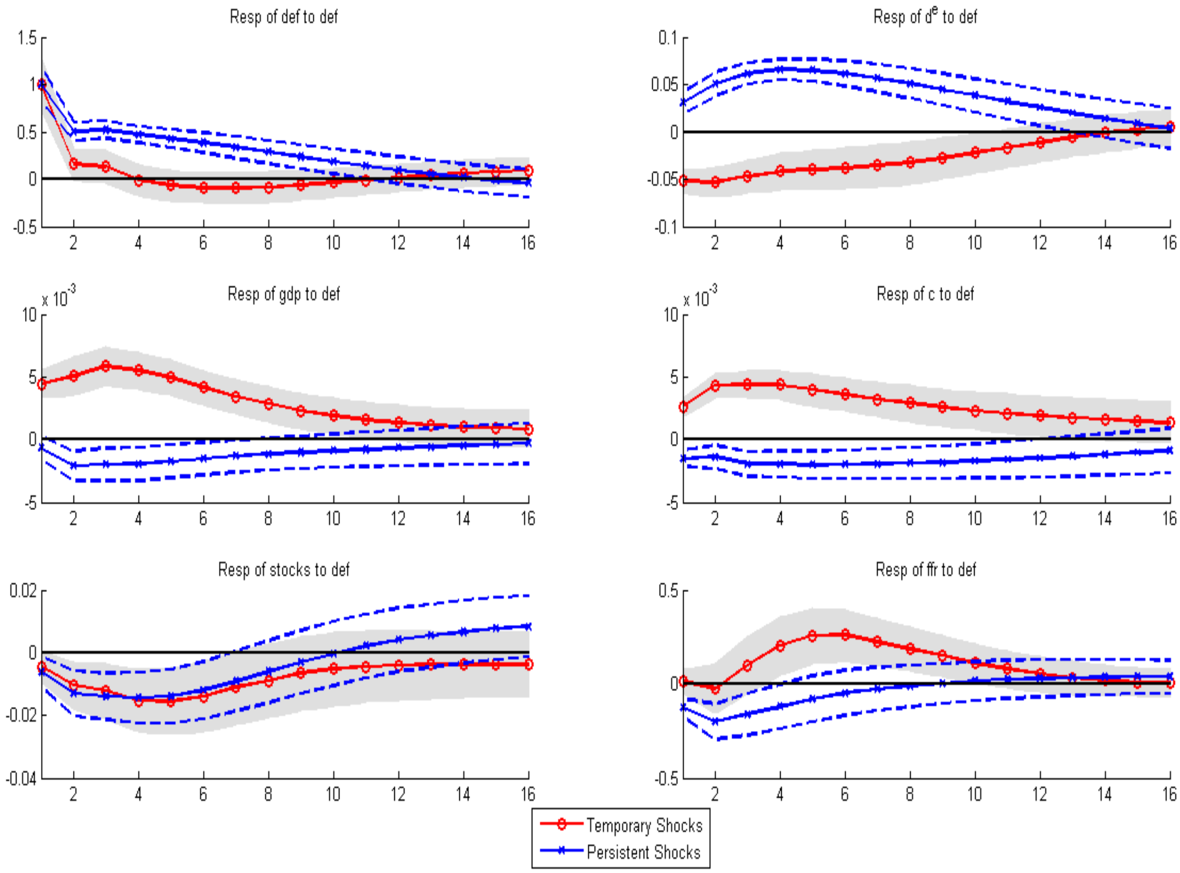


Figure 17: **Stocks - Test**

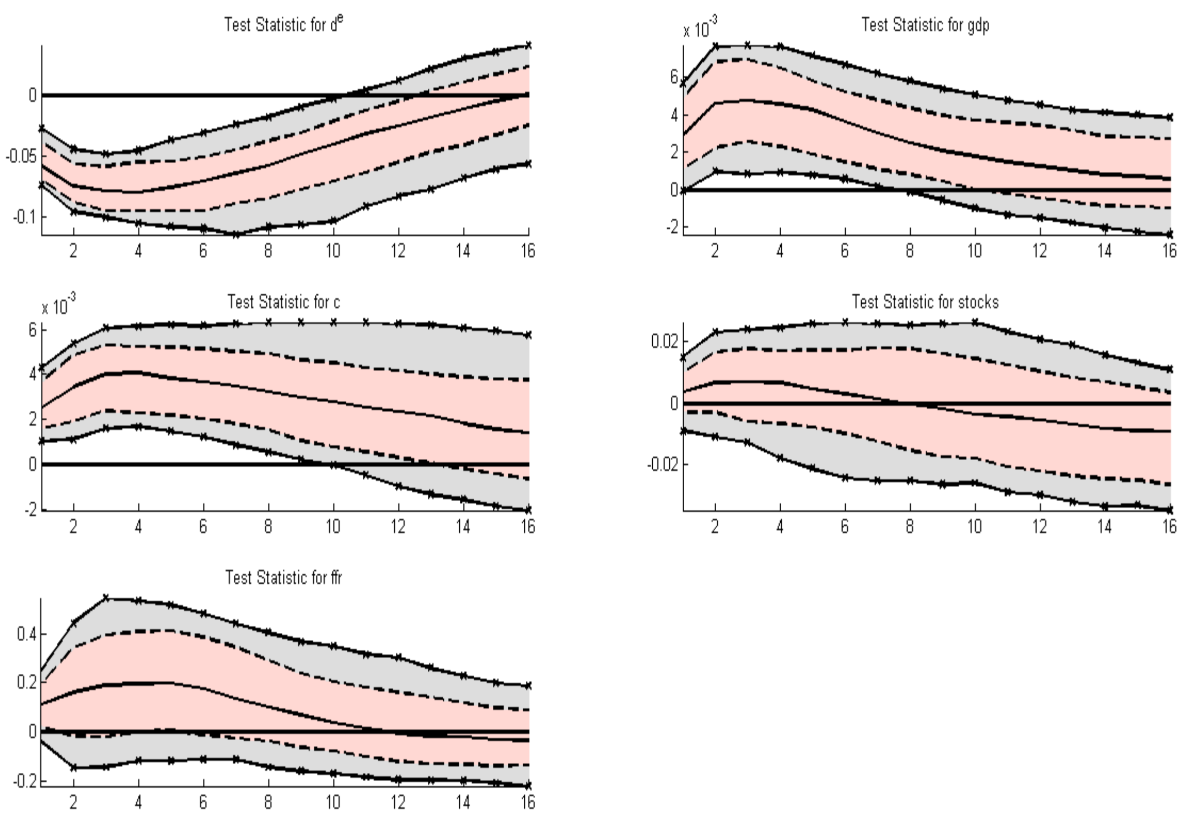


Figure 18: **Temporary and Persistent Fiscal Shocks - Term Premium**

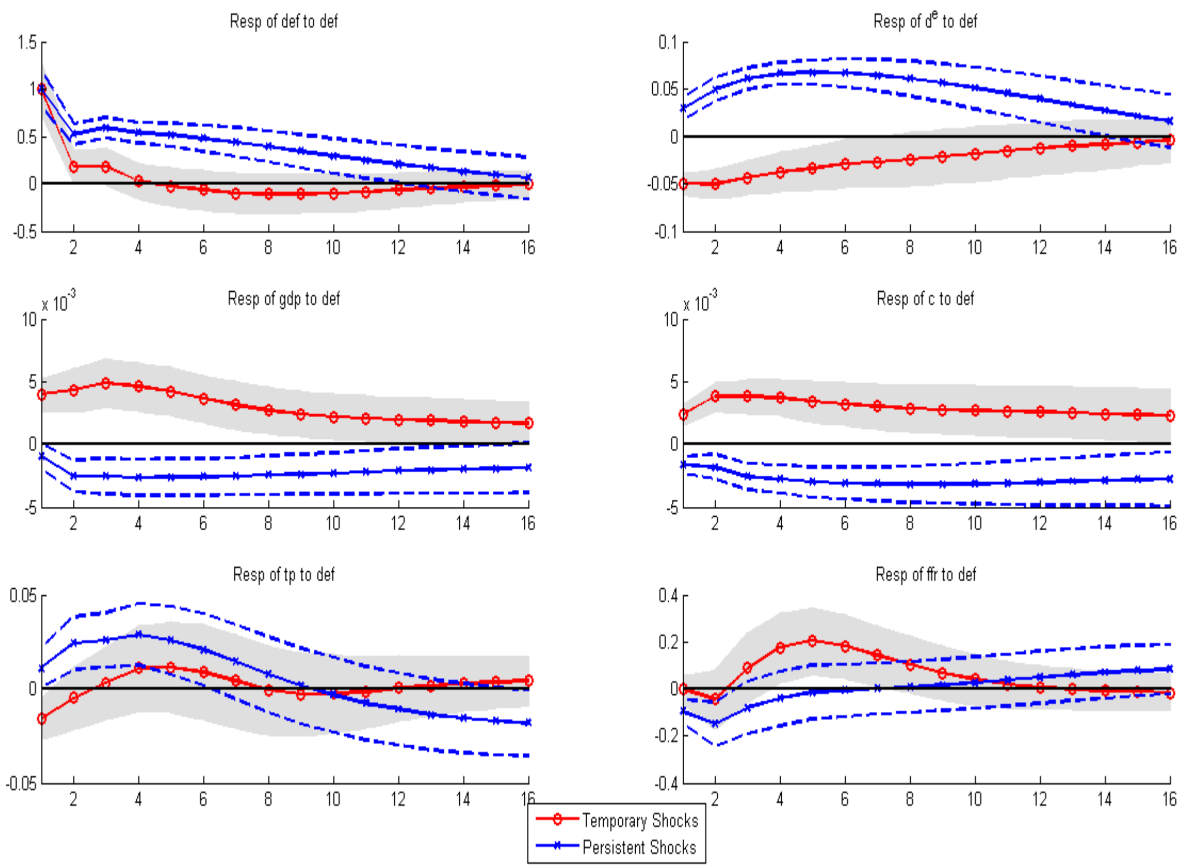


Figure 19: **Term Premium - Test**

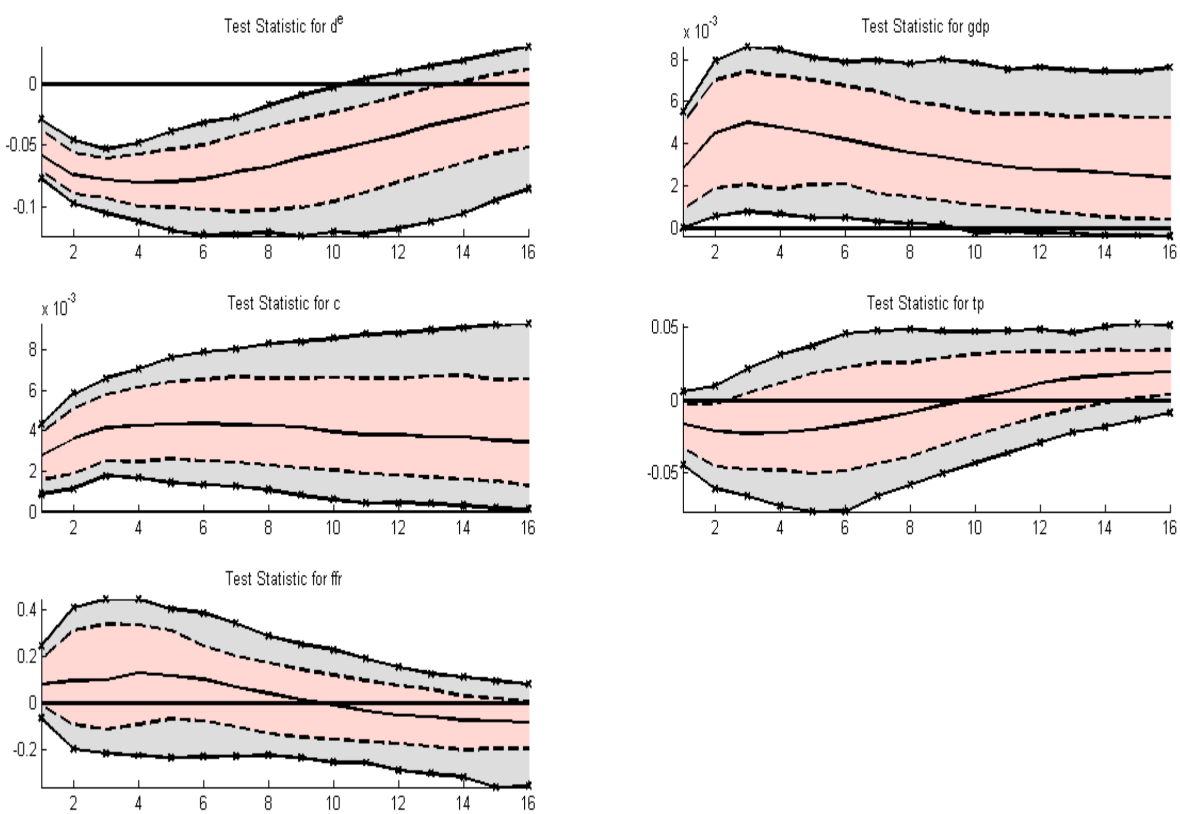


Figure 20: **Temporary and Persistent Fiscal Shocks - Current Account**

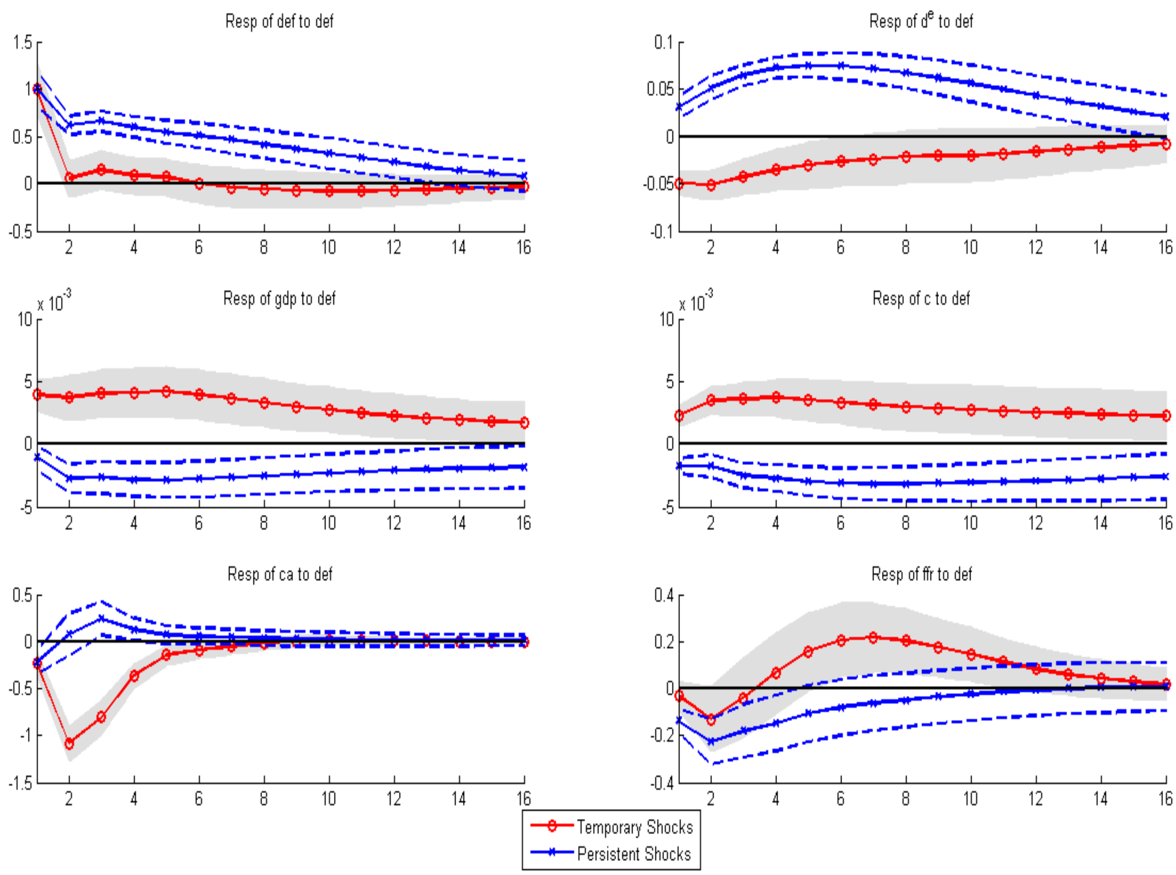
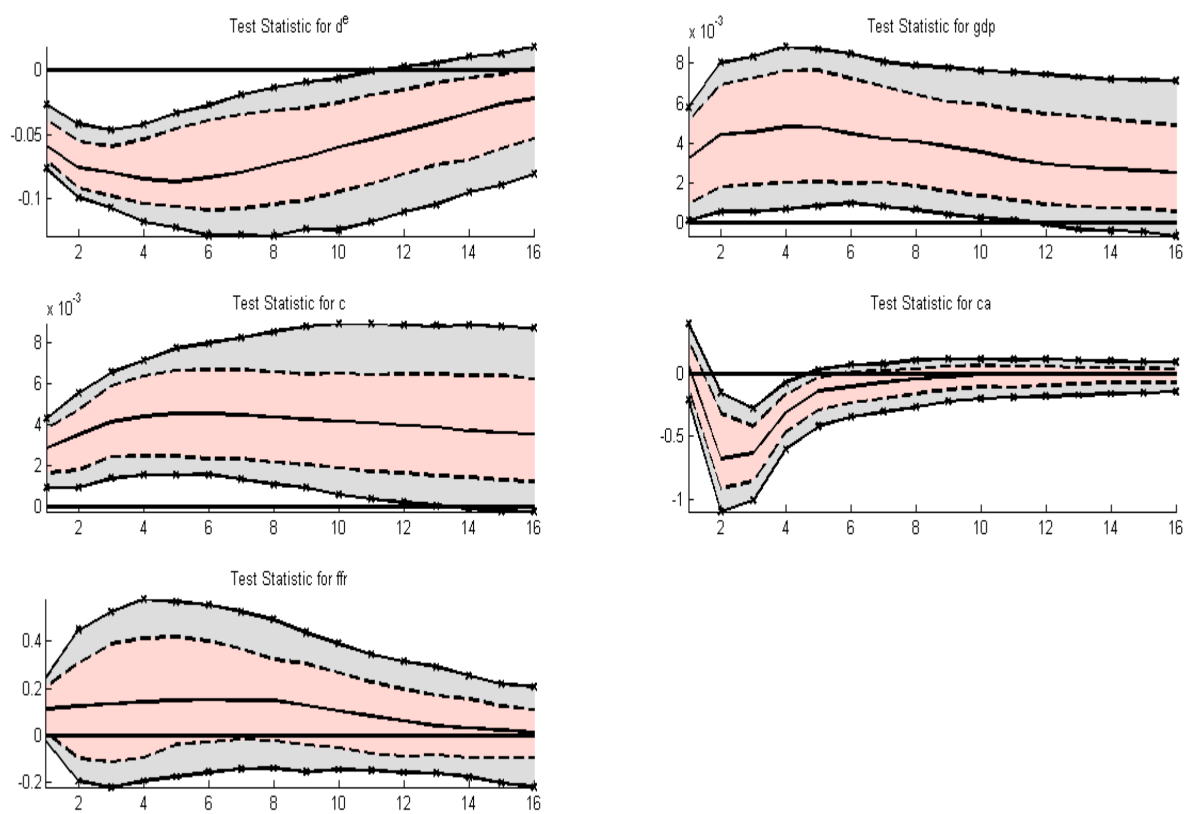


Figure 21: **Current Account - Test**



10 APPENDIX D - Non Linear Effects

Figure 22: **Temporary and Persistent Fiscal Shocks - Low Public Debt**

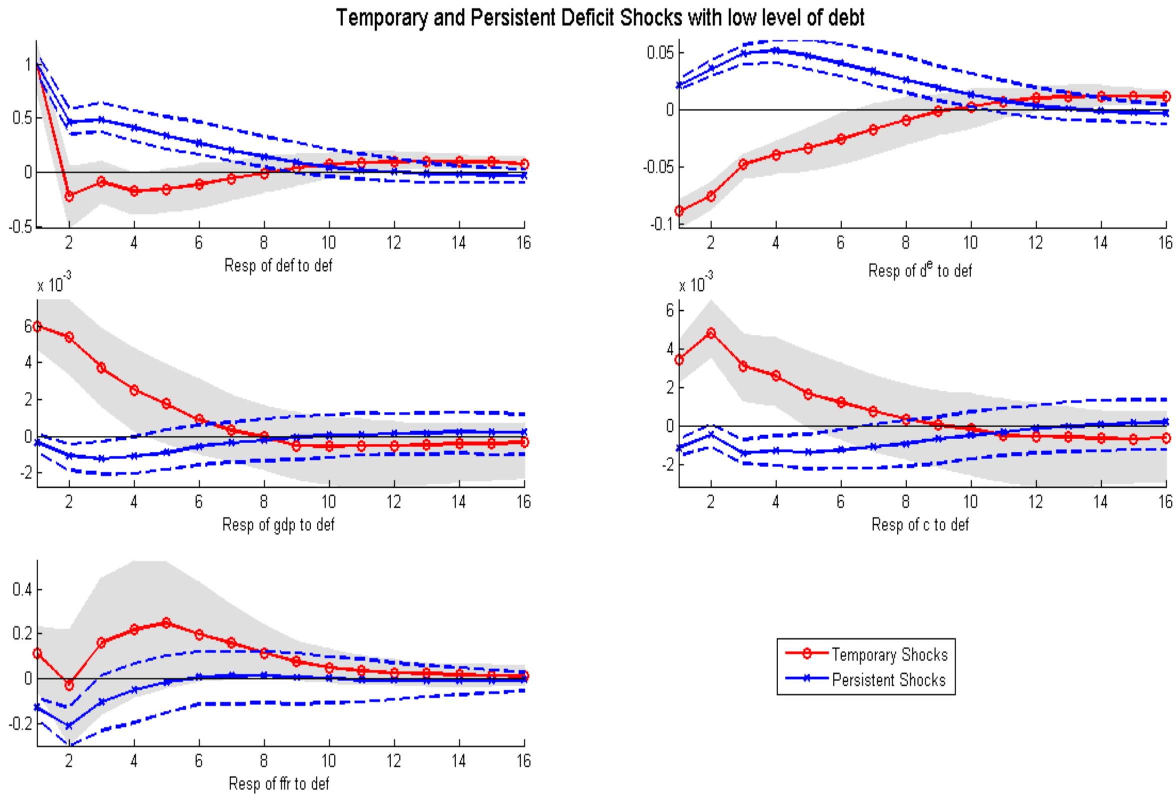


Figure 23: **Temporary and Persistent Fiscal Shocks - High Public Debt**

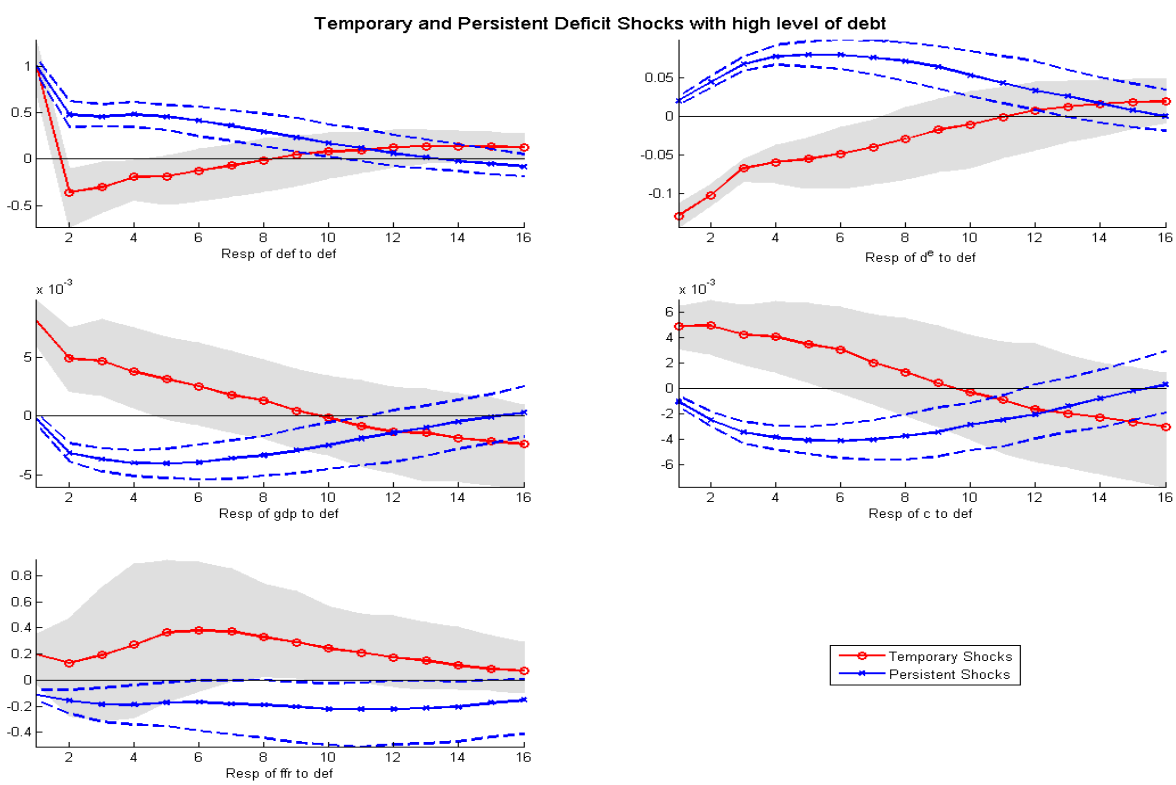


Figure 24: **Transition Function -** $F(z_t, \lambda)$

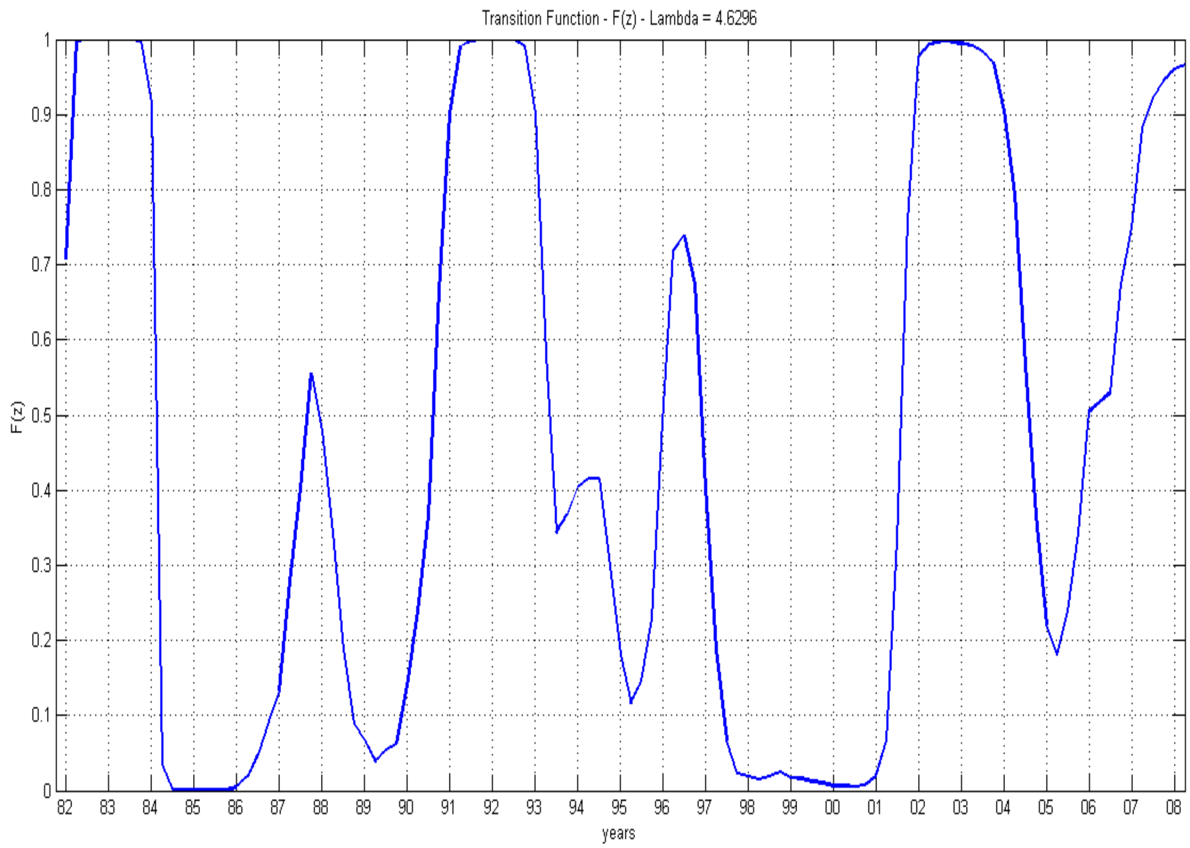


Figure 25: **Temporary and Persistent Fiscal Shocks in Expansions**

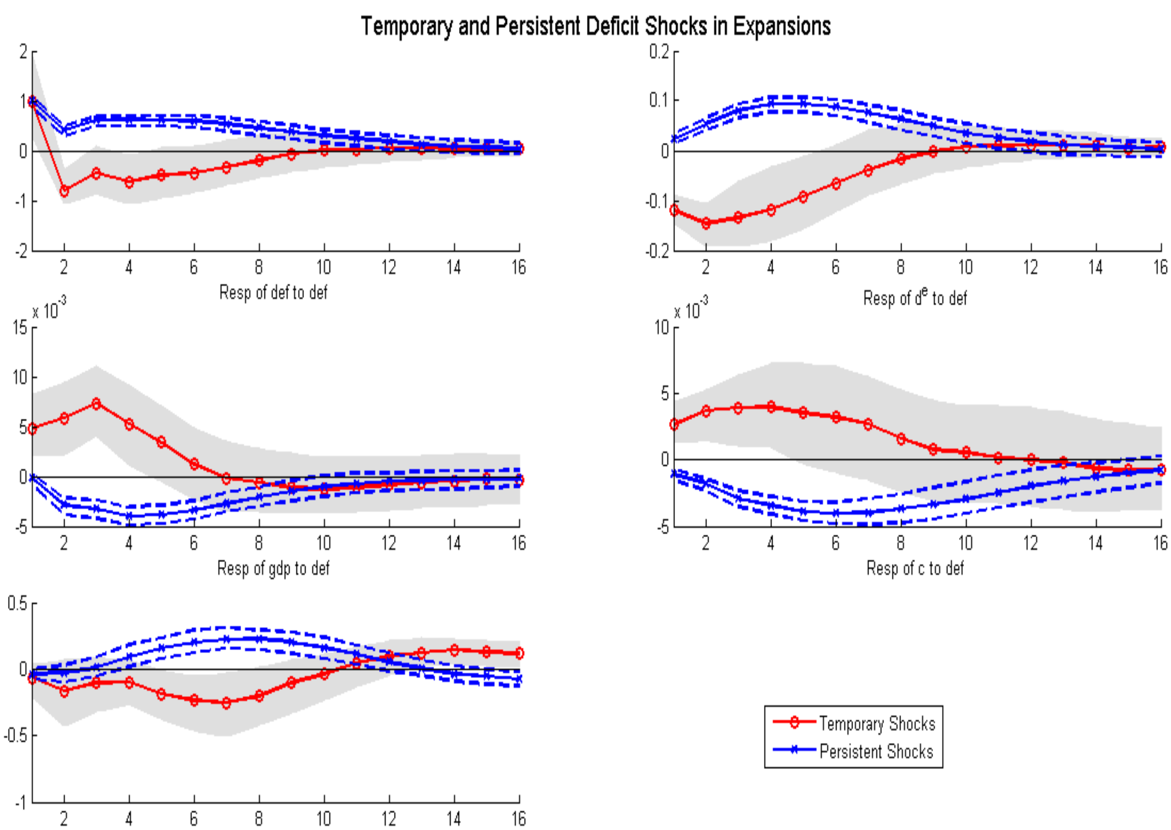
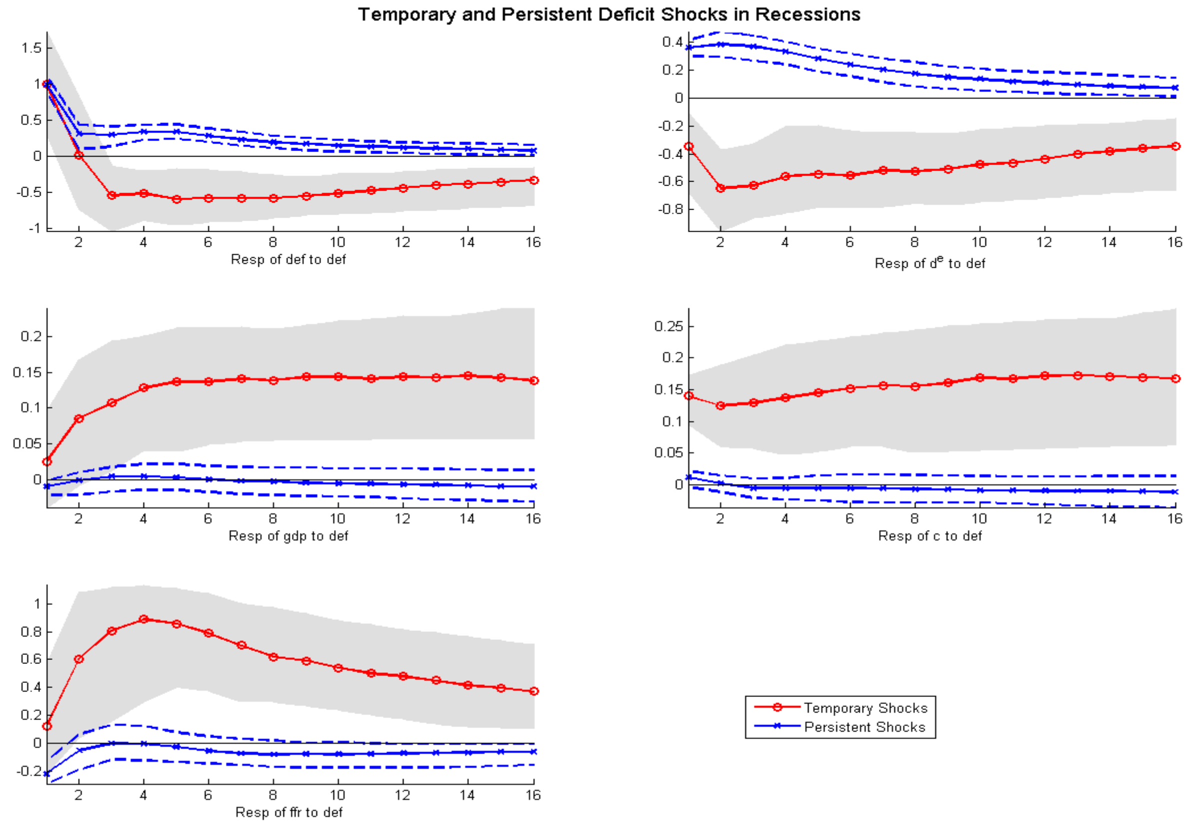


Figure 26: **Temporary and Persistent Fiscal Shocks in Recessions**



11 APPENDIX E - Small vs. Big Shocks

Figure 27: **Impulse Responses from Reaction Function**

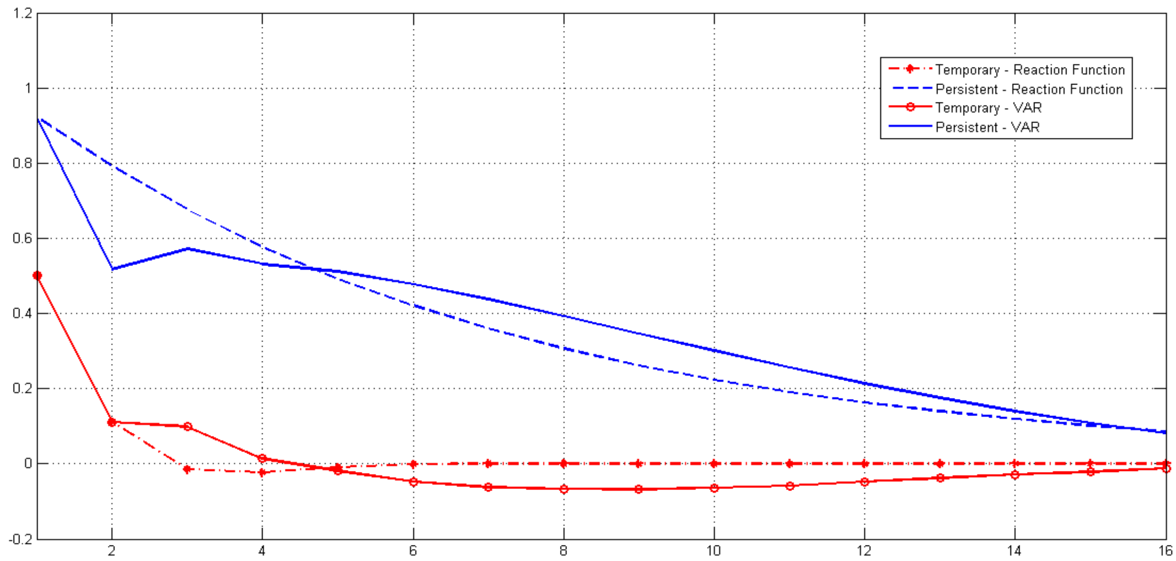


Figure 28: **Small vs. Big Shocks**