Essays in Macroeconomics

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Declaration

I certify that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

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Statement of Conjoint Work

I confirm that Chapter 2 was jointly co-authored with dr. Maria Grazia Attinasi, Economist at the European Central Bank. Each of us contributed equally to the creation, development and writing of the chapter. I confirm that Chapter 3 was jointly co-authored with dr. Daniela Bragoli, Researcher at the Catholic University of Milan, and Michele Modugno, Economist at the Federal Reserve Board. Each of us contributed equally to the creation, development and writing of the chapter.

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Introduction

The thesis contains three chapters. The first chapter studies optimal fiscal policy in a small open economy in the presence of sovereign default risk. In particular, it studies this topic in an environment characterized by asymmetric information where financial markets (lenders) do not have enough information about the creditworthiness of the government (borrower). The chapter investigates whether the asymmetric information environment justifies the implementation of fiscal austerity during a recession, as opposed to the standard countercyclical response. The main finding is that fiscal austerity is the optimal fiscal policy during a recession. Fiscal austerity, although detrimental to economic growth, benefits the economy providing a signal to financial markets about the creditworthiness of the government and reducing borrowing costs. When the inherited government debt-to-GDP ratio is high, this beneficial effect of fiscal austerity outweighs the costs of the policy even when fiscal austerity has a strong negative impact on economic activity, i.e. when the fiscal multiplier is larger than one. The findings of this chapter are useful to shed new light on the fiscal policy developments across Europe during the European debt crisis.

The second chapter of the thesis, co-authored with Maria Grazia Attinasi (ECB), studies empirically the effect of fiscal consolidation on the debt-to-GDP ratio for the Euro area countries, using a quarterly panel fiscal VAR. The main finding of this chapter is that following a fiscal consolidation episode, the debt-to-GDP ratio increases initially, for a period up to four quarters, and then starts to decline. The size and length of the initial debt increase depend on the composition of consolidation. In the case of revenue-based consolidations the increase in the debt-to-GDP ratio tends to be larger and to last longer than in the case of spending-based consolidations. The composition also matters for the long term effects of fiscal consolidations. Spending-based consolidations tend to generate a durable reduction of the debt-to-GDP ratio compared to the pre-shock level, whereas revenue-based consolidations do not produce any lasting improvement in the sustainability prospects as the debt-to-GDP ratio tends to revert to the pre-shock level. The findings of this chapter are of particular policy relevance in the context of the ongoing debate about the merits of fiscal consolidation as the main tool to restore debt sustainability in the Euro area countries. They suggest that short term considerations related to the detrimental impact of consolidation on growth and on the debt-to-GDP ratio need to be weighed against the long term benefits of a rebound in output growth and a durable reduction in the debt-to-GDP ratio.

The third chapter, co-authored with Daniela Bragoli (Catholic University) and Michele Modugno (Federal Reserve Board), compares the forecasting performance of GDP now-casting techniques through a dynamic factor model to the forecasts produced by the Central Bank of Brazil, which is the only central bank that collects predictions at a daily frequency. Results indicate that the Central Bank of Brazil forecasts perform as well as model based forecasts. The latter finding suggests that, on the one hand, judgemental forecasters do not have computational limitations and they are able to incorporate quickly new information in a way that is almost as efficient as a machine. On the other hand, it shows that a linear time invariant model does a slightly better job in now-casting Brazilian GDP and hence that eventual non linearities, time variations and soft information that could be incorporated by judgement, do not provide new important information.

Contents

Chapter 1

Fiscal Austerity and Reputation

1.1 Introduction

Since 2010, many European governments have implemented stringent fiscal austerity plans in periods of deep recession. Greece, Ireland and Portugal dramatically reduced their budget deficits. Italy, Spain and the UK enforced drastic cuts in public spending and/or increased taxation. The rationale of these choices has been extensively discussed. A common view in the academic debate is that fiscal austerity has been a mistake. Krugman (2010) and De Long and Summers (2012), among others, argue that fiscal multipliers are large and that a fiscal policy tightening only exacerbates the recession, without producing beneficial effects on public balances. They assume that interest rates are constrained by the zero lower bound and remain constant after the fiscal adjustment. We argue, however, that this view is incomplete, as it does not consider the effect of fiscal policy on the sovereign risk premium. Indeed, a fiscal tightening might reduce the market-perceived sovereign default probability and lower the interest rate, through the so-called reputational channel of fiscal policy.

This paper develops a theoretical framework to study the aforementioned reputational channel of fiscal policy. We use the model to compare the reputational effect of fiscal policy with its standard impact on output, through a large fiscal multiplier. We show that in a recession characterized by uncertainty about the creditworthiness of the government and by a high stock of public debt, a fiscal consolidation is the optimal response of a benevolent government. A fiscal adjustment implemented in such conditions improves the government's reputation, defined as the belief that financial markets form about the creditworthiness of the government. The reputation achieved through the fiscal adjustment reduces the perceived sovereign risk-premium and thus lowers the interest rate. Although the fiscal adjustment has a significant cost in terms of lower economic growth (the fiscal multiplier implied by the model is larger than one), the welfare gains derived from the reputational channel are bigger than the costs, justifying the implementation of austerity during a recession.

We formalize this mechanism in an endogenous sovereign default model along the lines of Arellano (2008). We augment the model with distortionary fiscal policy, private information and political turnover. There are three agents in the economy: a government, a household and foreign financial markets. The household does not have access to borrowing and chooses labour and consumption. The government decides whether or not to default and borrows on behalf of the household. Moreover, it sets distortionary taxation and chooses public spending. Foreign financial markets lend to the government, taking into account its default probability. We introduce private information in this setting assuming that financial markets do not observe the discount factor of the government in power. In the paper we show how a lower government discount factor implies a higher propensity to default. Using this framework, we are able to explain why a government that in general follows countercyclical policies, as in the case of European economies[1], might implement a procyclical fiscal policy exactly at the time of a recession. In particular, we find two distinct reasons to rationalize austerity: in a mild recession the government implements fiscal austerity for signalling considerations, while in a deep recession it does so for budgetary considerations. Our underlying assumption is that every country can be run by one of two types of government: either a high discount factor type (Good type, non present-biased), more willing to repay its debt, or a low discount factor type (Bad type, present-biased), less willing to do so. We show that in an environment with full information the Good type follows a countercyclical fiscal policy, while the Bad type follows a procyclical one. With private information the model produces different implications in terms of fiscal policy, as the two types of government and the lenders are engaged in a signalling game.

In this setting, we obtain the following results. First, in a mild recession a tighter fiscal policy aims at improving the government's reputation. Tighter fiscal policy acts as a credible signal for the Good government to convey information to the financial markets about its higher creditworthiness, on which depends the interest rate charged by foreign lenders. As a consequence, lenders charge the Good government a lower interest rate. A fiscal austerity implemented for this reason is what we name a *signalling austerity*. The government can

[1] See, for instance Kaminsky, Reinhart and Vegh (2004).

choose between lower borrowing and lower interest rates (austerity) - and higher borrowing and high interest rates (no austerity). The government chooses the former policy following welfare considerations. The welfare benefit of the austerity policy is in terms of a reputational benefit, which guarantees lower interest rates and lower repayments in the future. The welfare cost is in terms of lower public spending and a significant reduction in economic activity, as the model entails a fiscal multiplier larger than one. Nonetheless, since the benefits are greater than the costs, austerity is the optimal response.

Second, in a deep recession there is a different rationale for austerity. We show how in a deep recession financial markets compel the Bad government[2] to reduce its deficit up to the point where it never defaults in the following period. As the gains from defaulting in deep recession are very high for a Bad government, financial markets engineer an interest rate schedule that avoids them incurring in excessive losses. They simply charge the Bad government very high interest rates for high levels of borrowing. This tight interest rate schedule forces the Bad government to reduce its borrowing up to a level which carries zero default probability and that guarantees the risk-free bond price. Given this responsible behaviour of the Bad government, it is more difficult for the Good government to signal its type. We show that in a deep recession the Good type does not succeed in signalling its type and loses its reputation. Nonetheless, the Good government cuts its budget and tightens its fiscal policy, choosing the same level of borrowing as the Bad type. If the Good government did not reduce its borrowing, lenders would be uncertain whether they were lending to the Good type, who is following its full information countercyclical policy, or to the Bad type who is trying to exploit the lack of information and expand its budget. Hence, lenders would charge the unknown type of government a far too high interest rate. This higher interest rate would make the government budget unbalanced. In deep recessions the default probability (and therefore the interest rate) of the Bad type increases faster than the increase in the amount of borrowing. This makes the interest rate awarded in the case of no-austerity high enough to push any type of government beyond the peak of its debt Laffer curve. Anticipating this behaviour of financial markets, the government reduces its borrowing. The government does not even perform a welfare analyisis. It simply enforces austerity to improve its primary balance. A fiscal austerity implemented for such reason is what we name a *budgetary austerity.* The Good government implements the same fiscal policy as the Bad type because at this low level of borrowing they both already receive the risk-free interest rate. An additional reduction in borrowing would imply a null reputational benefit but positive welfare costs, removing any incentive for the Good government to send

[2]In case the government has access to financial markets.

a costly signal to financial markets.

The numerical simulations of the model show that, irrespective of the rationale behind the implementation of fiscal austerity, under the assumption of private information the Good government implements an overall mild procyclical fiscal policy. On the other hand, in the case of full information, it follows a standard countercyclical fiscal policy. Therefore, the presence of the private information constraint is crucial to determine the reversal in the fiscal policy cyclicality of the government. Moreover, the overall mild fiscal policy procyclicality under private information is the result of the average fiscal policy cyclicality between recession and expansion periods. We show that the government follows a different behaviour in such periods, generating a regime-change in its fiscal policy cyclicality. Indeed, conditional on the economy being in a recession, the Good government implements a procyclical fiscal policy, in order to prevent to be mimicked by the Bad type and to avoid the resulting high interest rates. It increases taxation and decreases borrowing as the productivity shock becomes more negative. On the other hand, when the economy is in expansion, the government follows its first best countercyclical fiscal policy, as it does not have to worry about the mimicking incentives of the Bad government.

The model is also useful to provide a formal definition of fiscal austerity. In the economic debate there is no agreement even on how to define fiscal austerity. The definitions range from “a self-defeating mistake” (Paul Krugman) to “the only option to restore credibility” (George Osborne). We define fiscal austerity as the fiscal policy tightening implemented in a recession, which is due to the presence of the private information constraint but that is not related to the macro fundamental conditions of the economy. The Good government, absent of any private information constraint, responds to a recession expanding its budget and following a standard countercyclical behaviour. However, in the presence of private information, it implements the opposite policy, restraining its budget. The difference in the fiscal policy stance between the unconstrained and constrained case is our measure and definition of fiscal austerity.

The last section of the paper provides some empirical evidence to show that the intuitions of the model are consistent with the data. We identify a period of private information with the first year of the mandate of a newly elected government, if this government is in power for the first time. We document that the OECD countries for the period 1995-2009 followed a procyclical behaviour in the periods characterized by the joint presence of private information, recession and high debt. In all other cases, they followed the standard textbook countercyclical fiscal policy.

The paper is structured as follows. Section 1.1.1 presents a literature review, while section 1.1.2 offers some stylized facts about the magnitude of the austerity measures implemented in Europe. Section 1.2 presents the model, while section 1.3 illustrates the intuitions of the model presenting a one-period snapshot of the model. Section 1.4 provides results in terms of the numerical simulation of the model. Section 1.5 offers some empirical evidence, documenting the consistency of the predictions of the model with the empirical findings. Section 1.6 concludes.

1.1.1 Literature Review

The paper is related to several strands of the literature. First, it relates to the literature analysing the effects of fiscal policy on economic activity. In particular, it relates to the body of work studying fiscal consolidations episodes. This literature, starting with Giavazzi and Pagano (1990) and Alesina and Perotti (1995), proposed the reputational channel as a mechanism able to explain why fiscal consolidations can foster economic growth, through a reduction in the sovereign risk-premium. Giavazzi and Pagano (1990) and Alesina and Perotti (1995) study empirically the effect of fiscal adjustments and inspect the relevance of the credibility channel. They document that this channel is most powerful when the economy is experiencing high debt levels. The same question has been further investigated by Alesina and Ardagna (1998, 2009), Ardagna (2004) and more recently by Favero, Giavazzi and Alesina (2012), in a series of empirical papers about expansionary fiscal consolidations. These papers have been highly criticized by the literature initiated by IMF with Guajardo, Leigh and Pescatori (2010). These authors, using a narrative approach to identify episodes of fiscal consolidations, find a contractionary effect of fiscal consolidation on economic activity. Despite the stark difference in the response of output to fiscal consolidation , even this literature finds that fiscal consolidation slightly reduces the interest rate, suggesting the presence of a reputational channel of fiscal policy. For what concerns the theoretical literature, to the best of our knowledge, there is not a theoretical framework useful to think about the aforementioned reputational perspective of fiscal policy. Our model is a first attempt. We use the model to study under which conditions the reputational channel is relevant and we evaluate the benefits and the costs of this mechanism. We find that this channel operates when the following conditions are met: 1) there is private information in financial markets about the creditworthiness of the government, 2) there is a strong enough recession, 3) the stock of public debt is high enough.

In the theoretical literature, few papers study the relationship between fiscal policy and government reputation. Corsetti, Kuester, Meier and Muller (2012) study the impact of a fiscal retrenchment in the presence of sovereign default risk. They show that if the risk-premium falls enough, a fiscal consolidation may have positive effects on output. However, the default decision is not modelled explicitly. They assume an exogenous negative relationship between the amount of government borrowing and the government interest rate. In a related paper, Corsetti and Dedola (2011) analyse the determinants of the sovereign risk-premium and show how it depend both on the fiscal policy and on market confidence. In this paper we provide a model that endogenously links fiscal policy, the government interest rate and economic growth.

Second, the paper draws on the literature studying sovereign default. The question of government reputation is intimately related to the question of sovereign default. Indeed, it is the option of defaulting that makes government reputation relevant, which in turn affects the interest rate the government receives. The core of our model is a sovereign default model, along the lines of Arellano (2008) and Aguair and Gopinath (2004). This model has been used to study the dynamics of sovereign default in emerging markets, abstracting from distortionary fiscal policy. Cuadra, Sanchez and Sapriza (2010) augmented the standard sovereign default model with distortionary fiscal policy. We build on Cuadra, Sanchez and Sapriza (2010), using their modelling framework to introduce fiscal policy in a sovereign default model. We build on Hatchondo, Martinez and Sapriza (2009) to model political turnover in the full model of section 4. However, we expand these models introducing asymmetric information about the type of government in charge. Our contribution is to augment the sovereign default literature by a signalling game with fiscal policy.[3]

Third, our paper is related to the literature that studies the cyclicality of government fiscal policy. This literature finds that advanced countries implement a mild countercyclical or even acyclical fiscal policy, while emerging countries implement a very procyclical one, e.g. Gavin and Perotti (1997), Kaminsky Reinhart and Vegh (2004), Ilzetzki and Vegh (2008). Our study finds that the presence of private information generates a regime-change in the fiscal policy cyclicality of a country. In the presence of private information, a country optimally follows a procyclical fiscal policy in recession and a countercyclical one in expansion.

[3] Other works study private information in sovereign default models, e.g. Cole, Dow and English (1994), Alfaro and Kanczuk (2003), Sandleris (2006), D'Erasmo (2011). However, none of these model explicitly fiscal policy.

1.1.2 Stylized Facts

This section provides some stylized facts regarding the fiscal policy stance in Europe during the period 2008-2014, in order to quantify the magnitude of the austerity measures implemented.

To address this question correctly we would need an exogenous measure of fiscal policy, able to reflect the willingness of the government to implement a fiscal consolidation independent from the economic cycle. However, the fiscal policy outcomes that we observe, namely the government budget items, are the result of the two forces at work in the real world: the intention of the government and the effect of the economic cycle. Although no general agreement to disentangle the two has been found, we propose three measures to quantify the fiscal policy stance. The first one refers to the change in the cyclically adjusted primary balance ($\Delta CAPB$). The second measure considers the change in discretionary government spending. The third is a narrative measure, as reported by OECD surveys and governmental provisional budget laws.

The first measure, the change in the CAPB, is one of the most common measures used in the literature to proxy the government fiscal position net of cyclical effects.[4] Figure 1 plots the change in the CAPB,[5] for Greece, Ireland, Italy, Portugal, Spain and the UK, from year 2008 to 2013. The figure makes clear how fiscal policy has changed during this period. In the first two years fiscal policy was expansionary in all the countries considered, but since 2010 the fiscal stimulus has been reverted and fiscal austerity has taken its place. Moreover, this has happened in a period of continuing economic vulnerability, as represented by a constant negative output gap. The country that experienced the tightest fiscal policy was Greece, where the cumulative value of the austerity measures reached 17.8% of GDP. The UK, Spain and Italy experienced a cumulative fiscal austerity of, respectively, 6.6%, 6.9% and 4.3% of GDP.

The second measure relates to the change in government spending. The first column of Table 1 reports the change in total government expenditure as a percentage of GDP, between 2009 and 2013. All the peripheral European countries and the UK experienced a decrease in the ratio of total government expenditure over GDP. Total government expenditure considers

[4]See Alesina and Ardagna (1998) for a more detailed digression. However, recently this approach has been challenged by Guajardo *et al* (2010). For this reason, we accompany this methodology with two other measures to identify the fiscal policy stance of a country.

[5]As a percentage of GDP

Figure 1. Change in Cyclically Adjusted Primary Balance (CAPB)

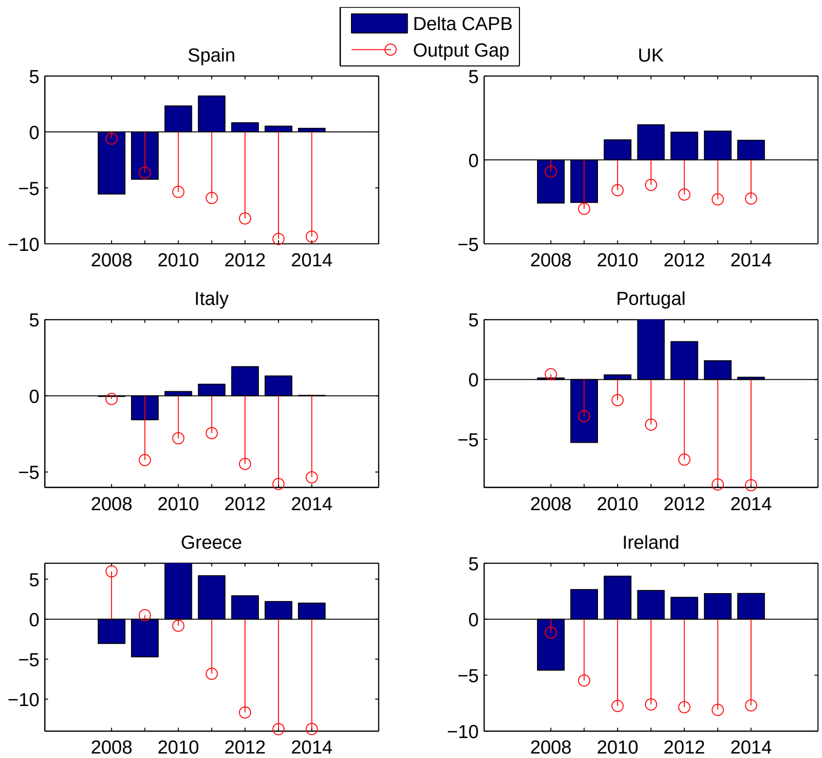

Figure 1 depicts the change in the Cyclically Adjusted Primary Balance ($\Delta CAPB$) as a percentage of GDP and the output gap, in percentage deviations from the trend. Data are from year 2008 to 2014. The countries considered are: Spain, the UK, Italy, Portugal, Greece and Ireland.

Table 1. $\Delta\%$ *Government Spending*

	$\Delta G/Y$ (2013 vs 2009)	$\Delta Gd/Y$ (2012 vs 2009)
Greece	-4.2%	-35.7%
Ireland	-5.4%	-12.8%
Italy	-1.3%	-7.8%
Portugal	-2.3%	-22.2%
Spain	-4.0%	-18.3%
UK	-2.5%	-5.8%

Table 1 (left column) reports the change in total government spending as a percentage of GDP (left column) between 2009 and 2012. Table 1 (right column) reports the change in the discretionary government spending as a percentage of GDP (left column) between 2009 and 2012.

all kinds of government spending, including the spending on automatic stabilizers, which automatically increases in a recession. The fact that nonetheless this form of spending declined is illustrative of the size of the fiscal austerity measures implemented. The second column of Table 1 reports the change in discretionary government spending.[6] This measure, netting out the main part of fiscal transfers, is less dependent on the economic cycle and should reflect more accurately the government fiscal policy stance. We report the rate of change of real discretionary government spending between 2009 and 2012.

The third measure that we propose is a narrative one, extracted from the OECD Fiscal Consolidation survey (2012) and from provisional government budget laws. It summarizes the *ex-ante* fiscal program of the various governments. This does not take into account the actual multiplier effect on output and unemployment resulting from the withdrawal of demand from the economy. Hence the figures provided can turn out to be different from the data realized, due to the economic cycle. The cumulative value of the fiscal austerity plans for the period 2010-2015, according to our narrative measure, ranges from 18.5% of GDP for Greece to 6.1% of GDP for Italy, as reported in Figure 2.

Overall, the three measures reported here suggest unambiguously that, starting from 2010, the countries analysed changed their response to the weak economic cycle. Before 2010 these countries responded in a countercyclical fashion, but from this date they implemented a very procyclical fiscal policy. In the next section we provide a modelling framework able to account for this behaviour, based on the joint presence of sovereign default risk and private

[6]Discretionary spending is calculated by subtracting from total government expenditure, social benefits and transfers in kind, capital transfers and other transfers. This measure is then transformed in real terms using the GDP deflator.

Figure 2. Narrative measure: Cumulative Fiscal Adjustment (2010-2015)

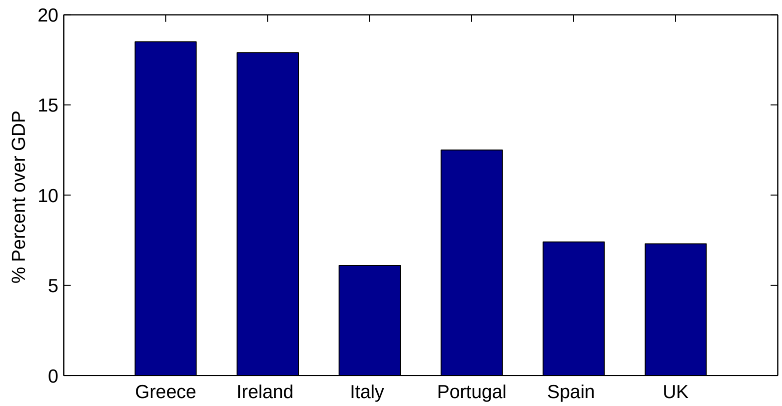

Figure 2 reports the cumulative fiscal adjustment (2010-2015), according to the narrative report in the OECD Fiscal Consolidation Survey (2012).

information in financial markets.

1.2 The model

In this section we present the model. There is a small open economy with three agents: household, government and foreign lenders. The household only decides how much to work and how much to consume. It cannot transfer resources from one period to another. The government is benevolent and acts to maximize household's utility. The government takes several decisions. First, it decides whether to default or not on its debt inherited from the previous period. Second, it borrows from abroad on behalf of the household. Third, it chooses the optimal level of government expenditure G and the optimal level of taxation T. Lenders are risk neutral and lend a non-state contingent bond to the government. The price that they charge accounts for the probability that the government in the following period will decide to default.

1.2.1 Household

In each period the representative household faces the same problem. It chooses how much to consume and how much to work, taking government actions as given. The household's utility function depends on consumption C, leisure $1-L$ and government consumption

G. Assuming a production function which depends on labour L and productivity Z, the household's problem is the following[7]:

$$Max\ \ E_t \sum_t \beta^t U(C_t, 1 - L_t, G_t^*) \tag{1}$$

$$s.t.\ \ (1 + T_t^*)C_t = Z_t F(L_t) \qquad (1.1)$$

Equation (1.1) is the consumer budget constraint, where T is a tax on consumption and $Z_t F(L_t)$ is total output Y_t. Productivity Z_t evolves over time according to a Markov process, with $H(Z_{t+1}|Z_t)$ representing the transition probability from Z_t to Z_{t+1}. β is the household's discount factor, with $\beta \in (0, 1)$.

The household problem is simple and does not involve any intertemporal decision. The household does not have access to financial markets and therefore cannot smooth consumption over time. The solution to the problem described by Equation (1) is given by the first order condition

$$(1 + T^*)\frac{U_l(C, 1 - L, G^*)}{U_c(C, 1 - L, G^*)} = ZF_l(L)$$

For any value of the tax T^* and government spending G^*, the household chooses consumption and leisure such that the marginal rate of substitution between consumption and leisure (adjusted by the tax) equals the marginal product of labour.

1.2.2 Government

The government solves a Ramsey problem, meaning that the government makes its decisions taking into account the reaction of the household. We assume that there are two possible types of governments and these governments alternate in power. The key parameter that defines the type of government is the value of its discount factor. A patient government (Good type) features a high discount factor, while an impatient government (Bad type) features a low discount factor. At the end of each period, the government in charge is replaced with probability π. The government in power takes first the default decision and after decides the internal fiscal policy.

[7] The variables with a star * are chosen by the government and they are considered by the consumer as given.

Default Decision

At the beginning of each period the government in charge decides whether to default or not on the debt inherited from the previous period. Given the productivity realization Z and the amount of bond holding inherited B, the government chooses the option which provides the higher utility. The benefit from defaulting derives from not having to repay the debt contracted in period $t-1$. The cost of defaulting is, as standard in the literature of sovereign default models, an output cost and an exclusion cost. The exclusion cost prevents the government from borrowing in the period of default. However, it regains access to financial markets in the following period with probability λ. The output cost follows the standard formulation of Arellano (2008):

$$Z^{default} = \begin{cases} \widehat{Z} & if\; Z \geqslant \widehat{Z} \\ Z & if\; Z < \widehat{Z} \end{cases}.$$

The optimal default decision of government i, denoted by $d_i(B, Z)$, is made comparing the value function of defaulting with the value function of not defaulting.

$$d_i(B, Z) = \begin{cases} 1 & if\; V_i^{Def}(B, Z) > V_i^{\neg Def}(B, Z) \\ 0 & if\; V_i^{Def}(B, Z) \leqslant V_i^{\neg Def}(B, Z) \end{cases} \tag{2}$$

The function $d_i(B, Z)$ shows, for every possible combination of productivity Z and bond B[8], what the optimal decision is in terms of defaulting or not. This defines a default set $D(B)$, i.e. a set of values for the productivity shocks Z such that it is optimal to default for any given bond holding B.

$$D_i(B) = \{Z\ s.t.\ \ d_i(B, Z) = 1\} \tag{3}$$

Integrating the transition function H for all the values of Z belonging to the default set we can recover the implied default probability in period t.

$$P_i(B', Z) = \int_{D_i(B')} H(dZ'|Z) \tag{4}$$

[8] B, the bond inherited from the previous period, is a state variable in period t.

The default probability is, for each Z and each bond choice B', the perceived probability in period t that the government will default at the beginning of period $t+1$. This probability is fundamental in determining the price of the bond in period t, as we show later.

Fiscal Policy Decisions

After the default decision, the government decides the level of borrowing, taxation and public spending. Let $V_i(B, Z)$ be the value function of government i, when i is in power. Let $W_i(B, Z)$ be the value function of government i, when $\neg i$ is in power. In a similar way, let $V_i^{Def}(B, Z)$ and $V_i^{\neg Def}(B, Z)$ be the value functions of defaulting and non-defaulting for government i, when i is in power. Let $W_i^{Def}(B, Z)$ and $W_i^{\neg Def}(B, Z)$ the value function of defaulting and non-defaulting for government i, when $\neg i$ is in power. The optimal borrowing, tax and spending decisions of a government that has not defaulted at the beginning of the period solve:

$$V_i^{\neg Def}(B, Z) = \max_{B_i', G_i, T_i} \left\{ U_i(C^*, 1-L^*, G) + \beta^i \left[\pi E_t W_i(B', Z') + (1-\pi) E_t V_i(B', Z') \right] \right\} \quad (5)$$

s.t.

$$G_i = T_i C_i^* + q_i(B_i', Z) B_i' - B \quad (6)$$

$$Z F(L_i^*) = (1+T_i) C_i^*$$

$$Z F_{L_i^*} = (1+T_i) \frac{U_l^i(C_i^*, 1-L_i^*, G_i)}{U_c(C_i^*, 1-L_i^*, G_i)}$$

where C^* and L^* represent the household's optimal choice of consumption and labour. The first constraint equation represents the government budget constraint, while the second and the third are, respectively, the consumer budget constraint and the consumer first order condition. The value function $V_i(B, Z)$ is computed as follows

$$V_i(B, Z) = \max \left\{ V_i^{Def}(B, Z), V_i^{\neg Def}(B, Z) \right\} \quad (7)$$

Because of political turnover, the government in power takes into account that in the next period it will be replaced with probability π. In this case its utility is represented by the value function W, which does not need to coincide with the value function V, since the choices of the government $\neg i$, if in power tomorrow, might differ from the optimal choices that government i would implement, if it remained in power in the following period. The intra-temporal choice between taxation and spending of the maximization problem 5 is given by the following Intra-Temporal condition:

$$U_c^i \frac{ZF(L_i^*)}{(1+T_i)^2} = U_g^i \left[\frac{ZF(L_i^*)}{(1+T_i)^2} + \frac{ZT_i F_{L_i}(L_i^*)}{(1+T_i)} \frac{\partial L_i^*}{\partial T_i} \right] \tag{8}$$

Should labour not depend on the tax rate, condition (8) boils down to the standard condition $U_c = U_g$, which equalizes the marginal utility of private consumption to the marginal utility deriving from public consumption.

The inter-temporal condition of problem 5 is given by:

$$U_{G_i}^i \left[q_i + B_i' \frac{\partial q_i}{\partial B_i'} - \frac{T_i Z}{1+T_i} \frac{\partial L_i}{\partial B_i'} \right] = \beta^i \left[(1-\pi) \int_{Z \notin D_i(B_i')} U_{G_i'}^i + \pi \int_{Z \notin D_{\neg i}(B_i')} U_{G_{\neg i}'}^i \right] \tag{9}$$

Equation (9) is an Euler equation, which represents the trade-off between public spending today and public spending tomorrow. The optimal level of G is set equating the marginal utility of government spending today to the expected present value of the marginal utility tomorrow.

The optimal borrowing, tax and spending decisions of a government that has defaulted at the beginning of the period solve instead the following problem:

$$\begin{aligned} V_i^{Def}(Z) = &\max_{B_i', G_i, T_i} U(C_i^*, 1-L_i^*, G_i) + \\ +\beta^i &\left[\pi \left(\lambda E_t W_i(0, Z') + (1-\lambda) E_t W_i^{Def}(Z') \right) + (1-\pi) \left(\lambda E_t V_i(0, Z') + (1-\lambda) E_t V^{Def}(Z') \right) \right] \end{aligned} \tag{10}$$

s.t.

$$G_i = T_i C_i^*$$

$$Z^{default} F(L_i^*) = (1+T_i) C_i^*$$

$$Z^{default} F_{L_i^*} = (1+T_i) \frac{U_l^i(C_i^*, 1-L_i^*, G_i)}{U_c^i(C_i^*, 1-L_i^*, G_i)}$$

The value function of government i when $\neg i$ is not in power and $\neg i$ does not default,

$W_i^{\neg Def}(B,Z)$, is given by:

$$W_i^{\neg Def}(B,Z) = U_i(C^*_{\neg i}, 1-L^*_{\neg i}, G^*_{\neg i}) + \beta^i\left[\pi V_i(B'_{\neg i}, Z') + (1-\pi)W_i(B'_{\neg i}, Z')\right] \qquad (11)$$

The value function of government i when $\neg i$ is not in power and $\neg i$ defaults, $W_i^{Def}(B,Z)$, is given by:

$$W_i^{Def}(B,Z) = U_i(C^*_{\neg i}, 1-L^*_{\neg i}, G^*_{\neg i}) +$$
$$+\beta^i\left[(1-\pi)\left(\lambda E_t W_i(0,Z') + (1-\lambda)E_t W_i^{Def}(Z')\right) + \pi\left(\lambda E_t V_i(0,Z') + (1-\lambda)E_t V^{Def}(Z')\right)\right] \qquad (12)$$

The value function $W_i(B,Z)$ is given by:

$$W_i(B,Z) = \begin{cases} W_i^{Def}(B,Z) & if\, d'_{\neg i} = 1 \\ W_i^{\neg Def}(B,Z) & if\, d'_{\neg i} = 0 \end{cases} \qquad (13)$$

1.2.3 Foreign Lenders

The market for lending to the small open economy is perfectly competitive. There is an infinite number of risk-neutral lenders who act in order to maximize their profits, taking prices as given. Lenders discounted profits Π are given by

$$\Pi = (1-\pi)\left[\frac{P_i(B'_i,Z)}{1+r^{risk-free}}0 + \frac{1-P_i(B'_i,Z)}{1+r^{risk-free}}B'_i\right] + \pi\left[\frac{P_{\neg i}(B'_i,Z)}{1+r^{risk-free}}0 + \frac{1-P_{\neg i}(B'_i,Z)}{1+r^{risk-free}}B'_i - qi(B'_i,Z)B'_i\right]$$

where $P_{\neg i}(B'_i,Z)$ and $P_i(B'_i,Z)$ are, respectively, the probability of default of government $\neg i$ and of government i, when the productivity shock is Z and government i chooses to borrow B'_i. The sum of the first four terms on the right hand side is the discounted value of the expected payoff from lending, while $qi(B',Z)B'$ is the cost. Using the zero profit condition we can recover the asset price condition:

$$q_i(B', Z) = \frac{1}{(1 + r^{risk-free})} [1 - \pi P_{\neg i}(B'_i, Z) - (1 - \pi) P_i(B'_i, Z)] \tag{14}$$

Equation (14) shows how the bond price depends on the default probability. When the default probability is zero, the interest rate implied by the bond price is the risk-free one. On the contrary, when the default probability is different from zero, the bond price changes with the level of borrowing and productivity.

1.2.4 Equilibrium concept

We focus on Markov-perfect equilibria. Krussel and Smith (2003) show that typically there is a problem of indeterminacy of Markov-perfect equilibria in an infinite economy. To avoid this problem, we restrict our attention to the equilibrium arising as the limit of a finite horizon economy.

Definition In public information, a Markov-Perfect Equilibrium is characterized by:

1. A set of value functions $V_i(B, Z)$, $V_i^{Def}(Z)$, $V_i^{\neg Def}(B, Z)$, $W_i(B, Z)$, $W_i^{Def}(Z)$,$W_i^{\neg Def}(B, Z)$, for $i = Good, Bad$.
2. A set of borrowing policies $B'_i(B, Z)$, spending policies $G_i(B, Z)$, tax policies $T_i(B, Z)$, default policies $d_i(B, Z)$ for $i = Good, Bad$.
3. A bond price function $q_i(B'_i, Z)$ for $i = Good, Bad$.

such that

- $V_i(B, Z)$, $V_i^{Def}(Z)$, $V_i^{\neg Def}(B, Z)$, $W_i(B, Z)$, $W_i^{Def}(Z)$,$W_i^{\neg Def}(B, Z)$ satisfy Equations (1)-(7);
- $B'_i(B, Z)$, $G_i(B, Z)$, $T_i(B, Z)$ and $d_i(B, Z)$ solve the maximization problem specified by Equations (1)-(7);
- $q_i(B'_i, Z)$ satisfies the zero profit condition.

1.2.5 Calibration

We assume the Good government has a discount factor $\beta^{Good} = 0.96$ whereas for the Bad government $\beta^{Bad} = 0.6$, in line with Hatchondo et al (2009).[9] Table 2 summarizes the calibration of the parameters of the model. The relative risk aversion takes the standard value of 2. The elasticity of the labour supply, given by the parameter $\frac{1}{\Psi}$, is 2.22. The risk-free interest rate is set equal to 1%, to match the average quarterly German yield. Productivity Z evolves according to the following process:

$$log(Z_t) = (1-\rho)Z + \rho log(Z_{t-1}) + \epsilon$$

with $\rho < 1$ and $\epsilon \sim N(0, \sigma_\epsilon^2)$. We calibrate ρ using Greek GDP data and we find ρ to be equal to 0.89 and σ_ϵ to be equal to 0.028. We calibrate the output cost $\widehat{Z}$ and the re-entry probability λ to match the mean and volatility of the spread in Greece, respectively of 1.4 and 2.6 percent, using the Good type discount factor. Finally, the probability of changing the government at the end of each period is left as a free parameter. Initially π is set at 0%, implying a stable economy. Later we set π equal to 5% to represent an unstable economy, where on average every five years there is a change in government. The production function is linear in labour, meaning that

$$F(L) = L$$

The household utility function takes the following GHH form:

$$U(C, G, 1-L) = \Phi \frac{G^{1-\sigma}}{1-\sigma} + (1-\Phi) \left[\frac{\left(C - \frac{L^{1+\psi}}{1+\psi}\right)^{1-\sigma}}{1-\sigma} \right]$$

where Φ represents the share of utility derived from government consumption and σ represents the risk aversion parameter. We use a GHH formulation because it entails a very positive fiscal multiplier in the presence of hand-to-mouth consumers, as it is the case in sovereign default models. In fact, the GHH functional form implies a labour supply function

[9] These values produce an equilibrium default probability of, respectively, 0% and around 5%.

given by:

$$L^* = \left(\frac{Z}{(1+T)}\right)^{\frac{1}{\Psi}}$$

When the household faces a higher marginal tax, it reacts by optimally lowering the labor supply and thus reducing output Y. The effect of the tax on output is easily understood by looking at the first derivative of output Y with respect to the tax rate T.

$$-(1/\Psi) * (Z/(1+T))^{1+\frac{1}{\Psi}} \tag{15}$$

Equation (15) quantifies the entity of output reduction following a unitary increase in the tax rate. From this equation and the tax-revenue equation we can recover the fiscal multiplier implicit in the model, which ranges from 1.11 and to 2.19, depending on the productivity shock and the tax rate.[10]

Table 2. Parametrization

Parameter	Symbol	Value
Discount rate Good	β^{good}	0.96
Discount rate Bad	β^{bad}	0.60
Weight in Utility	Φ	0.30
Risk-free interest rate	$r^{risk-free}$	0.01
Output Cost	$\hat{Z}$	0.876
Re-entry probability	λ	0.082
Risk aversion	σ	2
Elasticity of labor supply	$\frac{1}{\Psi}$	2.22
Autoregressive parameter	ρ	0.89
St. deviation shock	σ_ϵ	0.028
Political turnover	π	0, 0.05

Table 2 contains value used for the calibration of the model.

1.3 Results: Behaviour in period t with no default

In this section we look at the implications of the model in a representative period t when no type of government defaults. For ease of exposition, we describe the behaviour of the

[10]This range for the fiscal multiplier is coherent with those empirical estimates that find the highest impact of fiscal policy on output. See for instance Ramey (2011), Blanchard and Leigh (2013). Given the value of the multiplier, our model does not favour austerity, since the negative impact of a tax increase in terms of output is remarkable.

model in the case of $\pi = 0$, i.e. with no turnover between governments. This section is meant to give the intuition of the main results and mechanism. These intuitions are useful to understand the full behaviour of the model with $\pi \neq 0$, reported in terms of simulations in the next section. Furthermore, we present the results assuming that in each period foreign lenders forget about the type of government in charge in the previous period. With this assumption, the problem created by the presence of private information is static. A model of dynamic reputation in an infinite horizon framework would generate an issue of equilibria indeterminacy and goes beyond the scope of this paper.

1.3.1 Public information

The key parameter of the model is the government discount factor.[11] The lack of knowledge, from the point of view of foreign lenders, about the value of this parameter determines the private information setting arising in the paper. We first solve the model for the case in which the value of the discount factor is known to foreign lenders (public information case) and then we compare the results with the case where lenders are unable to observe this parameter (private information case). In this section we focus on the results arising in the public information setting. In particular, we show here that, according to the value of the discount factor, the model delivers different implications in terms of default, spending, taxation and borrowing decisions. The following figures summarize the results, in terms of the default set and the choices of spending, taxation and borrowing for each of the two possible types of government.

Figure 3 reports the default set for the Good and the Bad type, on the same state space. This set represents all the combinations of inherited borrowing B and productivity Z, both relative to period t, such that the government defaults at the beginning of period t. The vertical axis represents the productivity state, while the horizontal axis the level of borrowing. The higher the productivity, the less likely is the government to default. The higher the level of borrowing, the more likely is the government to default. The black area on the right represents all the possible combinations of bond holdings and productivity in which both types of governments find optimal to default. For values belonging to the white area on the left no one defaults. For values belonging to the grey intermediate area only the Bad government defaults, whereas the Good government does not. The picture shows that the Bad government has more states in which it defaults. The lower discount rate makes less

[11]The consumer discount factor coincides with the government discount factor.

attractive for the Bad government to repay the debt. Later we show how the Bad government, because of this higher propensity towards default, is charged a higher interest rate.

Figure 3. Default Set

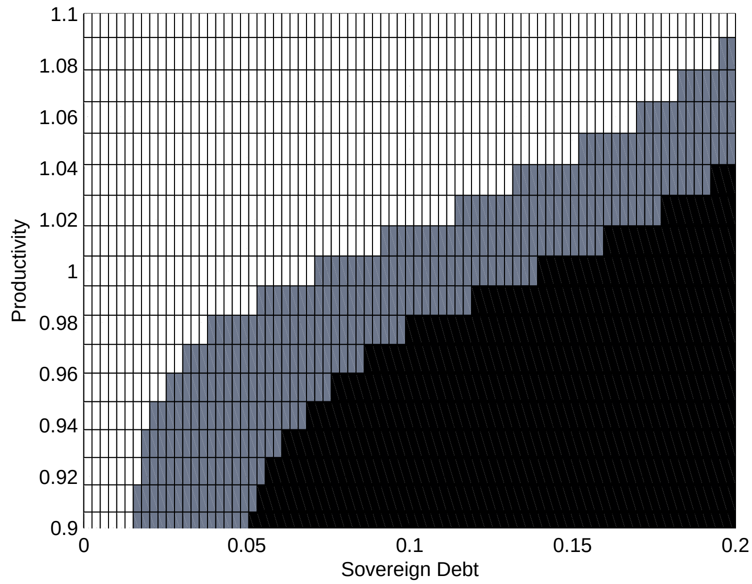

Figure 3 reports the default set for the two types. The black area represents the combination of bond holding and productivity states such that both governments default. The black area represents the area where no government defaults. The grey area represents the combination of bond holding and productivity states such that only the Bad government defaults.

Figure 4 (left panel) reports the choice of the tax rate in the representative period t for the two types of government, against productivity. To provide a neat intuition of the behaviour of the model, Figure 4 shows the fiscal policy choice of the government, for a given level of the inherited level of debt B.[12] The figure shows that, when the state of productivity is low, the Bad government cannot borrow much, as financial markets take into account its high propensity to default and reduce the level of lending. This makes the Bad government unable to raise enough funds to finance the desired higher level of public spending. In order to raise revenues it is forced to raise the level of taxation. At low productivity, it sets the tax rate above the rate chosen by the Good government. As productivity increases and it can borrow more, the Bad government reduces the tax rate. The Good government, instead, is not constrained by the default probability and keeps the tax rate constant.[13] Figure 4

[12]In this case the inherited bond B is set equal to the average value of debt.

[13]If both governments could borrow risk-free, the difference in the discount factor of the two governments would simply translate to a downward shift of the tax policy of the Bad government with respect to the

(right panel) reports the choice of spending over GDP for the two types of government, against productivity. When productivity is low, the Bad government (red line) chooses a level of spending lower than the Good government (blue line). When productivity is high, the opposite occurs. The reason is the same as the one highlighted for the tax policy. Indeed, the level of spending and the tax rate are related one to one with each other through the Intra-temporal FOC (8).

Figure 4. Left panel: Taxation. Right panel: Public Spending

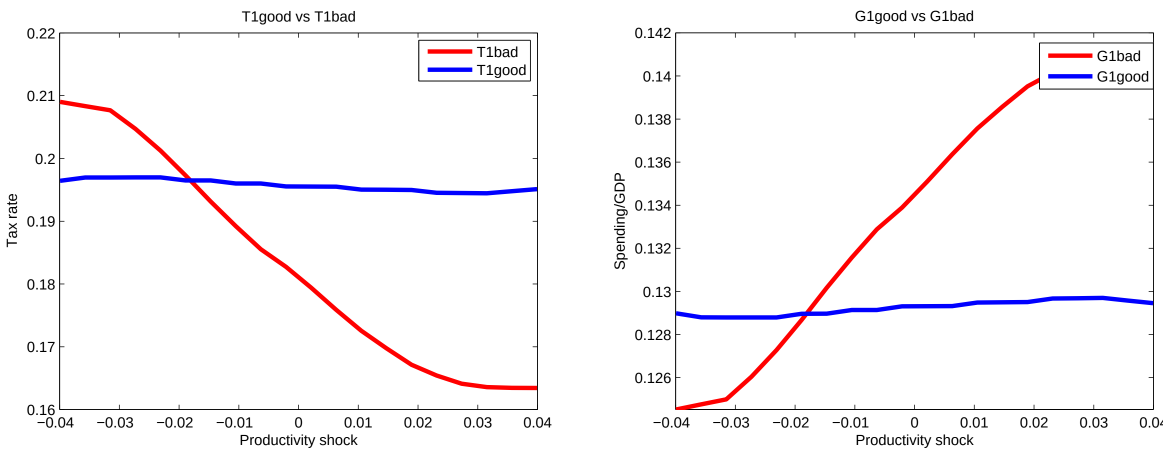

Figure 4 (left panel) reports the tax rate of the Good type (blue line), and of the Bad type (red line), across productivity states. Figure 4 (right panel) reports the spending policy (spending/GDP) of the Good type (blue line), and of the Bad type (red line), across productivity states.

Figure 5 (left panel) reports the borrowing policy for the two types, against productivity. The Good type's borrowing policy is mildly countercyclical. It borrows slightly more in recession and slightly less in expansion. In contrast, the Bad type borrowing policy is procyclical. It borrows less in recession, because it is constrained by the interest rate schedule, whereas it demands more borrowing in expansion. Figure 5 (right panel) shows the bond price obtained in equilibrium by the two types, for each state of productivity. The interest rate is simply the inverse of the bond price. The Good type always borrows risk-free, since it never defaults. However, the Bad type borrows risk free only for very low productivity levels. For such levels it has no choice other than to reduce its borrowing, choosing a level that guarantees to lenders that it will not have incentives to default the following period. For just slightly higher levels of borrowing the default probability increases so fast that it would not be convenient

Good government.

to borrow, as Lemma A shows. For values $Z > \bar{Z}$, the interest rate schedule becomes less steep and the Bad type can borrow more. For those states, it receives an interest rate higher than the risk-free one. The value $\bar{Z}$ is the productivity state identified by Lemma A (below)

Lemma A: $\bar{Z}$ is the highest productivity state that satisfies the following condition:

$$\lim_{B' \to \bar{B}^+} \frac{\partial \left[q^{Bad}(B', Z) * B' \right]}{\partial B'} \leq 0 \tag{16}$$

where $\bar{B} = sup \left\{ B \, s.t. \, D^{Bad}(B) = \varnothing \right\}$. The condition imposes that, taking the limit of the above expression calculated when B' tends to $\bar{B}$ (from the right), the amount of resources raised from financial markets does not increase with the increase of borrowing B'. This implies that the price function $q^{Bad}(B', Z)$, following an increase in B', decreases faster than the rate at which B' increases. When this condition is satisfied, for each $Z \leqslant \bar{Z}$, $\bar{B}$ is the maximum amount of borrowing that is sensible to borrow. A higher borrowing than $\bar{B}$ would imply simply less in resources $q \cdot B'$ today and higher repayments tomorrow. Therefore, for $Z \leqslant \bar{Z}$, the Bad government always borrows an amount $B \leqslant \bar{B}$. For each $B' \leqslant \bar{B}$, the corresponding interest rate $q(B', Z) = q^{risk-free}$, because $D^{Bad}(B, Z) = \varnothing$ by definition. For $Z > \bar{Z}$ the opposite condition holds, (i.e. $\lim_{B \to \bar{B}(+)} \frac{\partial [q(B,Z) * B]}{\partial B} > 0$) and the government can engage in risky borrowing, obtaining $B' > \bar{B}$ and $q(B', Z) < q^{risk-free}$, because for $B' > \bar{B}$ we have $D(B, Z) \neq \varnothing$.

Proof: See Appendix A

Role of Reputation In the public information setting there is no role for reputation. The government cannot alter the perceived creditworthiness it has towards lenders. Lenders are able to identify the type of government in charge with probability one and thus they apply the corresponding interest rate schedule. In this context, there is no link between the stance of fiscal policy and the government reputation. For every level of productivity, the Bad and the Good government make different choices in terms of G, T and B'. Given a productivity state, we can think at these choices as a separating equilibrium between the Bad and Good type. Overall, the solution of the model delivers a set of separating equilibria. The two types make different decisions and lenders are able to identify them. In the next section we study the consequences of introducing private information in this framework.

Figure 5. Left panel: Level of borrowing. Right panel: Bond price

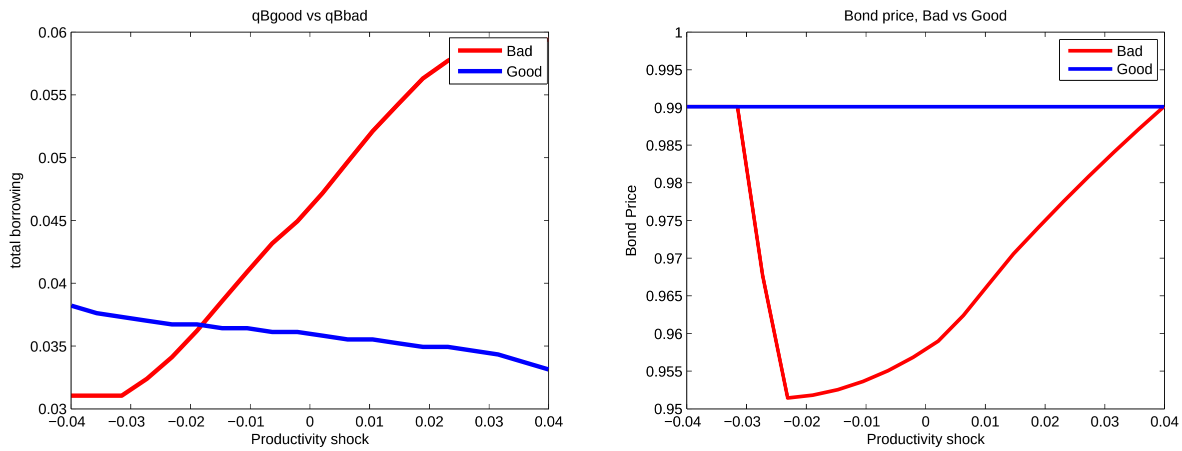

Figure 5 (left panel) reports the primary balance of the Good type (blue line), and of the Bad type (red line), across productivity states. Figure 5 (right panel) reports the equilibrium bond price of the Good type (blue line), and of the Bad type (red line), across productivity states.

1.3.2 Private information

As already said, we introduce private information in the model assuming that financial markets do not observe the discount factor of the government in charge and therefore do not know its actual default probability schedule. We define reputation as the financial markets' belief that the government is of the Good type,

$$\gamma(G, T, B') = Prob(Good|G, T, B')$$

In the case of public information $\gamma^{Good}(G, T, B') = 1$ while $\gamma^{Bad}(G, T, B') = 0$, by definition. In the case of private information this no longer has to hold. The Bad and the Good government might both have incentives to behave differently with respect to the public information case, in order to deceive the lenders. These incentives will have an impact on the reputation value $\gamma(G, T, B')$ and will affect the lenders' lending policy. It is mainly the Bad government that has incentives to change its choices. The Bad government pays a higher interest rate and would like to be perceived as a Good government in order to receive the risk-free interest rate. The Bad government, changing its behaviour, can try to look like a Good type. In order to do so, it has to make exactly the same choices as the Good government would make. Therefore, the sensible option for the Bad government is either

Figure 6. Incentive to mimic

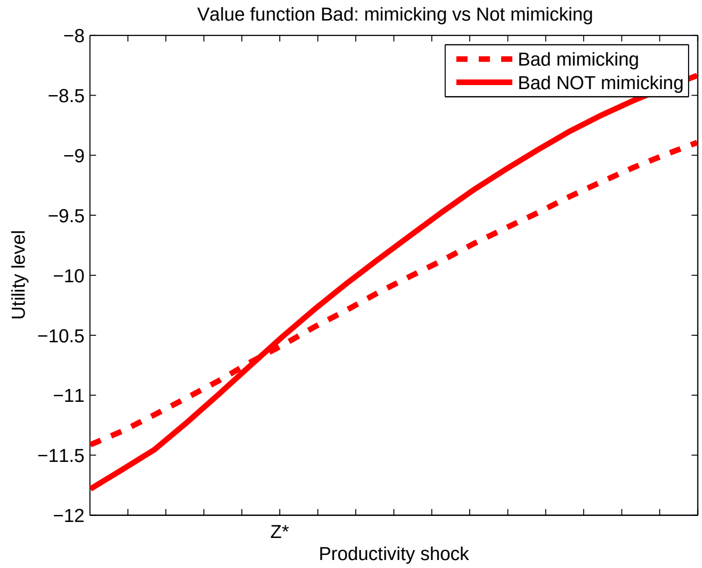

Figure 6 reports the value function of the Bad type when it mimics the Good type (dashed line) and the value function of the Bad type when it follows its own public information plan (solid line), across productivity states.

to stick to its public information plan, which results from the solution of a maximization problem, or to mimic the Good type's plan, in the cases where this alternative guarantees a higher utility. The Good type does not have a direct incentive to follow the Bad's type behaviour, since it does not receive any benefit. The incentives for the Bad government to behave differently with respect to the public information case are present only when the productivity shock is low enough. More precisely, only for those productivity states Z lower than Z^*, i.e. the productivity state corresponding to the point in Figure 4 where the public spending of the Bad and the Good type cross each other. We call Z^* this productivity threshold. Let $V^{Bad}(B, Z; mimic)$ represent the Bad type value function when it mimics the Good type (i.e. chooses the same level of G, T and B' as the Good type). Let $V^{Bad}(B, Z)$ represent the Bad type value function when it follows its own public information plan. Figure 6 shows that for $Z < Z^*$, $V^{Bad}(B, Z; mimic)$ is higher than $V^{Bad}(B, Z)$, meaning that for $Z < Z^*$ the Bad government has incentives to change its behaviour and to copy the Good government's choices. In section 1.3.1 we showed how, given low productivity states, the Bad type is forced to choose low levels of G and B', and high levels of T. However, if the Bad type wants to mimic the Good type, it can unambiguously increase its own utility, as it increases spending and borrowing, and reduces taxation. However, for $Z \geqslant Z^*$ the Bad government does not have incentives to change its behaviour. Overall, in the private information setting, for productivity levels lower than Z^* one of the agents has an incentive to deviate from its public information strategy. Therefore the public information separating equilibria are not sustainable when private information issues are present. With private information the model presents a different solution. According to the level of the productivity shock, the model delivers two different equilibria: a pooling equilibrium and a separating equilibrium. Before showing the solution of the model, in the context of private information we need to add to the equilibrium concept reported in section 1.2.4 the following requirement. We need to specify a rule that defines reputation $\gamma(G, T, B')$ for each possible state of the world, i.e. also for those out-of-equilibrium states of the world. In this case $\gamma(G, T, B')$ can be thought as a system of in-equilibrium and out-of-equilibrium beliefs. Given these beliefs, each agent must choose the actions that are the best responses to the strategies of the other agents.

Pooling equilibria

For each $Z < \bar{Z}$, the model delivers a pooling equilibrium in which both types pool on the same level of spending (G^P), taxation (T^P) and borrowing (B'^P). It is important to note that the optimal choices of B', G and T are inherently related to one another. In particular, if the two types of government choose the same level of borrowing, this implies they also choose the same level of spending and taxation, since the Intra-temporal condition and the budget constraint are the same for both types, irrespective of the discount rate. For this reason and for ease of notation we may think of the pooling equilibrium simply in terms of an equal choice of borrowing, and implicitly refer to an equal choice of spending and taxation.

Proposition 1: For each $Z \leq \bar{Z}$ the model generates a pooling equilibrium, where both types of government pool on the Bad type public information plan.

Proof: See Appendix A

When productivity is minimal ($Z < \bar{Z}$), the Good type reduces its borrowing and asks for exactly the same level of borrowing as the Bad type demands in public information. In other words, the Good type mimics the Bad type. Lenders charge the now unknown type of government an interest rate q^M, a weighted average of the two different interest rates that they would have charged the types in the case of public information:

$$q^M(B', Z) = q^{Good}(B', Z) \times \gamma(G, T, B') + q^{Bad}(B', Z) \times (1 - \gamma(G, T, B')) \qquad (17)$$

Reputation $\gamma(G,T,B')$ is now the prior lenders have about the government's being a Good type. However, in the pooling equilibrium, independently of the value of the prior:

$$q^M(B'^P, Z) = q^{risk-free}$$

given both $q^{Bad}(B'^P, Z)$ and $q^{Good}(B'^P, Z)$ are equal to $q^{risk-free}$, as shown by Lemma A.[14]

The pooling equilibrium is supported by out-of-equilibrium beliefs γ[15] as the following:

$$\gamma = \begin{cases} 1 & if \ B' < B'^P \\ 0 & otherwise \end{cases} \tag{18}$$

These beliefs imply that if the government chooses a level of B' lower than the equilibrium one, then it is perceived as Good with probability one. The beliefs also imply that if a type chooses to borrow more than the equilibrium quantity B'^P, lenders attach a zero probability to it being the Good type. Given the out-of-equilibrium beliefs, we can show that neither the Bad nor the Good type has incentives to deviate from the pooling equilibrium. No type has an incentive to choose a lower B', despite the gain in reputation. In fact, reducing the level of borrowing would only diminish utility without any benefit. Lower B' implies lower G and higher T but the same interest rate, since they already borrow risk-free. At the same time, no one has an incentive to increase B'. In this case, the deviating government would be rewarded with the Bad type interest rate schedule. In the previous section we showed how in this case, even the Bad government lowers its borrowing and settles on the lower level $B'^{Bad} = B'^P$.

The pooling equilibrium implies that the fiscal policies of the Good and Bad type are exactly the same. Lenders are not able to identify the type in charge and $\gamma^{Good}(G,T,B') = Prior$, $\gamma^{Bad}(G,T,B') = Prior$. However, reputation does not matter. The level of borrowing on which both types pool implies a zero probability of default for both. The Good type, mimicking the Bad type, implements austerity with respect to its choices in the case of public information. Facing an unavoidable loss in reputation, austerity is the optimal response to

[14] B'^P is exactly the same level of borrowing as the Bad type chooses in public information, B'^{Bad}. We showed that for this level of borrowing and for the productivity shocks we are considering, $Z < \bar{Z}$, the Bad type is charged the risk-free interest rate, because its default probability is equal to zero.

[15] $\gamma(Good)$ represents the out-of-equilibrium probability that the agent making the deviation will be perceived as the Good type

prevent an unsustainable interest rate. The pooling equilibrium arises from the fact that the Bad government wants to exploit the private information situation, in order to improve its reputation and to borrow more. The Good government does not manage to guarantee its own reputation but responds by taking actions that make reputation non-important, i.e. reducing borrowing and spending, and increasing taxation, lest financial markets mistake it as being less creditworthy than it is. The following propositions analyse the properties of the pooling equilibria above.

Proposition 1.1: The pooling equilibria are resistant to the Intuitive Criterion, as developed by Cho and Kreps (1987).

Proposition 1.2: Given the productivity shock, the pooling equilibrium is unique.

Proof: See Appendix A

Separating equilibria

For each $\bar{Z} < Z < Z^*$, the model delivers a separating equilibrium, different from the public information one. The Good type reduces borrowing and spending and increases taxation[16] as much as needed in order to send a credible signal to the markets about its discount rate. In this way lenders can identify the Good type and charge it with the interest rate schedule that reflects its true default probability. The Good type manages to maintain its reputation through its fiscal policy. The Good type restrains the minimum that is sufficient to discourage the Bad type from copying its decisions. Indeed, the Bad type is more present-biased and it finds more costly to tighten its budget, with respect to the Good type. Therefore, the Bad type does not have incentives to mimic the Good type and does not change its fiscal policy with respect to the public information case.

Proposition 2: For each $\bar{Z} < Z < Z^*$ the model generates a separating equilibrium. The Good type reduces spending and borrowing and increases taxation more than the Bad type does, in order to obtain the risk-free interest rate. The Bad type maintains its public information plan.

Proof: See Appendix A

[16]With respect to the public information case.

In contrast to the pooling equilibrium, in the separating equilibrium the Good type does not settle for the Bad type's public information plan: it restricts more. The reason is the following. If the Good government chose the Bad type's public information plan, lenders would not be sure about the type they are facing and they would charge both types with the interest rate $q^M(B'^{Bad}, Z)$, an average between the Good type's interest rate (the risk free) and the Bad type's interest rate (no longer risk-free for such productivity levels, as Lemma A shows). This interest rate would be high for the Good government and low for the Bad one. The Good government, given its high discount rate, finds it profitable to reduce spending and increase taxation up to the point where the Bad government is indifferent whether to mimic or not. At this point, the separating equilibrium, the Good government receives again the risk-free interest rate. The out-of-equilibrium beliefs that support the equilibrium are:

$$\gamma = \begin{cases} 1 & if\ B' < B^{Good} \\ 0 & if\ B' > B^{Good} \end{cases} \tag{19}$$

The out-of-equilibrium beliefs are similar to those in the pooling case. If lenders observe a level of borrowing lower than that of the Good type (B'^{Good}), they assume the deviating agent is a Good type. If lenders observe a borrowing level higher than that of the Good type, they attach a zero probability that the agent making the deviation is the Good type. As the equilibrium is a separating one, lenders can identify the agents and $\gamma^{Good}(G, T, B') = 1$, $\gamma^{Bad}(G, T, B') = 0$. The Good government maintains its reputation with respect to the public information case, but it has to pay a cost in terms of a more restrictive fiscal policy. The Bad government does not change its fiscal policy and sticks to its public information plan. The following propositions summarize the properties of the separating equilibria. For a more detailed discussion, see Appendix A.

Proposition 2.1: The separating equilibria are resistant to the Intuitive Criterion, as developed by Cho and Kreps (1987).

Proposition 2.2: Given the productivity shock, the separating equilibria are not unique. However, our separating equilibria are the unique equilibria resistant to the Intuitive Criterion.

Proof: See Appendix A

1.3.3 Discussion of the results

Here we summarize the results shown in section 1.3.2, with the reminder that what we have presented so far is the behaviour of the model in a representative period t, where no government defaults.[17] Figure 7 summarizes the two sets of equilibria that the model delivers in the case of private information. Very low productivity shocks ($Z < \bar{Z}$) generate the pooling equilibria. Higher productivity shocks ($\bar{Z} < Z < Z^*$) generate the separating equilibria. In the three panels of Figure 7, the red lines represent the Bad government's fiscal policy, which is the same in both the public and in the private information frameworks. The blue dotted lines represent the choices of the Good government in public information, while the blue solid lines represent the choices of the Good government in private information. We define fiscal austerity as the difference between the fiscal policy of the Good government in the two information settings.[18] The so-defined fiscal austerity is the fiscal policy tightening which depends only on the private information constraint, but that it is not related to the macro fundamental conditions of the economy. Fiscal austerity arises only in recession, in particular for those productivity shocks $Z < Z^*$. In those cases, the government reduces spending and borrowing, and increases taxation. Therefore, the government finds it optimal to provide a procyclical response, as opposed to the countercyclical/acyclical response it would implement in the unconstrained first best case, in the absence of the private information constraint.

It is important to highlight the intuition behind these results. Here we illustrate why fiscal austerity in recession is the optimal response of a benevolent government. Given a private information constraint, we show that fiscal austerity is the option that guarantees the lower loss for the household welfare. First, we focus on the welfare costs of fiscal austerity, in terms of lower government spending and lower private consumption. Second, we concentrate on the benefits, in terms of improved reputation and government budget. When the Good government raises taxation and reduces spending, it reduces the household welfare. As a consequence of the impact on output of the tax rise and of the tax itself, the tax hike depresses consumption, given that $C = \frac{Y}{(1+T)}$. As the household utility function is increasing in C and G, the tighter fiscal policy generates a welfare cost equal to $\left(\Delta W^C + \Delta W^G\right)$. However, the restrictive fiscal policy, together with this cost, generates a welfare gain, ΔW^R, related to the government reputation in financial markets. We can decompose the welfare gain into

[17] Moreover, we also remind that the results reported have been obtained fixing the level of the inherited bond B, set to an average value. In the next section we discuss how the results change with the level of the inherited bond B.

[18] We look at the Good government because the Bad government implements a procyclical fiscal policy and therefore always implements austerity in a recession. Instead, we want to focus on a government that in general conducts a countercyclical policy and changes its behaviour only in certain cases.

Figure 7. Equilibria in Private Information

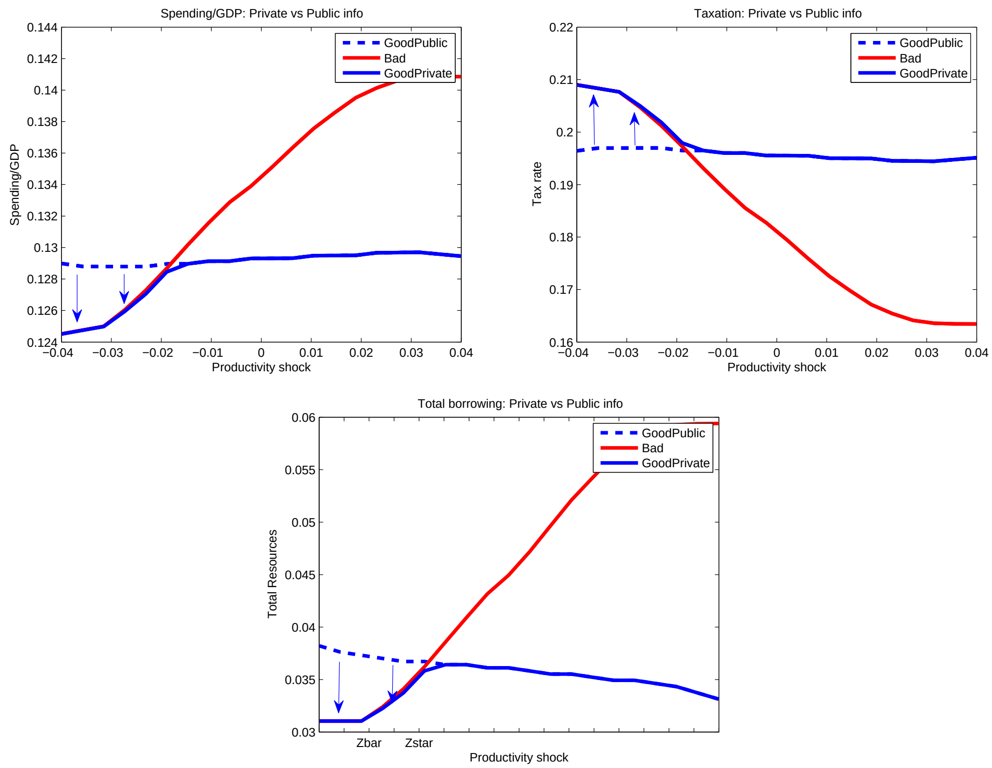

Figure 7 reports the tax, spending and borrowing policy of the Good type in public information (blue dashed line), the Good type in private information (blue solid line) and the Bad type in both information settings (red line).

two sub-components. The first component, ΔW^S, quantifies the benefit of borrowing at a lower rate and having fewer repayments in the next period. We refer to this as the benefit of austerity in terms of signalling. The second component, ΔW^{GB}, quantifies the benefit of having a balanced budget. Overall, $\Delta W^R = \Delta W^{GB} + \Delta W^S$. First, we show that for all the productivity shocks $Z \leq \bar{Z}$, $\Delta W^S = 0$ and $\Delta W^R = \Delta W^{GB}$. Second, we show that for all the productivity shocks $\bar{Z} < Z < Z^*$, $\Delta W^{GB} = 0$ and $\Delta W^R = \Delta W^S$.

We explained in the previous section that for $Z \leq \bar{Z}$, the Good government reduces its borrowing and settles on a level $B'^P = B'^{Bad} \leqslant \bar{B}$. Following Equation (18), if the government does not do so and asks for a borrowing $B' > B'^P$, it is charged a price $q^{Bad}(B', Z)$. Lemma A shows that when $Z \leq \bar{Z}$ a perceived Bad type raises less resources from financial markets if it borrows an amount $B' > \bar{B}$ (i.e. no austerity), than if it borrows an amount B'^P (i.e. austerity). This is because $q(B'^P, Z) * B'^P > q(B', Z) * B'$, despite $B'^P < B'$. In other words, a level of borrowing $B' > B'^P$ produces an unbalanced budget. The government does not succeed in raising enough resources from financial markets and it is forced to increase taxation and lower government spending more than it planned. This produces a welfare cost ΔW^R higher than the one produced in the case of a fiscal consolidation where the government borrows the amount B'^P. For this reason, the choice of the government about implementing the austerity plan or not is trivial. The government does not even trade-off a tighter fiscal policy with lower interest rates. It simply observes its budget and realizes that its budget and its fiscal policy are in better shape if it voluntarily borrows less. In this sense $\Delta W^S = 0$ and $\Delta W^R = \Delta W^{GB}$. We name this type of fiscal austerity a *budgetary austerity*.

On the other hand, for $\bar{Z} < Z < Z^*$, the state of the recession is not deep and government default probabilities are not too high. For these levels of productivity, if the government does not consolidate, the total amount of resources raised from financial markets is higher than the amount obtained if it does consolidate, i.e. $q(B'^S, Z) * B'^S < q(B'^{Good}, Z) * B'^{Good}$. This implies that $\Delta W^{GB} = 0$. However, if the government does not consolidate, it is charged a higher interest rate. The government implements austerity because its benefits in terms of lower interest rate, achieved through signalling, is higher that its cost in terms of reduced borrowing. In this case, as $\Delta W^{GB} = 0$ we have that $\Delta W^R = \Delta W^S$. For this reason we name this type of fiscal austerity a *signalling austerity*.

Role of inherited debt B

In this section we highlight the implications for fiscal policy of starting the representative period t with a different inherited levels of debt B. As we said, the results of the previous sections assumed the government inherited an average level of debt B. Here we show the effect of starting period t with a lower or higher level of debt. The main result is that a higher initial level of debt widens the range of productivity shocks for which the two governments are engaged in the signalling game. The higher initial debt increases the borrowing needs of the two governments. However, the Bad government cannot appeal to financial markets to borrow, given that it is already constrained by the default probability even with a lower initial level of debt. In order to repay the inherited bond B, the Bad government has to increase taxation and reduce spending even more. The Good government is instead less constrained and can resort more easily to financial markets, without having to increase taxation or decrease spending. This fact amplifies the difference between the fiscal policies of the two types of government and generates stronger incentives for the Bad government to mimic the Good government, increasing the range of shocks that produce the signalling game. At the opposite extreme, when initial debt is very low, the Bad type has to roll-over less debt and it is less constrained in borrowing. In case it is allowed by financial markets to borrow more than the Good type, this eliminates any need for the Bad government to copy the Good government. In such situation, there is no signalling game and each type follows its own public information fiscal policy plan, independently on the information environment.

Figure 8 summarizes the effect of initial debt on the range of productivity shocks that generate the signalling game. For low levels of B the two governments are not engaged in the signalling game: the presence of private information does not affect fiscal policy and there is no austerity. As debt increases, the range of productivity shocks generating the signalling game increases, as represented by the black area in Figure 8. Therefore, we conclude that the initial level of debt is a very important parameter, on which depend both the choice of implementing fiscal austerity and the magnitude of the fiscal consolidation to adopt.

Figure 8. Initial Debt B

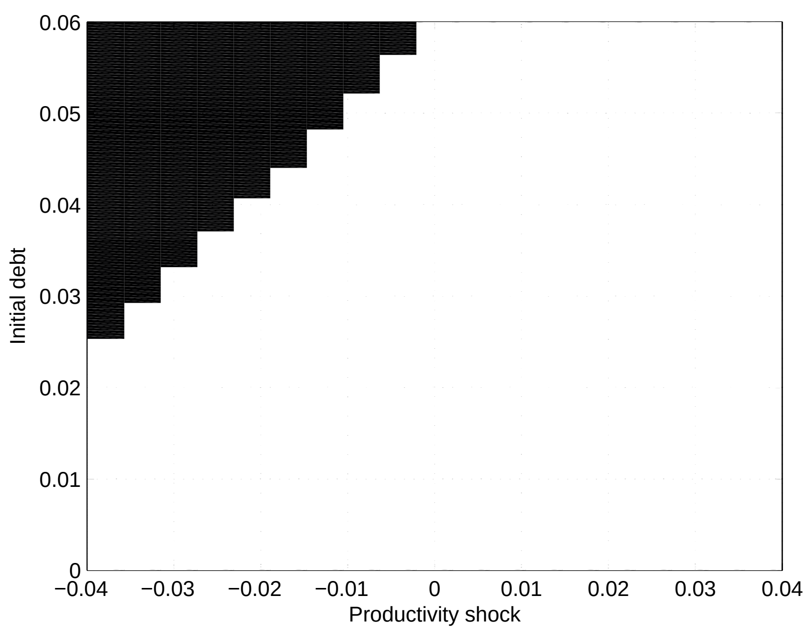

Figure 8 reports the range of productivity shocks that generate the signalling game (black area), for each possible initial level of debt B.

1.4 Results: Numerical simulations

In this section we present the results in terms of the simulation of the fully fledged model. We do not look anymore at the representative period t, which served only to describe the qualitative behaviour of the model. We now simulate the model and we analyse its quantitative properties. The model is solved both in the case of public information and in the case of private information. We run 1000 simulations of the model, each of length 1000 periods. First, we simulate the economy assuming each government is never replaced (i.e. $\pi = 0$), in order to highlight explicitly the different behaviour of the two types of government. Then we show how a different assumption on political turnover affects the results. Table 3 (first panel) reports, for the case of public information, the average correlation between de-trended output Y and primary balance $PB = q * B' - B$, and the correlation between de-trended output Y and the tax rate T, for the two types of governments.[19] With public information, following the intuitions oulined in section 1.3.1, the Good government follows a countercyclical policy: it borrows less in expansion and more in recession, increasing taxation as the economy improves. At the opposite extreme, the Bad government behaves in a very procyclical way. With private information, however, the implications of the model are different, as Table 3 (second panel) shows. While the Bad government does not change its policy with respect to public information and therefore the correlations are the same, the Good government implements a very different fiscal policy, generating a change in the average cyclicality of its fiscal policy. The Good government moves from a countercyclical fiscal policy to a procyclical policy. Following the same logic shown in section 1.3.2, depending on the productivity realization, the Good government either pools with the Bad government or separates. However, independently on the type of equilibrium achieved, the correlation coefficients make clear that with private information the Good government follows on average a procyclical fiscal policy. Moreover, as Table 3 (third panel) shows, there is a stark difference in the correlations once they are calculated conditional on the economy being in an expansion (i.e. when de-trended output is positive, $Y > 0$) and when calculated conditional on the economy being in a recession ($Y < 0$). The reason for this difference lies on the incentives of the Bad government to mimic. The Bad government mimics the Good government only when the productivity shock is negative enough. Only in these cases the Bad government is more constrained than the Good government with borrowing. For this reason, the Good government increases taxation and reduces borrowing, in order to avoid the rise in the interest rate that would appear if the Bad government copied its choices. This mechanism generates a procyclical behaviour in the Good government's fiscal policy in a recession. However, in an expansion, there are no incentives to mimic from the Bad type and the Good government can follow its first best countercyclical policy. The average between these two opposite fiscal cyclicalities produces an overall milder procyclical fiscal

[19] The variables Y, PB, T are de-trended using the Hodrick-Prescott filter, with a bandwidth equal to 1600.

policy for the Good government.

Table 3. Correlation coefficients: Public and Private Information

Public Information			Private Information		
	$\rho(T, Y)$	$\rho(PB, Y)$		$\rho(T, Y)$	$\rho(PB, Y)$
Good	0.23	-0.22	Good	-0.39	0.40
Bad	-0.38	0.41	Bad	-0.38	0.41

Private Information, Good		
	$\rho(T, Y)$	$\rho(PB, Y)$
Good, when $Y > 0$	0.13	-0.14
Good, when $Y < 0$	-0.73	0.75

Table 3 reports the correlation coefficients between the tax rate and output and the correlation coefficients between the primary balance and output obtained by simulating the model. The first panel reports the results for the case of public information; the second panel, for the case of private information. The third panel reports the results for the case of private information, for the Good government alone, distinguishing when $Y > 0$ and when $Y < 0$.

We now use the model simulations to illustrate in a dynamic setting the aforementioned difference in the fiscal policy of the Good government in recessions and expansions. In particular, we study the behaviour of the tax rate and primary balance of the Good government around a series of negative productivity shocks. However, these shocks cannot be such that the Bad government, if in power, would default.[20] Figure 9 reports the policy function of the Good government in the two private information settings, during five periods of the simulation characterized by such negative productivity shocks. In public information, the Good government reacts to the negative shock by decreasing taxation and increasing borrowing. The same Good government, in the case of private information, cannot provide the first best countercyclical response. In order to avoid high interest rates, it implements the opposite policy and it increases taxation and decreases spending, generating a very procyclical policy.

[20] In such cases the Good government follows its first best full information fiscal policy. The two governments separate through the default decision of the Bad government, as we explain better later in the text.

Figure 9. Tax rate and Primary Balance around a negative shock

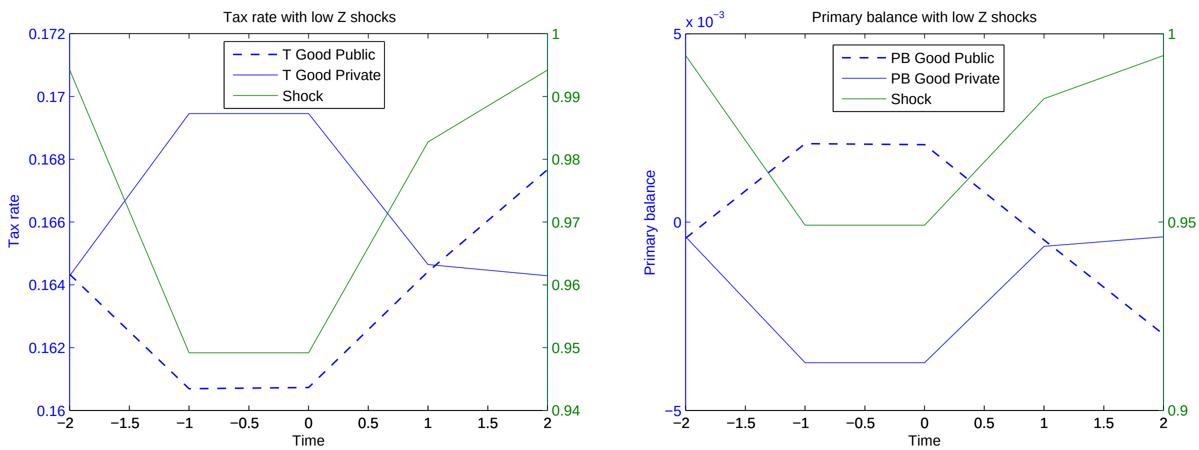

Figure 9 reports the evolution of the tax rate (left panel) and the cyclical primary balance (right panel) two periods before and two periods after a negative shock.

In case the productivity shock is too negative, the Bad government defaults. The two governments separates because one defaults while the other does not. The Good government can follow its full information plan even in a recession. However, this is a rare event, not able to influence the result in terms of the average procyclicality of the Good government fiscal policy during recession periods. Finally, given the calibration of the model, there is not a situation in which both government default, as the Good government never defaults in equilibrium, given its high discount rate in the parametrization of the model.

At the opposite extreme, when the economy is hit by a series of positive productivity shocks, the difference between the response of the Good government in the two information settings disappears, as Figure 10 shows. In this case, even if financial markets cannot directly observe the discount factor of the government, markets are able to charge the appropriate interest rate schedule to each government, because the Bad type does not want to mimic the Good type and the two types separate. The Good government, independently of the information setting, follows his first best fiscal policy and, following a positive shock, increases taxation and reduces borrowing.

We now study the effect of political turnover. The results shown were found in the case of $\pi = 0$. We now show how the simulations change when π is different from zero, in particular with $\pi = 5\%$. This value represents an unstable economy, implying an average

Figure 10. Tax rate and Primary Balance around a positive shock

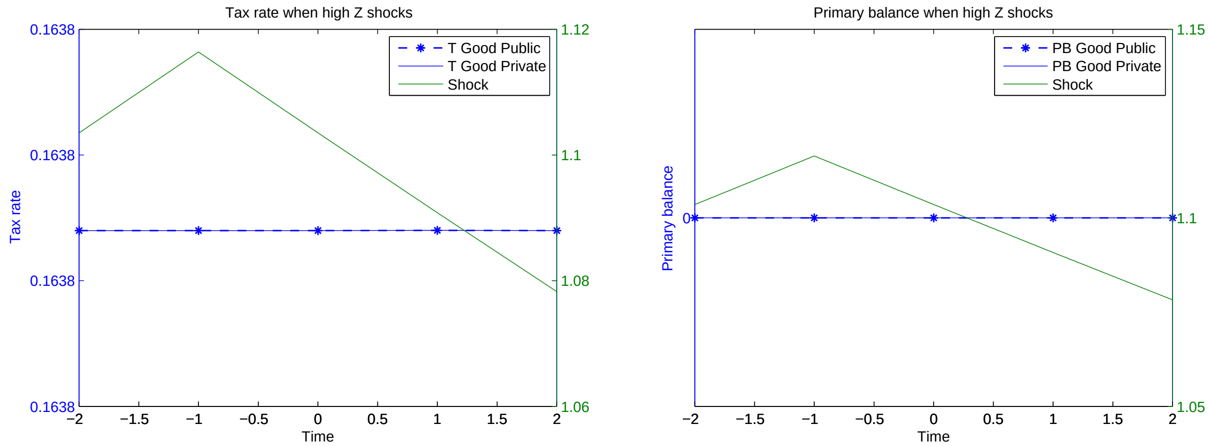

Figure 10 reports the evolution of the tax rate (left panel) and the cyclical primary balance (right panel) two periods before and two periods after a positive shock.

government tenure of 5 years. Table 4 reports the corresponding results.[21] The higher π generates a decrease in the degree of procyclicality of the Good government with private information. Following Equation (14), the interest rate schedule of the Good type is, ceteris paribus, higher with respect to when $\pi = 0\%$. For the Bad type, at the opposite, it is lower. The reduced difference in the interest rate schedule of the Good and Bad type reduces the gains from mimicking for the Bad government, which has fewer incentives to copy the Good government policy. This allows the Good government to follow more closely its own fiscal policy plan. Overall, the degree of political instability does not have a major impact on the qualitative results of the model, while it has an impact on the quantitative ones.

[21] We report the correlation coefficients for both types of government, calculated using only the periods in which each government is actually in power.

Table 4. Correlation coefficients, when $\pi = 5\%$

Public Information			Private Information		
	$\rho(T,Y)$	$\rho(PB,Y)$		$\rho(T,Y)$	$\rho(PB,Y)$
Good	0.26	-0.26	Good	-0.17	0.21
Bad	-0.37	0.40	Bad	-0.37	0.40

Private Information, Good	$\rho(T,Y)$	$\rho(PB,Y)$
Good, when $Y > 0$	0.18	-0.19
Good, when $Y < 0$	-0.45	0.50

Table 4 reports the same information as Table 3, calculated when $\pi = 0.05$.

1.4.1 Robustness

In this section we perform a robustness analysis. In particular we study the role of the degree of substitutability between private consumption and public spending and we analyse the case where the tax is levied on labour instead that on consumption. To study the influence of the functional form of the utility function, we consider a CES aggregation function for preferences in private consumption and public spending

$$X = \left[\delta G^{-\mu} + (1-\delta)\left(C - \frac{L^{1+\psi}}{1+\psi}\right)^{-\mu}\right]^{-\frac{1}{\mu}} \tag{20}$$

The utility function in this case is given by

$$U\left(C, 1-L, G\right) = \frac{X^{1-\sigma}}{1-\sigma} \tag{21}$$

When the parameter μ is close to -1, C and G are close to being perfect substitutes. When $\mu = 0$ we have a Cobb-Douglass aggregator, while μ towards infinity implies that private consumption and public spending are close to being perfect complements. We solve the model for values of μ equal to -0.9, 0 and 50. The model delivers virtually identical results. The only difference is in the magnitudes. As μ increases, the amount of public spending compared to private consumption increases, bringing the ratio C/G closer to 1. Table 5 reports the results in terms of correlation coefficients for the case of μ equal to -0.9, 0 and 50.

Table 5. Correlation for $\mu = -0.9$ (top panel) and $\mu = 50$ (bottom panel)

Public Information	$\rho(T,Y)$	$\rho(PB,Y)$
Good	0.24	-0.22
Bad	-0.38	0.41

Private Information	$\rho(T,Y)$	$\rho(PB,Y)$
Good	-0.40	0.40
Bad	-0.38	0.41

Private Information, Good	$\rho(T,Y)$	$\rho(PB,Y)$
Good, when $Y > 0$	0.12	-0.14
Good, when $Y < 0$	-0.58	0.60

Public Information	$\rho(T,Y)$	$\rho(PB,Y)$
Good	0.21	-0.21
Bad	-0.37	0.39

Private Information	$\rho(T,Y)$	$\rho(PB,Y)$
Good	-0.35	0.36
Bad	-0.37	0.39

Private Information, Good	$\rho(T,Y)$	$\rho(PB,Y)$
Good, when $Y > 0$	0.11	-0.13
Good, when $Y < 0$	-0.56	0.59

Table 5 reports the same results as Table 3. However, in this case the utility function used to solve the model is given by Equations (35) and (36). The parameter μ is set equal to 0.9 (top panel), while $\mu = 50$ (bottom panel).

Finally, we consider the case where the tax T is levied on labour, instead of consumption. The budget constraint of the household is now

$$C_t = (1 - T_t) A_t L_t$$

The optimal level of labour, $L^* = ((1-T)Z)^{\frac{1}{\Psi}}$, depends in the same manner on the tax rate as in the case of the consumption tax. The derivative of output with respect to the tax rate is given by $-\frac{1}{\Psi}((1-T)Z)^{\frac{1}{\Psi}-1}Z^2$ and implies very similar fiscal multipliers as in the benchmark case. The implication for fiscal policy is exactly the same, both in qualitative and quantitative terms.

1.5 Empirical evidence

In this section we provide some empirical evidence to support the intuitions proposed in the previous section. Despite not formally testing the model, we show that the model main implications are consistent with the empirical findings. In particular, we illustrate how on average fiscal policy is procyclical in a recession characterized by high debt and uncertainty about the type of government financial markets are lending to, meaning a period characterized by private information issues. After discussing how to identify such periods, we show that for the OECD countries in the period 1995-2009[22], fiscal policy in this type of recession correlates positively with the cycle, as predicted by the model.

To proxy for the presence of private information in debt markets, we use the distance in time from the general elections for a newly elected government. We argue that a new government taking power, if elected for the first time, is not trusted by financial markets. We consider the first year of the mandate of this government as a period characterized by private information. In this case, the dummy $PI_{i,t}$ takes value one, otherwise zero.[23]

In order to identify a recession,[24] we consider a dummy $R_{i,t}$, which takes value one when the output gap is negative and zero otherwise. Finally, the dummy $HD_{i,t}$ identifies the periods characterized by high debt, defined as periods where the debt-to-GDP ratio is higher than 60%. We interact the three dummies and we create the dummy

$$D_{i,t} = PI_{i,t} * R_{i,t} * HD_{i,t}$$

which proxies a period characterized by private information, recession and high public debt. In such periods the model predicts that governments will invert the cyclicality of fiscal policy

[22]We do not consider the years 2010-2014, so as to be confident that our results are not driven by the fiscal policy developments of the last few years in Europe

[23]The first year of the mandate of the Brazilian PM Lula is an illustrative example. Lula was distrusted by foreign financial markets as he was thought to bring Brazil to default. Just after his election in 2002, financial markets started to worry about the policies the new government was about to implement. Brazil experienced a rise in inflation and assets price collapsed. However, after a few months the government managed to convince the public through sound policies and gained trust in financial markets. The country then experienced a period of prolonged growth.

[24]Here with recession we mean a period of below capacity

and implement austerity. Table 6 reports the mean value of the dummy variables PI, R, HD and D. According to our measure $PI_{i,t}$, private information was present in 6.8% of the time periods covered by the sample. Among those cases, many of them are characterized by the presence of high debt and recession ($D_{i,t} = 1$ in 4.9% of the full sample[25]). To give an example, our measure $D_{i,t}$ captures year 1995 for Italy. In Italy, year 1995 was the first year of the mandate of the government held by Silvio Berlusconi (in power for the first time). The output gap was negative and the debt-to-GDP ratio was around 120%.

Table 6. Summary statistics

Dummy	Mean Value
$PI_{i,t}$	0.068
$R_{i,t}$	0.509
$HD_{i,t}$	0.575
$D_{i,t}$	0.049

To measure the cyclicality of fiscal policy we propose two approaches. The first one calculates sample correlations between the output gap and the fiscal policy indicators chosen, dividing the sample according to the dummy $D_{i,t}$. The second approach follows the methodology proposed by Alesina, Campante and Tabellini (2008) and uses regression analysis. We now report the results of the first approach. The two panels of Table 7 provide the correlations between the output gap and four indicators of fiscal policy: the change in the cyclically adjusted primary balance ($\Delta CAPB$), the change in the budget balance (ΔGB), the ratio of primary government spending to GDP (G/Y) and the ratio of primary discretionary government spending to GDP,[26] (G^D/Y). Appendix B reports detailed information about the definitions of the variables and the countries included in the empirical analysis. Panel A of Table 7 calculates the correlation coefficients dividing the sample according to the dummy $D_{i,t}$. The correlations show that there is a dramatic change in the degree of cyclicality of fiscal policy, when calculated with $D_{i,t} = 1$ and with $D_{i,t} = 0$. $\Delta CAPB$ and ΔGB correlate positively with the cycle in normal times, meaning that the government follows a countercyclical fiscal policy. However, the correlations change abruptly in the case of a recession characterized by private information and high debt. The same behaviour is observed for G/Y and G^D/Y. The negative correlations of G/Y and G^D/Y with the output

[25]There are 18 observations in the sample for which $D_{i,t} = 1$

[26]Discretionary government spending is calculated by subtracting all fiscal transfers and benefits in kind from government total expenditure.

gap in normal times represent a countercyclical policy while the positive correlations in recession periods represent a procyclical fiscal policy. Panel B calculates the same correlations dividing the sample according to the recession dummy indicator $R_{i,t}$, without distinguishing between recessions characterized by private information and those which are not. The same is done in panels C and D, dividing the sample according to $HD_{i,t}$ and $PI_{i,t}$. For each dummy, the respective fiscal policy cyclicalities calculated when the dummy is equal to one and when it is equal to zero are similar. This suggests that it is the joint presence of private information, recession and high debt that drives governments to change their fiscal policy behaviour, and not simply the stand alone presence of a recession, high debt or private information.

Table 7. Correlations: Panel A, B, C and D

	$\rho(\Delta CAPB, Gap)$	$\rho(\Delta GB, Gap)$	$\rho(\frac{G}{Y}, Gap)$	$\rho(\frac{G^D}{Y}, Gap)$
$D_{i,t} = 1$	-0.58	-0.34	0.17	0.04
$D_{i,t} = 0$	0.13	0.15	-0.30	-0.19
$R_{i,t} = 1$	-0.10	0.07	-0.2	-0.13
$R_{i,t} = 0$	-0.15	-0.08	-0.01	-0.12
$HD_{i,t} = 1$	-0.31	-0.07	0.12	-0.03
$HD_{i,t} = 0$	-0.35	-0.11	-0.06	-0.11
$PI_{i,t} = 1$	-0.40	-0.14	0.07	-0.03
$PI_{i,t} = 0$	0.21	-0.28	-0.01	-0.16

Table 7 reports the correlation coefficients between the different fiscal indicators and output. The top panel (panel A) calculates these correlations dividing the sample according to the dummy variable $D_{i,t}$. The second and third panel (panels B and C) do the same, dividing the sample according to $R_{i,t}$ and $HD_{i,t}$. The bottom panel (panel D), according to the dummy variable $R_{i,t}$.

The second approach that we propose to measure the cyclicality of fiscal policy in different economic conditions relies on the approach followed by Alesina, Campante and Tabellini (2008), which in turn adapt the Gavin and Perotti (1997) method. We measure the cyclicality of fiscal policy estimating the following regression:

$$\Delta F_{i,t} = \beta OutputGap_{i,t} + \alpha D_{i,t} + \Psi(OutputGap_{i,t} * D_{i,t}) + \lambda_1 F_{i,t-1} + \lambda_2 X_{i,t} + \gamma_i + \epsilon_{i,t} \quad (22)$$

where $F_{i,t}$ is the fiscal policy indicator chosen, $OutputGap_{i,t}$ is a measure of the business cycle and $D_{i,t}$ is the dummy variable in question. The term $(OutputGap_{i,t} * D_{i,t})$ represents the interaction between the output gap and the recession dummy. $X_{i,t}$ includes all the single, double and triple interaction terms.

Table 8 reports the results. Because Equation (22) involves a quadruple interaction, it is difficult to interpret the coefficients of the regressions. We report the results in terms of the average semi-elasticity of fiscal policy with respect to the output gap, for all the possible states of the economy. The semi-elasticities are calculated from the regression coefficients, adding among themselves the coefficients of the interaction terms relevant to defining each state of the economy. Once obtained, we test whether the semi-elasticities are statistically different from zero. The results show that, independently of the fiscal policy indicator chosen, governments implement a very procyclical policy in the states of the economy characterized by private information. The semi-elasticities relating to the periods with private information, recession and high debt are all very significant and indicate a positive co-movement between fiscal policy and the economic cycle. This contrasts with the general behaviour of fiscal policy in the other cases, where governments follow mainly a countercyclical or an acyclical policy.

Table 8. Semi-elasticity of fiscal policy w.r.t. the output gap

	$\Delta CAPB$	ΔGB	G/Y	G^{discr}/Y
Private+Recession+HDebt	-0.79***	-0.8***	0.72***	0.82***
Recession	0.23	0.69	-0.88***	-0.56
HDebt	-0.56***	-0.01	-0.07	-0.05
Private	-0.07	0.11	-0.09	0.06
Private+Recession	0.53	0.53	-0.71	-0.38
Recession+HDebt	-0.26	-0.08	0.04	0.24
Private+HDebt	-0.4***	0.43***	-0.58***	-0.51***

Table 7 reports the average semi-elasticity of fiscal policy with respect to the output gap, for the different possible states of the economy. The first row captures the case when jointly there is: 1) a recession, 2) a high level of public debt, 3) the presence of private information. The remaining rows of Table 7 report the remaining combinations among cases 1) to 3).

1.6 Conclusions

This paper investigates why a government might want to implement an austerity programme in an economic downturn, as opposed to a countercyclical response. The question is highly topical in the light of current events and holds several policy implications. Many countries around the world have been implementing restrictive fiscal policies despite a weak economic environment. These policies have been strongly criticized, both by economists and by the general public. It is therefore important to understand a possible rationale for these choices.

We show that, when financial markets do not have a perception about the type of government they are lending to, non-myopic governments optimally implement austerity in a recession. Austerity avoids the consequences of a possible loss in reputation, which would bring about very high interest rates. In a deep recession, the government implements austerity for budgetary considerations, while in a milder recession austerity conveys a signal to financial markets about the creditworthiness of the government.

The results of the model are useful in interpreting the current fiscal policy developments around the world. There is a general consensus that the European debt crisis was triggered by a loss of confidence of market participants in governments, starting when Greece revealed the true state of its national accounting at the end of 2009. In this sense, we can think of the crisis as a factor that shifted financial markets from a situation in which they were able to recognize the type of government in charge to a situation in which there was uncertainty about the type of government markets were lending to, i.e. a situation of private information. The model provides a rationale to explain the procyclical fiscal policies implemented by many European countries, as documented in section 1.2. Our interpretation of the recent European situation is the following. Current European governments are Good types, truly countercyclical, which are experiencing a particular type of recession, characterized by private information. In particular, we can think of the Euro Periphery countries as those countries that experienced the most severe recession. Because the state of the recession was too deep, these countries did not manage to signal their good credit standing. Nonetheless, they had to implement fiscal austerity to avoid an unsustainable rise in the interest rate caused by the inevitable loss in reputation. The effect of the fiscal retrenchment on the economy has been negative, but any alternative option would have resulted in worse outcomes. On the other hand, we can think of the UK as a country that experienced a milder recession. We can explain why the UK introduced austerity measures even if it was not hit by turbulence in the sovereign debt market. The UK government, anticipating the effect of private information, implemented fiscal austerity to send a credible signal to financial markets about its high creditworthiness. The austerity plan was adopted promptly and the UK maintained its reputation and obtained low interest rates.

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Appendix A: Proofs

Lemma A: $\bar{Z}$ is the highest productivity shock that satisfies the following condition:

$$\lim_{B \to \bar{B}^+} \frac{\partial \left[q^{Bad}(B,Z) * B \right]}{\partial B} \leq 0 \tag{23}$$

Proof: Using equation 14 we can write:

$$\lim_{B' \to \bar{B}^+} \frac{\partial \left[q^{Bad}(B',Z) * B' \right]}{\partial B'} = \lim_{B' \to \bar{B}^+} \frac{1}{1+r} \left(\left[1 - \pi P^{Good}(B'_{Bad},Z) - (1-\pi) P^{Bad}(B'_{Bad},Z) \right] - \right.$$
$$(1-\pi) \frac{\partial P^{Bad}(B'_{Bad},Z)}{\partial B'_{Bad}} B'_{Bad} - \pi \frac{\partial P^{Good}(B'_{Bad},Z)}{\partial B'_{Bad}} B'_{Bad} \tag{24}$$

For $Z \to 0$, $P^i(B',Z) \to 1$, for $i = Good, Bad$. Given that $\frac{\partial P^i(B',Z)}{\partial B'} B'$ is a positive number, we have that (24) is $\leqslant 0$. For $Z \to +\infty$, as $P^i(B',Z) \to 0$ we have that (24) is > 0. Indeed, there exists a Z low enough to satisfy condition (23). We call $\bar{Z}$ the highest Z that satisfies this condition. In the same way, every $Z < \bar{Z}$ satisfies condition (23), as $\lim_{B' \to \bar{B}^+} P(B',Z)$ and $\lim_{B' \to \bar{B}^+} \frac{\partial P(B',Z)}{\partial B'}$ are decreasing in Z. #

Proposition 1: Pooling Equilibrium. For $Z \leq \bar{Z}$ the model generates a set of pooling equilibria. The two types pool on a level of spending $G^P = G^{Bad}$, tax rate $T^P = T^{Bad}$ and borrowing $B'^P = B'^{Bad}$. The pooling interest rate $q(B^P,Z)$ is equal to $q^{risk-free}$. $\bar{Z}$ is the productivity shock identified by Lemma A.

Proof: Because of Lemma A, since $B'^P \leqslant \bar{B}$, then $q(B^P,Z) = q^{risk-free}$. We prove that for each $Z \leq \bar{Z}$ there are no incentives to choose either a lower or a higher level of borrowing than the pooling equilibrium level, for both types. For a given $Z < \bar{Z}$, take $B^+ < B'^P$. For Lemma A, as $B^+ < B'^P$, the interest rate $q(B^+,Z) = q^{risk-free}$. Given the constant q, each B^+ corresponds to a certain $T^+$and G^+, with $T^+ > T^P$ and $G^+ < G^P$. As utility U^i is increasing in G and decreasing in T, for $i = Good, Bad$ we have that $U^i(B^+,T^+,G^+) < U^i(B'^P,T^P,G^P)$.[27] Therefore there are no incentives to choose $B^+ < B'^P$, for both types. Now take $B^- > B'^P$. Because of (18) we have that $q(B^-,Z) = q^{Bad}(B^-,Z)$. Therefore, choosing a level of borrowing $B^- > B'^P = B'^{Bad}$, implies that $G^- > G^P = G^{Bad}$, $T^- < T^P =$

[27]given that $T^+ > T^P$, $G^+ < G^P$ and $q(B^+,Z) = q(B'^P,Z)$.

T^{Bad}, where $B'^{Bad}, G^{Bad}, T^{Bad}$ are the optimal levels of borrowing, spending and taxation in public information. As $B'^{Bad}, G^{Bad}, T^{Bad}$ are the solutions of the maximization problem described in section 1.2.2, by construction $U^{Bad}(B^-, T^-, G^-) < U^{Bad}(B'^{Bad}, T^{Bad}, G^{Bad})$. This also implies that $U^{Good}(B^-, T^-, G^-) < U^{Good}(B'^{Bad}, T^{Bad}, G^{Bad})$. Thereby, there are no incentives to choose $B^- > B^P$, for both types. #

Proposition 1.1: The pooling equilibrium is resistant to the Intuitive Criterion, as developed by Cho and Kreps (1987)

Proof: Testing that the pooling B'^P is resistant to the Intuitive Criterion requires the following. Suppose $\exists \widehat{B}$ s.t. Good type, deviating to $\widehat{B}$ is perceived as Good with probability 1. If $U^{Good}\left(\widehat{B}\right) > U^{Good}\left(B'^P\right)$ and if $\exists$ a belief for the Bad type s.t if the Bad type deviates towards $\widehat{B}$ then $U^{Bad}\left(\widehat{B}\right) > U^{Bad}\left(B'^P\right)$, then B'^P survives the Intuitive criterion.[28] Having in mind this requirement, suppose that $\hat{B} < B'^P$. The Good type, choosing a $\hat{B} < B'^P$, does not increase its utility, because the interest rate does not change and U is increasing in B'. There is no profitable deviation for the Good type in the first place. Suppose $\hat{B} > B'^P$. Deviating to a $\hat{B} > B'^P$ the Good type, perceived as Good with probability one, increases its utility, as U^{Good} is increasing in B' for a constant interest rate. However, the same occurs for the Bad type for beliefs γ close to 1, as U^{Bad} as well is increasing in the level of borrowing. In this case there is a profitable deviation for the Good type, but at the same time there are beliefs for the Bad type that allow both types (not only the Good type) to strictly increase their utility. This shows that the pooling equilibrium does not fail the Intuitive Criterion.

Proposition 1.2: Given the productivity shock, the pooling equilibrium is unique.

Proof: In the pooling equilibrium region, there cannot be no separating equilibrium. First of all, a separating equilibrium in which the Good type borrows more than the Bad type cannot exist: the Bad type would want to deviate and mimic the Good type, for the same arguments outlined in section 1.3.2. Second, there cannot be a separating equilibrium in which the Good type borrows less than the Bad type, which instead sticks to its public information plan. In fact, for all $Z \leq \bar{Z}$ the Bad type achieves the risk-free interest rate and the Good type would find profitable to increase its borrowing up to the Bad type's level, as this does not entails costs. Moreover, in the pooling equilibrium region there cannot be no

[28] In the case the condition holds for every possible $\widehat{B}$.

nor a different pooling equilibrium where both types pool on a different level of borrowing. If both types pool below B'^P they can increase utility deviating to a higher B' because, despite the beliefs, they would still borrow in the risk-free region. They cannot pool above B'^P because the Good type would receive a higher interest rate than the risk-free one and it would prefer, given the out-of-equilibrium beliefs, to reduce borrowing by ϵ and reach the risk-free interest rate.

Proposition 2: Separating equilibrium. For $\bar{Z} < Z < Z^*$ the model generates a set of separating equilibria. The Good type chooses a level of borrowing B'^S, a level of taxation T^S and a level of spending G^S. It obtains the risk-free interest rate. The Bad type chooses its public information plan, B'^{Bad}, T^{Bad} and G^{Bad} and obtains the corresponding public information interest rate $q(B^{Bad\prime}, Z)$, with $q(B'^{Bad}, Z) < q^{risk-free}$.

Proof: We prove that for $\bar{Z} < Z < Z^*$ there are no incentives to deviate from the separating equilibrium. For a given Z, suppose a type deviates towards $B^+ > B'^S$. According to (19) the deviating agent is perceived as Bad with probability 1 and is charged the Bad type's public information schedule $q^{Bad}(B^+, Z)$. For the Bad type, because $B'^{Bad}, G^{Bad}, T^{Bad}$ derive from the public information maximization problem, $U^{Bad}(B^+, T^+, G^+) < U^{Bad}(B'^{Bad}, T^{Bad}, G^{Bad})$. For the Good type, since by construction $U^{Good}(B'^{Bad}, T^{Bad}, G^{Bad}) < U^{Good}(B'^S, T^S, G^S)$, we have that $U^{Good}(B'^S, T^S, G^S) > U^{Good}(B^+, T^+, G^+)$. Hence, there are no profitable deviations towards $B^+ > B'^S$ for both types. Now suppose the Good type deviates towards $B^- < B'^S$. As $q(B^-, Z) = q(B'^S, Z) = q^{risk-free}$ because of (19), this implies $T^- > T^S$ and $G^- < G^S$. Thereby $U^{Good}(B^-, T^-, G^-) < U^{Good}(B'^S, T^S, G^S)$. For the Bad type, since by construction $U^{Bad}(B'^S, T^S, G^S) \leq U^{Bad}(B'^{Bad}, T^{Bad}, G^{Bad})$, we have that $U^{Bad}(B^-, T^-, G^-) < U^{Bad}(B'^S, T^S, G^S) \leq U^{Bad}(B'^{Bad}, T^{Bad}, G^{Bad})$. Thus there are no profitable deviations towards $B^- < B^S$, for either type. Finally, suppose that the Bad type deviates towards $B = B'^S$, obtaining the risk-free interest rate. The two different β of the two types imply a **single crossing condition**, meaning that for the Good type it is less costly to reduce the level of borrowing than for the Bad type. This guarantees that there exists a B'^S low enough to make $U^{Bad}(B'^S, T^S, G^S) \leq U^{Bad}(B'^{Bad}, T^{Bad}, G^{Bad})$ and $U^{Good}(B'^S, T^S, G^S) > U^{Good}(B'^{Bad}, T^{Bad}, G^{Bad})$.

Proposition 2.1: The separating equilibrium is resistant to the Intuitive Criterion, as developed by Cho and Kreps (1987)

Proof: In a similar way to Proposition 2.1, if the Good type chooses $\hat{B} < B'^S$, it does not increase its utility, because the interest rate does not change and U is increasing in B'. There is no profitable deviation for the Good type in the first place. Suppose $\widehat{B} > B'^S$. Deviating to $\hat{B} > B'^P$, the Good type, perceived as Good with probability one, increases its utility, but so does the Bad type for beliefs γ equal to 1.

Proposition 2.2: Given the productivity shock, the separating equilibrium is not unique. A strategy that prescripts the Bad type to follow its public information plan, and the Good type to reduce borrowing less than the level B'^S identified by Proposition 3 is also a separating equilibrium, using out-of equilibrium beliefs as in 19. However these equilibria are not resistant to the Intuitive Criterion. Other than these, no other equilibria exist.

Proof: In the region $\bar{Z} < Z < Z^*$ there are other separating equilibria, different from the equilibrium identified in Proposition 2.1 by $B'^S, B'Bad$. These equilibria are such that the Bad type still follows its public information plan while the Good type chooses a lower level of borrowing than B'^S. However, these equilibria are not resistant to the Intuitive Criterion. In fact, if we apply the reasoning of the Intuitive Criterion we can show that there are beliefs γ close to 1 for which only the Good type increases its utility by deviating away from this new equilibrium, failing the Intuitive Criterion. We now argue that no other equilibria exist in the region $\bar{Z} < Z < Z^*$. There cannot be a separating equilibrium where the Bad type borrows more than its Public information plan, because such level arises from its maximization problem in the case where lenders can identify its type, as in the separating equilibrium case. Also, there cannot be a separating equilibrium where the Good type borrows more than the Bad type, otherwise the Bad type would try to mimic. Finally, in the region $\bar{Z} < Z < Z^*$ the types cannot pool on the Bad type plan, because the Good type would find optimal to reduce the level of borrowing by ϵ and obtain a lower interest rate. Therefore, there cannot be a pooling above the Bad type plan, because both would want to deviate.

Appendix B: Data

The following is a description of the data used for Section 5. The countries considered in the empirical analysis are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, the United States. We did consider those OECD countries which are usually reputed to follow an average procyclical fiscal policy (for instance Mexico, Turkey, Slovakia, etc). This is because we want to focus only on inherently countercyclical countries, showing how under certain conditions even these countries can implement procyclical fiscal policies. The data are annual and span from 1995 to 2009. We stop at 2009 to avoid our result to be influenced by the recent developments in Europe. In order to measure political turnover we use the "Database of Political Institutions 2012", by P. Keefer. This dataset provides the data relative to every election and government formation, for all of the countries in our sample. The data for the output gap are taken from the OECD Economic Outlook No 93, June 2013. The data on debt ratios are taken from the OECD database: the nominal debt of each country is divided by the nominal GDP, in order to obtain the Debt-to-GDP ratio. The government spending ratio (discretionary and non-discretionary) and the government budget balance are obtained from the OECD database. The government spending ratio is obtained by dividing total nominal government expenditures by nominal GDP. The discretionary government spending ratio is obtained by subtracting from total expenditure the total transfers in kind, and dividing this difference by the nominal GDP. Finally, we use the "Underlying government primary balance, as a percentage of potential GDP" in the OECD database, to measure the cyclically adjusted primary balance.

Chapter 2

Is fiscal consolidation self-defeating? A Panel-VAR analysis for the Euro area countries

2.1 Introduction

The start of the sovereign debt crisis, in early 2010, and the growing tensions in the sovereign debt markets have compelled several Euro area countries to take action in an attempt to reduce fiscal imbalances and preserve their sovereign creditworthiness. Nonetheless, in most of the countries which have undergone significant, and sometimes unprecedented, efforts to correct fiscal imbalances, fiscal consolidation did not result, at least in the short run, in a reduction in the debt-to-GDP ratio whereas economic growth turned out weaker than expected. Against this background, many authors and observers (e.g., Batini et al. (2012), IMF (2012)) have argued in favour of a more temperate approach to fiscal consolidation since the drag of fiscal restraint on economic growth could lead to an increase rather than a decrease in the debt-to-GDP ratio, as such fiscal consolidation may turn out to be self-defeating. In particular, the fall in the GDP growth rate which follows a consolidation episode, at least in the short run, would affect the debt-to-GDP ratio not only via a denominator effect, but also via a numerator effect. The intensity of the latter depends crucially on the size of the automatic response of fiscal policy to a decline in GDP growth (i.e. so-called automatic stabilisers) which offsets, at least partially, the positive impact of a fiscal consolidation on the primary balance. In this regard, the net effect on the debt ratio depends not only on the size of the fiscal multiplier (which measures the change in output following a reduction in the deficit) but also, among other factors, on the size of the automatic stabilisers in the economy.[1] Moreover, should market interest rates increase in reaction to a fiscal consolidation episode and its growth implications, the debt-to-GDP ratio could increase also via this channel[2] (Boussard et al. 2012).

The aim of this paper is to investigate the effects of a fiscal consolidation on the general government debt-to-GDP ratio in order to assess whether and under which conditions self-defeating effects are likely to materialise and whether they tend to be short-lived or more persistent over time. We do so for a sample of Euro area countries for the period 2000Q1-2012Q1 using a panel VAR approach to which, following Favero and Giavazzi (2007), we add the government budget constraint. The main advantage of estimating a debt augmented fiscal VAR is that it allows to trace out the dynamics of the debt-to-GDP ratio while accounting for the simultaneous effects of consolidation on GDP growth, the primary balance and the government interest rate. Moreover, the framework is able to take into account the debt feedback effects, allowing the endogenous variables in the VAR to respond to changes in the debt-to-GDP ratio, as the fiscal rules theory (e.g. Bohn (1998)) suggests. To our knowledge, this is the first study to apply a debt-augmented panel VAR approach to a sample of Euro area countries and to explicitly account for the role of the composition of consolidation on the debt dynamics. In particular, the explicit reconstruction of the debt trajectory following a fiscal shock is another important contribution of our paper to the VAR literature on the macroeconomic effects of fiscal consolidations. In this literature, most of the issues related to the debt sustainability implications of fiscal consolidations have been largely left unaddressed. In fact, the effects of fiscal consolidations on the debt-to-GDP ratio have typically been investigated in the context of the literature on successful fiscal consolidations whose aim is to identify under which conditions a discretionary fiscal policy action is more likely to lead, among other things, to a reduction in the debt-to-GDP ratio compared to the pre-consolidation period. These studies typically use logit or probit specifications to evaluate the probability of successful consolidations (e.g. Alesina and Perotti (1995)). Although intuitive, this framework does not accurately account for the channels through which fiscal consolidation may affect the debt-to-GDP ratio, namely the implications for growth and the primary balance.[3]

[1] The size of the automatic stabilisers is usually proxied by the share of government spending on GDP, for a more formal treatment of the effects of consolidation on the debt ratio see European Commission 2012.

[2] Regardless of the reaction of interest rates to fiscal consolidation, interest payments would increase if the debt ratio increases following a fiscal consolidation episode.

[3] Although the use of a VAR methodology allows us to overcome the above shortcomings, it is worth noting that one limitation of the VAR approach in studying the growth effects of fiscal shocks is that it does

The main finding of our analysis is that following a fiscal consolidation episode, the debt-to-GDP ratio increases initially, for a period up to four quarters, and then starts to decline. The size and length of the initial debt increase depend on the composition of consolidation. In particular, in the case of revenue-based consolidations, the increase in the debt-to-GDP ratio tends to be larger and to last longer than in the case of spending-based consolidations. The composition also matters for the long term effects of fiscal consolidations. Spending-based consolidations tend to generate a durable reduction of the debt-to-GDP ratio compared to the pre-consolidation level, whereas in a revenue-based consolidation the debt-to-GDP ratio tends to revert to the pre-consolidation level without producing any lasting impact in terms of improved sustainability prospects. These findings are driven by two factors: a more pronounced fall in output (denominator effect) and a more subdued improvement in the primary balance (numerator effect) in the case of a revenue-based consolidation compared to a situation in which spending is cut. Moreover, whereas the first factor is more important in explaining the different response of debt on impact, the second one becomes more relevant in explaining the path of debt in the subsequent periods.

We also control for the role of the initial conditions at the time fiscal consolidation is undertaken. In particular, since most of the recent consolidation efforts have been prompted by tensions in the sovereign debt market, we include in the VAR a fiscal stress indicator. We construct this indicator as a dummy variable equal to 1 if a country's market interest rate exceeds its average implicit interest rate by a certain threshold, and equal to zero otherwise. The aim of this indicator is to control for the role of tensions in the sovereign debt markets experienced by some Euro area countries since 2010Q2 (i.e. Greece) and which were triggered by increasing fears about their fiscal sustainability. We find that fiscal consolidation efforts undertaken during a period of fiscal stress tend to be less successful in terms of achieving a sizeable reduction in the debt-to-GDP ratio compared to countries that are not confronted to such a situation. This result holds in particular for spending-based consolidations as the spending shock seems to be less persistent in the fiscally stressed countries than in the other group. On the contrary, tax based consolidations tend to produce self-defeating effects in both groups of countries.

The paper is structured as follows. Section 2.2 presents a review of the fiscal VAR literature, section 2.3 describes our estimation methodology whereas section 2.4 describes the data. Section 2.5 presents the empirical results related to our baseline specification whereas

not allow to differentiate between the effects of contractionary versus expansionary fiscal shocks. It follows that the growth effects of fiscal shocks are treated as symmetric.

section 2.6 illustrates the findings when distinguishing between countries that undertake consolidation at times of fiscal stress and those that are not fiscally stressed. Section 2.7 presents some robustness tests and section 2.8 concludes.

2.2 The macroeconomic effects of fiscal consolidation in the VAR literature

The macroeconomic effects of fiscal policy have been intensively debated over the last decade and the theoretical and empirical studies on the size of the fiscal multipliers have grown into a large body of literature. Existing evidence, however, is far from being conclusive as available estimates of fiscal multipliers span over a broad range of values for both government spending shocks and discretionary tax changes.[4] In their seminal paper on the growth impact of fiscal consolidations, Blanchard and Perotti (2002) apply a structural VAR to a dataset for the US in the postwar period. They find consistent evidence that positive government spending shocks have a positive effect on output, whereas positive tax shocks have a negative effect. They find that fiscal multipliers are often close to one for both instruments. The size and persistence of these effects vary across specifications and sub periods. In particular, the authors find that the size of the tax multiplier drops significantly (to about 0.5) when the eighties are excluded from the sample, whereas the opposite happens to the spending multiplier (it increases to about 1.8).

Burriel et al. (2009) use a structural VAR approach to analyse the effects of fiscal policy shocks on the output of the Euro area as a whole over the period 1981-2007, using a new dataset of quarterly fiscal data developed by Paredes et al. (2009). They find that output multipliers are, in general, very similar in both areas, small and typically below unity. The authors also provide evidence that output multipliers increased steadily after 2000 in both the EMU and the US. Using the same quarterly fiscal dataset as in Burriel et al. (2009), Kirchner et al. (2010) study the evolutions of the government spending multipliers for the Euro area over the period 1980-2008, using a Bayesian time-varying VAR. The main finding of their analysis is that the effectiveness of spending shocks in stimulating economic activity

[4] Boussard et al. (2012) and Coenen et al. (2012) provide a summary of the main results of both the expenditures and net-taxes multipliers in both the based on the VAR literature and the structural models literature

has substantially decreased over time, though in a non-monotonic way. In particular, until the late 1980s short-run spending multipliers increased to reach values above unity; they started to decline afterwards reaching values close to 0.5 in the current decade. At the same time, long-term multipliers show a substantial and continuous decline since the 1980s.

Using a narrative approach for a sample of OECD countries, Alesina, Favero and Giavazzi (2012) find that adjustments based on spending cuts are less recessionary than those based on tax increases and that the former are typically associated with milder and short lived recessions. Looking at the response of different components of aggregate demand to both types of shocks, the authors find that the faster recovery in private investment after a spending-based adjustment compared to a tax based one is the factor that explains best the difference in the response of output to spending-based and tax based adjustments. The possibility that the size of the fiscal multipliers is state and time dependent has received renewed attention since the onset of the ongoing sovereign debt crisis. In particular Auerbach and Gorodnichenko (2012), using a regime-switching structural VAR model, estimate the size of both tax and spending multipliers which vary over the business cycle. They find large differences in the size of fiscal multipliers across recessions and expansions compared to the linear case, with fiscal policy being more effective in times of recessions than in expansions.

However, most of the fiscal VAR studies mentioned above abstract from the implications of fiscal shocks on the debt dynamics. As pointed out in Favero and Giavazzi (2007) for the case of the US, this is an important weakness of standard VAR models, as the debt ratio evolves over time and the possibility that taxes and spending might respond to the level of the debt is not accounted for. The omission of a feedback from the debt level to changes in other fiscal variables causes the coefficients estimated and then used to compute impulse responses to be biased. As shown by the authors, an effect of such bias is that impulse responses are computed along unstable debt paths (i.e. paths along which the debt-to-GDP ratio diverges and the intertemporal budget constraint is not satisfied). Following the work of Favero and Giavazzi (2007), several other papers incorporate public debt in a VAR framework (e.g. Burriel et al. (2009)). Nonetheless, very few studies analyze explicitly the effect on debt of a fiscal shock and no one controls for the composition of the shock and whether it matters for the resulting debt trajectory. The closest paper to ours is Cherif and Hasanov (2012). They estimate the effect of primary surplus shocks on the public debt in the US, focusing on the post-1980 sample. The authors find that the public debt ratio falls in response to a shock to the primary surplus in the first 3 years and then reverts back to its pre-shock baseline in the long run. The lower growth resulting from the consolidation episode counteracts the austerity efforts. Moreover the authors find that when controlling for the initial conditions prevailing in 2011 (i.e. weak growth, low interest rates and inflation, high deficit and rising debt), fiscal consolidation is more likely to result in an increasing debt ratio. As a result, risks to a self-defeating consolidation are higher at times of weak economic growth than in normal times.

Differently from Cherif and Hasanov (2012) we find that, in the Euro area, fiscal consolidation is likely to lead to an increase in the debt-to-GDP ratio immediately after a fiscal shock materializes. In the long run the debt-to-GDP ratio falls to below the pre-shock level if consolidation is implemented on the expenditure side, whereas it reverts to the pre-shock level in case of revenue-based consolidations. Our finding, according to which the recessionary effects of spending-based consolidations are smaller and more short lived that those associated to tax based consolidations, is in line with the finding of Alesina, Favero and Giavazzi (2012).

2.3 Empirical Methodology

The estimation methodology we use is a panel VAR approach. As discussed above, most of the fiscal VAR literature does not consider debt as a variable in the VAR, although this is important for at least two reasons. First of all, the evolution of the debt level following a fiscal shock might affect the response of the main fiscal variables. Governments might react to a higher level of debt by decreasing expenditures or increasing taxation, as pointed out in the fiscal rules literature.[5] Second, changes in the debt ratio may lead to an increase in borrowing costs, thus affecting interest payments and the headline fiscal balance. Therefore, as suggested by Favero and Giavazzi (2007), failure to include the debt as a variable in the fiscal VAR may lead to biased coefficient estimates which in turn lead to biased impulse response functions.

The empirical literature suggests two methodologies to include a debt feedback in a fiscal VAR. The first one is the method adopted by Chung and Leeper (2007), which derive a log-linear approximation of the present value government budget constraint and impose it as a restriction on the coefficients of the VAR. The second one is the Favero and Giavazzi (2007)

[5]See Bohn (1998)

approach discussed above, which adds the government budget constraint as an identity to the model and traces out debt dynamics from it. In the remainder of this paper we follow the approach in Favero and Giavazzi (2007) and we estimate the following specification:

$$Y_{i,t} = \sum_{p=1}^{P} A_p Y_{i,t-p} + \sum_{p=1}^{P} \Gamma_p d_{i,t-p} + u_{i,t} \tag{1a}$$

$$d_{i,t} = \frac{1 + i_{i,t}}{(1 + \pi_{i,t}) * (1 + \Delta y_{i,t})} d_{i,t-1} - \frac{\exp(t_{i,t}) - \exp(g_{i,t})}{\exp(y_{i,t})} \tag{1b}$$

$Y_{i,t}$ is the vector of five variables $[t_{i,t} \;\; g_{i,t} \;\; y_{i,t} \;\; i_{i,t} \; \pi_{i,t}]$, expressed in logarithm, which include government total revenues $t_{i,t}$, expenditures $g_{i,t}$, output $y_{i,t}$, the implicit interest rate on outstanding government debt $i_{i,t}$ and inflation $\pi_{i,t}$. $d_{i,t}$ is the debt-to-GDP ratio, and $u_{i,t}$ is the vector of residuals. P represents the number of lags chosen, and A_p is the time invariant matrix of coefficients relative to the p lag. Γ_p is the coefficient relative to the weakly exogenous regressor d_{t-p}. The second equation, (1b), is a deterministic equation, necessary to reconstruct the debt series from the endogenous variables included in the VAR. This allows us to dynamically solve the model and analyse the response of the system to a shock to either government spending or revenues. Given the relatively short quarterly time series available for many of the Euro area countries in the sample, we estimate a PVAR instead of a country by country VAR. One advantage of the panel structure of the data is that we have a larger number of observations and more degrees of freedom. Moreover, in section 6 we also control for the impact of fiscal consolidation on the evolution of the debt-to-GDP ratio when a country is confronted to a situation of stress in the sovereign debt market. This would have not been possible by focusing on individual countries separately.[6] The panel VAR is estimated with OLS fixed effects. However, as a robustness check in section 7 we also use the Mean Group Estimator suggested by Pesaran and Smith (1995) which yields very similar results, lending support to our conclusions.

As the aim of the paper is to understand the effects of a consolidation episode on the evolution of the debt-to-GDP ratio and to assess under which conditions this ratio increases rather than decreases following a fiscal consolidation episode, it is insightful to look at the debt accumulation equation (2). In a more compact way $(1b)$ can be written as:

[6] A possible solution to these problems could be using Bayesian VAR. We plan to do so in future research.

$$d_t = \underbrace{\frac{1+i_t}{1+\Delta y_t^{nominal}} d_{t-1}}_{} - \underbrace{\frac{T_t - G_t}{Y_t}}_{} \quad (2)$$

The first part of the right hand side of the equation is the so called *snowball effect*. The second one is the *primary balance effect,* as $\frac{T_t - G_t}{Y_t} = pb_t$. Suppose the government reduces its expenditures by 1% of GDP. Will this imply a reduction in the debt-to-GDP ratio d_t by an equal amount? The answer is no. The reason for this is that the debt reducing effect of lower primary spending can be offset by two additional channels. The first channel affects the primary balance itself. Indeed, the primary balance pb can be decomposed as the sum of the cyclically adjusted primary balance ($capb$) plus the cyclical component(cc), such that $pb = capb + cc$. A fiscal consolidation of 1% of GDP (either on the spending or revenue side) is a 1% improvement in the $capb$. At the same time, however, the negative output effect of lower spending (or higher revenues) induces a deterioration in the cyclical component of the primary balance cc, via the so-called automatic stabilizers which operate via lower tax revenues (or higher spending) thus offsetting the positive effects of a decrease in spending. Therefore, the overall impact of a fiscal consolidation on the primary balance is milder. Following the calculations in European Commission (2012), the improvement in pb following a 1% increase in $capb$ can be approximated by $(1 - \epsilon\hat{M})$, where ϵ is the budget balance semi-elasticity and $\hat{M}$ is the adjusted fiscal multiplier, i.e. $\frac{\frac{\partial Y}{Y}}{\partial capb}$, the percentage variation of GDP over a unitarian increase in $capb$. The second channel works via the snowball effect. The fall in economic activity following the fiscal consolidation episode is represented by a lower g_t which, for a given implicit interest rate on outstanding debt and a given debt-to-GDP ratio in $t-1$, causes the first term in the right hand side of equation (2) to grow faster. After some algebraic manipulation of the debt accumulation equation it is possible to find the condition the adjusted fiscal multiplier must satisfy in order to prevent an increase of debt-to-GDP ratio on impact.[7]

$$\hat{M} < \frac{1}{d_{t-1}(1+g) + \epsilon} \quad (3)$$

For illustrative purposes, let's assume an elasticity of tax revenues to output $\epsilon = 0.5$ and $d_{t-1} = 120\%$ and $g = 0.02$, the above formula yields a value of the adjusted fiscal multiplier of 0.58: any value of the multiplier above this level leads to an increase rather than a decrease

[7] For more details on the precise derivation of this result please see European Commission (2012).

in the debt ratio on impact, hence to a self-defeating consolidation.[8],[9]

Against the background of the interactions described above between the debt-to-GDP ratio and fiscal policy shocks, the use of a VAR methodology augmented with the debt accumulation equation represents a very suitable tool to account for these interactions, their relative magnitudes, and their impact on the evolution of debt.

2.3.1 Identification strategy and Inference

A central issue in the fiscal VAR literature is the strategy used to identify the structural shocks. Equation (1a) is a reduced form, and we need to impose $\frac{N*(N-1)}{2}$ restrictions in order to identify the system. What we are interested in is the structural form

$$AY_{i,t} = \sum_{p=1}^{P} A_p' Y_{i,t-p} + \sum_{p=1}^{P} \Gamma_p' d_{i,t-p} + B\varepsilon_{i,t}$$

In particular we want to identify two types of shocks: a spending shock and a tax revenue shock. To this purpose we use the sign restrictions approach developed by Canova and De Nicoló (2002). The use of sign restriction is motivated by the need to overcome a well-documented (though counterintuitive) result in the VAR literature, namely that output grows following a positive tax shock.[10] The use of sign restrictions allows us to impose that the response of output to a positive tax shock must be negative, overcoming the problem outlined above. At the same time we impose a positive response of output to a (positive)

[8] The standard fiscal multiplier, by definition, is $M = \frac{\partial Y}{\partial (T-G)}$. The relationship between M and $\hat{M}$ is the following, $\hat{M} = \frac{M}{1+capbM}$. This formula allows deriving the standard fiscal multiplier from equation 3.

[9] Another channel through which fiscal consolidation might affect the evolution of debt ratio is the interest rate.If the interest rate on government borrowing falls (raises) after a consolidation episode, this movement will progressively feed into the effective interest rate thus counteracting (reinforcing) the negative effect of a lower output growth thus causing the debt ratio to grow at a slower (faster) pace. The above derivation, however, abstracts from this effect .

[10] The measure of government revenues and spending we use in our VAR is a total measure, as such the variables $g_{i,t}$ and $t_{i,t}$ include also those components whose behaviour depends on the cycle (i.e. they are endogenous).

expenditure shock.[11,12] We can think of the residual $u_{i,t}$ as a linear combination of the true structural shocks $\varepsilon_{i,t}$, $u_{i,t} = B\varepsilon_{i,t}$. From the covariance matrix $\sum = E(u_{i,t}u'_{i,t}) = E(B\varepsilon_{i,t}\varepsilon'_{i,t}B)$ we can recover $\frac{N*(N+1)}{2}$ restrictions, while the remaining $\frac{N*(N-1)}{2}$ need to be imposed. This is achieved first through a Choleski decomposition. Then, sign restrictions[13] narrow down the set of acceptable B by restricting the sign of the impact response of the variable to a structural shock.[14]

The set of restrictions that we impose is summarized in Table 1.

Table 1. Sign restrictions

Response	G	T	Y
G shock	+	+	+
T shock	?	+	-

Table 1 reports the sign restrictions imposed to identify the spending shock and the tax revenue shock

The uncertainty of the identification strategy, together with parameters uncertainty, is then used to construct the confidence bounds for the impulse response functions, as we explain later.

[11]In order to identify unambiguously the two shocks, we impose that tax revenues respond positively to a spending shock. This can be justified arguing that an increase in spending raises GDP and thereby increases taxable income and tax revenues.

[12]An issue in the identification of fiscal shocks has been recently highlighted by Ramey (2011). The author argues that government spending shocks estimated by the econometrician in SVAR models are likely to be anticipated, and that this can lead to spurious findings. To test for the presence of this effect, Ramey (2011) runs Granger-Causality tests to study whether government spending forecasts from the Survey of Professional Forecasters have any predictive power for the spending shocks estimated in the model. However, this information is not available at quarterly frequency for the Euro area countries and we cannot perform such test. We rely on the result of Perotti (2011), which shows that fiscal foresight does not alter the results of SVAR models.

[13]We impose the restrictions on impact only

[14]The exact procedure we follow is the following: we orthogonalize the residual matrix through a Choleski decomposition, obtaining a matrix Σ_0. We then draw a matrix X from a random orthonormal distribution. We apply the QR decomposition to matrix X, in order to obtain $X = Q * R$. We multiply $Q * \Sigma_0$ and we call it S. If S satisfies the sign restriction we imposed, we calculate the IRFs using S as our identified structural matrix and we store the results. We then repeat the procedure 10.000 times.

Table 2. Out-of-sample RMSE

	G	T	Y	i	π
RMSE 1 lag	0.0176	0.0134	0.0065	0.0005	0.0020
RMSE 2 lags	0.0119	0.0144	0.0055	0.0005	0.0018
RMSE 4 lags	0.0109	0.0124	0.0051	0.0004	0.0018

Table 2 reports the RMSE obtained simulating the model in a pseudo out-of-sample fashion

2.3.2 Lag structure

To determine the number of lags to include in the main specification of the model, we conduct various specifications tests. The Hannan-Quinn and Schwarts information criteria suggest to use 4 lags. The Schwarts criterion instead suggests 1 lag. To decide between these options we simulate the VAR in a pseudo out-of-sample fashion; the preferred number of lags is the one that produces the lowest RMSE.[15] Table 2 below reports the RMSE for different lag lengths. Since the model with 4 lags behaves better than the one with 2 lags and 1 lag, we select it as our baseline specification. Nonetheless, as shown in section 7, the main results of the paper are robust to different choices in the lag structure.

2.4 The data

We use quarterly data for eleven Euro area countries,[16] over the period 2000Q1-2012Q1.[17] The use of data at quarterly frequency allows us to assume that there are implementation lags in the response of fiscal policy to the cycle (i.e. fiscal policy cannot respond to changes in the cycle within the same quarter but only with a lag of one quarter).[18] We can thus apply first a

[15] To be more precise, we simulate the model out of sample, 1 step ahead

[16] The countries are Austria, Belgium, France, Finland, Germany, Greece, Ireland. Italy, Netherlands, Portugal and Spain.

[17] Since 1995 Eurostat started to collect quarterly data according to the ESA95 procedure. This makes us confident that the series we are using are not the result of interpolation from annual series, and thus they represent genuine quarterly data.

[18] Although the use of quarterly data for the Euro area countries has been challenged as Euro area budgetary plans are prepared following an annual budgetary cycle, a recent strand of the literature has shown that intraannual fiscal data contains valuable and useful information, e.g. Prez (2007) and Onorante et al (2009).

Choleski structural decomposition and after the sign restriction approach outlined in section 3.1. We use EMU countries' data for two reasons. First of all the main focus of the paper is to understand the effects of fiscal consolidation in Europe, which is now at the center of the debate about debt reduction. Second, EMU countries have a common monetary policy, so we can better disentangle the effects of fiscal policy from the interactions with monetary policy. y_t is GDP, t_t is total tax revenues, and g_t is total government expenditure minus interest payment expenses.[19] The difference between t_t and g_t represents the primary balance. All variables are in real terms, deflated using the GDP deflator. i_t is the implicit interest rate, calculated as interest payments at time t over total stock of debt at time $t-1$. We use the implicit interest rate instead of the market interest rate because we need to be able to reconstruct the debt level from the primary surplus and the other variables present in the debt accumulation equation. The implicit interest rate can be seen as a moving average of the market interest rates, where the length of this moving average process depends on the average duration of public debt. π_t is inflation, calculated as first difference of the GDP deflator. Finally, d_t is the debt-to-GDP ratio at time t. All data are seasonally adjusted by the source. Only Greece, starting from 2011Q1 presents data NSA. In this case only we perform ourselves the seasonal adjustment, using the X11 procedure.

2.4.1 Recovering Debt

As discussed in section 3, in our estimation framework the debt-to-GDP ratio at time $t-1$ is included as a weakly exogenous regressor in the VAR. Its trajectory is then reconstructed using a deterministic equation which includes the primary balance, the output growth rate, the implicit interest rate and the rate of inflation (equation 1b in section 3). In order to be able to use this framework correctly we need to check that the debt series obtained through the deterministic equation match the actual values as close as possible. In Figure 1 we plot the two series, the actual and the simulated debt-to-GDP ratio. In most of the cases the two match almost perfectly. Only for some countries the simulated and the actual debt series diverge. This is the case of Finland, Ireland and Greece for which the discrepancies are quite large. The main reason behind these inconsistencies is the fact that the debt accumulation equation used to reconstruct the debt series assumes that the size of the stock-flow adjustment is zero, whereas in some of these countries this item can be quite sizeable

[19] y_t, t_t and g_t are real, per capita, and in natural logarithm.

especially since the onset of the financial crisis.[20] As an example, in early 2000 Finland invested its budget surplus to buy financial assets instead of paying back debt. Once we take this effect into account, we are able to reconstruct the debt series in a rather accurate way. In particular, by subtracting the (cumulated) stock-flow adjustment on consolidated gross debt series from the original debt level series we are able to derive the adjusted debt level. Dividing this by nominal GDP it is possible to recover the adjusted debt-to-GDP ratio.[21] Overall, the maximum discrepancies between the actual and the reconstructed debt series is 2%, though for many of the countries considered this difference is much lower.[22]

2.5 Empirical Results

This section illustrates the results of our baseline specification. As it is common in most of the VAR studies, we report our results in the form of impulse response functions. IRFs are computed as follows:[23]

- we solve the model dynamically[24] generating a baseline scenario.

- we solve the model dynamically again, adding the structural shock in the first period. (Specifically, this means setting the structural shock equal to one in the first period, generating a shocked scenario).[25]

[20] The debt accumulation equation typically includes a third variable which is the stock-flow adjustment. Normally, in empirical applications this items is assumed to be equal to zero owing also to the difficulty to obtain reliable data at a quarterly frequency for this variable.

[21] The adjusted debt series is the variable that we use in the estimation of our debt-augmented PVAR estimation for Finland, Ireland and Greece.

[22] Ilzetzki (2011) in a similar exercise accepts simulated debt series that on average differ from the actual one by not more than 2%.

[23] Because of the non-linear debt equation, it is not possible to invert the VAR obtaining a moving average representation.

[24] This means iterating forward the model with no shock, producing an out-of-sample baseline forecast.

[25] Although our model is non-linear, we believe that the non-linear effects of the VAR residuals are not significant.Indeed, the debt equation we add to the VAR model is deterministic. As this equation has no shocks, our model is barely sensitive to non-linear effects of VAR residuals. Thereby, when calculating the IRFs, we impose that our shock is equal to 1 in the first period of the IRF calculation, and equal to o from the second period onwards.

- we compute the impulse responses as the difference between the shocked and the baseline scenarios

- we compute confidence intervals using identification uncertainty and parameters uncertainty.[26]

The resulting IRFs represent the behaviour of the average country in our sample. Initial conditions matter for the dynamics of the IRFs. In this analysis we choose as initial conditions the cross country average of the latest available data in our sample, i.e. 2011Q3-2012Q1.[27] This choice reflects our willingness to evaluate the system at the current conditions, in order to have results well suited to analyse the current European situation. In the next subsection we analyse how initial conditions and the size of the shocks affect the behaviour of the model.

Results are summarized in Figure 2.[28] In the left column we report variables' responses to a negative government spending shock. The right column analyses responses to a positive tax shock. The ordering of the variables along each column is: g, t, y and d. The first panel on the left represents the evolution of the spending shock itself. As for the other panels on the left, following the shock in expenditure, tax revenues decrease on impact, dampening the positive effect of the reduction in spending on the primary balance. In the subsequent quarters taxes revert back to zero. The behaviour of output, depicted in the third panel, is fairly standard. It falls on impact and starts to recover after one year.[29] The output response implies a fiscal multiplier on the spending side of 0.41 on impact. This size of the fiscal multiplier is consistent with a standard neoclassical model, which predicts a fiscal multiplier lower than one, contrary to the classic textbook Keynesian model. This value for the multiplier is also consistent with the existing empirical literature, in particular with Perotti (2004). The most interesting result in Figure 2 concerns the evolution of the debt-to-GDP ratio (fourth panel).

[26] Following Sims and Zha (1999), we assume that the posterior density of the regression coefficients and the covariance matrix belongs to the Normal-Wishart family. We draw all parameters jointly from the posterior, discarding explosive draws as in Cogley and Sargent (2005). For each draw of the parameters we calculate the IRFs using sign restrictions and we save the median, the upper and the lower percentile. This gives us a number of estimates of the median, the lower and the upper percentile. As baseline, we report the median of all medians. As confidence bands, we report two different statistics. The first statistic is the 16th and 84th percentile of the distribution of the medians. In this case the error bands account for parameter uncertainty and reflect the uncertainty about the true median that comes from a limited sample size. As a second statistic we report the median of the lower and upper percentile across all parameter draws. In this case the error bands reflect identification uncertainty.

[27] Given we have 4 lags, we need 4 data points for each variables in the VAR as initial conditions

[28] In each graph, the horizontal axis represents quarters and the vertical axis the size of the shock to each variable.

[29] The horizontal axis represents quarters

Following a spending shock, debt increases on impact and remains on a upward trajectory in the subsequent quarters before starting to decline after approximately one year. In the long run the resulting debt-to-GDP ratio is below the pre-shock level. This means that a fiscal consolidation, when implemented on the expenditure side, generates an effective and lasting reduction in the debt-to-GDP ratio. The initial increase in public debt can be explained by two factors: the contemporaneous decrease in tax revenues, which offsets the positive effect of lower spending on the primary balance, and the negative effect on the output growth rate. To better understand the underlying dynamics, it is useful to look again at the debt accumulation equation

$$d_{i,t} = \frac{1 + i_{i,t}}{(1 + \pi_{i,t}) * (1 + \Delta y_{i,t})} d_{i,t-1} - \frac{\exp(t_{i,t}) - \exp(g_{i,t})}{\exp(y_{i,t})}$$

In the first quarters the snowball effect, driven by the recessionary effects of the government spending shock, dominates the improvement in the primary balance. After 4 quarters, the pick-up in output growth determines a (cyclical) improvement of the primary balance which, coupled with a shrinking snowball effect, leads to a reduction in the debt-to-GDP ratio. The effects on interest rate and inflation (not reported) are not significant.

We now turn to the analysis of the consequences of a tax revenues shock. Compared to a spending shock, the tax shock is not persistent, and after a few quarters it dies out. Government expenditure reacts increasing on impact and later stabilizes. The motivation behind this behaviour could lie in the fact that our data for government spending includes transfers, such as unemployment subsidies which, in an economic downturn, automatically increase thus driving government expenditure up.[30] The response of output to a tax shock is stronger than to an expenditure shock. On impact output decreases by more and the recovery is more gradual. The resulting fiscal tax multiplier is 0.52. This strongest fall in output, combined with the behaviour of the primary balance following the tax shock, determines a path for debt as depicted in fourth panel on the right of Figure 2. As in the case of an expenditure shock, debt increases on impact and stays on an upward trend over the first four quarters. However, compared to the expenditure shock, the increase is much larger. From the fifth quarter onwards it starts declining, slowly reverting back close to the pre-shock level (i.e. approaching zero) at the end of the time horizon considered (20

[30] Another explanation relies on political economy arguments. When a government implements a tax increase, it feels less pressure on the spending side. It might thus react increasing public expenditure to counter act the negative effect of increased taxation.

quarters).

To better visualize the debt dynamics under the two shocks as well as the driving forces behind them, Figure 3 illustrates the behaviour of the primary balance and output growth, against the evolution of the debt-to-GDP ratio in the case of an expenditure shock (left panel) as well as a tax shock (right panel). On impact, the primary balance improves for both types of shocks. As a result, at least initially, the different magnitude of the increase in debt in the case of a tax shock is due to the stronger output response compared to a spending shock. In the subsequent quarters, the behaviour of the primary balance in the two cases diverges markedly. In the case of the spending shock, the primary balance recovers to the pre-shock level fairly quickly and then remains slightly positive until the end of the horizon considered. In the case of the tax shock, the deterioration in the primary balance is much more pronounced and it recovers back to the baseline level only after approximately two years. This different behaviour in the primary balance, which is also explained by the more dynamic recovery in the output level in the case of a spending shock, explains the more favorable evolution of debt-to-GDP ratio in the longer run in the case of spending-based consolidations.[31]

From the baseline scenario it is clear that there is a difference between a fiscal consolidation implemented on the revenue side and one implemented on the expenditure side. The former is successful in the objective of reducing the debt burden: after an initial increase in the first few quarters, debt starts to decrease and settles to a lower level than the baseline in the long run. The latter instead is more recessionary and leads to self defeating effects of fiscal consolidation, as the level of debt increases for a longer period and does not manage to attain a significant reduction in the long run.

2.5.1 Initial conditions and size of the shock

As our model is non-linear, in theory the results presented so far could be highly dependent on the choice of the initial conditions and on the size of the shocks chosen when computing the IRFs. In this section we study how the results change when using different initial conditions and sizes of the shocks. In order to do this, we implement two sets of experiments. In the first one we change the size of the shocks, holding constant the baseline initial conditions. In the second one, we change the initial conditions, holding constant the size of the shocks.

[31] A similar conclusion can be drawn from Figure 4, which illustrates the behaviour of the primary balance and output growth, for the 1 lag specification.

From the first set of experiments it emerges that the size of the shocks impacts linearly on the results. Doubling the size of the shocks, the scale of the IRFs doubles. Figures 5, 6, and 7 report the IRFs calculated using three different sizes of the shocks.[32] Compared to the baseline (Figure 2), results are virtually the same once the different scaling is taken into account.

From the second set of experiments it emerges that initial conditions have a minor non-linear impact on the shape and magnitude of the IRF. We choose the alternative initial conditions as to represent a few possible economic conditions a country might face. We consider initial conditions that represent a country facing poor economic condition (low GDP, high interest rate, high debt-to-GDP ratio, high spending, low tax revenues) and initial conditions representing a country that faces good economic conditions (high GDP, low debt-to-GDP ratio, low interest rate, low spending, high tax revenue).[33] Results (Figure 8 and 9) are not substantially different across different initial conditions, as the shape of the IRFs is similar. However, different initial conditions have an impact on the magnitude of the increase in the trajectory of the debt-to-GDP ratio. In particular, our results show that if consolidation is undertaken under poor economic conditions, the decline in the long run debt-to-GDP ratio following consolidation is lower compared to a situation of good economic conditions. Finally, we test the influence on the results of each single variable as initial condition. We produce the IRFs changing just one initial condition at the time with respect to the baseline case. The initial level of debt is the only variable that influences the results, while the other variables do not play a significant role. Figure 10 and 11 report the IRFs calculated starting respectively from a high initial level of debt and from a low level of debt. When the starting level of debt is high, the self-defeating effect of fiscal consolidation (whether implemented through spending or through taxation) is bigger than in the baseline scenario. When the system starts from a low level of debt, fiscal consolidation is more self-defeating, compared to the baseline scenario, in case of a tax shock.

The two sets of experiments suggest the influence on our results of the initial conditions and the size of the shock is, at best, modest.

[32]The sizes of the shocks used to generate Figure 5, 6 and 7 are, respectively, 0.5, 2 and 0.2 times as big as the shocks in the baseline scenario.

[33]In our experiments, "high" and "low" are represented by the variable being 50% higher (lower) than the baseline level

2.6 Controlling for fiscal stress

In this section we study whether the behaviour of the debt-to-GDP ratio after a fiscal shock differs when a country undertakes fiscal consolidation in a period of fiscal stress. The construction of our fiscal stress index is described in the following subsection whereas here we explain the methodology used to incorporate such an indicator into the fiscal VAR. Following Ilzetzki et al (2011), the construction of such an indicator amounts to splitting the sample according to whether a country is in a situation of fiscal stress or not. Once we construct this time varying index we interact it with the regressors and we add the index to the set of regressors. In this way we can account for the possible different slope and different intercept when the index is equal to one and when it is equal to zero. The regression we estimate is then :

$$Y_{i,t} = \sum_{p=1}^{P} A_p Y_{i,t-p} + \sum_{p=1}^{P} \Gamma_p d_{i,t-p} + D_{i,t} + \sum_{p=1}^{P} D_{i,t} A_p^D Y_{i,t-p} + \sum_{p=1}^{P} D_{i,t} \Gamma_p^D d_{i,t-p} + u_{i,t}$$

where $D_{i,t}$ is our index, A_p^D and Γ_p^D the coefficient relative to the interacted variables. The coefficient matrices A_p and Γ_p describe the dynamics for the non dummied countries, while $\overline{A_p} = A_p^D + A_p$ and $\overline{\Gamma_p} = \Gamma_p + \Gamma_p^D$ describe the dynamics for the dummied ones. Similarly for the constant term.

In this way we capture the difference, if any, between the average dummied country and the average non-dummied country. To save degrees of freedom, we use the one lag specification throughout the whole section. For this reason the results we obtain in this section are not directly comparable with the ones provided in the baseline with Figure 2. For comparison purposes, Figure 17 in the Appendix reports the baseline results when one lag is used.

In the next subsection we explore whether there are substantial differences in the behaviour of fiscally stressed countries with respect to non fiscally stressed countries.

2.6.1 Fiscal Stress

We define fiscal stress as a situation in which the market interest rate on 10-year government bonds (i.e. the secondary market interest rate) exceeds the implicit interest rate on outstanding government debt by a certain threshold. The aim of this measure is to account for those situations in which tensions in a sovereign's bond market may hinder its capacity to refinance outstanding debt or to issue new debt. Fiscal consolidation then becomes the main tool to restore sovereign creditworthiness and return to a normal functioning of the bond market. The purpose of our analysis is to assess whether these specific circumstances affect the findings of the previous section on the impact of consolidation on the evolution of the debt-to-GDP ratio. In our view this issue is of particular policy relevance as it resembles quite closely the developments in some Euro area countries since early 2010.

Most of the existing studies control for the role of initial conditions by looking at the initial debt-to-GDP ratio and whether this is above a certain threshold. This is often used as a measure of fiscal stress, with the debt threshold usually set at 90 per cent of GDP.[34] According to this criterion, countries like Italy and Greece would always be considered fiscally stressed in our sample, although until at least mid-2009 financial markets did not significantly differentiate these countries from countries with a lower debt-to-GDP ratio. At the same time, Spain would not be classified as being fiscally stressed, as its debt-to-GDP ratio was below 90%, despite the country having experienced significant bond market pressures.[35] Given these issues, we decide to define fiscal stress in the following way. For every country, in each quarter we compute the difference between the market interest rate (10 years government bond) and the implicit interest rate. Whenever this difference is at least one standard deviation above its average value, we consider the country to be in a situation of fiscal stress and our index takes the value of 1. Otherwise the index takes the value of 0. Applying this measure to the sample of countries under consideration, we find that the subsample of fiscally stressed countries includes Greece, Ireland, Italy, Portugal and Spain over different time periods, starting from 2010Q2. Figure 12 reports the financial stress index for Spain, Italy and Greece.

Figure 13 illustrates the IRFs when including the fiscal stress indicator in our PVAR and compares the effects of a reduction in government spending in countries that undertake

[34] Perotti (1999), Corsetti et al (2011), Ilzetzki et al (2011)

[35] An alternative definition of fiscal stress is found in Burriel et al. (2009). They include the growth rate of the debt-to-GDP ratio in their VAR to control for fiscal stress and potential non-linearities.

fiscal consolidation at time of fiscal stress (FS, on the left) and in those that are not fiscally stressed (NFS, on the right) according to our indicator. There are significant differences between the two groups of countries already in the pattern of the shocked variable. Indeed, the spending shock is much more persistent in the NFS countries, whereas in FS countries the initial reduction in primary spending is almost immediately reversed. In both groups of countries tax revenues fall in response to the spending shock, although in the NFS group the decline on impact is much larger. This is the consequence of a stronger fall in output in response to the spending shock in this group of countries. The larger response of economic activity to spending cuts in NFS countries might look difficult to interpret, as in principle one would assume that a country under financial markets pressure is also a country whose growth performance is weak and close to a recession. Since in the latter case the multiplier is thought to be higher than in normal times, one would also expect a more recessionary impact of fiscal consolidation in the group of fiscally stressed countries. In our case, however, the two situations do not always coincide. For many of the quarters in which the countries are considered as fiscally stressed according to our index, economic growth has been low but remained in a positive territory. Moreover, another factor that could explain the smaller multiplier in FS compared to NFS countries is the behaviour of the implicit interest rate. Although it is not statistically significant, the implicit interest rate of FS countries decreases on impact, whereas it increases in the other group. This result could be interpreted as evidence of favourable "confidence effects" materializing in the fiscally stressed countries that implement an expenditure based consolidation (i.e. the risk premium these countries pay to borrow from the financial market falls because the (perceived) default probability decreases). Given that the implicit interest rate is a moving average (which depends on the average debt maturity), it is plausible to assume that the actual effect of an expenditure shock on the market interest rate would be even higher. On the contrary, in the NFS countries, the implicit interest rate remains unchanged on impact and it increases in the subsequent quarters. This increase could be explained by a shift in the maturity structure of government debt as governments may try to lengthen the duration of their outstanding debt in order to reduce their refinancing risk. Finally, we consider the effect of the spending shock on the debt-to-GDP ratio. In the fiscally stressed countries the debt ratio decreases on impact. This initial decrease is quite steep and in the long run the debt ratio converges to a lower level than the pre-shock one. In the non fiscally stressed countries, the debt ratio increases almost imperceptibly on impact, before starting to decrease steadily to a much lower long run level compared to the pre-shock situation. The different response on impact of the debt-to-GDP ratio across the two groups of countries is due to the different responses of output and interest rate, which are more favorable in the case of stressed countries. In the long run, however, these positive effects die out, and the higher persistence of the fiscal shock in the NFS countries dominates.

Figure 14 reports the results following a tax shock, again for FS countries (left) and NFS (right). The response of output does not differ substantially across the two groups: it falls on impact and it does not revert to the pre-shock level in the long run. The evolution in the debt ratio is also qualitatively similar. In both cases we have self-defeating effects. However, for the group of fiscally stressed countries, debt increases more on impact and takes longer to revert to a downward path, without falling below the pre-shock level in the long run. This is due to a less favorable behaviour in the primary balance for fiscally stressed countries, driven by the strongest increase in spending after the tax shock.

What stands clear from Figure 13 and 14 is again, that a fiscal consolidation is more successful in reducing the debt burden when it is implemented on the expenditure side. Moreover, it is more effective, in the sense of being able to reduce more the long run debt-to-GDP ratio, when it is implemented in a period of non fiscal stress. In a period of fiscal stress it will have some immediate positive effects, but in the long run debt will decrease less. In order to be confident that the dynamics highlighted above are due to the fiscal crisis and not to the average behaviour of the countries included in the two groups, we provide the results for the two groups of countries over the whole sample period. Figure 15 and 16 in the appendix present the results. The dynamics for the two groups of countries are qualitatively similar at least in the case of a spending shock and in what concerns the response on impact of output and the long run reduction in the debt-to-GDP ratio achieved in both groups. This gives strength to the hypothesis that the results found in this section are actually due to a different behaviour for the countries that enter a period of fiscal stress.

2.7 Robustness checks

In this section we perform some robustness checks. We first check whether the use of a different number of lags affects the results of our baseline specification. In VAR analysis, results can change dramatically with the adoption of a different number of lags. Figure 17 reports the results for the specification with 1 lag. The effects of a negative spending shock are depicted on the left side, and those of a tax shock are on the right side. It is reassuring that the results of our baseline specification (i.e. four lags) still hold for the one lag case, in spite of less rich dynamics. In the long run the debt ratio decreases much more after an expenditure shock than after a tax shock, and the debt that starts declining already one quarter after the spending shock. For the revenue shock we observe a rise of debt on impact. The level of debt falls below the initial level only after twelve quarters. The output multipliers are basically the same as in the 4 lags case. Figure 18 reports the results for the two lags case, confirming the results we already commented.

Second, we control for the robustness of our results to the estimation technique. A particular concern is whether the OLS fixed effect estimator is a consistent estimator. Pesaran and Smith (1995) show that this estimator is in fact inconsistent if there is slope heterogeneity in a panel framework. To overcome this problem they propose an alternative estimator, called the Mean Group Estimator. This estimator takes into account the possible difference in the dynamics of the single countries. It basically assumes that the coefficient matrices in regression (1a) are country-specific, i.e. $A_{i,p} = A_p + \varepsilon_{i,k}$ where A_p is the average coefficient matrix and $\varepsilon_{i,k}$ captures the country specific variation. Figure 19 reports the results obtained using the mean group estimator. The results are very similar to those obtained using the fixed effect estimator, thus confirming the robustness of our findings.

Finally, we control for the effect of the financial crisis of 2008 by restricting the estimation period to 2000Q1-2007Q2. Figure 20 reports the results. For both the expenditure and the revenue shock the debt ratio takes more time to decrease, and decreases by less in the long run. The tax shock appears to be self-defeating across all the time horizon considered, while the expenditure shock brings a reduction in debt after the first few quarters. Overall the main conclusion of our baseline specification remains valid, namely that a fiscal consolidation is more effective in reducing the debt ratio in the long run when implemented through a reduction in expenditure side as opposed to an increase in revenues.

2.8 Conclusions

In this paper we analyse the effects of a fiscal consolidation on the behavior of the debt-to-GDP ratio for a panel of Euro area countries, over the period 2000-2012 using a PVAR estimation technique with sign restrictions. Although based on a different estimation framework, the findings of our analysis are in line with those of the literature on successful consolidation, namely that the composition of fiscal consolidation matters and that a durable reduction in the debt-to-GDP ratio is more likely to be achieved if consolidation is implemented on the expenditure side, rather than on the revenue side. In particular, when fiscal consolidation is implemented via an increase in taxation, the debt-to-GDP ratio reverts back to its pre-shock level only in the long run, thus failing to generate an improvement in the debt ratio, and producing what we call a self-defeating fiscal consolidation.

When controlling for the initial conditions, and in particular for whether a fiscal consolidation is implemented during period of fiscal stress, we find that fiscally stressed countries benefit from an immediate reduction in the level of debt when reducing spending. However, the long run benefits in terms of a lower debt ratio are more sizeable for countries that are not confronted to a situation of fiscal stress. A tax shock instead produces similar detrimental effects in the two groups of countries and always leads to self-defeating effects.

The findings of our analysis are of particular policy relevance in the context of the debate on the merits of fiscal consolidation as the main tool to restore debt sustainability in the Euro area countries. They suggest that short term considerations related to the detrimental impact of consolidation on growth and on the debt-to-GDP ratio need to be weighed against the long term benefits of a rebound in output growth and a durable reduction in the debt-to-GDP ratio. This strategy is more likely to succeed when the consolidation strategy relies on a durable reduction of spending, whereas revenue-based consolidations do not appear to bring about a durable improvement in the sustainability prospects of a country. Moreover, delaying fiscal consolidation until financial markets pressures threaten a country's ability to issue debt may have a cost in terms of a less sizeable reduction in the debt-to-GDP ratio for given consolidation effort, even if it is undertaken on the spending side. This is an important policy lesson also in view of the fact that revenue-based consolidations tend to be the preferred form of austerity, at least in the short run, given also the political costs that a durable reduction in government spending entails.

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Appendix

Figure 1. Actual and simulated debt

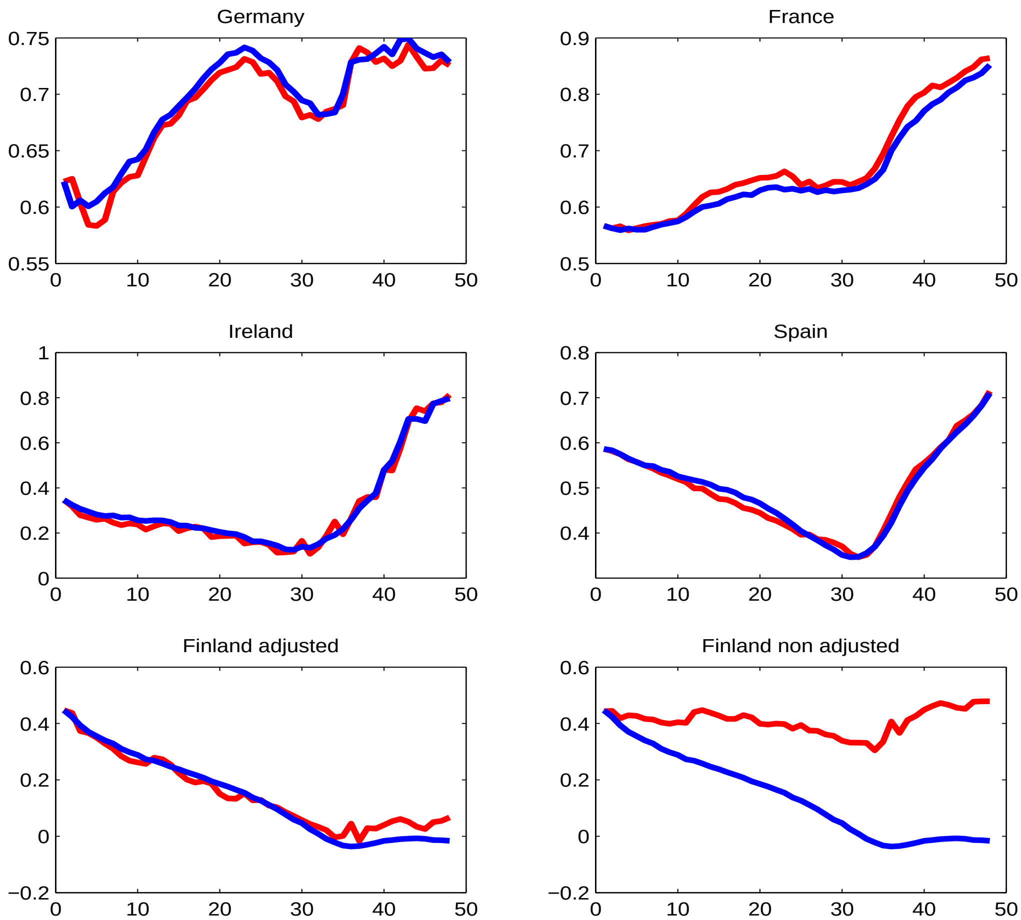


Figure 1 reports the actual debt (red line) and simulated debt (blue line)

Figure 2. Baseline: 4 lags

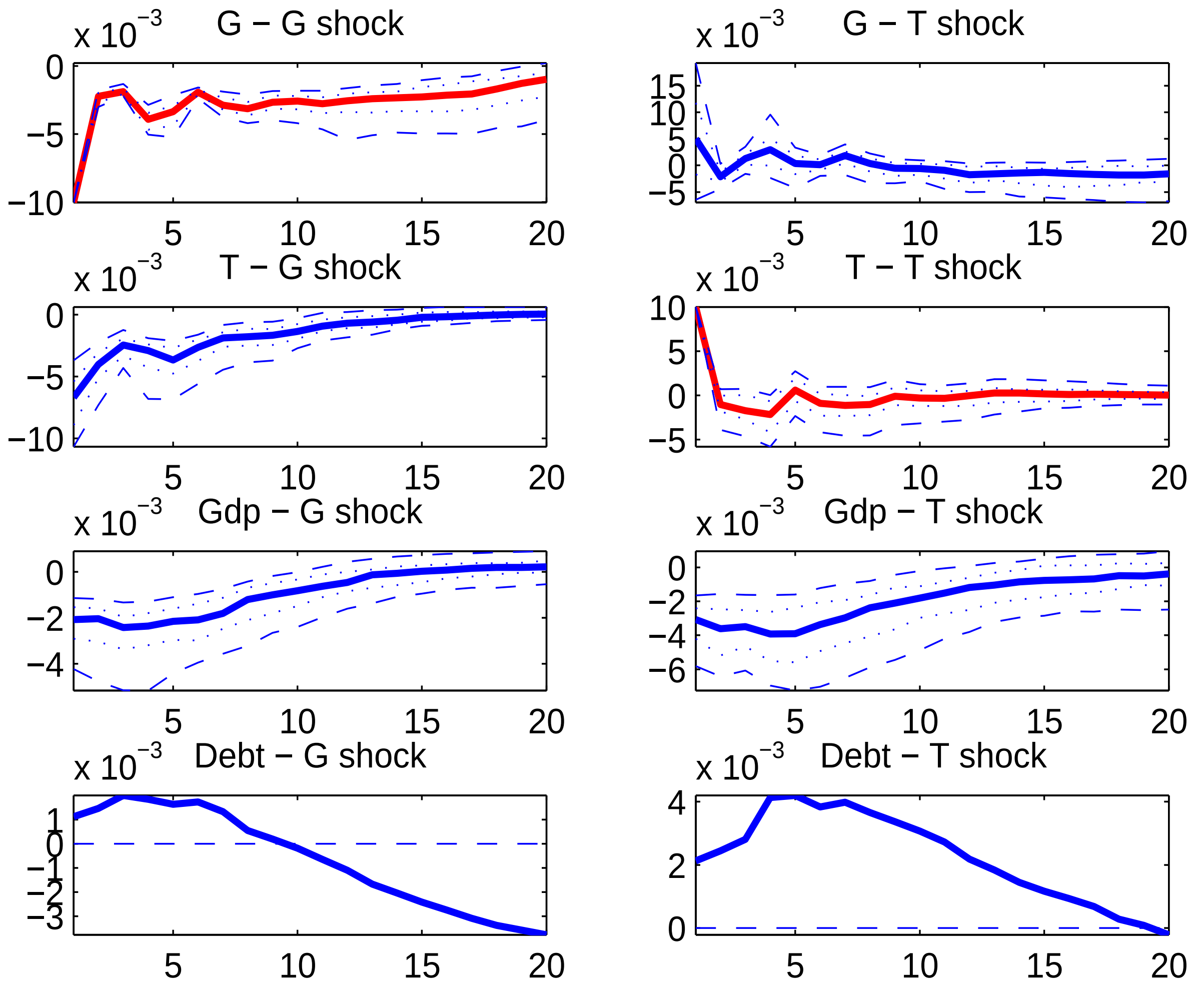


Figure 2 reports the IRFs for the baseline scenario, calculated using 4 lags. G shock on the left. T shock on the right

Figure 3. Evolution of Primary Balance and Output, 4 lags

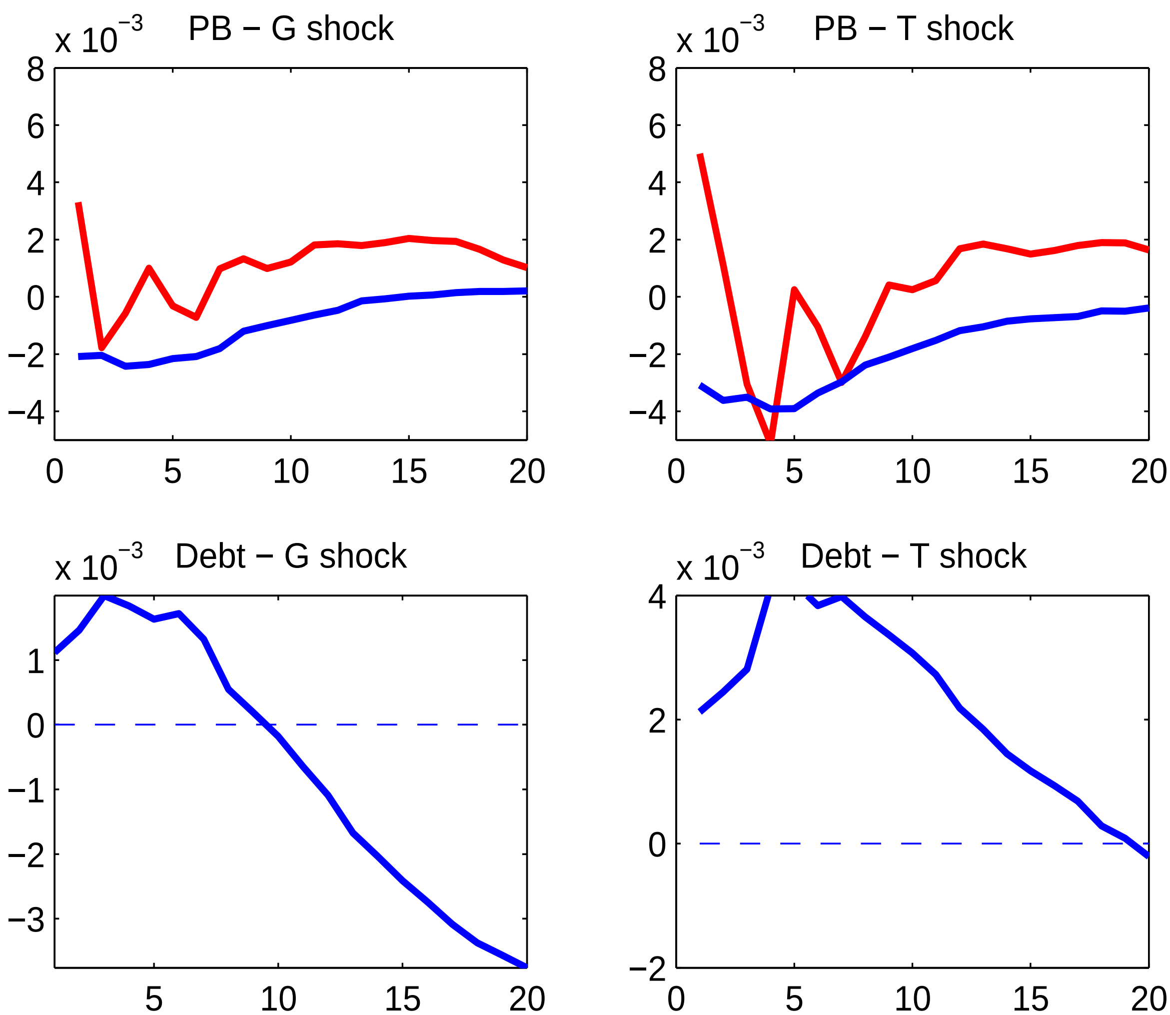


Figure 3 reports the IRFs (4 lags) in terms of the evolution of the Primary Balance PB (red line), output Y (blue line) and debt-to-GDP ratio. Spending shock on the left panels, tax shock on the right panels.

Figure 4. Evolution of Primary Balance and Output, 1 lag

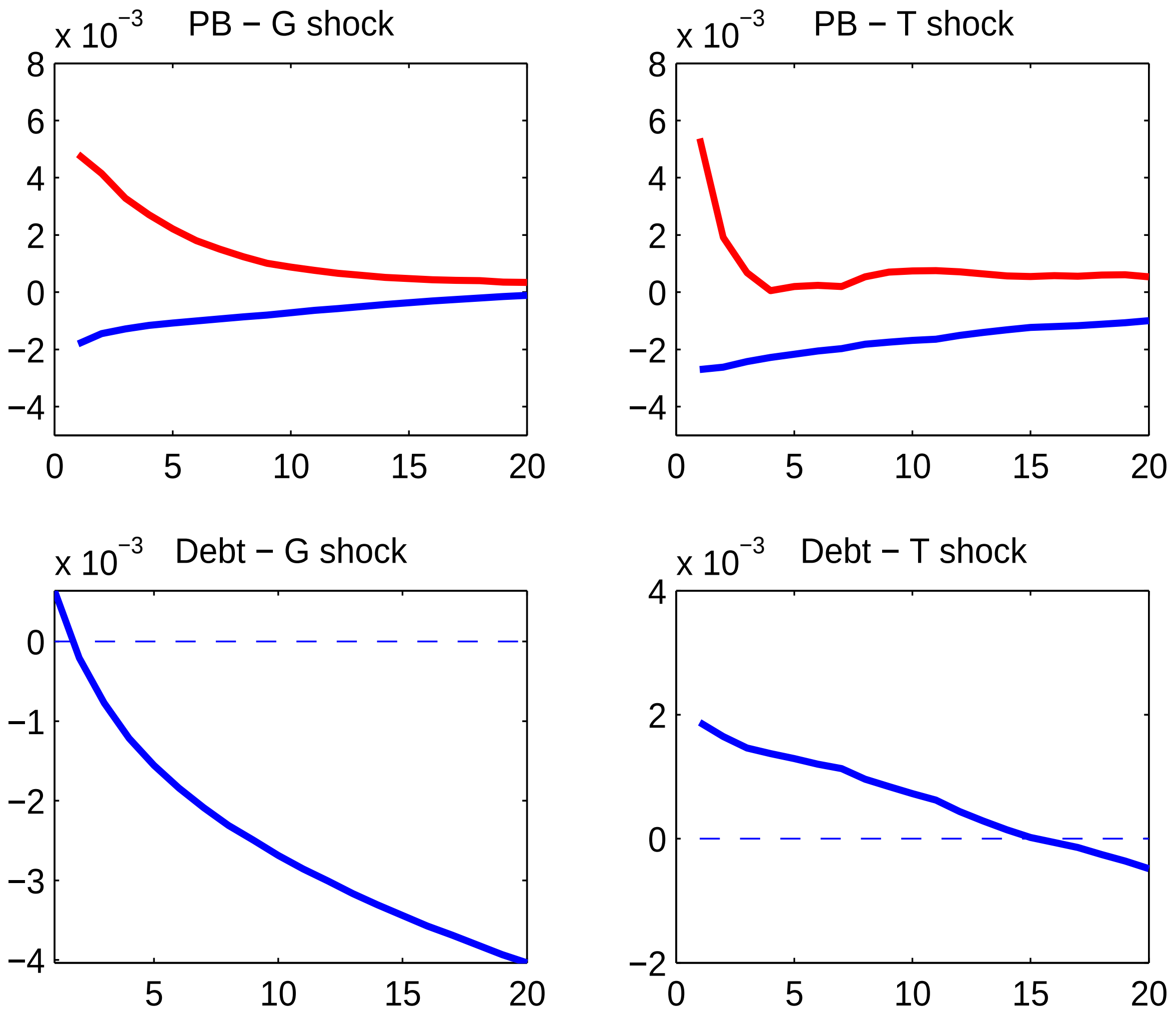


Figure 4 reports the IRFs (1 lag) in terms of the evolution of the Primary Balance PB (red line), output Y (blue line) and debt-to-GDP ratio. Spending shock on the left panels, tax shock on the right panels.

Figure 5. IRFs: Small shock

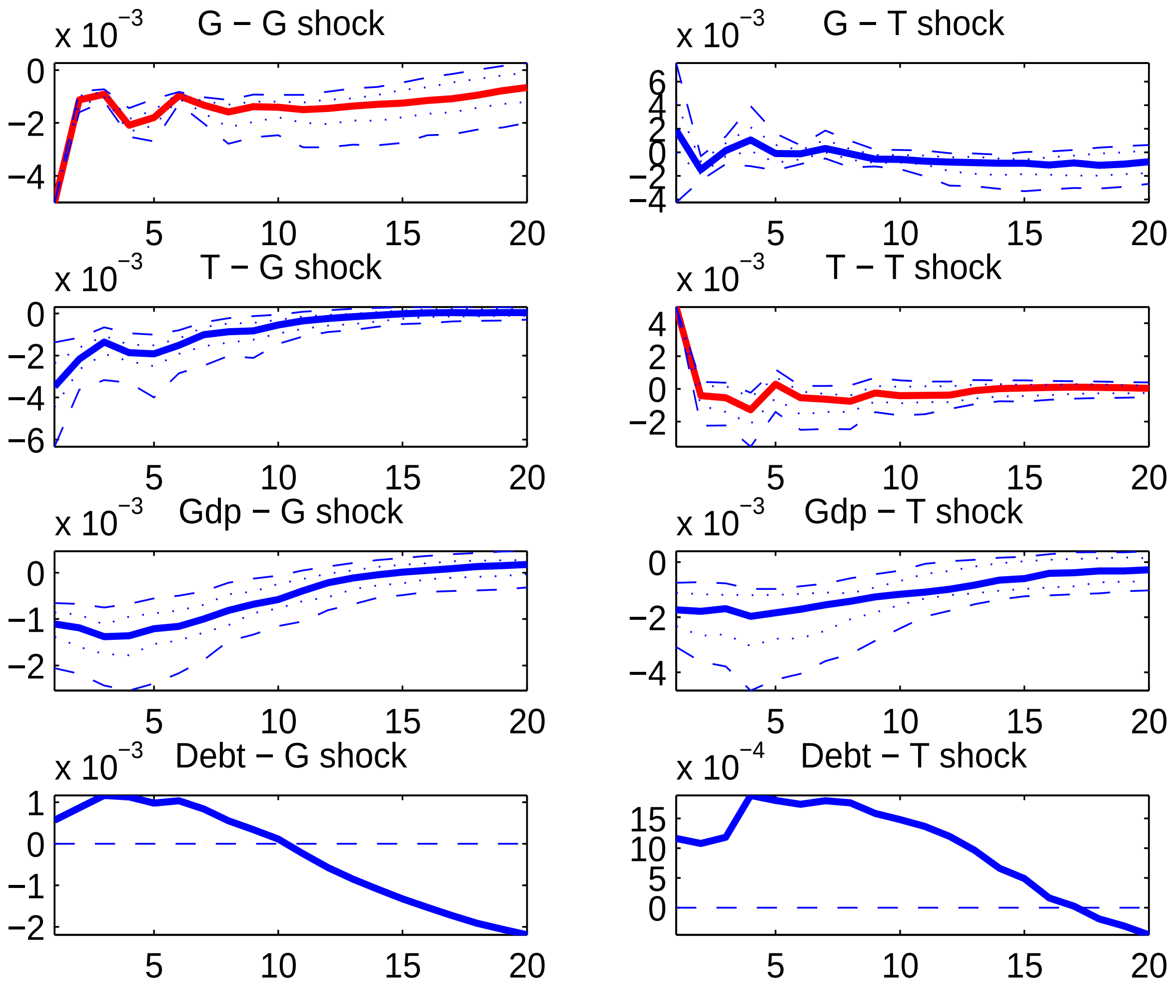


Figure 5 reports the IRFs calculated when the shocks (both spending shock and tax shock) are a 0.5 times as big as in the baseline scenario.(i.e the shocks are 0.5 standard deviations)

Figure 6. IRFs: Big shock

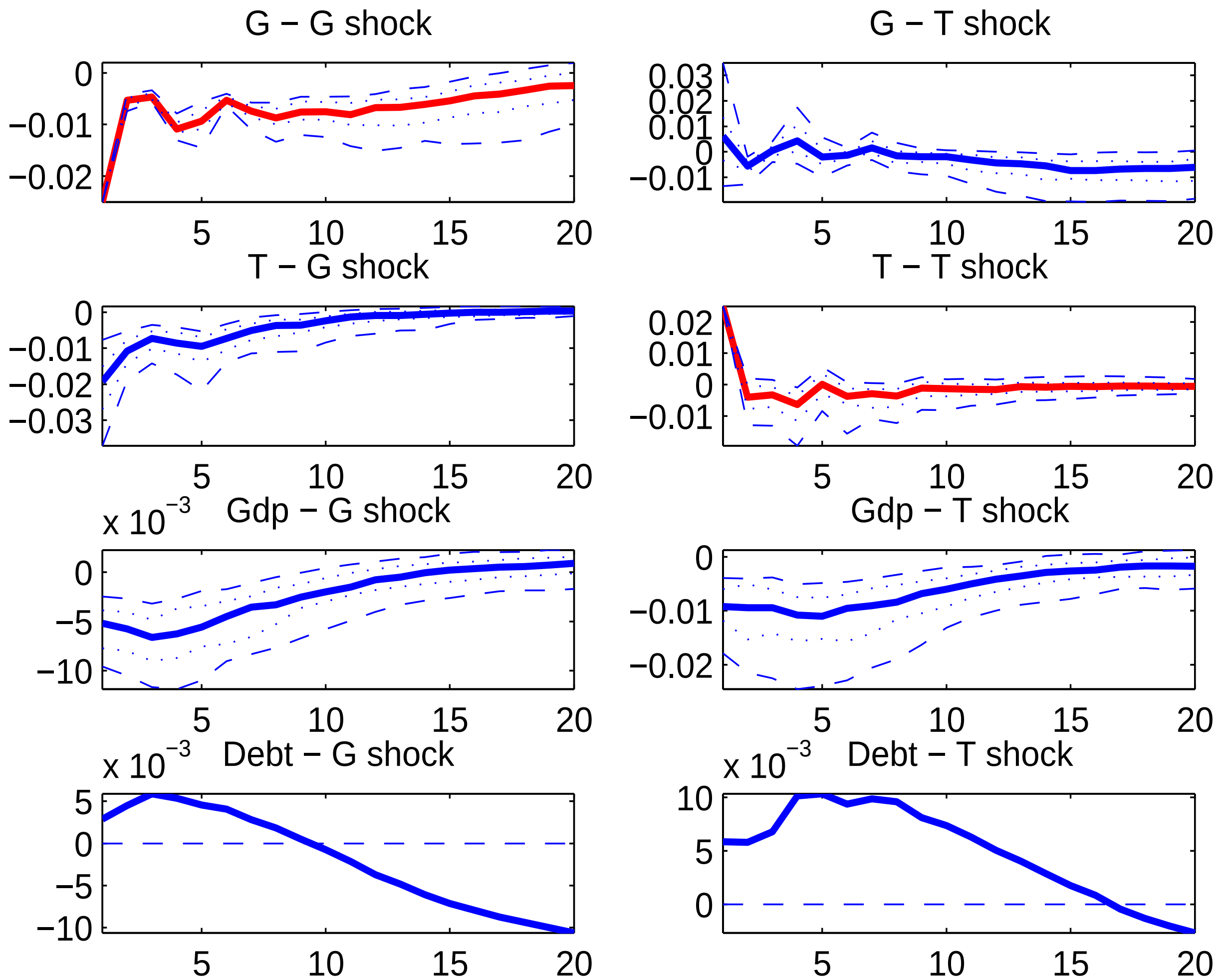


Figure 6 reports the IRFs calculated when the shocks (both spending shock and tax shock) are a 2 times as big as in the baseline scenario.(i.e the shocks are 2 standard deviations)

Figure 7. IRFs: Very small shock

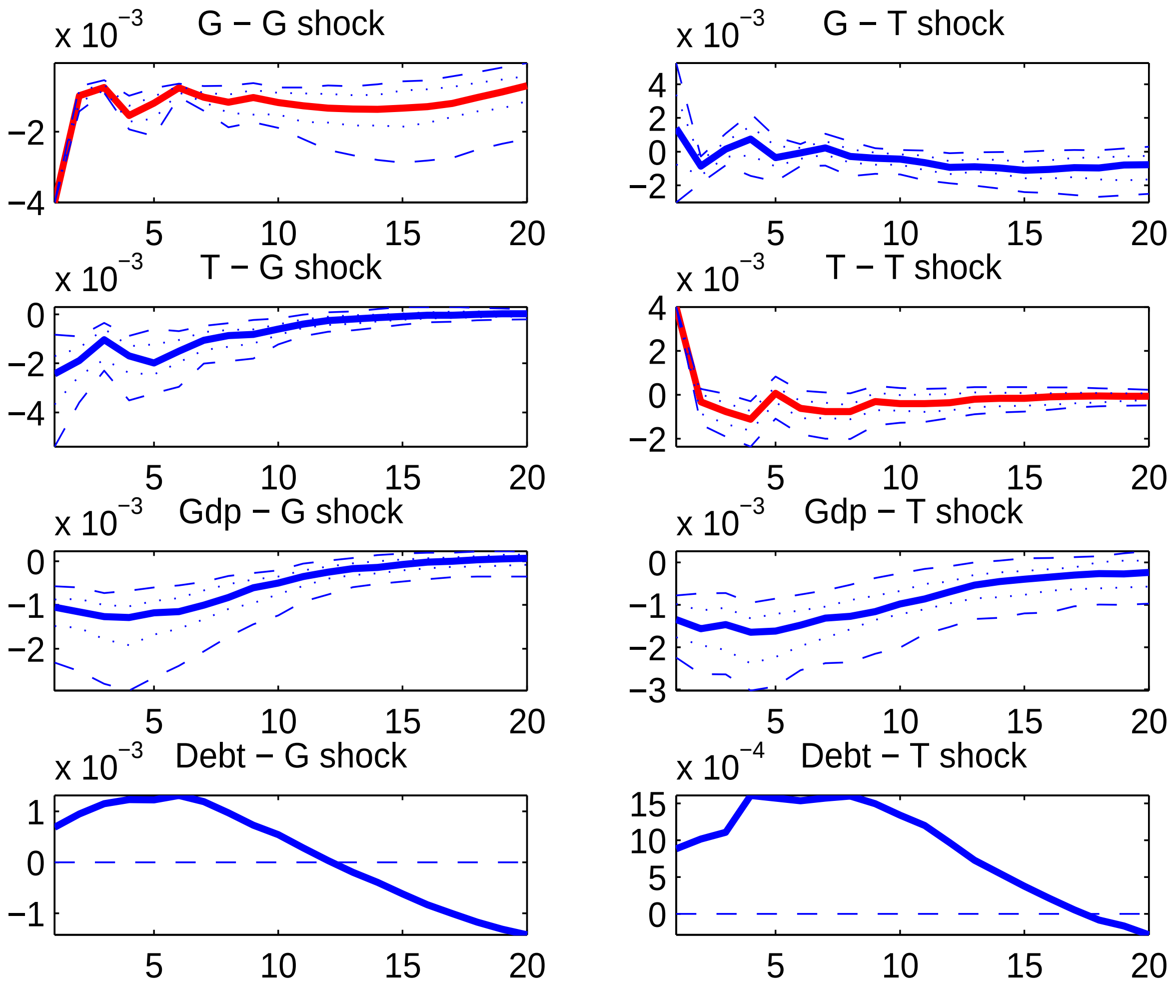


Figure 7 reports the IRFs calculated when the shocks (both spending shock and tax shock) are a 0.2 times as big as in the baseline scenario.(i.e the shocks are 0.2 standard deviations)

Figure 8. Poor economic conditions

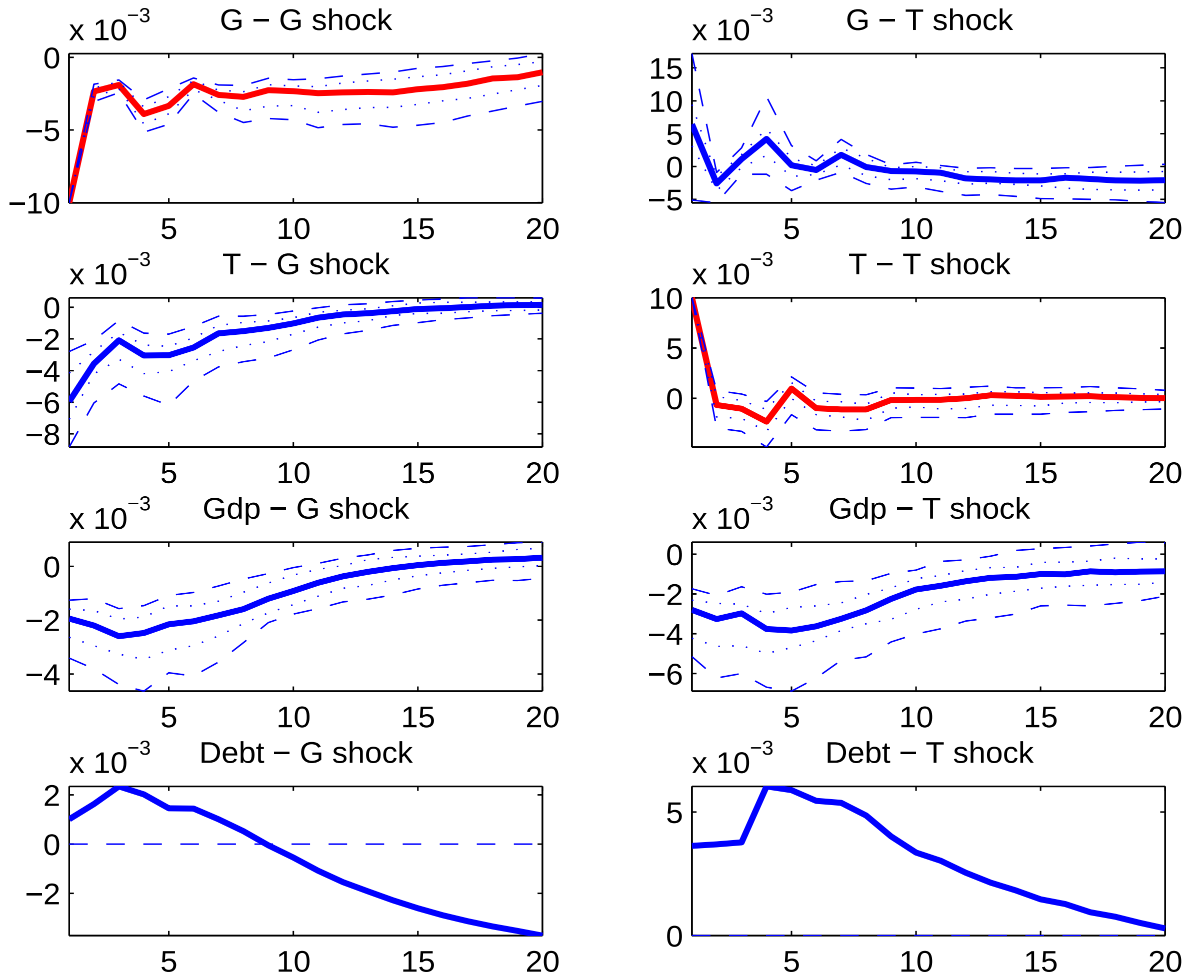


Figure 8 reports IRFs calculated with initial conditions representing poor economic conditions. This means low GDP, high spending, low tax revenues, high interest rate, high inflation and high debt-to-GDP ratio.

Figure 9. Good economic conditions

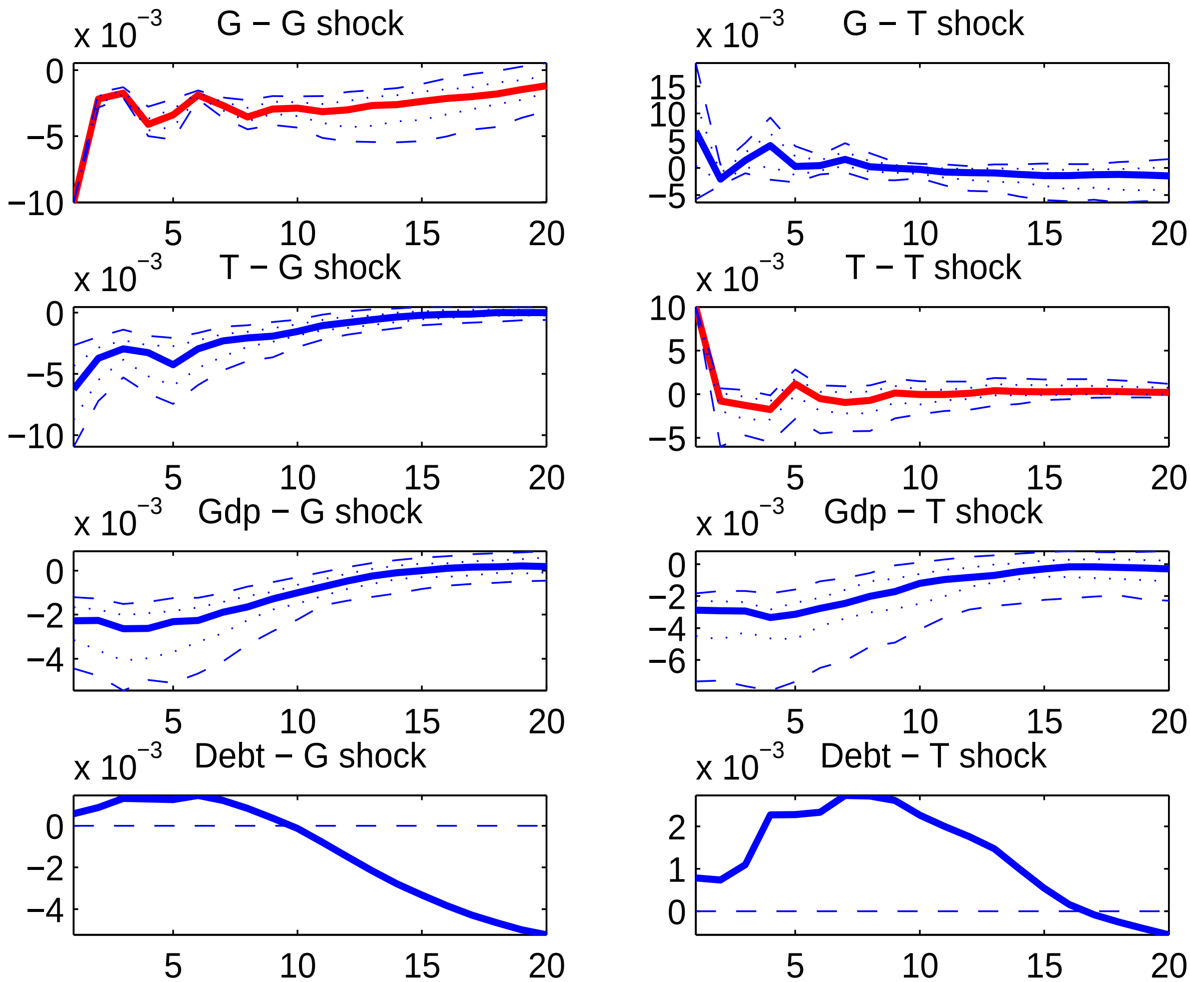


Figure 9 reports the IRFs calculated with initial conditions representing good economic conditions. This means high GDP, low spending, high tax revenues, low interest rate, low inflation and low debt-to-GDP ratio.

Figure 10. High initial debt

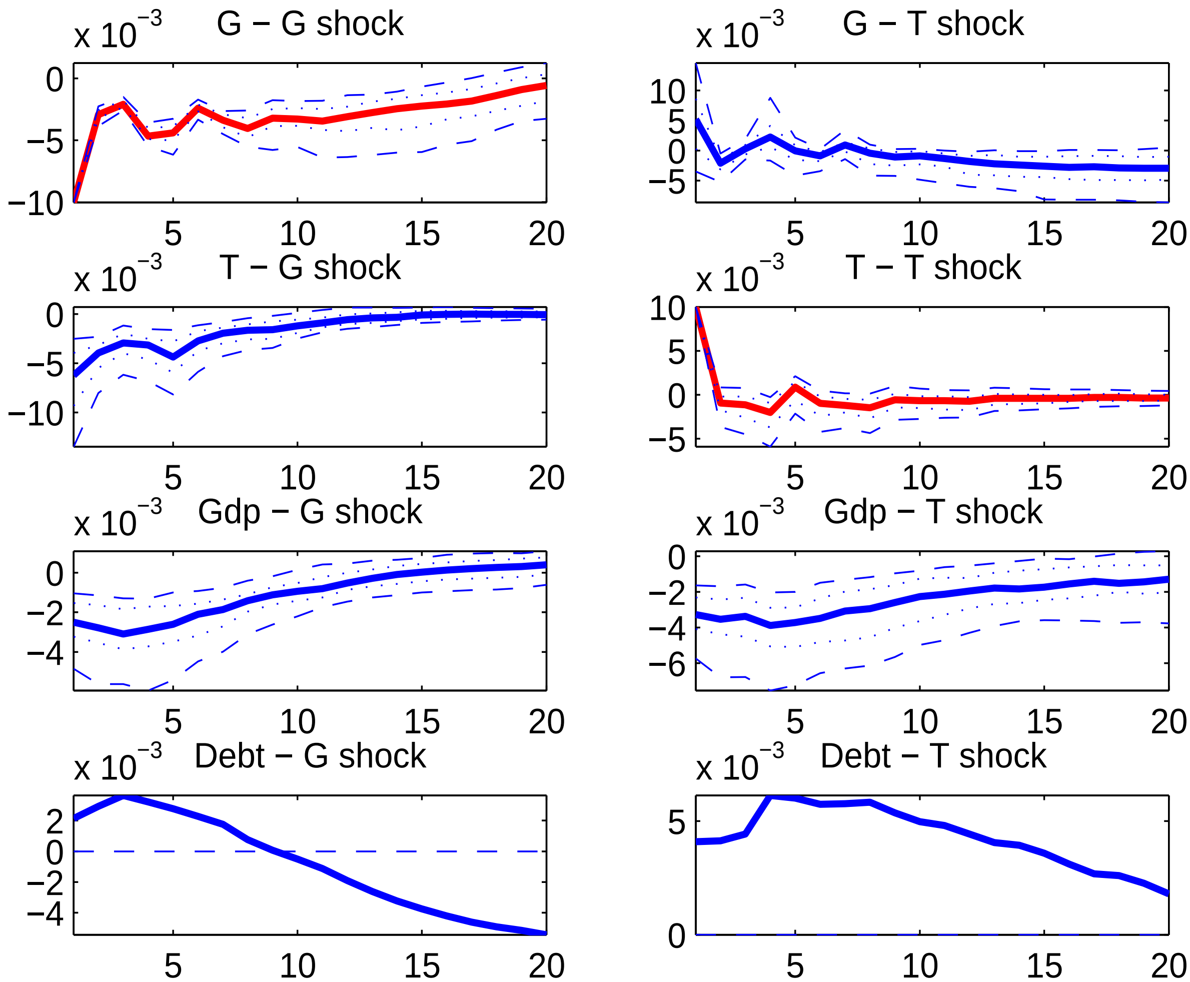


Figure 10 reports the IRFs calculated when initial debt-to-GDP is 50% higher than the baseline. All the other initial conditions are the same as in the baseline scenario.

Figure 11. Low initial debt

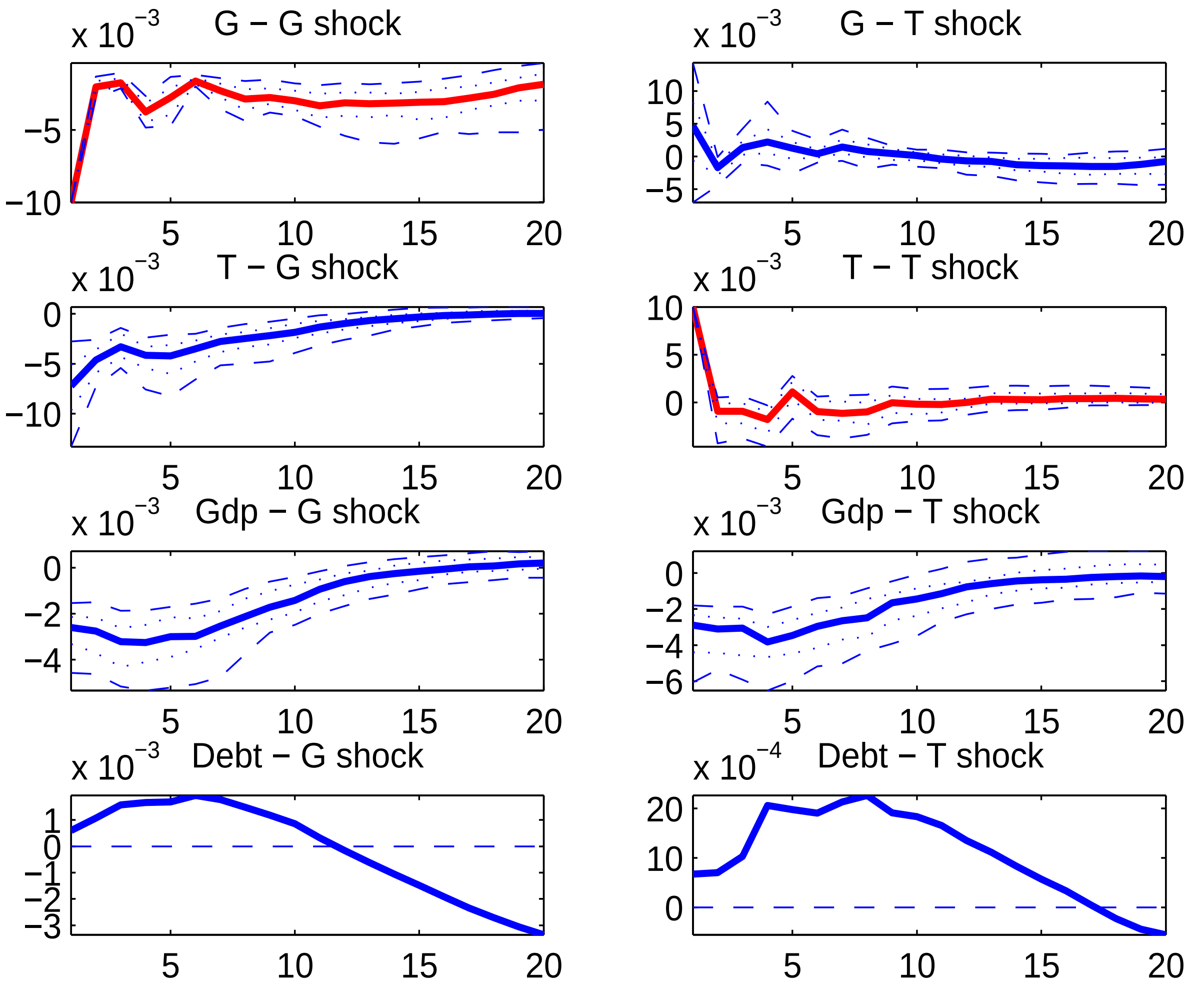


Figure 11 reports the IRFs calculated when initial debt-to-GDP is 50% lower than the baseline. All the other initial conditions are the same as in the baseline scenario.

Figure 12. Implicit interest rate and market interest rate

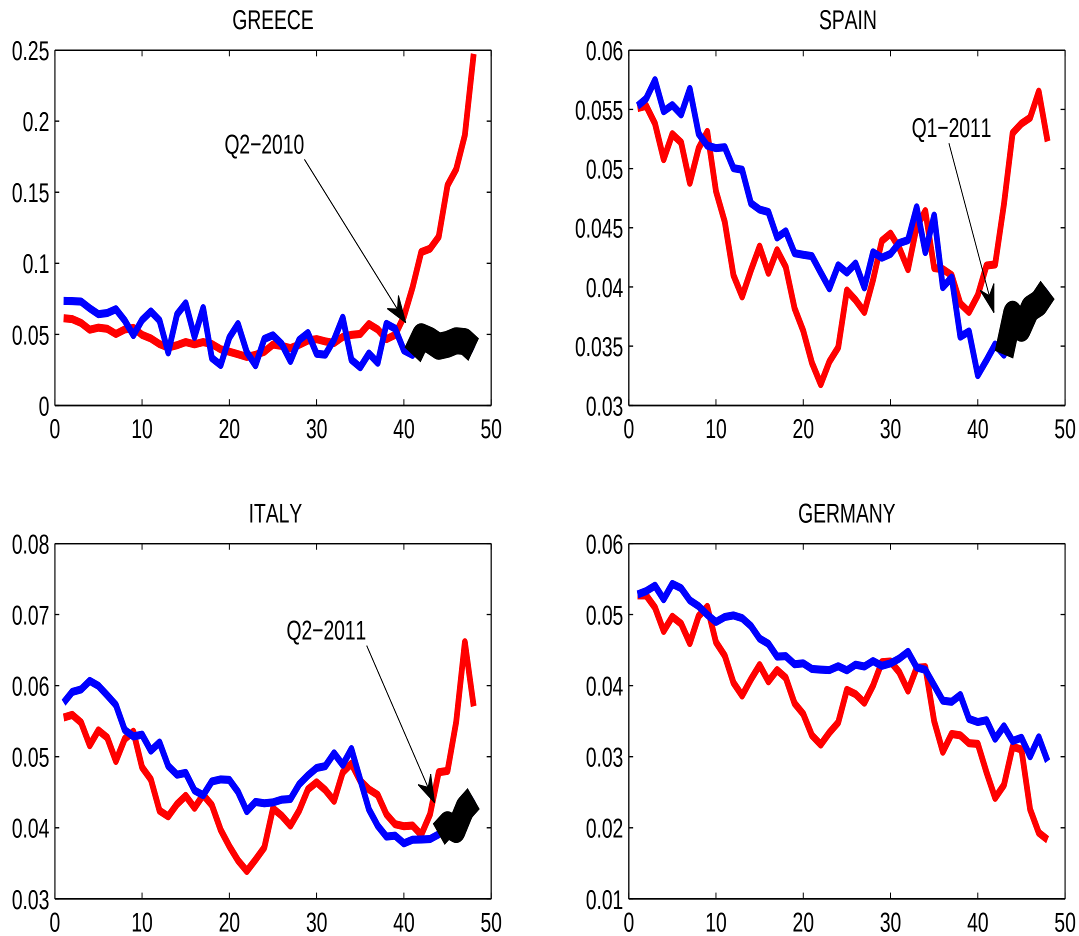


Figure 12 reports the implicit interest rate (blue line) and market interest rate (red line). The dotted points represent quarters in which the country is considered fiscally stressed

Figure 13. G shock: FS and NFS countries

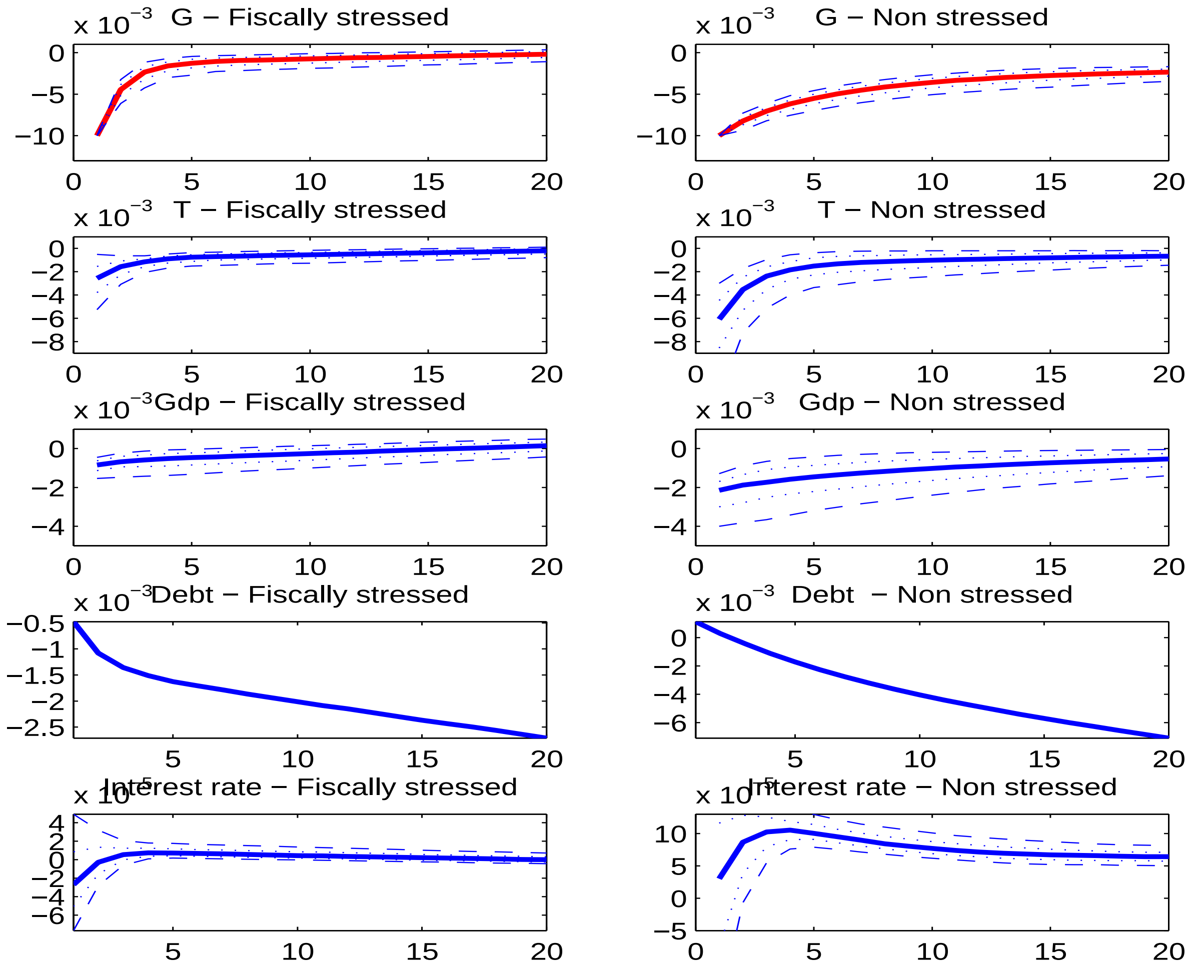


Figure 13 reports the IRFs to a spending shock for the fiscally stressed (FS) countries (left panels) and non-fiscally stressed (NFS) countries (right panels)

Figure 14. T shock: FS and NFS countries

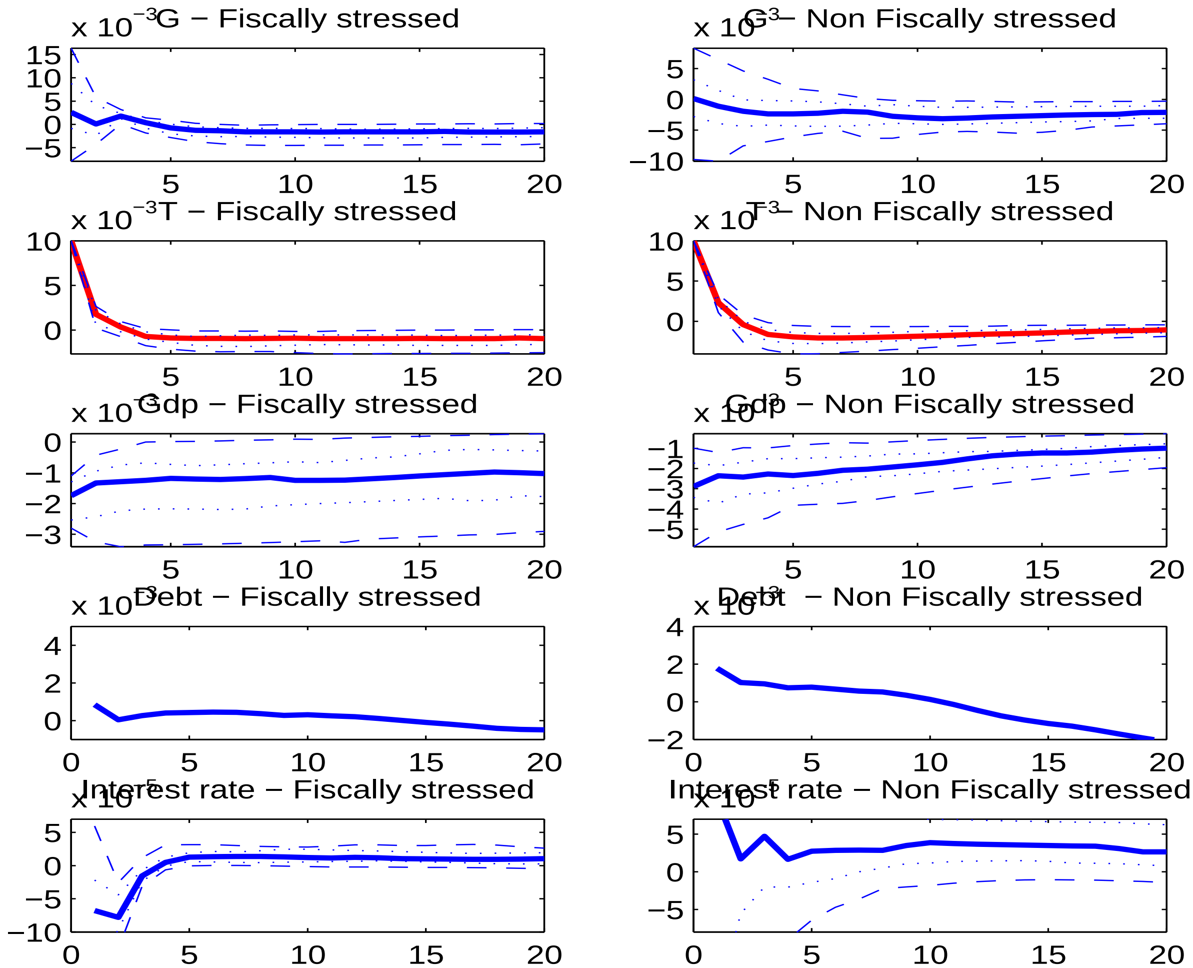


Figure 14 reports the IRFs to a tax shock for the fiscally stressed (FS) countries (left panels) and non-fiscally stressed (NFS) countries (right panels)

Figure 15. G shock: vulnerable countries vs non-vulnerable (whole sample)

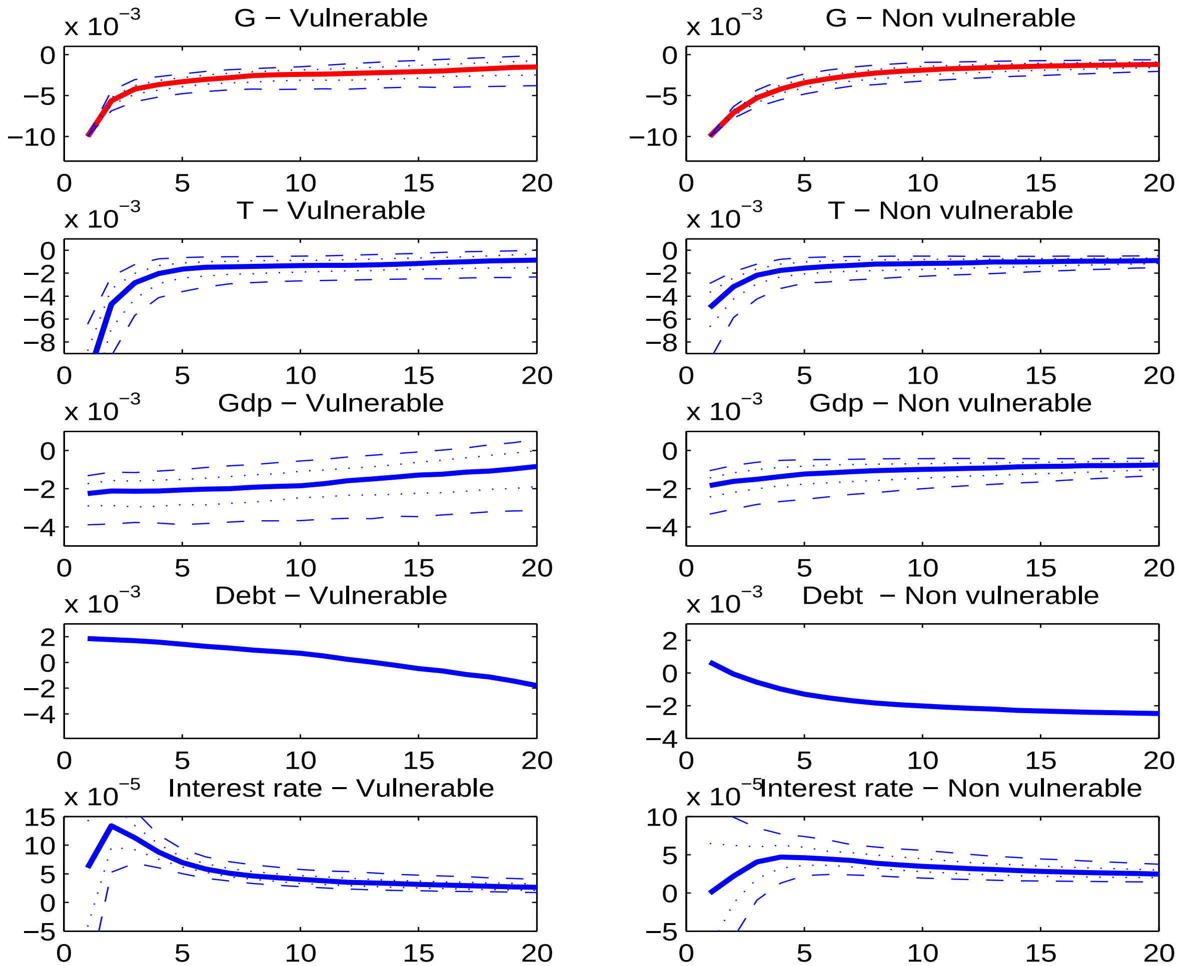


Figure 15 reports the IRFs to a spending shock for the vulnerable countries (left panels) and non-vulnerable countries (right panels)

Figure 16. T shock: vulnerable and non-vulnerable countries (whole sample)

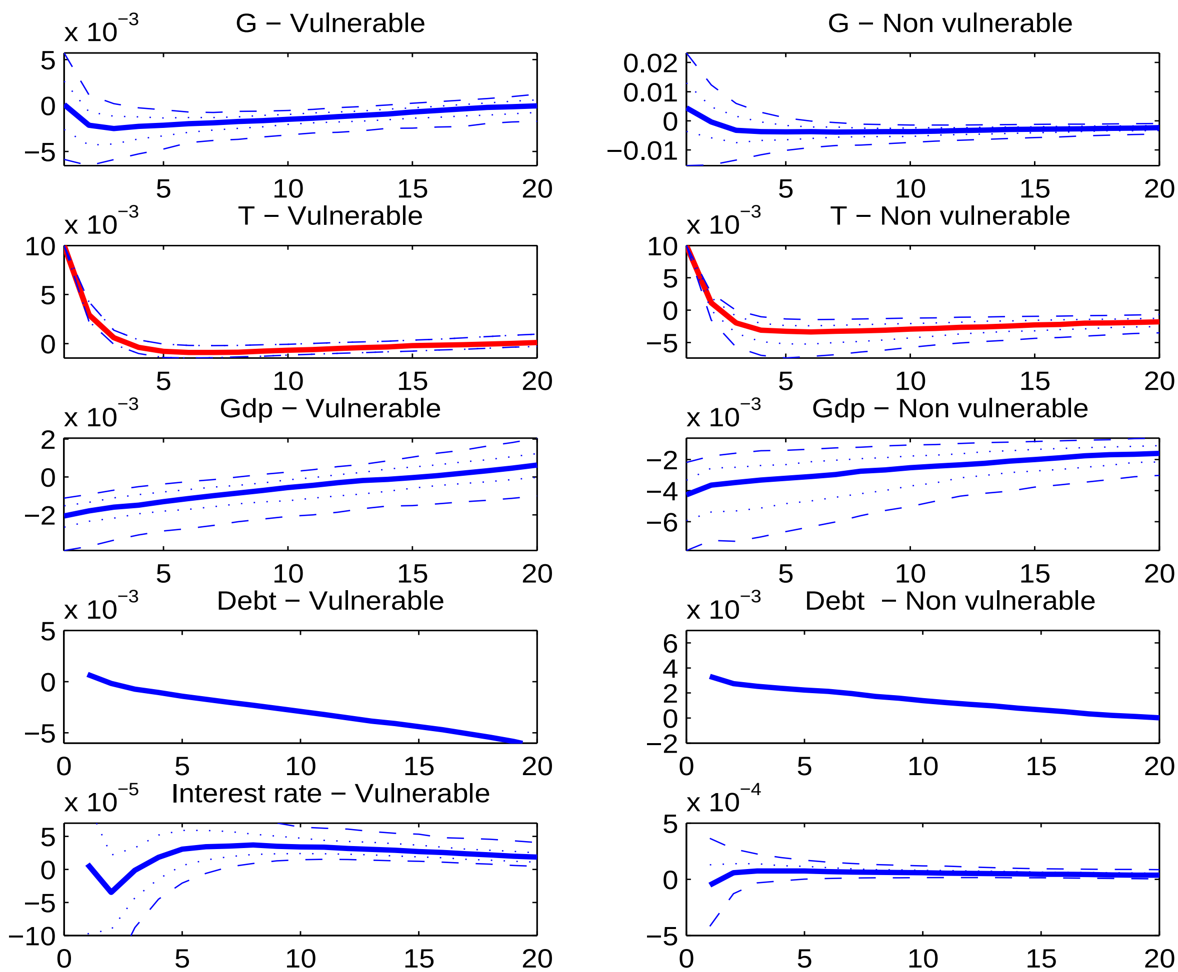


Figure 16 reports the IRFs to a tax shock for the vulnerable countries (left panels) and non-vulnerable countries (right panels)

Figure 17. Baseline: 1 lag

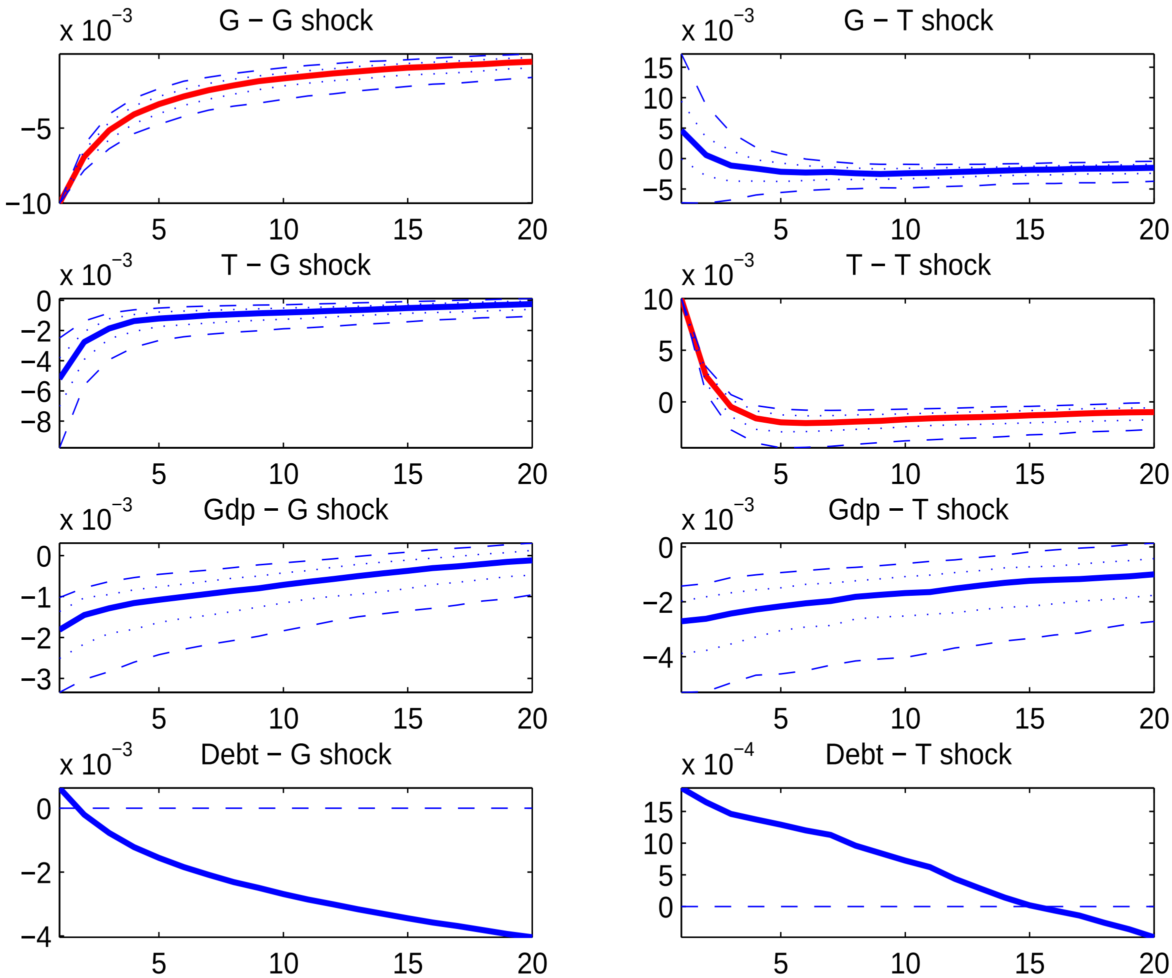


Figure 17 reports the IRFs for the baseline scenario, calculated using 1 lag. G shock on the left. T shock on the right

Figure 18. Baseline: 2 lags

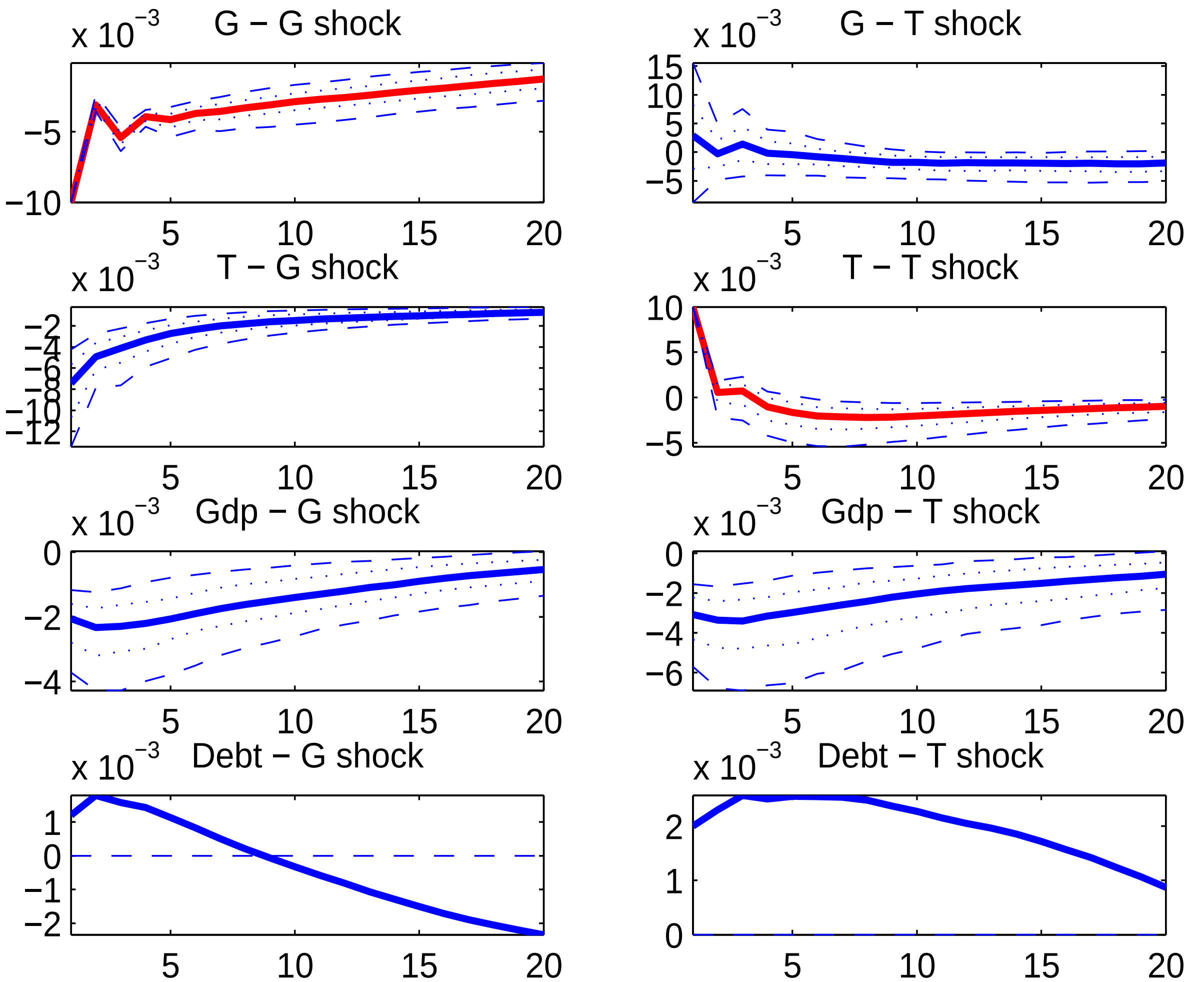


Figure 18 reports the IRFs for the baseline scenario with 2 lags. G shock on the left. T shock on the right

Figure 19. Mean Group Estimator

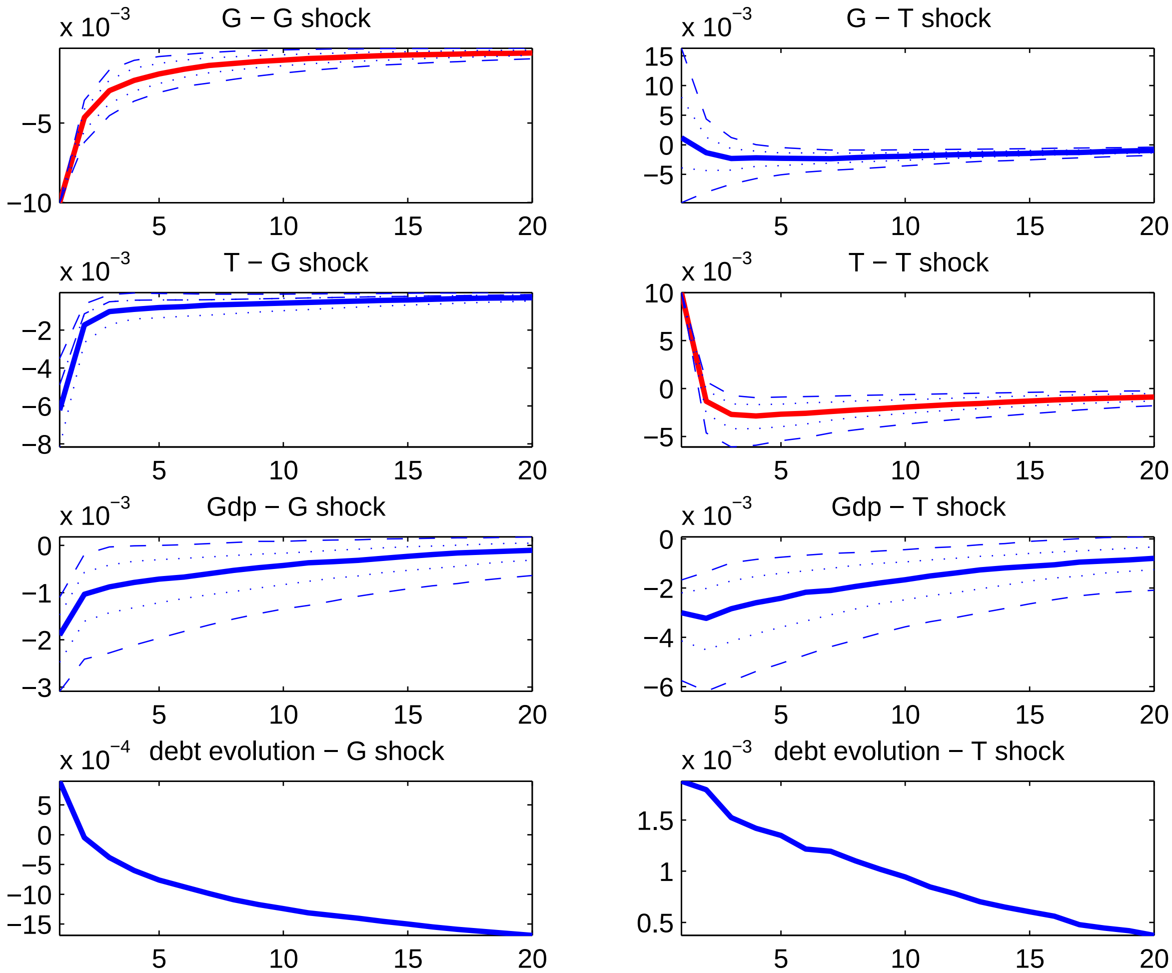


Figure 19 reports the IRFs when the PVAR is estimated using the Mean Group estimator

Figure 20. Baseline 2000-2007

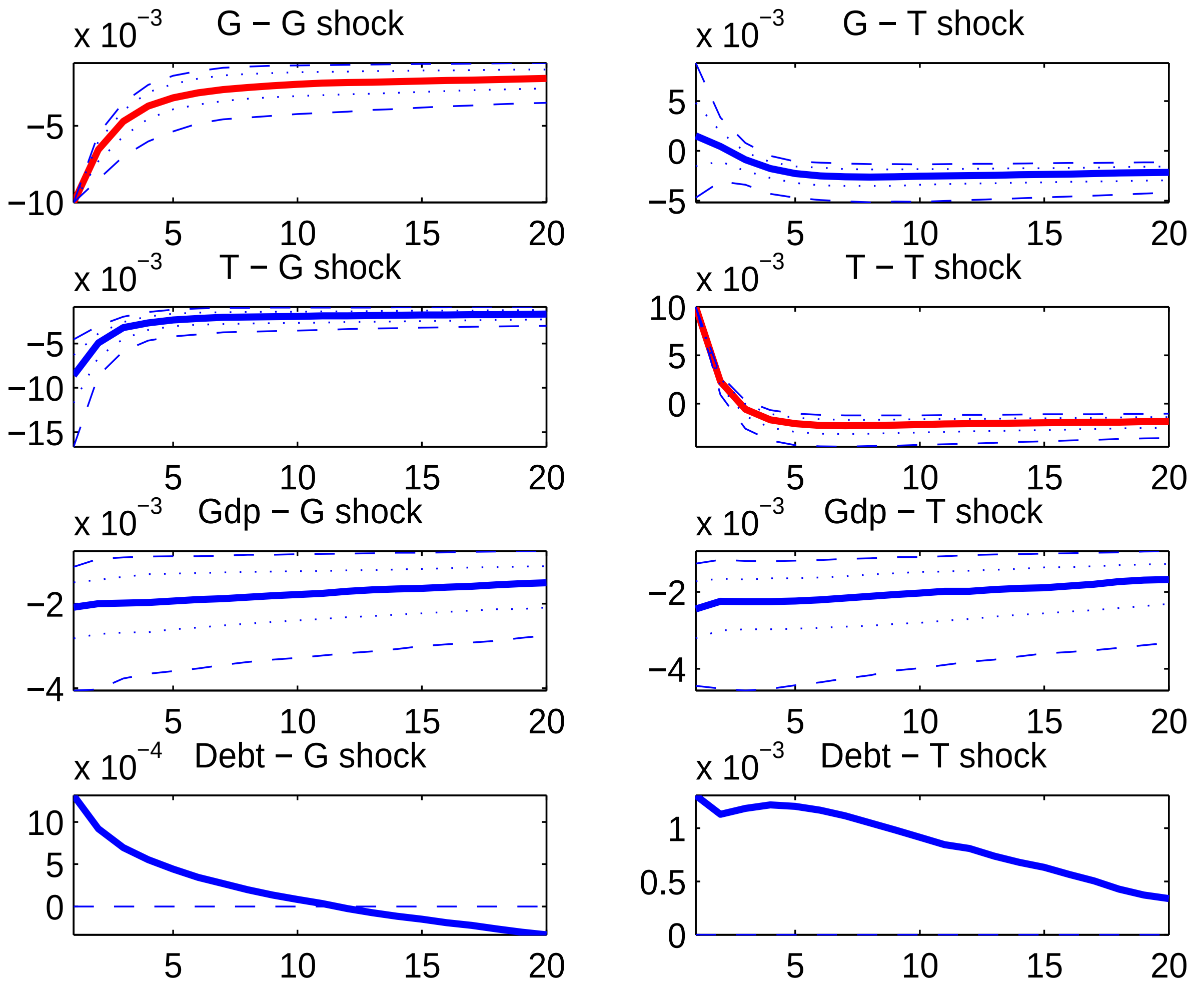


Figure 20 reports the IRFs when the model is estimated over the sample 2000-2007

Chapter 3

The Importance of Updating: Evidence from a Brazilian now-casting model

3.1 Introduction

Monitoring short-term economic developments, in particular real GDP growth, is the instrument through which market participants and policy institutions all over the world make their decisions on how to invest or on how to conduct monetary and fiscal policy. Real GDP growth in many countries, including Brazil, is a quarterly variable that is released by the national statistical office with a delay that could be, at times, significant. In the case of Brazil the delay is two months. In other words, real GDP growth related to the first quarter (January to March) is disclosed only in May. Given this limitation it is nevertheless reasonable to think that it is possible to learn the current economic condition by monitoring other indicators that are linked to GDP growth and that are released at a higher frequency. Newspapers, statistical offices, and central bank websites release daily data (for instance releases on industrial production, on the number of vehicles sold, on the confidence of consumers, etc.) that can be used to produce early estimates of GDP growth. Market participants monitor these data too. Global information services, such as Bloomberg and Forex Factory, report a calendar of data releases that is highly regarded by the markets. Bloomberg and Forex Factory also assign a measure of importance to each release, which reflects the usage by markets. Bloomberg, in addition, conducts a survey and collects forecasts from analysts and economists on each release they report and publishes it the day before the release is disseminated.

Academia has also moved toward incorporating this more timely information into formal econometric forecasting models. Two seminal papers (Evans, 2005, and Giannone et al., 2006) have modeled, within the same statistical framework, the joint dynamics of GDP and the monthly indicators. According to this literature, it is worth while to update economic predictions often, as the incorporation of the continuous data flow makes the forecasts more and more accurate. Professional forecasters, however, do not publish short-term economic forecasts frequently. The Organisation for Economic Co-operation and Development (OECD) and the International Monetary Found (IMF) report their forecast twice a year, many central banks (e.g. Bank of England, Bank of Canada, and the Federal Reserve Open Market Committee) four times a year and, only a few institutions update their forecasts monthly (e.g. Banque de France, Bank of Japan, Bundesbank, the Conference Board). The process through which they revise their forecasts is not clear. The Central Bank of Brazil (BCB), not only disseminates its official forecasts every quarter as other central banks, but also collects and publishes the results of professional forecasters' survey data at a daily frequency. It is, in fact, responsible for the set up of an interesting Market Expectation System, a web interface where financial institutions, consulting firms, and universities report their expectations for various macroeconomic variables including GDP.

The aim of this paper is to understand how sensible it is for an institution, such as the BCB, to produce such regular predictions of GDP growth. The aim is to evaluate the forecasting performance of the BCB Survey and to compare it with the mechanical forecasts based on state-of-the-art nowcasting techniques. Results indicate that both model and market participants' predictions are well behaved, i.e. as more information becomes available their accuracy and correlation with the out-turn increases. In addition, our results show that model based forecasts perform slightly better than institutional forecasts. According to this last result, the often-cited superiority of professional forecasts (see Ang et al., 2007, Clements, 2010, Jansen et al., 2012) turns out to be weak in our sample confirming findings in Giannone et al. (2006) and Liebermann (2011).

Recently, there has been a lot of interest in applying this statistical environment to various economies, including the United States (Lahiri and Monokroussos, 2013), the Euro Area (Angelini et al., 2010; Angelini et al., 2011; Camacho and Perez-Quiros,2010) , France (Barhoumi et al., 2010), Germany (Marcellino and Schumacher, 2010), Ireland (D'Agostino et al., 2008; Liebermann, 2012), the Netherlands (de Winter, 2011), the Czech Republic

(Arnostova et al., 2011; Rusnák, 2013), New Zealand (Matheson, 2010), Norway (Aastveit and Trovik, 2012), Switzerland (Siliverstovs, 2012) and for China (Yiu and Chow, 2010). For a survey, see Bańbura et al. (2012) and Bańbura et al. (2013). In the case of Brazil, Issler and Notini (2013) propose an interpolation method based on state-space models to estimate monthly Brazilian GDP, through the use of coincident indicators. This methodology is part of the literature on coincident indicators of economic activity, where an unobserved state of the economy is estimated from a multivariate model. Chauvet (2001) constructs an indicator of Brazilian monthly GDP through the use of a Markov switching dynamic factor model. In this article, instead, we aim at pure nowcasting, defined as timely estimation of GDP. The rest of the paper is structured as follows. Section 2 describes the structure of the data releases in Brazil. Section 3 introduces the model and estimation technique. Section 4 describes the BCB survey and the other benchmarks. Section 5 introduces the empirical analysis and comments on the results. Section 6 concludes.

3.2 The Data Set

The Brazilian statistical office publishes real GDP growth two months after the end of the quarter. The aim of the statistical model we propose in this paper is to predict GDP before the official figures are published by taking advantage of the information in the flow of economic data releases that precede them and updating our prediction with each successive data release. We include in our model those variables whose headline number is reported by the main statistical sources and central banks; in addition we consider those indicators monitored by financial markets and by the press. We choose the transformations that guarantee stationarity of the variables (see Table 1), which are the same as the ones reported by the media and Bloomberg, making the comparison easier. We consider only real data and surveys. We disregard prices and financial variables, nominal variables, and sector-specific series. This choice reflects the results of previous research, in which the inclusion of these variables does not improve the model's forecasting performance (see Bańbura and Modugno, 2010, and Bańbura et al., 2012).[1] The target variable is quarterly Real GDP growth, reported as a quarter-on-quarter (QoQ) transformation, the headline series on which market participants focus their attention on.[2] The input series, which are of monthly frequency, are reported as month-on-month (MoM) transformations, with the exception of PMI Manufacturing, which is in levels but behaves like a MoM for how it is constructed. [3] The fact of linking the QoQ target variable with MoM input series is standard in this literature (see among others Mariano and Murasawa, 2003, Camacho and Perez-Quiros, 2010 and Bańbura and Modugno, 2014).

Table 1 reports some details on the selected series, in particular the timing of the release and the importance that the financial markets attach to the series, according to the Bloomberg

[1]It is true that financial variables, which are available at very high frequency might, in principle, carry information on expectations of future economic developments (Andreou et al., 2008), however we only consider macro indicators and surveys given that other studies on this topic - see Bańbura et al. (2013), Stock and Watson (2005) and Forni et al. (2003) - indicate that "financial variables do not help improving the precision of GDP now-cast", because the news from financial variables is highly volatile and leads to revisions in different directions. Moreover, Bańbura et al. (2013) show that there is correlation between some financial variables and GDP, but only at low frequency: this indicates that while financial variables are not important for short term forecast they could instead be important for long term forecast. This is also confirmed by the fact that market participants mostly monitor real variables.

[2]Brazil also has a Nominal Monthly GDP series, but this is not the headline series, so we consider it as an input variable.

[3]In order to construct the PMI index, respondents are asked to state whether business conditions for a number of variables have improved, deteriorated or stayed the same, compared with the previous month. Therefore the index is comparable to a MoM transformation. PMI is produced by Markit, see web page http://www.markit.com/product/pmi.

Table 1. *Series used in the model*

Name	Timing	Publishing lag	Frequency	Source	Available from	Transf.	Relevance Bloomberg
Formal employment	20^{th} month	20 days	M	IBGE	Jan-85	Monthly change	63.5
Merchandise exports	first days	2 days	M	MDIC	Jan-54	MoM	40.4
Merchandise imports	first days	2 days	M	MDIC	Jan-59	MoM	36.5
Capacity utilization	first week	one month	M	CNI	Dec-91	Monthly change	32.7
Industrial production	first days	one month	M	IBGE	Jan-91	MoM	90.4
Consumer confidence index	last week	current month	M	FGV	Sep-05	Monthly change	17.3
Economic activity index	middle	1-2 months	M	BCB	Jan-03	MoM	23.2
Monthly GDP	end	one month	M	BCB	Mar-90	MoM	-
Manufacturing sales	first days	one month	M	CNI	Dec-91	MoM	-
PMI manufacturing	first days	2 days	M	BancoRl	Feb-06	Levels	75.0
Extended retail trade	middle	1-2 months	M	IBGE	Jan-03	MoM	-
Retail trade: volume	middle	1-2 months	M	IBGE	Jan-03	MoM	71.1
Real GDP	first days	2 months	Q	IBGE	Q1-90	QoQ	80.1

Notes. Timing: is approximately the number of days from the end of the reference period; **Frequency:** indicates whether the series is monthly (M) or quarterly (Q);**Available from:** indicates the starting date of the series; **Sources:** MTE (Ministério do Trabalho e Emprego), IBGE (Fundaçâo Instituto Brasileiro de Geografia e Estatística), MDIC (Ministério do Desenvolvimento, Indústria e Comércio Exterior), CNI (Confederaçâo Nacional da Indústria), FGV (Fundaçâo Getúlio Vargas), BCB (Banco Central do Brasil), BancoRL (Banco Real); **Bloomberg:** reports the market relevance of each variable according to Bloomberg's relevance index, that ranges from 0 to 100.

index. The peculiarity of the Brazilian data set is the fact that it includes two indicators that are strictly related to the target variable (quarterly GDP). The first is the monthly nominal GDP, published by the BCB, based on monthly indicators for economic activity and prices. The second is the economic activity index (EAI), also published by the BCB. The EAI is a monthly coincident indicator based on the same methodology used to measure the Brazilian quarterly GDP, which consists of a set of proxies of economic behavior in the different economic sectors (agriculture, industry, distributive trade, transportation, services). As the EAI is a recent indicator, it still does not relate directly to the monthly nominal GDP, whose calculations follow an older methodology. The rest of the variables can be divided into four categories: surveys, labor, production, demand, and trade indicators. Among surveys, we consider the consumer confidence index and the purchasing manager index (PMI). The consumer confidence index is very timely and it is the only piece of information in Brazil published within the reference period, though Bloomberg does not rank it as important (17.3%). The PMI is released at the beginning of the following month and is a relevant series according to the markets (75.0%). For labour, we include formal employment (FE), which is rated fairly important by Bloomberg (63.5%). For production, we track industrial production (IP), which is rated highly for importance by Bloomberg (90.4%). For domestic demand, we track capacity utilization (CU), real manufacturing turnover (RMT), extended retail trade (ERT) and retail trade (RT). ERT, differently from RT, reports the volume of sales of formally established companies with 20 or more employed persons and whose main activity is retail trade which includes "Vehicles, motorcycles, parts and accessories" and "Construction material". Bloomberg comments RT and rates it fairly high in terms of importance (71.1%). The trade category is particularly important for the Brazilian economy given its timeliness. Exports and Imports have the same publication lag as the PMI. Most of the hard data series (employment, retail sales and industrial production) are published with a three to six weeks lag after the end of the reference month. Trade variables (exports and imports) are published at the beginning of the following month. Differently from other countries the statistical office, the Brazilian Institute of Geography and Statistics (IBGE), disseminates a monthly GDP indicator, which is published four weeks after the reference period.

3.3 The Nowcasting Problem and the Econometric Framework

The problem of nowcasting lies in estimating GDP in the interval of time between the beginning of the reference quarter and its official release, exploiting the information coming from other higher frequency variables[4]. More formally, the nowcast of GDP (y_t^Q) can be defined as the orthogonal projection of y_t^Q on the available information set Ω_v[5], which contains mixed-frequency variables ($x_{k_j,t_j}, j = 1, ..., J_{v+1}$) and is characterized by a "ragged edge" structure given that the time of the last available information varies from series to series. Each time new information arrives, a new nowcast is produced. This nowcast can be decomposed as follows:

$$E[y_t^Q|\Omega_{v+1}] = E[y_t^Q|\Omega_v] + E[y_t^Q|I_{v+1}]. \tag{1}$$

The new forecast $E[y_t^Q|\Omega_{v+1}]$ is just the sum of the old forecast $E[y_t^Q|\Omega_v]$ and the revision $E[y_t^Q|I_{v+1}]$, where

$$I_{v+1,j} = x_{k_j,t_j} - E[x_{k_j,t_j}|\Omega_v], \tag{2}$$

with $j = 1, ..., J_{v+1}$. This revision ($I_{v+1,j}$) is the expected value of our target variable conditional to the difference between the actual release of any variable ($x_{k_j,t_j} \in \Omega_{v+1}$) and what our model was predicting for that release ($E[x_{k_j,t_j}|\Omega_v]$): this revision is the only element that leads to a change in the nowcast, because it is the "unexpected" (with respect to the model) part of the data release and we call it "news". As shown by Bánbura and Modugno

[4]In this section we closely follow Giannone et al., 2006; Bańbura Modugno, 2010; Bańbura et al., 2012; and Bańbura et al., 2013.

[5]Denotes a vintage of data corresponding to a particular release date v.

(2010), the revision can be decomposed as a weighted average of the news in the latest release. We can find a vector $B_{v+1} = [b_{v+1,1}, ..., b_{v+1,J_{v+1}}]$, through the Kalman smoothing procedure, such that the following holds:

$$E[y_t^Q|\Omega_{v+1}] - E[y_t^Q|\Omega_v] = B_{v+1}I_{v+1} = \sum_{j=1}^{J_{v+1}} b_{v+1,j}(x_{k_j,t_j} - E[x_{k_j,t_j}|\Omega_v]). \quad (3)$$

The magnitude of the forecast revision depends both on the size of the news and on its relevance for the target variable, as represented by the associated weight $b_{v+1,j}$.[6] Through this mechanism, it is possible to trace the contribution of each series to the revision of the nowcast, in particular putting in relation the revision of the target with the unexpected developments of the inputs.

The model we use in order to compute the nowcast and the news is a dynamic factor model (DFM). This model produces a good representation of the data and guarantees, at the same time, parsimony. It exploits the fact that there is a large amount of co-movement among macroeconomic data series, and hence that relatively few factors can explain the dynamics of many variables (see Sargent and Sims, 1977; Giannone et al., 2005; Watson, 2004; and Stock and Watson, 2011). The model can be written as a system with two types of equations: a measurement equation (Equation 4) linking the observed series (i.e GDP and all the indicators listed in Table 1) to a latent state process, and the transition equation (Equation 5), which describes the state process dynamics. Equations 4 and 5, written in a state space form, allow the use of the Kalman filter to obtain an optimal projection for both the observed and the state variables. The Kalman filter generates projections for all of the variables in the model (GDP but also all the other data releases). The DFM model is described by the following equations:

$$y_t = \Lambda f_t + e_t, \quad (4)$$

$$f_t = A_1 f_{t-1} + A_2 f_{t-2} + ... + A_p f_{t-p} + u_t \qquad u_t \sim i.i.d.N(0, Q), \quad (5)$$

$$e_{i,t} = \rho_i e_{i,t-1} + v_{i,t} \qquad v_{i,t} \sim i.i.d.N(0, \sigma_i^2), \quad (6)$$

[6] Equation 3 can be considered as a generalization of the usual Kalman filter update equation to the case in which new data arrive in a non-synchronous manner. See Bánbura and Modugno (2010) for further detail.

where $y_t = [y_{1,t}; y_{2,t}; ...; y_{n,t}]'$ denotes a set of standardized stationary monthly variables, f_t is a vector of r unobserved common factors with zero mean and unit variance, Λ is a matrix of coefficients collecting the factor loadings for the monthly variables, and $e_t = [e_{1,t}; e_{2,t}; ...; e_{n,t}]'$ is a n-dimensional vector of idiosyncratic components uncorrelated with f_t at all leads and lags. This last assumption, which means that all of the joint correlation between observables is explained by the common factors, is strong and unrealistic, however Doz et al. (2006) have shown that the effects of this mispecification on the estimation of the common factors is negligible for large sample size (T) and the cross-sectional dimension (n). We consider only one factor and two lags in Equation 5 and an AR(1) process for the idiosyncratic components described in Equation 6.[7] In order to incorporate quarterly variables into the model, we construct for each of them a partially observed monthly counterpart in which the value of the quarterly variable is assigned to the third month of the respective quarter. We assume that the "unobserved monthly" growth rate of GDP (y_t^{UM}) admits the same factor model representation as the monthly real variables:

$$y_t^{UM} = \Lambda_Q f_t + e_t^Q, \tag{7}$$

$$e_t^Q = \rho_Q e_{t-1}^Q + v_t^Q \qquad\qquad v_t^Q \sim i.i.d.N(0, \sigma_Q^2). \tag{8}$$

To link y_t^{UM} with the observed GDP data, we construct a partially observed monthly series and we use the approximation of Mariano and Murasawa (2003):

$$y_{i,t}^Q = y_{i,t}^{UM} + 2y_{i,t-1}^{UM} + 3y_{i,t-2}^{UM} + 2y_{i,t-3}^{UM} + y_{i,t-4}^{UM}. \tag{9}$$

The estimation procedure is quasi maximum likelihood. As shown in Doz et al. (2006), the estimator, apart from being robust to model mispecification, is feasible when n is large (as in the case of Brazil) and easily implementable using the Kalman smoother and the EM algorithm, initialized using principal components, as in traditional factor analysis. Given that most of the indicators we include in our model are characterized by missing data at the beginning of the sample (as it is in the case of the consumer confidence index, which starts in September 2005, or the PMI, which starts in February 2006) and by a "ragged edge" structure, due to unsynchronized data releases at the end of the sample, we follow Bańbura and Modugno (2014), that propose a solution for estimating factor models in the presence

[7] We use Bai and Ng (2002) Information Criteria to select the number of factors in Equation 4 and Akaike Information Criteria to select the lag order of Equation 5. See the appendix for details.

of datasets characterized by arbitrary patterns of missing data.

3.4 The BCB Survey and Other Benchmarks

The BCB has set up a Market Expectation System, a web interface where financial institutions, consulting firms, and universities, which are required to have a specialized team on macroeconomic projections, report their expectations for various macroeconomic variables including GDP growth. The process through which these institutions revise their forecasts is not clear, nevertheless it is reasonable to think that these predictions are not entirely model based, but that a certain amount of judgment is also used.[8] Every business day at 5:00 pm (GMT-2) the information is consolidated and several statistics are generated: averages, medians, standard deviations, coefficients of variation, and minimum and maximum values of the projections recorded by the participants. Of the universe of qualified institutions, most of them alter their expectations weekly. For the purposes of our exercise, we consider the median projection. The other important benchmark we consider is Bloomberg, which conducts a survey and collects forecasts from analysts and economists in order to produce predictions for GDP and other market-relevant variables before their release dates. Bloomberg publishes predictions as soon as they have at least three respondents to their questionnaire, which is generally around two weeks before the release of the relevant data series. Thereafter the prediction is continually revised until 24 hours before the release. The final number is usually close to the actual release value. Surveys of professional forecasters are forecast combinations that have the advantage of performing better than single forecasts (see Bates and Granger, 1969; Diebold and Lopez, 1996; Newbold and Harvey, 2002; and Clements and Hendry, 2004). In addition, short term forecasts, produced by the surveys, are based on real-time information. We also consider as benchmarks the OECD, IMF (released twice a year), and the BCB quarterly forecasts to compare the model results on calendar year forecasts.

3.5 Model Evaluation

In order to evaluate the performance of the model we report a "pseudo real time" historical reconstruction from 2007:Q1 to 2013:Q1. We estimate the model recursively (the estimation

[8]This statement was confirmed by a BCB forecasting expert.

period starts in January 1995) and we take account of information from each new data release (real-time), but we do not consider revisions (pseudo).[9] This last point can in principle distort the results in favour of the model, given that the BCB short term forecasts and the Bloomberg survey rely on real time information. However, given the robustness of factor models to data revision errors (see Giannone et al., 2006 and Bańbura et al., 2013), we expect this not to be the case. The results of the historical evaluation are reported in the figures below. Figure 1 compares the year-on-year GDP nowcast and the BCB Survey with the actual realization of GDP in panel (a), and the calendar year now-cast and the IMF, OECD and BCB forecasts with the actual realization of GDP in panel (b). Figure 1 shows that the nowcasting model mimics very well the actual realization of GDP.

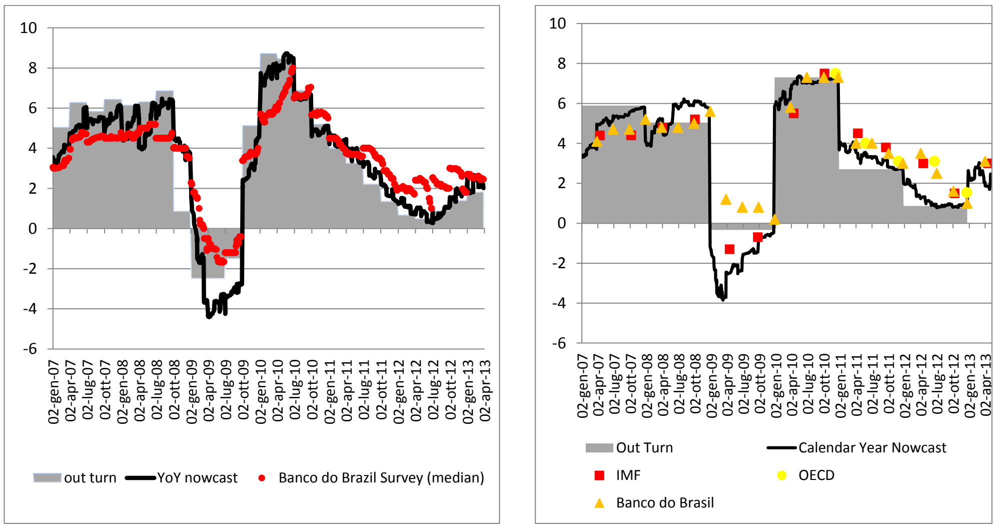
Figure 2 compares the root-mean-squared forecast error (RMSFE) of the model - on average for all of the calendar quarters in the historic reconstruction period - with the short-term forecast of BCB, the Bloomberg's survey of independent forecasters (published the day before the preliminary GDP release) and an auto-regressive forecast, which changes only when GDP is released. Given that the BCB GDP Survey reports YoY figures, we evaluate the model on a YoY basis. Results do not differ significantly if we consider QoQ figures.

The model's quarterly GDP growth prediction is first made 90 days before the start of a given quarter. It is then updated with each successive data release until the release of preliminary GDP, which takes place 145 days after the start of the calendar quarter. Thereby for each calendar quarter there is a period of 235 days (the "prediction period") over which the prediction is continuously updated. This period is measured by the X-axis. The Y-axis measures the root-mean-squared forecast error (RMSFE) for each different series of predictions.

In Table 2, we report the RMSFE reduction by release, in each of the three months of the reference quarter. Specifically, real GDP, Exports, industrial production, PMI and formal employment are the data releases that have the most impact in improving the accuracy of the model's prediction.

[9] We cannot conduct a real time analysis given that we do not have real time information for all the data series included in the model. To our knowledge only the OECD reports real time information on Brazil, but only on a small number of series, namely GDP, industrial production, retail trade, export and import. See http://stats.oecd.org/mei/default.asp?rev=1. This means that we estimate the model using the last available vintage of our input data. Then we compare the performance of the model with alternative benchmarks, which are however based on real time vintages of data

Figure 1. GDP nowcast



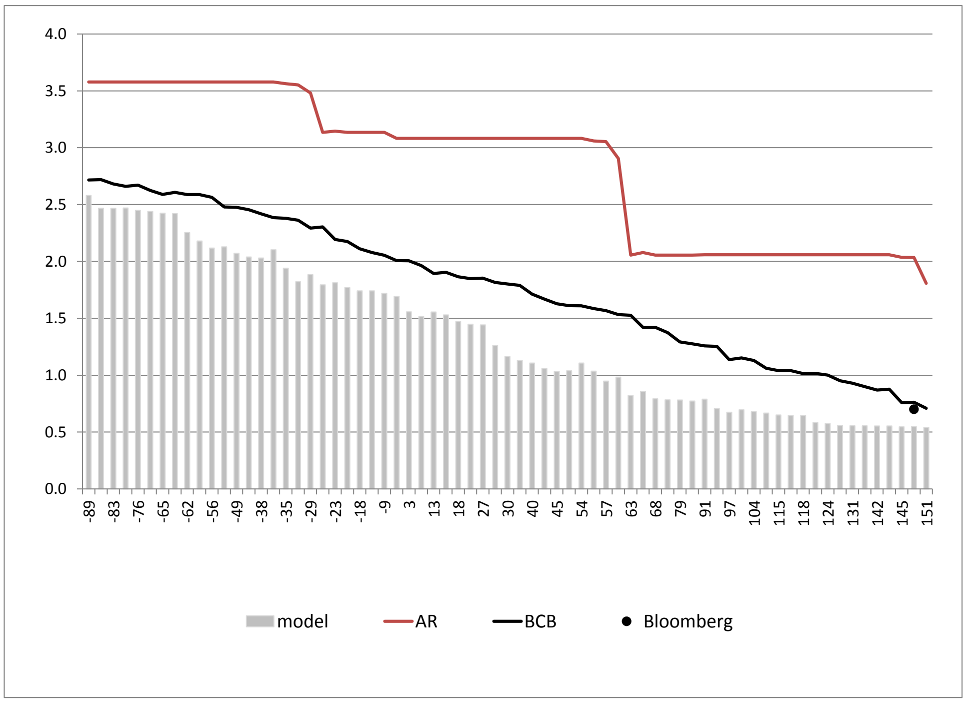
a) year-on-year (YoY) nowcast **b) calendar year nowcast**

Notes. Panel a), reports the comparison between GDP nowcast, GDP actual value, and the BCB survey (year-on-year). Panel b), reports the comparison between GDP nowcast, GDP actual value, OECD, IMF and Banco do Brasil forecasts (calendar year).

3.5.1 Tests

The BCB professional forecasts seem to be highly collinear with the nowcasts and equally accurate. In Table 3, we report the Diebold-Mariano (2002) test of equal predictive accuracy to check whether the difference in forecasting performance between models is significant. For each month, we report the sample average of the difference between the squared errors of the AR and the BCB professional forecasts both with respect to the nowcasting model (benchmark), in coincidence with the first Brazilian release (exports). We report the value of the DM test and its standard deviation estimated using heteroskedasticity and autocorrelation robust (HAC) standard errors (see appendix A.2 for details). The test confirms better performance in terms of accuracy of the nowcasting model in comparison with the AR (in the

Figure 2. RMSFE



Notes. The Y-axis reports the root-mean-squared forecast error (RMSFE) over the period 2007:Q1 to 2013:Q1. The forecast accuracy is evaluated from the first month of the previous quarter to the time when GDP is released. The X-axis reports the distance in terms of days from the beginning of the current quarter.

Table 2. *Average MSFE Reduction by Variable*

	m1	m2	m3
Merchandise exports	-5.3	-29.9	0.7
Merchandise imports	-3.1	-2.4	-4.4
PMI Manufacturing	6.9	-24.7	-10.3
Industrial Production	-37.2	-19.6	-7.7
Manufacturing Sales	-5.1	-2.3	3.9
Capacity Utilization	-5.9	0.5	-1.2
Economic Activity Indicator	-6.7	-6.5	-1.4
Extended Retail Trade	-7.3	-4.4	-6.6
Retail Trade: Volume of Sales	-1.5	-0.4	-0.8
Formal Employment	-15.8	-11.5	-1.1
Consumer Confidence Index	-0.6	-0.3	0.0
Monthly GDP	-5.9	15.4	-1.6
Real GDP			-37.3

Notes. These results are referred as the first (m1), second (m2), and third (m3) months of the nowcast period.

forecast, nowcast and backcast) and a slightly better performance in comparison with the BCB forecasts (only in the nowcast and in the backcast).

From Figure 2 we can see that the model's RMSFE declines more or less continuously over the prediction period, which means that new information has a monotonic and negative effect on uncertainty. In order to formally test the decline in uncertainty, as more data arrive we apply the test for forecast rationality proposed by Patton and Timmerman (2012). Table 4 reports the p-values of three monotonicity tests for, respectively, the forecast errors, the mean-squared forecast, and covariance between the forecast and the target variable (see the appendix for a description of the test). Monotonicity cannot be rejected by any of the three tests confirming the evidence of Figure 2 and proving the importance of incorporating new information as it arrives in the forecast update.

Table 3. Diebold-Mariano test of equal forecasting accuracy

	Forecast		Nowcast		Backcast	
	AR	BCB	AR	BCB	AR	BCB
1m	6.42	0.62	6.95	1.24	3.78	1.03
	(3.37)	(1.26)	(2.95)	(0.68)	(1.45)	(0.31)
2m	8.06	1.55	8.26	1.80	3.98	0.64
	(3.76)	(1.11)	(3.21)	(0.71)	(1.50)	(0.17)
3m	9.37	1.86	8.63	1.48		
	(3.86)	(1.16)	(3.24)	(0.47)		

Notes. The table reports the estimated constant and the HAC estimator of its standard error in the first, second, and third month of the forecast, nowcast, and backcast, respectively. The AR and BCB professional forecasts are compared against the nowcast model.

Table 4. Monotonicity Tests

	$\Delta^e \geq 0$	$\Delta^f \geq 0$	$\Delta^c \geq 0$
nowcast model	0.4965	0.4978	0.5012

Notes. The table reports the p-values of three monotonicity test for, respectively, the forecast errors, the mean-squared forecast, and covariance between the forecast and the target variable.

3.5.2 The News

The importance of calculating the news is twofold: first, given that the news is defined as the difference between the actual value of the data release and the value predicted by the model, it is possible to check whether the model is well specified in all of its dimensions. The average of the news for each release should be close to zero, and the standard deviation should be such that $|mean| < 2$ standard deviation. Table 5 confirms the previous statement. In addition, the table also compares the model's performance in predicting each of the series with that of the Bloomberg survey. We show that, for most series, the model's predictions are comparable to the Bloomberg survey predictions. Finally, we include in Table 5 the mean and standard deviation of the revisions for each of the series in the data set. As the means of the revisions are close to zero and the standard deviations are such that $|mean| <$ 2 standard deviation, this suggests that the model's relative performance would have been similar in real time.[10]

Table 5. Average news and standard deviation

		Model		Bloomberg		Revisions	
	Units/ Transformation	Mean	StD	Mean	StD	Mean	StD
Merchandise exports	US$/MoM	-0.32	6.97	0.74	11.68	0.85	8.95
Merchandise imports	US$/MoM	0.82	6.01	0.39	10.31	0.43	8.53
PMI Manufacturing	D.I./Levels	-0.14	1.69	-0.07	0.22	0.01	0.13
Industrial production	Index/MoM	-0.12	1.98	0.38	1.09	-0.05	0.54
Manufacturing sales	Index/MoM	-0.17	2.29				
Capacity utilization	Percentage/Diff.	-0.02	0.37	-0.81	0.68	-0.80	0.46
Economic activity index	Index/MoM	-0.07	0.81				
Extended retail trade	Index/MoM	0.08	2.62	-0.10	2.00	-0.08	2.67
Retail trade: volume	Index/MoM	0.30	0.85	-0.05	0.85	-0.01	0.60
Formal employment	Index/Diff.	0.04	0.18				
Consumer confidence index	Index/Diff.	-0.24	3.34	-0.48	6.06	0.22	4.41
Monthly gross domestic product	Mil. Reais/MoM	-0.24	2.12				
Real gross domestic product	Index/MoM	0.14	0.55	0.04	0.45	-0.07	0.56

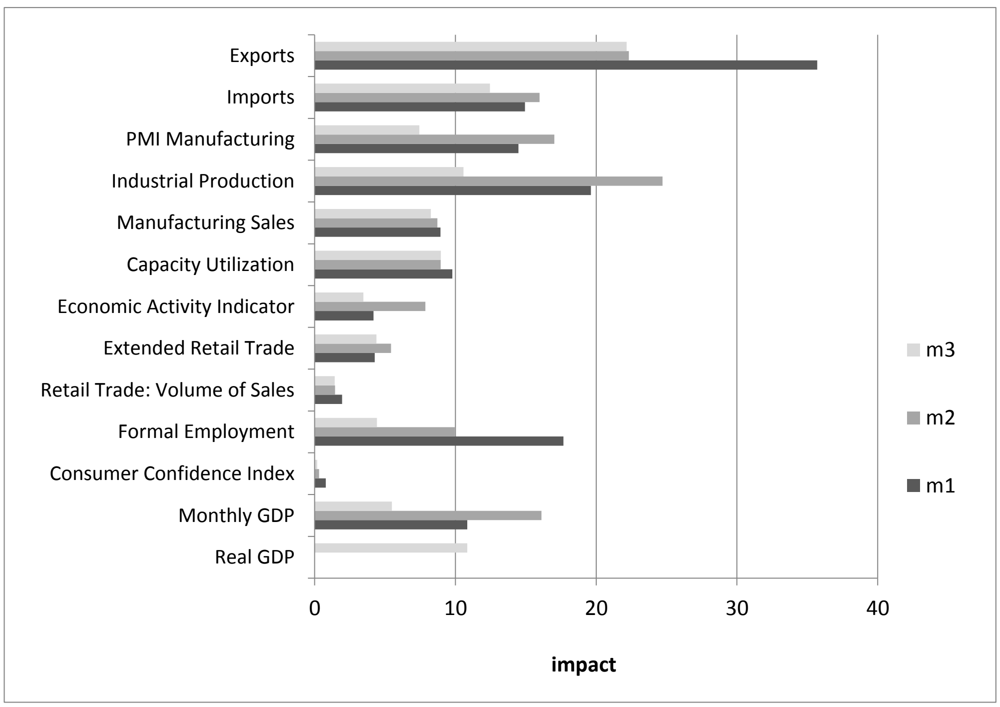
Notes. D.I.= diffusion index; Diff.= differences; Thous. Units = Thousand Units; Manuf. = Manufacturing; Mil. Reais = Million Reais.

The second important feature of the news within a nowcasting framework is that it allows interpretation of all the data releases in terms of the signals they give about current economic conditions (Bańbura and Modugno, 2010). It is possible, with the use of Equation 3, to decompose the forecast revision into contributions from the news in individual series. The

[10] Note that the Bloomberg survey is conducted in real time, and the respondents whose forecasts it reflects are attempting to predict the first release of each series, whereas the reconstruction of the model's predictions is based on the last available vintage of data, ignoring revisions.

impact that a given release has on the GDP nowcast is the product of two variables: the news (or the unexpected component of the release value), and the relevance of the series in relation to GDP, which is expressed as its weight (i.e., impact = news standard deviation[11] x weight). Figure 3 shows the average impact of each variable in the first, second, and third month of the quarter. Trade variables have a huge impact on the forecasting revision given their timeliness, but also industrial production, PMI and employment variables seem to have a relevant contribution to the forecast revisions of GDP. See appendix A.4 for the decomposition of the average impact.

Figure 3. Variables' relevance



Notes. Variables' average impact in the first (m1), second (m2), and third (m3) month of the nowcast.

[11] We consider the standard deviation instead of the mean because the latter should be close to zero and also in order to discard the sign.

3.6 Conclusions

In the nowcasting literature it has always been stressed the importance of developing models that can incorporate large information and that can be updated taking the continuous data flow into account. In this paper we propose a model for nowcasting Brazilian real GDP, which mechanically updates the predictions as new information becomes available. The results of the model are compared with the survey of professional forecasts, collected by the Central Bank of Brazil at a daily frequency. The latter comparison gives a unique opportunity to relate, over the same frequency, forecasts based on a mechanical model with forecasts that incorporate some form of judgment. Results indicate that both model and market participant predictions are well behaved, i.e. as more information becomes available their accuracy and correlation with the actual realization increases. In terms of performance the model seems to be slightly better than the institutional forecasts in the nowcast and backcast. In addition, the nowcasting model can be a useful instrument to stress the single variable's relevance to the updating process. In Brazil, trade variables (in particular exports), given their timeliness, turn out to have a huge impact on the forecasting revisions. Industrial production, manufacturing PMI and employment variables are also relevant.

Appendix

A1. Selecting the Number of Factors and Lags

We select the optimal number of factors using an information criteria approach. The idea is to choose the number of factors that maximizes the general fit of the model using a penalty function to account for the loss in parsimony. Bai and Ng (2002) derive information criteria to determine the number of factors in approximate factor models when the factors are estimated by principal components. They also show that their information criterion (IC) can be applied to any consistent estimator of the factors provided that the penalty function is derived from the correct convergence rate. Table A.1 reports the information criterion and the sum of the variance of the idiosyncratic components for the different specifications, which allow for a different number of factors. The IC selects the model with one factor.

Table A1. Model selection (number of factors)

	Sample 1		Sample 2		Sample 3	
	IC	V	IC	V	IC	V
1	-0.03	0.68	-0.03	0.69	-0.06	0.68
2	0.03	0.50	0.01	0.51	0.05	0.55
3	0.35	0.48	0.29	0.48	0.25	0.48
4	0.31	0.32	0.40	0.39	0.29	0.36
T	11		47		128	
N	13		11		13	

Notes. IC stands for Information Criteria, V is the sum of the variance of the idiosyncratic component.

Given that our data set is strongly unbalanced at the top, and some series are more recent than others, we report the test on three different samples. The first (sample 1) considers a balanced panel in the estimation period 1995:Q1 to 2006:Q4 (13 series and 11 observations), the second (sample 2) a restricted balanced panel where we exclude two of the most recent series (11 series 47 observations), the third (sample 3) is a balanced panel that incorporates the whole sample (estimation and forecasting period). The choice of one factor is confirmed across the different samples.

In order to select the number of lags in Equation 5 of the model, we report in Table A.2 the results on the Akaike information criterion, which selects two lags.

Table A2. Model selection (number of lags)

Number of lags	Akaike information criteria
1	0.82
2	0.68
3	0.72
4	0.73

Notes. The lag is chosen in correspondence with the minimum AIC value.

A2. Diebold-Mariano Test

Denote the loss associated with forecast error e_t by $L(e_t)$ and the time-t loss differential between forecasts 1 and 2 as $d_{12t} = L(e_{1t}) - L(e_{2t})$. The Diebold-Mariano (DM) requires only that the loss differential is covariance stationary:

$$E(d_{12t}) = \mu, \forall t$$
$$cov(d_{12t}, d_{12t-\tau}) = \gamma(\tau), \forall t$$
$$0 < var(d_{12t}) = \sigma_2 < \infty$$

The key hypothesis of equal predictive accuracy (i.e., equal expected loss) corresponds to $E(d_{12t}) = 0$, in which case, under the maintained assumption DM:

$$DM_{12} = \frac{\bar{d}_{12}}{\hat{\sigma}_{\bar{d}_{12}}} \xrightarrow{d} N(0,1),$$

where $\bar{d}_{12} = \frac{1}{T}\sum_{t=1}^{T} d_{12t}$ is the sample mean loss differential and $\sigma_{\bar{d}_{12}}$ is a consistent estimator of the standard deviation of $\bar{d}_{12}$. DM is thus an asymptotic $z-test$ of the hypothesis that the mean of a constructed but observed series (the loss differential) is zero. Forecast errors, and hence loss differential, though, may be serially correlated for various reasons. In this paper, we calculate the DM statistics by regression of the loss differential on an intercept, using heteroskedasticity and autocorrelation robust (HAC) standard errors. In a fully articulated econometric model in which we have pseudo out-of-sample forecasts, following West (1996), we define the test on the sample mean quadratic loss as follows:

$$\bar{d}_{12} = \frac{\sum_{t=t^*+1}^{T}(e^2_{1,t|t-1} - e^2_{2,t|t-1})}{T - t^*},$$

where $e_{t|t-1}$ is a time-t pseudo out-of-sample one-step ahead forecast error. We do not consider a rolling scheme, so results should be taken with caution, as the test ignores estimation uncertainty.

A3. Monotonicity Test

We rely on the first three tests of Patton and Timmermann (2012) based on the multivariate inequality tests in regression models of Wolak (1987, 1989). We report the p-values for the nowcast model.

Test 1: Monotonicity of the forecast errors

Let us define $\tilde{y}_t = y^k_{t,1}$ and $e_{t|\Omega_v} = \tilde{y}_t - E[\tilde{y}_t|\Omega_v]$ as the forecast error obtained on the basis of the information set corresponding to the data vintage Ω_v and by $e_{t|\Omega_{v+1}}$ that obtained on the basis of a larger more recent vintage $v+1$ and $v = 1, ..., V$.

The mean squared Error (MSE) differential is $\Delta^e_v = E[e^2_{t|\Omega_v}] - E[e^2_{t|\Omega_{v+1}}]$.

The test is: H0 : $\Delta^e \geq 0$ vs H1 :$\Delta^e \ngeq 0$, where the $(V-1) \times 1$ vector of MSE-differentials is given by $\Delta^e \equiv (\Delta^e_1, ..., \Delta^e_{V-1})'$.

Test 2: Monotonicity of the mean squared forecast

Define the mean squared forecast (MSF) for a given vintage as $E[\tilde{y}^2_{t|\Omega_v}] = E[E[\tilde{y}^2_t|\Omega_v]]$ and consider the difference $\Delta^f_v = E[\tilde{y}^2_{t|\Omega_v}] - E[\tilde{y}^2_{t|\Omega_{v+1}}]$ and its associated vector Δ^f.

The test is H0 : $\Delta^f \leq 0$ vs H1 : $\Delta^f \nleq 0$.

Test 3: Monotonicity of covariance between the forecast and the target variable

Here we consider the covariance between the forecast and the target variable for different vintages v and the difference $\Delta_v^c = E[\tilde{y}_{t|\Omega_v}\tilde{y}_t] - E[\tilde{y}_{t|\Omega_{v+1}}\tilde{y}_t]$. The associated vector is defined as Δ^c and the test is H0 : $\Delta^c \leq 0$ vs H1 : $\Delta^c \nleq 0$.

Wolak (1987, 1989) derived a test statistic whose distribution under the null is a weighted sum of chi-squared variables.

A4. Impact of the Releases on the Nowcast

Table A3. Impact of the Releases on the Now-cast

	A			B			C		
	m1	m2	m3	m1	m2	m3	m1	m2	m3
Merchandise Exports	4.497	4.139	2.938	7.941	5.392	7.543	35.708	22.318	22.163
Merchandise Imports	2.907	2.679	1.923	5.138	5.963	6.477	14.937	15.975	12.454
PMI Manufacturing	10.936	8.930	4.052	1.324	1.906	1.835	14.478	17.023	7.436
Industrial Production	9.970	9.606	8.799	1.969	2.573	1.202	19.629	24.712	10.575
Manufacturing Sales	4.070	3.920	3.596	2.197	2.225	2.295	8.943	8.724	8.253
Capacity Utilization	25.777	25.600	23.613	0.380	0.350	0.380	9.783	8.956	8.964
Economic Activity Indicator	7.199	6.825	5.980	0.580	1.153	0.578	4.177	7.869	3.458
Extended Retail Trade	1.988	1.903	1.606	2.147	2.853	2.731	4.268	5.431	4.387
Retail Trade: Volume of Sales	1.988	1.880	1.716	0.981	0.771	0.828	1.950	1.450	1.420
Formal Employment	75.902	66.813	30.721	0.233	0.149	0.144	17.673	9.954	4.431
Consumer Confidence Index	0.186	0.122	0.060	4.241	2.571	3.083	0.787	0.312	0.184
Monthly GDP	6.375	5.734	3.452	1.700	2.810	1.591	10.838	16.112	5.490
Real GDP			19.749			0.549			10.838

Notes. A is the average weight; B is the news standard deviation; C is the average impact equal to $A \cdot B$.