Three Essays on the Role of Fiscal Stress for the Size of the Government Spending Multiplier

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Abstract

This thesis examines the role of fiscal stress on the size of the government spending multiplier. First, it explores the dynamic consequences of empirically identified government spending shocks in Italy in a regime with high sovereign bond yield spreads and a regime with low spreads. It finds that cumulative multipliers are lower when sovereign risk spreads are high. Secondly, the thesis explains the empirical result of small government spending multipliers in times of high levels of fiscal stress in the context of a DSGE Model. In this model, an increase in government spending crowds out private investment. A fragile banking sector and aggregate risk amplify the crowding out of investment sufficiently to imply small multipliers in the presence of fiscal stress. Finally, I analyze the role of fiscal stress on the multiplier, when the economy is at the zero lower bound for nominal interest rates and find that in this scenario, the effect of fiscal stress is reversed and the government spending multiplier is large.

Zusammenfassung

Gegenstand dieser Dissertation ist die Rolle fiskalischen Stresses auf die Größe des Staatsausgabenmultiplikators. Hierbei werden zuerst die Folgen von empirisch identifizierten Staatsausgabenschocks in Italien untersucht. Dies geschieht sowohl in einem Zustand mit hohen Risikospreads auf Staatsanleihen, als auch in einem Zustand mit niedrigen Risikospreads. Das Resultat ist, dass kumulative Multiplikatoren kleiner sind, wenn das Ausfallrisiko von Staatsanleihen hoch ist. Zweitens erklärt die Dissertation dieses empirische Resultat im Rahmen eines DSGE Modells. Im Model verdrängt ein Anstieg der Staatsausgaben private Investitionen. Der Verdrängungseffekt wird durch fragile Banken und die Rolle aggregierten Risikos ausreichend verstärkt, so dass fiskalischer Stress zu sehr kleinen oder sogar negativen Multiplikatoren führen kann. Zuletzt untersuche ich die Rolle fiskalischen Stresses auf den Staatsausgabenmultiplikator unter der Nebenbedingung, dass die nominale Zinsuntergrenze bei null bindet. In diesem Szenario kann sich der Effekt fiskalischen Stresses ins Gegenteil verkehren und der Staatsausgabenmultiplikator groß werden.

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Chapter 1

Introduction

The Great Recession and the sovereign debt crisis in the Eurozone have revived the debate on the size of the government spending multiplier. The disruption of global financial markets had asymmetric consequences for the member countries of the Eurozone. While the economies of some countries quickly recovered from the crisis, others experienced a long-lasting economic depression, high unemployment, and spiking sovereign risk spreads on their government bonds. As monetary policy in the currency area is conducted on the union-wide level, its ability to address country-specific challenges is impaired. In this environment, fiscal policy came into the focus of the public policy debate. To restore confidence into the sustainability of their public finances, countries that were facing steep increases on their sovereign yield spreads, have been implementing large programs of fiscal austerity, that included sizable cuts to government spending. These spending cuts have started a controversial debate on their effects on aggregate output, or in other words, on the government spending multiplier.

In a survey of the literature on the government spending multiplier, (Ramey, 2011a) concludes that in the context of linear SVARs and estimated DSGE models, the multiplier varies between 0.8 and 1.5. In recent years, the empirical and theoretical literature on this topic has shifted attention to the notion that under certain conditions, the size of the multiplier can either be much larger or much smaller, or even negative. A well-known example is the contribution by (Auerbach and Gorodnichenko, 2012), who estimate the effects of government spending shock in the US using a smooth transition VAR. Their econometric framework allows them to distinguish the effects of shocks in economic expansion from shocks in recessions. They report cumulative multipliers over a time horizon of 20 quarters of -0.33 for expansions and 2.24 for recessions.[1] In the theoretical literature, it is a common

[1] For other examples of empirical studies of state-dependent multiplier see, e.g., (Baum et al., 2012), (Batini et al., 2012), (Auerbach and Gorodnichenko, 2014), (Ramey and Zubairy, 2014), (Jorda and Taylor, 2015)

finding that exceptionally large government spending multipliers can be generated in models, in which the zero lower bound on interest rates is binding.[2] In the context of the European debt crisis, (Blanchard and Leigh, 2013) prominently argue, that the deep recession and the binding zero lower bound implied that “conditions for larder-than-normal multipliers were ripe”.[3]

However, next to the deep recession and the close-to-zero monetary policy rate, fiscal stress in the form of high debt-to-GDP ratios and high sovereign yield spreads was another aspect that shaped the economic environment in the European sovereign debt crisis. In contrast to the other two aspects, the presence of fiscal stress is typically associated with small government spending multipliers. This thesis contributes to the understanding of government spending multipliers in the Eurozone, and to the literature on the determinants of the multiplier in general, by investigating the role of fiscal stress for the size of the multiplier. In doing so, it emphasizes that the claim of larger-than-normal multipliers should be taken with a grain of salt.

In the second chapter of my this thesis, I conduct an empirical investigation on the impact of fiscal stress on the multiplier in Italy, and find that indeed the multiplier is lower in Italy, when risk premiums of government bonds are high. In the third chapter, I offer an explanation for this finding in the context of a dynamic stochastic general equilibrium (DSGE) model with leverage constrained and risk-averse banks. I argue that banks restrict their credit supply in the face of higher fiscal stress, triggering a fall in investment and a small multiplier. Finally, in the fourth chapter of the thesis, I show within the context of the same model that the effect of fiscal stress on the government spending multiplier can be reversed and that the multiplier can be large when the economy is at the zero lower bound.

In the 1990’s, interest in the relationship between the state of public finances and the fiscal multipliers was sparked by (Giavazzi and Pagano, 1990) who showed in a case study that fiscal contractions in Denmark and Ireland were associated with an expansion of output. In panel data studies, (Alesina and Perotti, 1997), and (Perotti, 1999) confirm the possibility of an ’expansionary fiscal contraction’. (Perotti, 1999) shows that government spending multipliers are much smaller, when debt-to-GDP ratios are high. Against the backdrop of the Eurozone crisis, the debate around the role of public finances on fiscal multipliers has been revived. (Perotti, 2011) and (Guajardo et al., 2014) critically revisit the claim of expansionary fiscal contractions

[2] see, e.g., (Woodford, 2010), (Christiano et al., 2011), (Eggertson, 2011), (Eggertson and Krugman, 2012). For empirical support of this result, see (Miyamoto et al., 2016).

[3] During the Euro crisis the European Central Bank slowly lowered its main refinancing rate from 150 bp to 0bp. Absolute zero was only reached in March 2016. It is not entirely clear at which proximity to the zero lower bound it has an effect on the multiplier.

and find no evidence of negative multipliers. The result that higher levels of fiscal stress, as measured by high debt-to-GDP ratios or public deficits are associated with smaller government spending multiplier, has been confirmed, however, in several panel data studies.[4]

The second chapter of my thesis, “Fiscal Retrenchment and Sovereign Risk”, adds to the empirical literature on the link between fiscal stress and the government spending multiplier. The design of the study in this chapter includes two novelties. First, I use the sovereign bond yield spread as an indicator of fiscal stress, which I argue to be a more accurate measure than the debt-to-GDP ratio or the public deficit. Secondly, I employ the smooth transition VAR developed by (Auerbach and Gorodnichenko, 2012), to analyze the dynamic consequences of identified shocks to government spending in a regime with high fiscal stress and a regime with low fiscal stress. This approach allows me to exploit all observations in my sample for the estimation of either regime. For the analysis, I use Italian data between 1993Q3 and 2013Q2. The case of Italy is uniquely suited for this analysis, as Italy has experienced high public debt for several decades, and recurrent period of high and volatile interest rate spreads. An additional advantage of choosing this case is that, in my sample, the correlation of sovereign yield spreads and output growth is small and not statistically significant. This helps me to circumvent the problem that states of high sovereign default risk are often associated with recessions, which are likely to produce unusually large multiplier.[5] As my sample furthermore does not feature episodes, in which the monetary policy rate is zero, the effect of fiscal stress on the government spending multiplier can be studied in relative isolation. I analyze cumulative government spending multipliers over different time horizons and find no evidence for an ’expansionary fiscal contraction’, i.e. for a negative multiplier. However, I find that for horizons longer than 7 quarters, the government spending multiplier is smaller in the sovereign risk regime that in normal times. Thus, using a state of-the-art method, I confirm that the predominant finding in the literature that high fiscal stress is associated with small government spending multipliers also applies to Italy, a country, which stands at the center of the European debt crisis.

In my third chapter, “The Government Spending Multiplier, Fiscal Stress, and Risk”, I take the result of the empirical literature as a starting point and develop a medium scale DSGE model, that offers an explanation for how the presence of fiscal stress can lead to small government spending multipliers. In the model, endogenously leverage

[4] see, e.g., (Corsetti et al., 2012), (Ilzetzki et al., 2013), and (Guajardo et al., 2014)

[5] In an analysis that is very similar to mine, (Born et al., 2015) construct a data set of interest-rate-based measures of sovereign default risk of 38 countries and find that in times of high sovereign default risk, multipliers are actually larger than in normal times. However, they admit that in their sample, periods of sovereign risk are highly correlated with recessions, which are likely to contribute to large multipliers.

constrained banks à la (Gertler and Karadi, 2011) hold sovereign bonds on their balance sheets, which are subject to default risk. In this setting, I analyze government spending multipliers obtained by a first-order approximation, as well as a third-order approximation to equilibrium dynamics using the non-linear moving average approach by (Lan and Meyer-Gohde, 2013). Employing a third-order approximation allows me to capture the effect of aggregate risk on the dynamic consequences of the government spending shock and to account for the precautionary motive of the agents in the economy.

To the extent that a positive shock to government spending increases the debt-to-GDP ratio, it raises the degree of fiscal stress and exerts an adverse effect on the balance sheet of banks holding the bonds. Consequently, it impairs the capability of banks in the model to provide credit to firms, leading to reduced aggregate investment and dampening the initial output stimulus of the shock. Thus, a crowding-out of investment via the banks' balance sheets reduces the multiplier, and the more so, the higher the initial degree of fiscal stress. However, I show that whether this effect is quantitatively relevant depends on the order of approximation up to which the model is solved.

While the impact of fiscal stress on the multiplier is negligible, when the model is solved linearly, it is considerably amplified, when aggregate risk and the precautionary behavior is accounted for. Key to this twist is the financial accelerator embedded in the model, that is enhanced by the precautionary behavior of risk averse banks. An expansion of government spending deteriorates the financial position of banks. When they consider the risk of future, potentially also detrimental shocks to their balance sheet, they reduce the exposure to risky assets more strongly. Consequently, in the presence of fiscal stress, the fiscal expansion triggers stronger fire sales of assets, a sharper contraction of the credit supply, a deeper fall of investment, and a smaller government spending multiplier. Additionally, I show that the impact of fiscal stress on the multiplier is particularly strong, when the government is highly indebted and when banks are highly leveraged at the time of the fiscal expansion. In the extreme case, the multiplier can even become negative.

Whereas chapters two and three of this thesis study the role of fiscal stress in isolation from other potential determinants of the government spending multiplier, the fourth chapter, "The Government Spending Multiplier, Fiscal Stress, and the Zero Lower Bound", investigates the multiplier in a setting, in which, next to fiscal stress, the zero lower bound (ZLB) on nominal interest is considered as a second feature of the Eurozone crisis, which has been associated with unusual fiscal multipliers. During the Euro crisis the European Central Bank only slowly lowered its main refinancing rate from 150 bp to 0bp. Absolute zero was only reached in March 2016. It is not entirely clear at which proximity to the ZLB it has an effect on the multiplier. In the investigation in this chapter, however, I adopt the perspective of (Blanchard and Leigh, 2013) that the ZLB was relevant in the crisis. I conduct the analysis in the same model that was developed in the third chapter with the only alteration that now the nominal interest rate is required to be non-negative. To solve the model with the occasionally binding constraint, I employ the piece-wise linear approach by (Guerrieri and Iacoviello, 2015) and their software toolkit OccBin.

I find that despite the presence of fiscal stress, the multiplier is large at the ZLB. The finding of the previous chapter, that the multiplier is lower, when the initial degree of fiscal stress is higher, is reversed. Key to the mechanism that drives this result is the role of the real interest rate at the ZLB. To force the economy to the ZLB, I simulate a crisis shock that triggers a recession together with deflation. When the nominal rate is zero, the expectations of a deflationary spiral translate into a high real interest rate that causes a drop in aggregate investment. In this scenario, an expansion of government spending, that raises aggregate demand and increases inflation expectations, lowers the real interest rate, thereby actually stimulating investment and boosting aggregate output. The deeper the initial crisis and the longer the duration of the ZLB episode, the larger is the output multiplier.

At the ZLB, the presence of fiscal stress has two effects. Since it makes banks more vulnerable to the crisis shock, it deepens the recession and the deflation. Thus, the inflationary impulse of the government spending shock counters a more severe inflation and its stronger effect on the real interest rate stimulates investment and output by more. Secondly, the large output response to the fiscal expansion actually lowers the debt-to-GDP ratio, and thereby the measure of fiscal stress in the model. Thus, declining fiscal stress contributes to increasing asset prices, relaxing the leverage constraint of banks and enhancing their capability to supply credit. Hence, I find that the multiplier is larger, the higher the initial degree of fiscal stress. For a duration of the ZLB of 5 periods and a debt-to-GDP ratio of 1.3, as experienced by Italy in the crisis, the cumulative government spending multiplier over a time horizon of 20 quarters can be larger than two.

The differential results of the second and third chapter on the one hand, and the fourth chapter on the other hand, highlight that the presence of fiscal stress has the potential to either lower the government spending paper or to raise it, depending on the underlying structure of the economy and other side conditions. Nesting the analysis of the third and the fourth chapter is not straightforward, since the piece-wise linear approach by (Guerrieri and Iacoviello, 2015) to deal with the occasionally binding ZLB constraint, only handles linearized equilibrium conditions, whereas the analysis in the third chapter requires a third order approximation to equilibrium dynamics to capture the effects of risk. Adjusting the model to make it suitable for a global solution method that allows to analyze more than one determinant of the multiplier at a time, would be a natural next step in the investigation of the multiplier. Fiscal stress, the deep recession, the ZLB, the instability of the financial sector, capital flight out of several countries, and political uncertainty are only some factors that might have had an important impact on the size of the government spending multiplier during the sovereign debt crisis. Against this background, and considering the relevance of the research question, a further investigation of the size of multipliers in the Eurozone presents an important and fruitful field for further research.

On the methodological side, a common theme of this thesis is the use of non-linear methods to flesh out the effects of fiscal stress on the multiplier. That these methods have been developed in recent years, reflects that the Great Recession and the European debt crisis have sparked a growing awareness of the state dependence and the non-linearity of the consequences of monetary and fiscal policy shocks. By taking advantage of the methodological progress and investigating the role of fiscal stress, this thesis takes a step in the direction of a more complete understanding of the government spending multiplier.

Chapter 2

Fiscal Retrenchment and Sovereign Risk

Abstract

How does sovereign risk affect the dynamic consequences of identified contractionary government spending shocks? I apply a regime-switching SVAR on Italian data and find that in periods in which government bond yield spreads are high, cumulative government spending multipliers are smaller than in the calm regime. This empirical finding supports theoretical arguments that associate fiscal distress with low multipliers (e.g. Corsetti et al. (2013)). An additional result is that in the crisis regime, risk spreads increase after contractionary government spending shocks. This challenges the suggestion that declining risk premiums are the reason for the attenuated output response in the crisis regime.

Keywords: Government Spending Multipliers, Sovereign Risk, Fiscal Distress, Fiscal Retrenchment
JEL Classification: E32, E62, E63, H60

2.1 Introduction

In the recent years, sovereign bond yields have spiked in several countries in the eurozone, signaling the risk of impending sovereign defaults. As a reaction, these countries are running programs of fiscal retrenchment cutting government expenditures with the goal to consolidate their public finances. The effects of fiscal policy depend on the economic conditions under which it is conducted. One of the most important fiscal policy tools is government spending. As turmoil in the sovereign bond markets has been an important feature of the economic environment in the eurozone, a natural question to ask is: How does the presence of sovereign risk affect the dynamic consequences of government spending shocks?

This paper identifies empirical government spending shocks and shocks to the growth rate of public debt applying the regime-switching STVAR approach, developed by Auerbach and Gorodnichenko (2012). This technique allows for differences in the impulse responses to identified shocks across a crisis and a calm regime, focussing on the interaction of government spending, output and the sovereign risk spread. In the sovereign risk crisis regime, sovereign bond yields are high and volatile, indicating uncertainty in the financial market about the sustainability of public finances. While often sovereign risk is associated with low output growth, which itself has an influence on the effectiveness of fiscal policy[1], in the case of Italy, correlation between the growth rate of GDP and the risk spread measure I apply to separate the regimes is small and insignificant. This prevents the difference of the government spending multipliers in the two regimes from being driven by output growth dynamics, and allows me to study in isolation the influence of sovereign risk on multipliers as a particular determinant.

In a comparison of the effects across regimes, I find that the cumulative government spending multipliers over a horizon of 7 or more quarters are smaller in a sovereign risk crisis than in the calm regime, providing evidence for a dampening impact of the presence of sovereign risk on the effects of government spending shocks. Impact multipliers do not differ significantly across regimes. An additional result is that after a negative government spending shock in the crisis regime, the risk spread on government bonds rises on impact, presenting a challenge to the hypothesis that fiscal retrenchment calms down financial markets.

The finding of a weaker output response to fiscal retrenchment in times of sovereign risk, presents evidence which is in line with theoretical considerations on fiscal multipliers in the presence of strained public finances. The strongest statement in this regard in the theoretical literature is the expansionary fiscal contraction hypothesis (EFC), which posits the possibility that fiscal multipliers can even be negative. Much of the arguments of the proponents of this hypothesis relies on the idea, that fiscal consolidation may restore the credibility of public the government's commitment for sustainable finances, thus creating a more stable environment for the economy. In such a case a cut of government spending may over-proportionally crowd in private demand (see e.g. Bertola and Drazen (1993), Alesina and Perotti (1997)). Blanchard (1990), Bertola and Drazen (1993) and Sutherland (1997) argue that when agents perceive the current fiscal path to be unsustainable, a pronounced fiscal consolidation may over-proportionally crowd in consumption. More recently and motivated by the crisis in the Eurozone, Corsetti et al. (2013), focus on the effect of fiscal retrenchment in the presence of sovereign risk. In the context of a

[1] see e.g. Auerbach and Gorodnichenko (2012), Baum et al. (2012) Batini et al. (2012)

New Keynesian model with financial frictions they find that to the extent, that a fiscal contraction decreases risk premiums on public debt, it facilitates financial intermediation and thus stimulates lending and investment, thereby dampening the contractive effects of fiscal consolidations.[2] Similarly, van der Kwaak and van Wijnbergen (2015) show that in a model with financial frictions à la Gertler and Karadi (2011) sovereign risk can lower the government spending multiplier substantially.
While I do not find not find government spending multipliers, my findings are consistent with the general notion, that the presence of fiscal stress attenuates the effects of fiscal retrenchment. However, the initial increase in the spread is at odds with arguments that rely on a decline of risk premiums.

The empirical literature on state-dependent multipliers has been growing in the last years. Closest to my paper are Born et al. (2015). They investigate on the difference of government spending multipliers in times of high and low fiscal stress in a panel of countries. For this, they employ a panel smooth transition autoregressive model which, like the STVAR, allows for differences in the impulse responses to identified fiscal shocks across a crisis and a calm regime. They base their indicator for fiscal stress on default risk spreads is based on global bond and CDS data. They find that a negative government spending shock lowers output in the risk regime, and expands output in the calm regime. With regard to the default premium they find that fiscal retrenchment increases the premium in the crisis regime. The latter finding is in line with my results. My analysis differs from theirs in some key aspects. The main difference is that, I study the case of a single country, namely Italy, instead of a panel of country. As the literature shows, the heterogeneity of fiscal multipliers across countries is substantial. Thus, the focus on a specific country is likely to add information to the pooled results of a panel analysis. Additionally, while Born et al. (2015) document that typically sovereign risk spreads tend to be negatively correlated with output growth, Italy represents a case, in which sovereign risk spreads and output growth are only weakly correlated, enabling me to separate the influences of recessions and sovereign risk on the multiplier.

Further papers that are close to mine in their motivation are Perotti (1999), Corsetti et al. (2012) and Ilzetzki et al. (2013), who investigate on the difference of government spending multipliers in times of high and low fiscal stress in a panel of countries. These authors find that the multipliers are lower, when the fiscal stress is high. The main difference between the approach of my paper and these studies is that they use

[2] In the model by Corsetti et al. (2013) a prerequisite for the relation between the fiscal multiplier and sovereign risk is that monetary policy does not act to no neutralize the effects of risk premiums on lending condition. The authors model monetary policy to be at the zero lower bound. In most of my sample, monetary policy is not constrained. However, in those periods in my sample, in which the volatility of bond yields is most pronounced, the central bank either does not lower the policy rates, or the policy rate is very close to the ZLB such that monetary policy does not have much leeway.

the debt-to-GDP ratio or the public deficit as indicators of fiscal stress. However, debt measures can only be imperfect proxies to sovereign risk. Naturally, the sustainability of public finances does not rely on the public debt measure alone, but also on factors such as, for example, the monetary policy regime, the exchange rate regime, output growth, political risk, and non-fundamental factors. Exploiting the sovereign bond yield has the advantage that, in principle, it should reflect the expectations of market participants about all relevant factors, making it a more comprehensive measure of sovereign risk. Corsetti et al. (2012) find the differences between the multipliers in the regime to be rather small, whereas Perotti (1999) finds it to be sizable. Ilzetzki et al. (2013) even find evidence for large, negative long-run fiscal multipliers in their group of high debt countries.

Empirical studies, which find evidence supporting the expansionary fiscal contraction hypothesis, analyze episodes of fiscal consolidation in the 1980s, mainly with a focus on Denmark (e.g. Giavazzi and Pagano (1990), Alesina and Perotti (1997), Alesina and Ardagna (2010), Bergman and Hutchison (2010)). In these episodes, they find evidence for a stimulating effect of fiscal retrenchment. Alesina and Perotti (1997) reach a similar conclusion for a panel of OECD countries. More recently, some studies have cast some doubt on these empirical results. Perotti (2011) discusses expansionary effects of fiscal consolidation for episodes in Denmark, Ireland, Sweden and Finland, and finds that only in the first case domestic demand was stimulated, while in the other three increased exports were driving output growth. In a panel of OECD countries Guajardo et al. (2014) identify fiscal shocks with the narrative approach and do not find evidence which would support the EFC.

While theoretical arguments and empirical studies link fiscal distress with lower fiscal multipliers than in normal times, larger-than-normal multipliers are typically associated with situations, where the economy is at the zero lower bound (see, e.g. Christiano et al. (2011) and Eggertson and Krugman (2012)) or recessions (see, e.g. Auerbach and Gorodnichenko (2012), Baum et al. (2012) and Batini et al. (2012)). Referring to these studies, Blanchard and Leigh (2013) state that "conditions for larger-than-normal multipliers were ripe" in Europe, and suggest that the fiscal impact multipliers during the Eurozone crisis were potentially far higher than 1.0. As my study focusses on sovereign risk instead of output growth dynamics, and since as mentioned above the correlation between output growth and the volatility measure is close to zero, the low fiscal multipliers that I find in the sovereign risk regime do not contradict the results of the studies that focus on the effect of fiscal policy in recessions. However, they cast a very different light on the effects of fiscal policy in the eurozone crisis.

The remainder of the paper is structured as follows: section two discusses the choices of the sovereign risk indicator as well as the sample period with regard to fiscal developments in Italy. Section three outlines the econometric methodology. The fourth section presents the results of the analysis. Section five concludes.

2.2 Sovereign risk and the case of Italy

The case of Italy provides an ideal case for the analysis of sovereign risk for several reasons. Italy has had a long history of high sovereign debt. As can be seen in the lower panel of figure (2.1), its debt-to-GDP ratio has been higher than 100 percent for two decades, and it experienced several periods of high and volatile risk spreads. Nonetheless, it did not experience a default event that would have resulted in a structural break in the pricing of default risk. Thus, Italy represents the rare case for which time-series data of sufficient length is available to analyze sovereign risk in conjunction with macroeconomic dynamics. In the empirical analysis, I use quarterly data for the period 1993Q3-2013Q2. Sovereign risk enters the study in two ways. First, the sovereign risk indicator used as a variable in the VAR is the real interest rate spread of Italian government securities with a five-year term over German Bunds with the same term. Secondly, a moving average of the spread is used to distinguish two regimes. The regime with high and low real interest rate spreads are labeled crisis regime and calm regime, respectively. These choices are discussed below.

The sample starts in 1993Q3. Data on Italian sovereign bond yields is available as of 1978. However, at that time the secondary market for Italian Treasury bills was very tightly regulated (see Frattiani and Spinelli (1997), Vercelli and Fiordoni (2003)) and the bond yields were managed by the fiscal and monetary policy makers. The central bank actively participated in government bond auctions. Banks were required to hold a fixed percentage of their new flow of deposits in government bonds, which was regularly adjusted by the authorities. Strict capital controls were in place, and the discount rate was set by the Treasury instead by the Italian central bank. During the 1980s and until the beginning of the 1990s, the Italian policy mix shifted considerably from fiscal dominance towards an empowerment of the central bank, and the financial sector underwent a step-wise liberalization. Portfolio restriction for banks disappeared in 1987. Capital and exchange rate controls were fully abolished in May 1990 (Frattiani and Spinelli (1997)). In 1992, the central bank was granted the right to set the discount rate. The shift in the Italian monetary policy regime was part of the plan to join the European Exchange Rate Mechanism (ERM), and, eventually, to introduce the Euro. Yet, as monetary policy became more restrictive, fiscal policy was slow to adjust, and kept running large deficits. The stock of public debt, which grew rapidly in the 1980s, exceeded the Italian GDP for the first time in 1992. Throughout the whole sample period, the Italian debt-to-GDP ratio is above 100 percent. Thus, Italy represents a country, which is being confronted with fiscal vulnerability for more than two decades. Small changes in the interest rate of government yields have a sizable effect on the debt service of Italy. In the view of this situation, explaining the periods of high and volatile bond yield spreads with sovereign default risk is plausible, and excluding the 80s and first years of the 90s, ensures that fluctuations in the bond yields are not distorted by active management by policy makers. An additional distortion to the bond yield as a sovereign risk measure is the influence of exchange rate risk. In 1992, speculative attacks forced several countries to depreciate their currencies below the narrow bands around the Deutsche Mark that were instituted in the ERM. While the interest rate differentials between most European sovereign bonds and German Bunds increased, the Italian-German interest rate differential spiked higher than most. It then decreased again in the beginning of 1993 after the lira had depreciated against the Deutsche Mark by roughly 25 percent. The high bond spreads in Europe at that time are typically explained with exchange rate risk instead with sovereign risk. Hence, I discard the observations before 1993Q3 from the sample, to ensure that the risk drives Italian bond yields is mainly credit risk. However, also for the other years prior to 1999, fluctuations in yield are affected by exchange rate movements.

By subtracting the inflation differential of Italy and Germany from the nominal yield spread of Italian bond with a five year maturity over German bonds with the same maturity, I construct a simple an ex-post real interest rate spread to capture sovereign risk in the VAR. [3] Regarding the high nominal yield spreads in the 90s of the European countries, cases have been made for sovereign credit risk, as well as for devaluation risk, driven by fears about high inflation, as drivers of the bond yield spreads (see Wright (2014)). However, in a study of asset swap data of these countries, Codogno et al. (2003) find that security yield spreads of Italy and Spain stand out, insofar as they were driven almost entirely by the underlying default risk. The third panel in figure (2.1) shows the difference between the spread used in this study, and the nominal spread. Between 1993Q3 and 1997Q4 the real interest rate spread is consistently lower than the nominal spread. The closer the date of the accession to the Euro comes, the smaller is the gap between the two spreads, and in the quarters directly before the accession, the gap is virtually closed. After

[3] Yang (2007) finds that the inclusion of forward looking variables into a fiscal SVAR with the Blanchard-Perotti identification scheme, reduces the size of the multiplier. She interprets this as tentative evidence for fiscal foresight. This paper does not address the invertibility problem, that comes along with fiscal foresight and which is carefully explained by Leeper et al. (2008). However, the inclusion of the forward looking spread, should to some degree mitigate this problem (see Sims and Zha (2006)), while partly accounting for the low fiscal multipliers that I find.

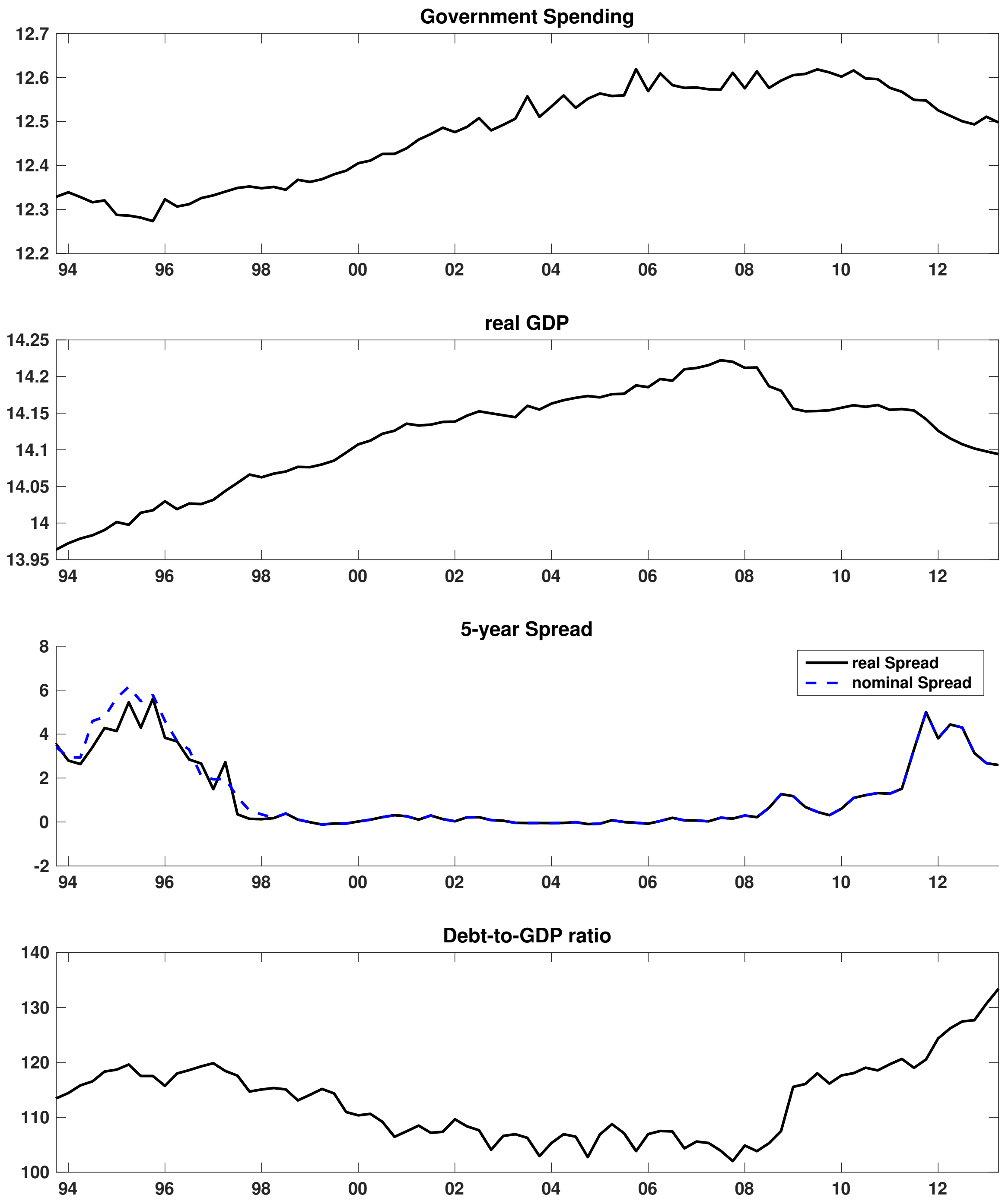

Figure 2.1: Real log government expenditures (seasonally adjusted), real log GDP (seasonally adjusted), real and nominal interest rate spreads of 5-year Italian government bonds over German bonds, and the debt-to-GDP ratio

the accession to the Euro, the exchange rate risk is systematically eliminated, the inflation risk becomes irrelevant, and the real spread and the nominal spread coincide.

Two periods in the sample feature particularly high bond yield spreads. The first one is in 1994, shortly before the still growth of public debt halted and the Italian debt-to-GDP ratio reached its maximum (see figure (2.1)). In this year the non-partisan government led by Carlo Azeglio Ciampo, who, as the former governor of the central bank had led the period of disinflation in the 80s, and was regarded as committed to fiscal consolidation, was replaced in the elections. The new government coalition led by Silvio Berlusconi only lasted for a few months and collapsed in December 1994.

Additional to this political instability, which threatened to undermine fiscal consolidation, Borio and McCauley (1998) ascribe the increased volatility in the Italian bond markets at the same time to the experience of the Mexican peso crisis, which made investors unwilling to finance potentially unsustainable public debt. A smaller peak of the spread can be observed in 1997, before it became clear that the government would be accepted in the first round of accession to the Euro area. In this year, the Italian Treasury announced a seven percent primary surplus and, thus, demonstrated a commitment to decrease the public debt. The second period with particularly high bond yield spreads represents the high-time of the recent eurozone crisis, around 2012. This period was preceded by a financial crisis in several countries and a slump of the world economy in 2009. The risk of an impending sovereign default in Greece quickly spilled over to other European countries, including Italy, where the debt-to GDP ratio was rising again. While other countries in Europe suffered from bursting housing bubbles or collapses of major banks, the banking system at that time appeared to be relatively stable in Italy. Hence, while bank rescue measures heavily contributed to the public debt in other countries in Europe, Italy spent only small amounts on bank aid in crisis times. The contribution of bank rescue measures to official public debt in Italy have only been roughly 4bn Euro.[4]

The second sovereign risk indicator in this study determines the choice of the regime. Here, I use a lagged three quarter moving average of the real interest spread described above. This choice ensures that the indicator is not driven by contemporaneous shocks. Furthermore, it allows me to limit outlier effects of observations with particularly high spreads, and to smooth the dynamics of the states and make the estimation feasible. The structural break that the accession to the Euro area arguably presents will hence be captured, by a marked decline in the sovereign risk indicator, which pushes the economy towards the calm regime.

[4] Financial guarantees to the financial sector, which, did not affect the debt of the general government were larger, yet, measured in percentage of GDP, still small in comparison to other cases in Southern Europe. (see: http://ec.europa.eu/eurostat/web/government-finance-statistics/excessive-deficit/supplemtary-tables-financial-crisis)

The deepest recessions in the sample period are in 2009, in the aftermath of the subprime crisis in the US, and in 2002 after the dot-com bubble. Notably, periods of higher spreads do not necessarily coincide with periods lower output growth. More importantly, as mentioned above, output growth and sovereign risk are virtually uncorrelated. In the sample, the crisis indicator and the growth rate of output are virtually uncorrelated. The correlation between GDP growth and the risk spread is at -0.166 and is statistically insignificant at a significance level of 5%. The correlation between GDP growth and the sovereign risk indicator, which separates the regimes, is at -0.099 and is statistically insignificant at a significance level of 10%. Hence, the difference between my results in the crisis and in the calm regime will not be driven by underlying business cycle movements.

2.3 Econometric Methodology

The three variables used in the VAR are the general government final consumption expenditures, GDP and the bond yield spread, discussed above, in the quarters 1993Q3-2013Q2. The nominal series for government consumption and GDP are deflated using the GDP deflator. [5] I demean all variables and remove a linear quadratic trend from real government consumption and real GDP.

As an econometric framework, I employ the smooth transition vector autoregression method (STVAR) developed by Auerbach and Gorodnichenko (2012). This method models the economy as fluctuating between two states, which in this application are simply labelled ”crisis regime” and ”calm regime”. Each period the economy is to a certain degree (or probability) in one state and to a degree in the other.[6] The degree to which the economy is in a crisis or in a calm regime is determined by an underlying state variable.[7] This approach has the advantage that in the estimation for each regime it exploits all observations. The estimation and inference results are thus more stable than SVARs estimated separately for each state which - in the study at hand - would

[5]The series for general government final consumption expenditures, nominal GDP and the GDP deflator are from stats.OECD (Series: B1_GE, Measures CARSA and DOBSA). The first two are already seasonally adjusted. The series for the Italian interest rate for government bonds with a five-year term stem from the Banca di Italia (Series: MFN_BMK.D.020.922.0.EUR.205), and their German counterpart stems from the Bundesbank (Series: BBK01.WZ9816)

[6]In this aspect it differs from the threshold VAR (TVAR) approach, which assigns to each observation a regime, based on an estimation of the threshold, which separates the different regimes. While the TVAR is an interesting alternative, I prefer to take a more moderate stand on whether particular observations belong to the calm or the crisis regime.

[7]For the question at hand, this is an advantage over time-varying coefficient models (TVC), as in the latter approach the variation of the coefficients is unrelated to the state of the economy (see Auerbach and Gorodnichenko (2012)).

be based on relatively few observations in each state. The STVAR approach allows for the contemporaneous responses to structural shocks and for the dynamic responses to differ across states. As discussed, the state variable which determines, in to what degree the economy is in which state, will be three-quarter moving average of the intra-quarter volatility of the yield of Italian government bonds with a five-year term. The econometric specification reads:

$$X_t = (1-F(z_t))A_{CA}(L)X_{t-1} + F(z_t)A_{CR}(L)X_{t-1} + u_t \tag{2.1}$$

$$u_t \sim N(0,\Omega_t) \tag{2.2}$$

$$\Omega_t = \Omega_{CA}(1-F(z_t)) + \Omega_{CR}F(z_t) \tag{2.3}$$

$$F(z_t) = \frac{exp(-\gamma z_t)}{1+exp(-\gamma z_t)}, \quad \gamma > 0 \tag{2.4}$$

$$var(z_t) = 1; \qquad E(z_t) = 0, \tag{2.5}$$

where $X_t = [D_t, Y_t, S_t]'$, and D_t, Y_t and S_t are the measures for debt, GDP and the spread, as discussed above. The lag polynomial in (1) is a weighted average of the lag polynomials in the calm and in the crisis state ($A_{CA}(L)$ and $A_{CR}(L)$, respectively). The VAR is estimated with two lags.[8] The weights are determined by the function $F(z_t)$, depending on the state variable, denoted by z_t, and the parameter γ. Ω_t is the covariance matrix of the residual vector, u_t, and is also a state weighted average of its state dependent counterparts. The functional form of $F(z_t)$ is chosen such its values are bounded between 0 and 1. Thus, the weighted sum spans a continuum of states between the calm state and the crisis state as extremes with the function values $F(z_t) \approx 0$ and $F(z_t) \approx 1$, respectively. The state variable, z_t is demeaned and its variance is normalized to 1. Figure (2.2) shows the crisis weights in the sample period. Auerbach and Gorodnichenko (2012) point out that, although, in principle, it is possible to estimate $\{\gamma, A_{CA}(L), A_{CR}(L), \Omega_{CA}, \Omega_{CR}\}$ simultaneously, such an identification of γ is not reliable as the value of the parameter depends on non-linear moments and may hence be sensitive to few observations.[9] This is particularly relevant for this study, as the sample period is quite short. Accordingly, I search a grid of different fixed values for γ, and estimate $\{A_{CA}(L), A_{CR}(L), \Omega_{CA}, \Omega_{CR}\}$ conditional on γ. The larger the value of γ, the more pronounced the weight differences between calm and crisis times. For values above 3, the dynamics are stationary, and the median responses to shocks are robust to changes in the parameter value. In the baseline calibration I use $\gamma = 4$.

[8] This is in accordance with the SIC criterion for a linear VAR.

[9] In several trial runs, I found that the mean estimate for γ is sensitive to the initial condition of the parameters and does not converge even in very long chains.

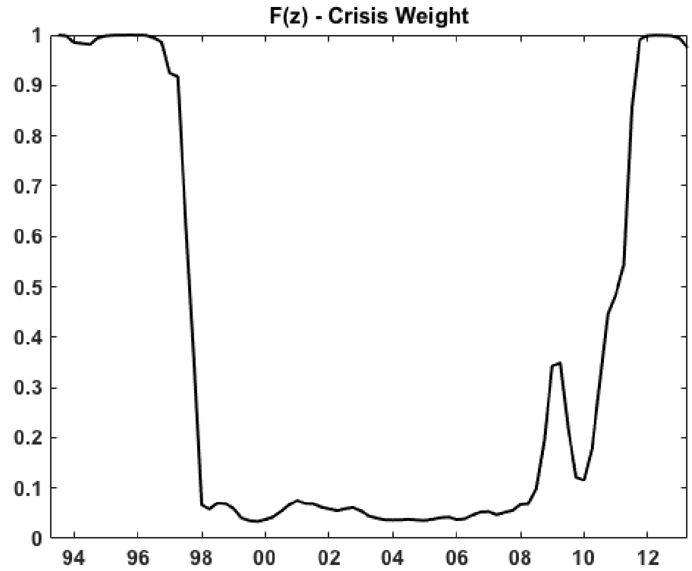

Figure 2.2: F_z - Weight on the crisis regime

The maximum likelihood estimation uses the MCMC approach by Chernozhukov and Hong (2003) for estimation and inference. Since the chains converge only slowly to stationary distributions, I use 200,000 draws for the estimation of the baseline specification and the robustness estimates and discard the first third of the chain. Further details of the estimation method are provided in Auerbach and Gorodnichenko (2012) and Chernozhukov and Hong (2003). Confidence intervals for the impulse response functions are bootstrapped as in Caggiono et al. (2014).

In the identification of the government spending shocks in each regime, I follow Blanchard and Perotti (2002), and exploit the fact that the fiscal authorities react to changes in economic conditions such as interest rates and output with a delay. Fiscal policy measures need to be prepared by the executive branch of the government, discussed within the government, the ruling parties, and finally in the parliament. When they are passed by the legislative, it takes additional time to implement these policies. Thus, it is reasonable to assume that any discrete policy measures that are undertaken in response to shocks to the sovereign risk premium or output shocks are not yet effective in the quarter in which the shock hits. Hence, I use a recursive identification with government spending ordered first.

2.4 Results

Figure (2.3) shows the impulse responses to a contractionary government spending shock. The shock has the magnitude of 1 percentage point. The median responses are plotted as solid lines, and the dashed lines show the 95% confidence intervals for the horizon of 20 quarters after the shocks. Note, that while the crisis weights for the Italian economy vary over the sample period, impulse response functions are simulated for the illustrative extreme cases of the crisis regime $F(z_t) = 1$ and the calm regime $F(z_t) = 0$. Responses are plotted in blue for the calm regime and in red for the crisis regime.

The second row of figure (2.3) shows the responses of median output. Output reacts stronger to the government spending shock in the calm regime than in the crisis regime. The impact response in the calm regime is slightly stronger than in the crisis regime. In the calm regime, output returns briefly to its initial level before falling again more persistently in the third quarter. The maximum drop of median output is reached after two years at -0.19%. The response in the crisis regime is markedly different. Here median output also falls after the fiscal contraction, but the drop reaches its maximum at -0,18% already after 4 quarters before the recessionary impact of the shock fades out.
The persistence of the reaction of government spending to the shock is roughly similar. As a consequence, in the crisis regime, the median cumulative multiplier is smaller than in the calm regime for time horizons longer than 7 quarters. This difference becomes significant after two and a half years after the shock.

Table 2.1: Cumulative Government Spending Multipliers

$\Sigma_h Y_h / \Sigma_h G_h$*	Crisis Regime			Calm Regime		
Horizon	5th %ile	median	95th %ile	5th %ile	median	95th %ile
1 quarter	-0.025	0.412	0.829	0.254	0.559	0.872
1 year	0.467	1.119	1.745	-0.241	0.488	1.263
2 years	0.397	1.053	1.641	0.222	1.213	2.494
3 years	0.391	1.080	1.678	0.397	1.814	3.601

*Accumulated change in GDP (in Euro) per accumulated change in government spending (in Euro)

Table (1) shows the government spending impact multipliers and the cumulative multipliers for the horizon of one, two and three years, measured as change in output in Euro per change in government spending in Euro. The median impact multipliers are with 0.412 (crisis regime) and 0.559 (calm regime) relatively small for both regimes. After the first year the cumulative multiplier in the crisis regime is even larger than in the calm regime, however, the differences are not significant at the 5%-level. Reflecting the longer recession in the calm regime, for a time horizon of two years the cumulative multiplier in the calm regime (1.213) is larger than in the crisis regime (1.053). The longer the time horizon, the more pronounced the difference becomes. At the horizon of three years, the difference between the cumulative multipliers is

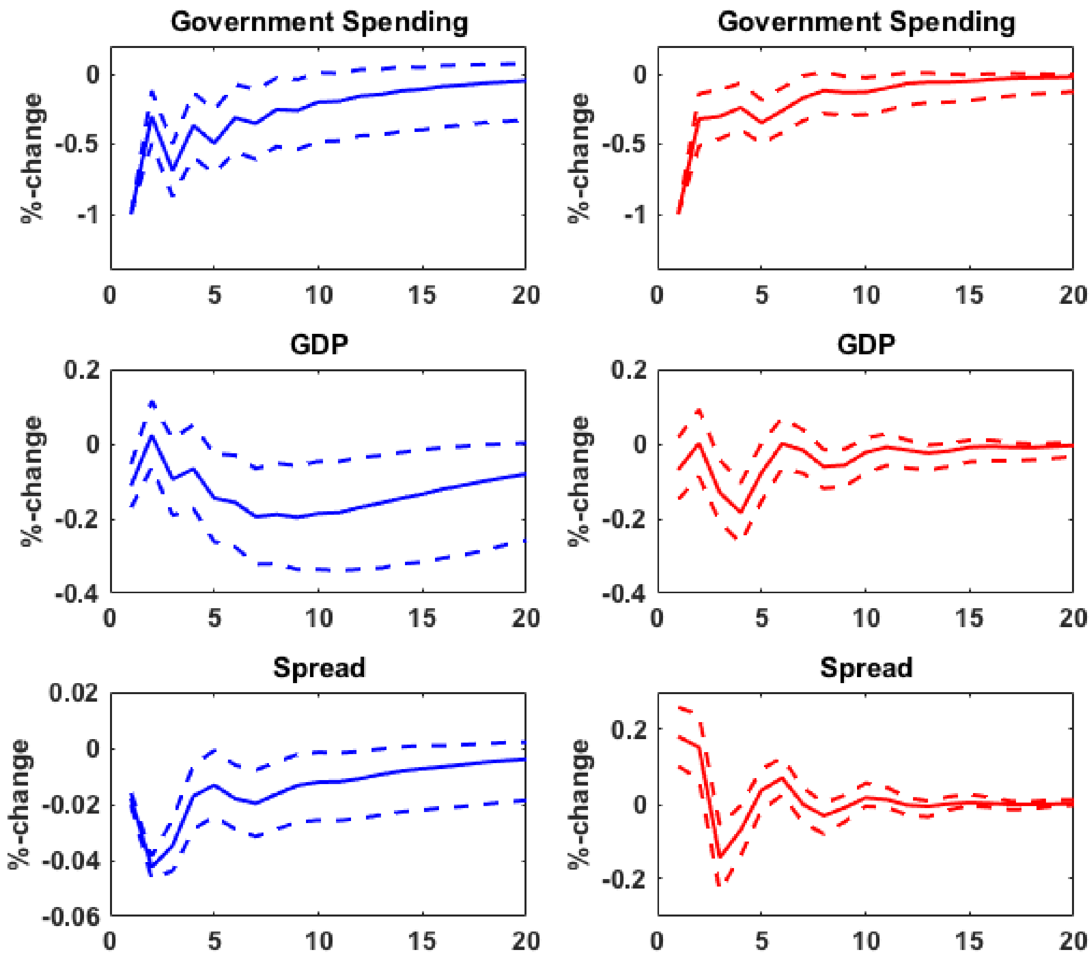

Figure 2.3: Impulse response of government spending, real GDP, and the sovereign risk spread to a 1 percentage point increase in government spending. The dashed lines show the 95% confidence intervals that are bootstrapped as in Caggiono et al. (2014).

substantial (1.814 and 1.080) and statistically significant.

The smaller cumulative multipliers in the crisis regime show that the presence of sovereign risk attenuates the effects of fiscal consolidations on output. This result can be taken as supportive evidence for theoretical arguments that make the case that fiscal retrenchment is less harmful, when the fiscal sustainability is in doubt. While I do not find support for negative multipliers, as claimed by the EFC, my results are consistent with the attenuated output response in the models by Corsetti et al. (2013) and van der Kwaak and van Wijnbergen (2015).

The weaker output response in the crisis regime in Italy is at odds with the findings by Born et al. (2015), who find positive multipliers in the crisis regime and negative multipliers in the calm regime for a panel of countries. A potential explanation for the difference between their finding and mine is that the correlation between output growth and sovereign risk in Italy is relatively weak compared to the average correlation within their sample. This makes my results less likely to be affected by recessionary periods that often come with typically come along periods of high sovereign risk spreads, and tend to increase government spending multipliers.

Empirical studies, which assess the influence of high public debt on the effect of fiscal shocks in panels of countries, find strong differences for low-debt and high-debt countries. For instance, in their panel SVAR, Ilzetzki et al. (2013) find that for the high-debt countries in their sample, the long-run fiscal multiplier is roughly minus three, while for low-debt countries it is minus 0.36. Perotti (1999) finds that higher debt lowers the impact multiplier by 1.61. Although the difference between the cumulative multipliers that I find across regimes is smaller than in these studies, it is qualitatively consistent with their results.

Notably, in the crisis regime the risk spread increases, in direct response to a fiscal contraction. This is at odds with the common assumption in the theoretical literature that the risk spread on government bonds decreases with the decline in debt which should come along with fiscal retrenchment. However, the higher spread in response to a persistent negative government spending shock is in line with the corresponding result by Born et al. (2015). A possible explanation is that the fiscal contractions undertaken by the Italian government in crisis periods were not judged to be sufficient to restore investors confidence in the sustainability of public finances. Also, the increase in the spread could potentially capture an increase in political instability in consequence of the contractionary shock, as austerity typically weakens the popularity of the government and is associated with a higher instability of coalitions in the parliament.[10]. While the design of this study is unable to provide a conclusive explanation of the rise in the risk spread, this finding contradicts explanations of the attenuated output response to the fiscal contraction that hinge on a decline on risk premiums in the economy (see, e.g. Alesina and Perotti, 1997; Corsetti et al., 2013).

2.5 Conclusion

The main goal of this paper is to characterize the dynamic effects of a contractionary government spending shock during and outside a sovereign risk crisis. This study presents empirical evidence which should serve as a stepping stone for understanding the working of fiscal policy in a sovereign risk crisis. From the econometric analysis I draw the following main conclusions.

The contractionary impact on output of fiscal retrenchment in the form of a negative shock to government spending, is weaker in crisis times than outside sovereign risk crises. I find that while impact multipliers are close to zero and insignificant for both regimes, for a time horizon longer than seven quarters, the median cumulative multipliers are lower in the crisis regime. With regard to the current eurozone crisis, my results give a different picture of government spending multipliers in crisis than studies that focus on the influence of underlying output dynamics, instead on variations in sovereign risk. When assessing the effects of fiscal retrenchment, it is recommended to keep both empirical results in mind. The results of this paper serve to emphasize the role of sovereign risk, as an additional determinant for the effectiveness of fiscal policy. Secondly, I find that the risk spread rises in response to a fiscal contraction in the crisis regime, challenges the argument, that in times of fiscal distress, fiscal contractions may stabilize the economy through a decline in the risk premiums.

Caveats of this study are the short sample and that I focus exclusively on Italian data. Ilzetzki et al. (2013) and Baum et al. (2012) find vastly different fiscal multipliers for different countries. It is likely that the same heterogeneity across countries applies for fiscal multipliers in sovereign risk periods. However, the focus on sovereign risk makes an analysis of other countries difficult, as Italy presents the rare case of a country with a prolonged history of sovereign risk, no default, and available data for this time. While, my results are thus not one-to-one transferrable to other countries, they can serve as supportive evidence for theoretical arguments that link the presence of sovereign risk to lower fiscal multipliers. With the growing availability of longer time-series of macroeconomic and fiscal data for a larger group of countries, it will be fruitful to investigate further into the relation between sovereign risk and the size of fiscal multipliers, and to compare the results for different countries and fiscal instruments.

[10] As mentioned, Italy saw three different government coalitions in the crisis year of 1994.

Chapter 3

The Government Spending Multiplier, Fiscal Stress and Risk

Abstract

According to a growing empirical literature, the government spending multiplier appears to be relatively small in times of fiscal stress. I employ a medium-scale DSGE model with leverage constrained banks and sovereign default risk to analyze how the presence of fiscal stress can affect the transmission of government spending shocks. I find that the role of fiscal stress for the size of the government spending multiplier is negligible when analyzing the linearized economy. When the model is solved using a third-order approximation to equilibrium dynamics, however, and the effects of risk on the transmission of a government spending shock are therefore accounted for, the presence of fiscal stress can lead to a substantial decrease of the government spending multiplier, which is in line with the empirical evidence. For plausible calibrations of the model, the cumulative multiplier can even become negative.

Keywords: Government spending multiplier; Fiscal stress; Aggregate risk; Financial frictions
JEL Classification: E32, E 44, E62, H30, H60

3.1 Introduction

During the recent sovereign debt crisis in the Eurozone several European countries have experienced sharp increases of their debt-to-GDP ratios and their sovereign bonds yields. To strengthen the sustainability of their public finances, these countries started programs of fiscal consolidation which included steep government spending cuts. This raises the question: How does fiscal stress affect the size of the government spending multiplier? A number of empirical papers find that the government spending multiplier is smaller, when public finances are weak.[1] This paper propose a

[1] See, e.g., (Perotti, 1999), (Corsetti et al., 2012) and (Ilzetzki et al., 2013)

medium scale DSGE model that offers an explanation for this empirical link between the degree of fiscal stress and the size of the government spending multiplier.

A key feature of this model are endogenously leverage constrained banks as in (Gertler and Karadi, 2011), which, in addition to private capital assets, hold government bonds that are subject to default risk. As stressed by (van der Kwaak and van Wijnbergen, 2014), the exposure of banks in the Eurozone to domestic sovereign bonds is substantial. Thus, fluctuations in the degree of fiscal stress are likely to affect the conditions of the banks' asset side, and therefore their ability to supply loans to firms. Indeed, as highlighted by (Corsetti et al., 2013), sovereign risk spreads and private credit spreads have been highly correlated in those countries in the Eurozone, which experienced increasing degrees of fiscal stress. Introducing the link between fragile banks and risky government bonds into the model allows me to capture that variations in government spending, to the extent that they affect the degree of fiscal stress, can have an immediate impact on the credit supply, and therefore on investment in the economy. Fiscal stress is captured in the model by the probability of a sovereign default modeled in the form of a fiscal limit function as discussed by (Leeper and Walker, 2011) and used in similar variations by other authors.[2] This function maps the debt-to GDP ratio into the probability of a sovereign default. In this setting, I analyze government spending multipliers obtained by a first-order approximation, as well as a third-order approximation to equilibrium dynamics. using the non-linear moving average approach by (Lan and Meyer-Gohde, 2013). Employing a third-order approximation implies that the degree of aggregate risk affects the equilibrium dynamics, and hence the response of the economy to a government spending shock. As a consequence, the precautionary motive of agents is accounted for.

I find that the degree of fiscal stress does affect the government spending multiplier in my model. An increase in government spending increases both, aggregate output and public debt. Initially, the debt-to-GDP ratio, and therefore also the sovereign default probability, decrease due to the output stimulus triggered by the increase in government spending. After a few quarters, however, as the stimulus fades out and public debt remains high, the debt-to-GDP ratio and the sovereign default probability increase above pre-shock level. The increase in the default probability raises the interest rate on government bonds, and as prices of capital assets and bonds are determined jointly in equilibrium, they also raise the interest rate on loans that the bank extend to firms. Thus, the increase in fiscal stress contributes to a crowding out of investment, dampens the output stimulus, and lowers the government spending

[2] Examples include: (Bi and Traum, 2012a), (Bi and Traum, 2012b), (Corsetti et al., 2013), (van der Kwaak and van Wijnbergen, 2013), (van der Kwaak and van Wijnbergen, 2015), (Bi et al., 2014).

multiplier.

However, whether this effect is quantitatively important depends on the way the model is solved. In the linearized economy, the effect of this ’fiscal stress channel’ on bond prices and on the output response to the shock is negligible. In contrast, when the model is solved with a third-order approximation, and therefore the role of aggregate risk for the transmission of the shock is accounted for, the ’fiscal stress channel’ can become sizable.

The financial accelerator embedded in the model, and the probability of a sovereign default, are key to generating a relevant effect of risk on the equilibrium dynamics. A positive government spending shock worsens the balance sheet position of risk averse banks. When the risk of future shocks, that have the potential to further weaken the balance sheet of banks, is accounted for, the banks reduce their exposure to the risky asset to a larger degree. The fall in credit supply and investment is stronger, and the output stimulus is smaller and more short-lived than in a linear world, where the degree of risk has no impact on the dynamics of the model. The smaller output stimulus leads to a more immediate and more pronounced increase in the debt-to-GDP ratio, and hence also the sovereign default probability. This in turn further aggravates the balance sheet position of banks, reducing the credit supply, and further decreasing the government spending multiplier. The fiscal stress channel is more important for the government spending multiplier, the higher the debt-to-GDP ratio, the higher the sensitivity of fiscal stress to the debt-to-GDP ratio, and the higher the leverage ratio of banks. When the debt-to-GDP ratio is calibrated to 1.3, roughly matching the debt-to-GDP ratio observed in Italy in the recent years, the cumulative multiplier even becomes negative. Hence, solving the model non-linearly opens the door for a quantitatively relevant role of fiscal stress, and helps to explain why in the presence of higher fiscal stress, the government spending multiplier can be smaller.

A number of empirical papers find that the government spending multiplier is smaller, when public finances are weak. Analyzing data from a panel of 19 OECD countries from 1965 to 1994, (Perotti, 1999) finds evidence of substantially smaller government spending multipliers for countries that are characterized by high public debt levels or deficits. This finding of smaller multipliers in the presence of higher debt is corrobated by (Corsetti et al., 2012), (Guajardo et al., 2014), and (Ilzetzki et al., 2013). The latter find surprisingly large, negative long run multipliers for countries with high public debt. (Klein, 2016) finds that high public debt levels reduce the government spending multiplier, regardless of whether the stock of private debt in the economy is high or low. Recently, (Born et al., 2015) and (Strobel, 2016) employ regime-switching SVARs to analyze the effects of government spending shocks, when risk premiums on government bonds are high. (Born et al., 2015) analyze a panel of 38 developing and developed countries and find that in periods of higher risk premiums on government bonds, the government spending multiplier is higher than in periods with lower risk premiums. However, they acknowledge the challenge of disentangling the effects of higher sovereign spreads and the effects of recessions on the multiplier in their sample.[3] To circumvent this difficulty, (Strobel, 2016) focusses on the case of Italy, between 1993 and 2013, as in this sample the correlation between fiscal stress, measured by the risk spreads on Italian government bonds, and output growth is low. Here, cumulative government spending multipliers for a time horizon of three years are significantly lower in a regime with higher sovereign yield spreads . Thus overall, the literature tends to find smaller multipliers in the face of fragile public finances.

This paper is not alone in analyzing the relation between fiscal stress and the government spending multiplier. The paper closest to mine is (van der Kwaak and van Wijnbergen, 2015). As I do in this paper, they employ the model framework by (Gertler and Karadi, 2011) augmented by risky long-term government bonds to investigate the link between the government spending multiplier and sovereign default risk. They find that due to the leverage constraint on banks, deficit financed government spending crowds out loans to private firms, which decreases the government spending multiplier. Furthermore, a longer duration of government bonds and the presence of default risk decreases the effectiveness of government spending. While my paper confirms their main findings, it differs from theirs along two dimensions: First, while in their model fiscal stress is determined by the level of public debt, in mine the fiscal stress indicator is a function of the debt-to-GDP ratio. This changes the dynamic response of the fiscal stress indicator the government spending shocks, as the output stimulus after the shock initially decreases the debt-to-GDP ratio. As a consequence, in my linearized model, the link between fiscal stress and the government spending multiplier is drastically weaker than it is in (van der Kwaak and van Wijnbergen, 2015). Secondly, I additionally demonstrate the effect of risk on the size of the multiplier, which in my framework allows me to generate the negative relation between the degree of fiscal stress and the multiplier found in the empirical literature.
Another recent theoretical paper on government spending and the presence of fiscal stress is (Corsetti et al., 2013). They argue that in the presence of fiscal stress , fiscal retrenchment, insofar as it stabilizes public finances, may also enhance the stability of the macroeconomy. In the extreme case this may even imply a negative government spending multiplier. The possibility of a expansionary fiscal contraction was originally proposed by (Giavazzi and Pagano, 1990). (Bertola and Drazen, 1993) build a model in which a fiscal retrenchment improves the expectations of households on the

[3]In contrast to fiscal stress , recessions are associated with higher government spending multipliers. (See, e.g. (Christiano et al., 2011), (Auerbach and Gorodnichenko, 2012))

future growth path and increases consumption. (Alesina and Perotti, 1997) suggest that lower risk premiums provide a channel through which fiscal contraction may stimulate investment and economic growth. [4]

A number of panel data studies investigate the drivers of sovereign yield spreads. Examples include (Alesina et al., 1992), (Bernoth et al., 2003), (Manganelli and Wolswijk, 2009), (di Cesare et al., 2012), (Beirne and Fratzscher, 2013) and others. Generally, these studies find that higher public debt and lower growth raise risk premiums in the same period. (Beirne and Fratzscher, 2013) suggest that there was a contagion effect spilling over from Greece. Among others, they argue that there has been a "fundamental contagion" which caused the markets to become more aware of the economic fundamentals in periphery countries. As only the periphery countries with high public debt and low GDP growth were affected by these spells, the results of this literature points towards an increase of the sensitivity of default risk to economic fundamentals in crisis time. In my framework, I model the relationship between fundamentals and the probability of a sovereign default in the form of a fiscal limit function a la (Leeper and Walker, 2011). I use a logistic distribution function, which increases with the debt-to-GDP ratio, and calibrate it using parameter values from the structural estimation on Italian data by (Bi and Traum, 2012a). The shape of this function allows for capturing the empirically observed non-linear relationship between fundamentals and sovereign yield spreads.

The role of aggregate risk for equilibrium dynamics in DSGE models is investigated by a strand of the literature, which was started by (Bloom, 2009).[5] The focus of this literature lies on the effects of stochastic exogenous volatility. Capturing the effects of volatility shocks requires a third-order approximation to the equilibrium dynamics. As the focus of the paper at hand is the analysis of a government spending shock, I abstract from volatility shocks (often called "risk shocks" or "uncertainty shocks") and hold the degree of risk constant. Typically, an impulse response function to a level shock is an object for which a first-order approximation is regarded to be sufficient for its analysis. In my framework however, the financial accelerator mechanism together with the presence of fiscal stress generate sufficient amplification, so that the impact of aggregate risk for the transmission of the government spending shock is strong enough to create a non-negligible difference between multipliers generated with a first-order approximation and a third-order approximation. In

[4] Other examples of papers that discuss explain the possibility of expansionary fiscal contraction are: (Blanchard, 1990) and (Sutherland, 1997). For emipirical evidence in support of the this hypothesis, see, e.g., (Giavazzi and Pagano, 1990), (Alesina and Ardagna, 2010) and (Bergman and Hutchison, 2010). Studies who cast doubt on the empirical evidence for the expansionary contraction hypothesis are (Perotti, 2011) and (Guajardo et al., 2014).

[5] see also, e.g., (Fernandez-Villaverde et al., 2011), (Basu and Bundick, 2015) (Bachmann and Bayer, 2013)

turn, taking into account risk and the precautionary behavior of agents, allows me to generate the negative relationship between the degree of fiscal stress, and the size of the government spending multiplier, that is found in the empirical literature.

The remainder of the paper is structured as follows: Section two gives an overview of the model. Section three discusses the calibration and the solution method. The fourth section provides an anatomy of the dynamic consequences of government spending shocks, and an analysis of the dynamic effects of government spending shocks for the model with fiscal stress. It compares linear impulse response functions with their non-linear counterpart, and compares the dynamics of a model with fiscal stress to a model in which the effects of fiscal stress for the multiplier are shut off. Section five highlights conditions under which the fiscal stress channel is particularly important for the government spending multiplier, and section six concludes.

3.2 The model

The environment

The model builds on the framework used by (Gertler and Karadi, 2011), and adds an extra twist to make it suitable for the analysis of the link between fiscal stress and the government spending multiplier. In particular, in addition to capital assets, banks hold government bonds as a second asset on their balance sheets, and the default probability of government bonds is tied to the debt-to-GDP ratio.
Time is discrete, and one period in the model represents one quarter. The model features households, banks, intermediate good producers, capital good producers, retailers, a fiscal and a monetary authority. Figure (3.1) provides an illustration of the model structure. Households consume, supply labor, and save in the form of bank deposits. The firm sector consists of three types of firms. Intermediate good producers employ labor and capital to produce their goods. Each period, after producing their output, they sell their used capital stock to the capital goods producers. The latter repair it, and invest in new capital. At the end of the period they re-sell the capital to the intermediate good producers, which use it for production in the next period. The intermediate good producers finance their purchases of capital with loans from the banks. Intermediate goods are purchased by retailers, which repackage them, and sell them with a markup as final goods to households, the capital producers, and to the government. Banks hold loans and government bonds on the asset side of their balance sheets. On the liability side are deposits and the banks net worth. The government consumes final goods, collects taxes, and issues government bonds, which are subject to default risk. Monetary policy takes the form of a Taylor rule.
The model includes habit formation in consumption, convex investment adjustment

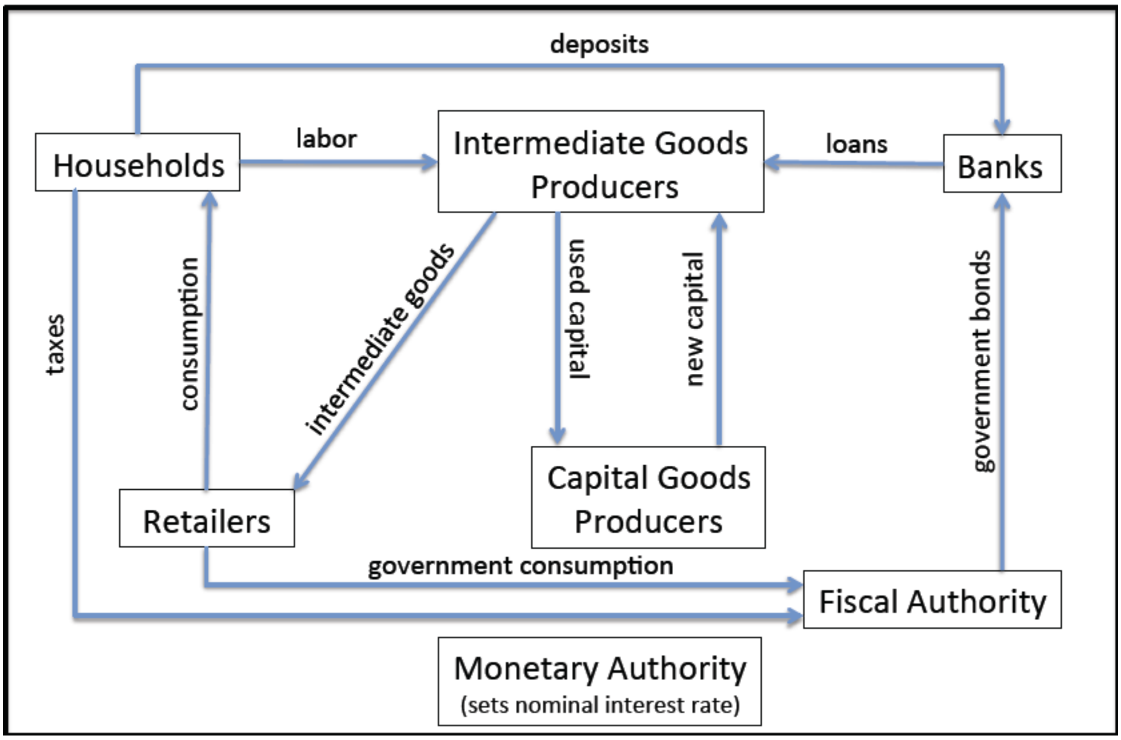

Figure 3.1: Overview of the model

costs, sticky prices, and price indexation to enhance the empirical plausibility of the model dynamics, and to facilitate the comparability of my results with the results by other authors which have used this framework.

Households

There is a continuum of households with a unit mass. As in (Gertler and Karadi, 2011) a constant fraction f of each household's members works as banker, whereas the other fraction $(1-f)$ consists of workers who supply labor to the intermediate good producers. While workers receive their wage income every period, bankers reinvest their gains in asset holdings of the bank over several periods, and contribute to the households income only when exiting the banking sector, bringing home the accumulated profits. To ensure that both fractions of the household face the same consumption stream, perfect consumption insurance within the household is assumed. Households' expected lifetime utility is as follows

$$E_0 \sum_{t=0}^{\infty} \beta^t [\ln(C_t - hC_{t-1}) - \frac{\chi}{1+\phi} L_t^{1+\phi}],$$

where C_t is consumption and L_t is labor that the workers supply to intermediate good producers. β is the discount factor, h is the parameter of the habit formation, ϕ is the inverse of the Frisch elasticity, and χ scales the weight of the disutility from labor in the preferences. Households can save via a one period bank deposit, which earns the riskless interest rate, R_t. The income stream of the household is thus composed of the wage income W_tL_t, banker's profits Υ_t^b, firm profits, Υ_t^f net the payment of lump sum taxes T_t. It uses this income to purchase consumption goods or to renew its deposits. The budget constraint thus reads

$$C_t + D_t = W_tL_t + R_{t-1}D_{t-1} + \Upsilon_t^b + \Upsilon_t^f - T_t.$$

Maximizing life-time utility with respect to consumption, labor and deposit holdings subject to the sequence of budget constraints yields the first order conditions of the household

$$W_t = \frac{\chi L_t^\phi}{U_{c,t}}, \tag{3.1}$$

$$U_{c,t} = (C_t - hC_{t-1})^{-1} - \beta h E_t(C_{t+1} - hC_t)^{-1}, \tag{3.2}$$

$$1 = E_t\beta\Lambda_{t,t+1}R_t, \tag{3.3}$$

with

$$\Lambda_{t,t+1} = \frac{U_{c,t+1}}{U_{c,t}}. \tag{3.4}$$

Firm sectors

The model contains three types of firms. Intermediate goods are produced by perfectly competitive firms, which use capital and labor as inputs for production. Monopolistically competitive retailers buy a continuum of intermediate goods, and assemble them into a final good. Nominal frictions as in (Calvo, 1983) make the retailers optimization problem dynamic. Additionally, a capital producing sector buys up capital from the intermediate good producer, repairs it, and builds new capital, which it sells to the intermediate good sector again. Investment in new capital is subject to investment adjustment costs.

Intermediate good producers

In this setup dynamic pricing and investment decisions are carried out by retailers and capital good producers, respectively. Thus, the optimization of the intermediate good producers can be reduced to a sequence of static problems. Their production function takes a standard Cobb Douglas form, given by

$$Y_{mt} = A_t(\xi_t K_{t-1})^\alpha L_t^{1-\alpha}, \tag{3.5}$$

where $0 < \alpha < 1$ and A_t is an index for the level of technology. K_{t-1} is the capital purchased and installed in period $t-1$, which becomes productive in period t, and ξ_t is a shock to the quality of capital which can be interpreted as obsolesce of the employed capital. (Gertler and Kiyotaki, 2010) and (Gertler and Karadi, 2011) use this capital quality shock to simulate the banking crisis preceding the Great Recession in the US. In the context of this analysis it allows me to account for a source of risk for the price of capital assets.

At the end of each period the intermediate good producer sells the capital stock that it used for production to the capital producer which repairs the capital, and purchases the capital stock that it is going to use in the next period from the capital producer. To finance the purchase of the new capital at the price Q_t per unit, it issues a claim for each unit of capital it acquires to banks, which trade at the same price. The interest rate the firm has to pay on the loan from the bank is $R_{k,t}$. Under the assumption that the competitive firms make zero profits, the interest rate on their debt will just equal the realized ex-post return on capital. The resale value of the capital used in production depends on the realization of the capital quality shock, and the depreciation rate. Capital evolves according to the following law of motion

$$K_t = (1-\delta)\xi_t K_{t-1} + I_t. \tag{3.6}$$

Hence each period the firm in its investment decision maximizes

$$E_t[\beta\Lambda_{t,t+1}(-R_{k,t+1}Q_tK_t + P_{m,t+1}Y_{m,t+1} - W_{t+1}L_{t+1} + (1-\delta)Q_{t+1}K_t\xi_{t+1})]$$

with respect to K_t. In optimum the ex-post return then is as follows

$$R_{k,t+1} = \frac{P_{m,t+1}\alpha\frac{Y_{m,t+1}}{K_t} + (1-\delta)Q_{t+1}\xi_{t+1}}{Q_t}. \tag{3.7}$$

Additionally, the optimal choices of labor input yields the first order conditions

$$W_t = P_{mt}(1-\alpha)\frac{Y_{mt}}{L_t}. \tag{3.8}$$

Capital good producers

The capital good producer's role in the model is to isolate the investment decision that becomes dynamic through the introduction of convex investment adjustment costs, which is a necessary feature to generate variation in the price of capital. Capital good producers buy the used capital, restore it and produce new capital goods. Since capital producers buy and sell at the same price, the profit they make is determined by the difference between the quantities sold and bought, i.e. investment. Thus they choose the optimal amount of investment to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \Lambda_{0,t} \left\{ [(Q_t - 1) I_t - f\left(\frac{I_t}{I_{t-1}}\right) I_t \right\}.$$

The first order condition of the capital producer reads

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - E_t \beta \Lambda_{t,t+1} \left(\frac{I_t}{I_{t-1}}\right)^2 f'\left(\frac{I_t}{I_{t-1}}\right), \tag{3.9}$$

where the functional form of the investment adjustment costs is

$$f\left(\frac{I_t}{I_{t-1}}\right) = \frac{\eta_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2.$$

Retailers

Retailers produce differentiated goods by re-packaging the intermediate goods. They operate under monopolistic competition and face nominal rigidities à la (Calvo, 1983). As an additional element to smooth the equilibrium dynamics of inflation, it is assumed that in each period the fraction of firms that cannot choose its optimal price, γ, indexes its price to the inflation of the foregoing period. The parameter of price indexation is γ_p. Aggregate final output, Y_t, is described by a CES aggregator of the individual retailers' final goods, Y_{ft}

$$Y_t = \left(\int_0^1 Y_{ft}^{\frac{\epsilon-1}{\epsilon}} df\right)^{\frac{\epsilon}{\epsilon-1}}.$$

where $\epsilon > 1$ is the elasticity of substitution between different varieties of final goods. Thus the demand for its final goods that the retailer faces is

$$Y_{ft} = \left(\frac{P_{ft}}{P_t}\right)^{-\epsilon} Y_t,$$

where P_{ft} is the price chosen by retailer f. The aggregate price index is

$$P_t = \left(\int_0^1 P_{ft}^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}},$$

which due to the specific assumptions on the nominal rigidity can be written as

$$\Pi_t^{1-\epsilon} = (1-\gamma)(\Pi_t^*)^{1-\epsilon} + \gamma \Pi_{t-1}^{\gamma_p(1-\epsilon)}, \tag{3.10}$$

where $\Pi_t := \frac{P_t}{P_{t-1}}$, and $\Pi_t^* := \frac{P_t^*}{P_{t-1}}$. As the retailers' only input is the intermediate good which is sold by competitive producers, the marginal cost of the retailers equals the price of the intermediate good. Hence, each retailer chooses its optimal price to maximize the sum of its expected discounted profits

$$E_t \sum_{i=0}^{\infty} (\gamma\beta)^i \Lambda_{t,t+i} \left\{ \frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i} (\Pi_{t+k-1})^{\gamma_p} - P_{m,t+i} \right\} Y_{f,t+i},$$

subject to the demand constraint. The first order condition for optimal price setting reads

$$E_t \sum_{i=0}^{\infty} (\gamma\beta)^i \Lambda_{t,t+i} \left\{ \frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i} (\Pi_{t+k-1})^{\gamma_p} - \frac{\epsilon - 1}{\epsilon} P_{m,t+i} \right\} \left(\frac{P_t^*}{P_{t+i}} \right)^{-\epsilon} Y_{t+i} = 0.$$

Accordingly, the optimal choice of the price implies

$$\Pi_t^* = \frac{\epsilon}{\epsilon - 1} \frac{F_t}{Z_t} \Pi_t, \tag{3.11}$$

where F_t and Z_t are defined recursively as

$$F_t = Y_t P_{mt} + \beta\gamma \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon} \Pi_t^{-\gamma_p \epsilon} F_{t+1}, \tag{3.12}$$

$$Z_t = Y_t + \beta\gamma \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon-1} \Pi_t^{-\gamma_p(\epsilon-1)} Z_{t+1}. \tag{3.13}$$

Equations (13)-(16) constitute the equilibrium conditions, which in a linearized form are equivalent to a New Keynesian Phillips Curve with price indexation. Aggregate output of final goods, Y_t, is related to the aggregate intermediate output, Y_{mt}, in the following way

$$Y_{mt} = \Delta_{p,t} Y_t, \tag{3.14}$$

where Δ_t is the dispersion of individual prices, which evolves according to the law of motion

$$\Delta_{p,t} = \gamma \Delta_{p,t-1} \Pi_t^{\epsilon} \Pi_{t-1}^{-\gamma_p \epsilon} + (1 - \gamma) \left(\frac{1 - \gamma \Pi_t^{\epsilon-1} \Pi_{t-1}^{-\gamma_p(\epsilon-1)}}{1 - \gamma} \right)^{\frac{\epsilon}{\epsilon-1}}. \tag{3.15}$$

The markup X_t of the monopolistic retailers is the inverse of their marginal costs, which is equivalent to the price of the intermediate good

$$X_t = \frac{1}{P_{mt}}. \tag{3.16}$$

Banks

Banks finance their operations by creating deposits, D_t, which are held by households, and by their net worth, N_t. They use their funds to extend loans to intermediate good producers for acquiring capital, K_t, and for the purchases of government bonds, B_t at their market price Q_t^b. The balance sheet of bank j is given by

$$Q_t K_{jt} + Q_t^b B_{jt} = N_{jt} + D_{jt}. \tag{3.17}$$

The banks retain the earnings, generated by the return on their assets purchased in the previous period, and add it to their current net worth. Thus, the law of motion for the net worth of a bank is given by

$$N_{jt} = R_{kt} Q_{t-1} K_{j,t-1} + R_{bt} Q_{t-1}^b B_{j,t-1} - R_{t-1} D_{j,t-1}. \tag{3.18}$$

Note that while the interest rate on deposits raised in period $t-1$, is determined in the same period, the return of the risky capital assets and risky government bonds purchased in period $t-1$ is determined only after the realization of shocks at the beginning of period t. Substituting the balance sheet into the law of motion for net worth yields

$$N_{jt} = (R_{kt} - R_{t-1}) Q_{t-1} K_{j,t-1} + (R_{bt} - R_{t-1}) Q_{t-1}^b B_{j,t-1} + R_{t-1} N_{j,t-1}. \tag{3.19}$$

Bankers continue accumulating their net worth, until they exit the business. Each period, each banker faces a lottery, which determines, regardless of the history of the banker, whether he exits his business or stays in the sector. Bankers exit the business with an exogenous probability $1-\theta$, or continue their operations with probability θ. The draws of this lottery are i.i.d.. When a banker leaves the sector, it adds his terminal wealth V_t to the wealth of its household. Therefore, bankers seek to maximize the expected discounted terminal value of their wealth

$$\begin{aligned} V_{jt} &= \max E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} N_{j,t+1+i} \\ &= \max E_t [\beta \Lambda_{t,t+1} (1-\theta) N_{j,t+1} + \theta V_{j,t+1}]. \end{aligned}$$

As banks operate under perfect competition, with perfect capital markets the risk adjusted return on loans and government bonds would equal the return on deposits. However, bankers face an endogenous limit on the amount of funds that households are willing to supply as deposits. Following (Gertler and Karadi, 2011), I assume that bankers can divert a fraction of their assets and transfer it to their respective households. However, if they do so, their depositors will choose to withdraw their remaining funds and force the bank into bankruptcy. To avoid this scenario, households will keep their deposits at a bank only as long as the bank's continuation value is higher or equal to the amount that the bank can divert. Formally, the incentive constraint of the bank reads

$$V_{jt} \geq \lambda Q_t K_{jt} + \lambda_b Q_t^b B_{jt}, \tag{3.20}$$

where λ, is the fraction of loans that the bank can divert, and λ_b is the fraction of government bonds it can divert. I calibrate λ_b to be smaller than λ. This is motivated by the fact, that, in general, the collateral value of government bonds is higher than that of loans.[6] The reason is that loans to private firms are less standardized than government bonds contracts. Additionally, information on the credit-worthiness of the government is publicly available, while the credit-worthiness of private firms is often only known to the bank and the firm, and not easy to assess for depositors, making it easier for banks to divert a fraction of their value.

The initial guess for the form of the value function is

$$V_{jt} = \nu_{kjt} Q_t K_{jt} + \nu_{bjt} Q_t^b B_{jt} + \nu_{njt} N_{jt}, \tag{3.21}$$

where ν_{kjt}, ν_{bjt} and ν_{djt} are time varying coefficients. Maximizing (23) with respect to loans and bonds, subject to (22) yields the following first order conditions for loans, bonds, and μ_t, the Lagrangian multiplier on the incentive constraint

$$\nu_{kjt} = \lambda \frac{\mu_{jt}}{1+\mu_{jt}}, \tag{3.22}$$

$$\nu_{bjt} = \lambda_b \frac{\mu_{jt}}{1+\mu_{jt}}, \tag{3.23}$$

$$\nu_{kjt} Q_t K_{jt} + \nu_{bjt} Q_t^b B_{jt} + \nu_{njt} N_{jt} = \lambda Q_t K_{jt} + \lambda_b Q_t^b B_{jt}. \tag{3.24}$$

Given that the incentive constraint binds[7], a bank's supply of loans can be written as

$$Q_t K_{jt} = \frac{\nu_{bjt} - \lambda_b}{\lambda - \nu_{kjt}} Q_t^b B_{jt} + \frac{\nu_{njt}}{\lambda - \nu_{kjt}} N_{jt}. \tag{3.25}$$

As (27) shows, the supply of loans decreases with an increase in λ, which regulates the tightness of the incentive constraint with respect to capital, and increases with an increase in λ_b, which makes the holding of bonds more costly in terms of a tighter constraint. Plugging the demand for loans into (23), and combining the result with (24) and (25) one can write the terminal value of the banker as a function of its net worth[8]

$$V_{jt} = (1+\mu_{jt}) \nu_{njt} N_t. \tag{3.26}$$

A higher continuation value, V_{jt} is associated with a higher shadow value of holding an additional marginal unit of assets, or put differently, with a higher shadow value of

[6] This is in the vein of Meeks et al. (2014), who use the same approach to distinguish between the collateral values of loans and asset backed securities.

[7] The constraint binds in the neighborhood of the steady state. For convenience, I make the assumption that it is binding throughout all experiments.

[8] Detailed derivations are delegated to the appendix.

marginally relaxing the incentive constraint. Defining the stochastic discount factor of the bank to be

$$\Omega_{j,t} \equiv \Lambda_{t-1,t}((1-\theta)+\theta(1+\mu_{jt})\nu_{njt}), \tag{3.27}$$

plugging (28) into the Bellman equation, and using the law of motion for net worth, one can then write the value function as

$$\begin{aligned} V_{jt} &= E_t[\beta\Lambda_{t,t+1}(1-\theta)N_{j,t+1}+\theta V_{j,t+1}] \\ &= E_t[\beta\Omega_{j,t+1}((R_{k,t+1}-R_t)Q_tK_{j,t}+(R_{b,t+1}-R_t)Q_t^bB_{j,t}+R_tN_{j,t-1})], \end{aligned}$$

and verify the initial guess for the value function as

$$\nu_{kjt} = \beta E_t\Omega_{jt+1}(R_{k,t+1}-R_t), \tag{3.28}$$

$$\nu_{bjt} = \beta E_t\Omega_{jt+1}(R_{b,t+1}-R_t), \tag{3.29}$$

$$\nu_{njt} = \beta E_t\Omega_{jt+1}R_t. \tag{3.30}$$

Aggregation of financial variables

To facilitate aggregation of financial variables, I assume that banks share the same structure to the extent that they derive the same respective values from holding loans and bonds, and from raising deposits (i.e., $\forall j: \nu_{kjt}=\nu_{kt}, \nu_{bjt}=\nu_{bt}, \nu_{njt}=\nu_{nt}$). Furthermore, I assume that all banks have the same ration of capital assets to government bonds, $\varsigma_t \equiv \frac{Q_tK_t}{Q_t^bB_t}$, in their portfolio. As an implication, the leverage ratio of banks does not depend on the conditions that are specific to individual institutes, and all banks share the same weighted leverage ratio[9]

$$\phi_t \equiv \frac{\nu_{nt}(1+\varsigma_t)}{(\lambda-\nu_{kt})(1+\frac{\lambda_b}{\lambda}\varsigma_t)} = \frac{Q_tK_t+Q_t^bB_t}{N_t}.^{10} \tag{3.31}$$

Note that the lower divertability of government bonds relative to capital assets, allows the bank to increase its leverage ratio, compared to a scenario in which banks only hold capital assets. The aggregate balance sheet constraint reads

$$Q_tK_t+Q_t^bB_t = D_t+N_t. \tag{3.32}$$

The net worth of the fraction of bankers that survive period $t-1$ and continue operating in the banking sector, θ, can be written as

$$N_{ot} = \theta\left[R_{kt}Q_{t-1}K_{t-1}+R_{bt}Q_{t-1}^bB_{t-1}-R_{t-1}D_{t-1}\right]. \tag{3.33}$$

[9] Details are delegated to the appendix.

[10] Note that if the collateral values of capital assets and bonds were the same ($\lambda=\lambda_b$), the leverage ratio would take the same form as in (Gertler and Karadi, 2011), or in (Kirchner and van Wijnbergen, 2016)

A fraction $(1-\theta)$ of bankers leaves the business. There is a continuum of bankers, and the draws out of the lottery, which determines whether a banker stays in business or exits the sector, are iid. Hence, by the law of large numbers, it follows that the share of assets that leaves the sector is a fraction $(1-\theta)$ of the total assets. At the same time, new bankers enter the sector. New bankers are endowed with "start-up funding" by their households. The initial endowment of the new bankers is proportionate to the assets that leave the sector. The net worth of the new bankers, N_{nt}, can be written as

$$N_{nt} = \omega \left[Q_{t-1}K_{t-1} + Q^b_{t-1}B_{t-1} \right], \tag{3.34}$$

where ω is calibrated to ensure that the size of the banking sector is independent of the turnover of bankers. Aggregate net worth, N_t, is then the sum of the net worth of old and new bankers

$$N_t = N_{ot} + N_{nt}. \tag{3.35}$$

Fiscal policy

The fiscal sector closely follows the structure in (van der Kwaak and van Wijnbergen, 2013) and (van der Kwaak and van Wijnbergen, 2015). The government finances its expenditures, G_t, by issuing government bonds, which are bought by banks, and by raising lump sum taxes, T_t. Government spending is exogenous and follows an AR(1) process

$$G_t = Ge^{g_t}, \tag{3.36}$$

$$\text{and} \quad g_t = \rho_g g_{t-1} + \epsilon^g_t, \tag{3.37}$$

where G is the steady state government consumption, ρ_g is the autocorrelation of government consumption, and ϵ^g_t is a shock to government spending. Taxes follow a simple feedback rule, such that they are sensitive to the level of debt and to changes in government expenditures

$$T_t = T + \kappa_b(B_{t-1} - B) + \kappa_g(G_t - G), \tag{3.38}$$

where T and B are the steady state levels of tax revenue and government debt, respectively. κ_b is set to ensure that the real value of debt grows a rate smaller than the gross real rate on government debt. As shown by (Bohn, 1998), this rule is a sufficient condition to guarantee the solvency of the government. If κ_g is set to zero, increases in government expenditures are entirely debt-financed. In turn, when $\kappa_g = 1$, changes in government spending are tracked one-to-one by changes in taxes.

To allow for the calibration of a realistic average maturity of government debt, bonds are modeled as consols with geometrically decaying coupon payments, as in

(Woodford, 1998) and (Woodford, 2001). A bond issued in period t at the price of Q^b_t, pays out a coupon of r_c in period $t+1$, a coupon of $\rho_c r_c$ in period $t+2$, a coupon of $\rho_c^2 r_c$ in $t+2$, and so on. Setting the decay factor ρ_c equal to zero captures the case of a one-period bond in which the entire payoff of the bond is due in period $t+1$. Setting $\rho_c = 1$ delivers the case of a perpetual bond. The average maturity of a bond of this type is $1/(1-\beta\rho_c)$. For investors, this payoff structure is equivalent to receiving the coupon r_c and a fraction, ρ_c, of a similarly structured bond in period $t+1$. The beginning-of-period debt of the government can thus be summarized as $(r_c + \rho_c Q^b_t)B_{t-1}$.

At the beginning of each period, the government has the option to default and write of a fraction of its debt, $D \in (0,1)$. Investors take this into account, and demand a higher return on government bonds, when the expected probability of a sovereign default, Δ^d_{t+1}, increases. The return to government bonds, adjusted for default risk, can thus be written as

$$R_{b,t} = (1-\Delta^d_t * D)\left[\frac{r_c + \rho_c Q^b_t}{Q^b_{t-1}}\right]. \tag{3.39}$$

The flow budget constraint of the government reads

$$\begin{aligned} G_t + R_{bt} Q^b_{t-1} B_{t-1} &= Q^b_t B_t + T_t, \qquad (3.40)\\ \text{or:}\quad G_t + (1-\Delta^d_t * D)\left[\frac{r_c+\rho_c Q^b_t}{Q^b_{t-1}}\right] Q^b_{t-1} B_{t-1} &= Q^b_t B_t + T_t. \end{aligned}$$

Linking the probability of a sovereign default to the level of public debt or the debt-to-GDP ratio is common in the literature (see, e.g., (Eaton and Gersovitz, 1981), (Arellano, 2008) or (Leeper and Walker, 2011)). A higher level of public debt implies a higher debt service, and, in turn, requires higher tax revenues to service the interest rate payments. As tax increases are not popular and only up to a maximum level politically feasible, it is plausible to posit a maximum capacity of levying taxes, or fiscal limit. With an increasing public debt, the economy moves closer to the fiscal limit.
The probability of a sovereign default is described by the logistical distribution function

$$\Delta^d_t = \frac{exp\left(\eta_1 + \eta_2 \frac{B_t}{4Y_t})\right)}{1 + exp\left(\eta_1 + \eta_2 \frac{B_t}{4Y_t}\right)}, \tag{3.41}$$

which depends on the debt-to-GDP ratio, and is depicted in figure (3.2). The fiscal limit function is pinned down by the parameters η_1 and η_2. I use the results of the structural estimation of an RBC model on Italian data by (Bi and Traum, 2012a) to calibrate these parameters.

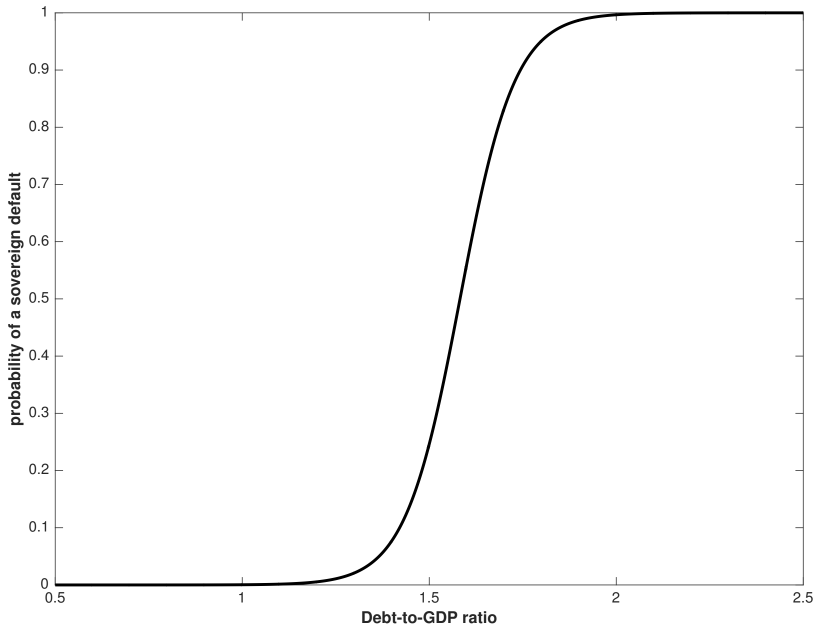

Figure 3.2: Default indicator, Δ_t^d

Monetary policy and good market clearing

The policy tool of the central bank in this economy is the nominal interest rate, i_t, which is set to the Taylor-type rule

$$i_t = \rho_i i_{t-1} + (1-\rho)(i + \kappa_\pi \pi_t + \kappa_y \hat{mc}_t) + \epsilon_t^i, \tag{3.42}$$

where the smoothing parameter ρ_i lies between zero and one, ϵ_t^i is a monetary policy shock, and $\kappa_\pi > 1$ to satisfy the Taylor principle and guarantee the determinacy of the rational expectation equilibrium. The real interest rate on deposits and the nominal policy rate of the central banked are linked via the Fisher equation

$$1 + i_t = R_t \frac{E_t P_{t+1}}{P_t}. \tag{3.43}$$

Finally, the good market clears

$$Y_t = C_t + I_t + f\left(\frac{I_t}{I_{t-1}}\right) I_t + G_t. \tag{3.44}$$

The equilibrium conditions of the full model are collected in the appendix.

3.3 Calibration and solution method

Calibration

The calibration of the model is motivated by the case of the Italian economy, which represents a case of a large, relatively closed economy with high public debt, and recurring periods of high interest rate spreads in the last decades. The model is calibrated to quarterly frequency. Table 1 lists the parameter values used in the model. A major source for the parameter values is (Bi and Traum, 2012a). (Bi and Traum, 2012a) estimate an RBC model with a sovereign default indicator on Italian data from 1999.Q1 and 2010.Q3. As values for the discount factor, β, and the coefficient of relative risk aversion they choose 0.99 and 1.00, respectively. In addition, they choose for the deterministic steady state a debt-to-GDP ratio of 1.19, and an output share of government spending of 0.1966 to match the respective means in their sample. In accordance with their estimation results, I set the parameter for consumption habit, h, to 0.14, the persistence and standard deviation of the technology shock, ρ_a and σ_a to 0.96 and 0.01, and the persistence and standard deviation of the government spending shock, ρ_g and σ_g to 0.84 and 0.01, respectively. Furthermore they obtain the values 0.3 for κ_b and 0.53 for κ_g. Under the assumption of a haircut of 37.8 percent on the outstanding debt in case of a sovereign default, their estimation results imply a default function with the parameter values $\eta_1 = -21.5285$ and $\eta_2 = 3.4015$.[11]
The values of the parameters of the default function reflect that the estimation by (Bi and Traum, 2012a) is based on a sample that largely contains years in which the market for Italian government bond was calm. They imply a quarterly default rate of 0.0048 on sovereign bonds, and a low sensitivity of the default rate to movements in the debt-to-GDP ratio at the deterministic steady state. Similarly, the calibration of the parameters associated with the government spending shock and the technology shock reflects a mixture of calm years and crisis years. I choose these parameter values by (Bi and Traum, 2012a) as my benchmark calibration, since an empirically plausible calibration of the default function is crucial for the assessment of the role of fiscal stress for the multiplier. Also, an empirically plausible calibration of the shock processes is important for the assessment of the role of aggregate risk for the dynamics of the model at a third-order approximation. In section 4.3., however, I deviate from the benchmark calibration, and analyze, among others, how the results are affected, when the calibration is adjusted such as to match features of the recent debt crisis in the Italy in which the debt-to-GDP ratio rose to levels of 1.3 and arguably the sensitivity of fiscal stress to changes in the debt-to-GDP ration, and the degree of aggregate risk in the economy may have been higher.[12]

[11]For more details on the estimation procedure, see (Bi and Traum, 2012a).

[12]The literature on stochastic volatility argues that the volatility of real and financial variables increases during crisis times (see, e.g., (Bloom, 2009), (Fernandez-Villaverde et al., 2011), (Basu and Bundick, 2015)).

In the calibration of the parameters associated with the different firm sectors, I borrow from the model by (Gertler and Karadi, 2011), which is the fundament of the framework at hand.[13] The effective capital share, α is 0.33. The depreciation rate is 0.025 in the deterministic steady state. Parameter η_i, which governs the investment adjustment costs is set to 1.72 and the elasticity of intra-temporal substitution, η, is set to 4.167. The Calvo parameter, $\gamma = 0.779$ implies an average price duration of roughly four and a half quarters. The degree of price indexation, γ_p is rather low at 0.241.
Further parameter values that I use from (Gertler and Karadi, 2011), are the inverse of the Frisch elasticity, φ, the feedback parameters in the Taylor rule, κ_π and κ_y, the persistence of the capital quality shock ρ_ξ, and some parameters of the banking sector. In the calibration of the banking sector, I follow a similar strategy as (Gertler and Karadi, 2011), and choose the fractions of the assets that the banks can diverge, λ and λ_b, the survival probability of the bankers, θ, and the transfer to new bankers, ω, in order to target a steady state leverage ratio of 4, an average time horizon of the bankers of a decade, and the steady state spreads of the returns on the banks assets over the deposit rate. For the steady state spread of the return on capital over deposits I use the same target as in (Gertler and Karadi, 2011). For the steady state spread of government bonds over deposits I take the estimate by (Bocola, 2016) as a guideline.

The difference of the steady state spreads of the two assets is reflected by the values of the respective divertability parameters, λ and λ_b. In the deterministic steady state these two parameters are linked by the relation

$$\frac{\lambda}{\lambda_b} = \frac{R_k - R}{R_b - R}.$$

The coupon rate on the long-term government bond, r_c, is set to 0.04, and the rate of decay of the bonds, ρ_c, is set to 0.96 as in (van der Kwaak and van Wijnbergen, 2015). The standard deviations of the monetary policy shock and the capital quality shock are set to 0.01. The parameter χ, which weighs the disutility of labor is chosen such as to balance the labor supply equation in the deterministic steady state.

Solution method

The model is solved using a third-order approximation to equilibrium dynamics. I employ the algorithm developed by (Lan and Meyer-Gohde, 2013).[14] Their solution method solves for the policy functions in the form of a nonlinear moving average. Let

[13] In turn, (Gertler and Karadi, 2011) borrow most of their parameter values from (Primiceri et al., 2006), who estimate a medium scale model on US data.

[14] (Lan and Meyer-Gohde, 2013) show that for the nonlinear moving average method it holds that, if the first-order solution is stationary and saddle-stable, these properties carry over to higher-order approximation.

Table 3.1: Calibration of Parameters

β	discount factor	0.99	Bi and Traum (2012)
h	habit formation	0.14	Bi and Traum (2012)
χ	weight for disutility of labor	4.7125	
φ	inverse of Frisch elasticity	0.276	Gertler and Karadi (2011)
α	effective capital share	0.33	Gertler and Karadi (2011)
δ	depreciation param.	0.025	Gertler and Karadi (2011)
η_i	invest. adjust. param.	1.728	Gertler and Karadi (2011)
ϵ	elasticity of substitution	4,167	Gertler and Karadi (2011)
γ	Calvo param.	0.779	Gertler and Karadi (2011)
γ_p	price indexation param.	0.241	Gertler and Karadi (2011)
$Rk-R$	steady state spread	0.01	Gertler and Karadi (2011)
$Rb-R$	steady state spread	0.005	Bocola (2015)
λ	divertibility of capital assets	0.4479	
λ_b	divertibility of bonds	0.2239	
θ	survival probability of banker	0.975	Gertler and Karadi (2011)
ω	transfer to new bankers	0.0018	
κ_π	interest rate rule	1.5	Gertler and Karadi (2011)
κ_y	interest rate rule	-0.125	Gertler and Karadi (2011)
G/Y	share of gov. spending	0.1966	Bi and Traum (2012)
$B/4Y$	debt-to-GDP ratio.	1.19	Bi and Traum (2012)
κ_b	tax rule param.	0.3	Bi and Traum (2012)
κ_g	tax rule param.	0.53	Bi and Traum (2012)
η_1	fiscal limit parameter	-21.5285	Bi and Traum (2012)
η_2	fiscal limit parameter	3.4015	Bi and Traum (2012)
D	haircut	0.378	Bi and Traum (2012)
r_c	coupon rate	0.04	v.d.Kwaak and v. Wijnbergen (2014)
ρ_c	rate of decay of consol	0.96	v.d.Kwaak and v. Wijnbergen (2014)
ρ_i	intrest rate smoothing	0.0	v.d.Kwaak and v. Wijnbergen (2014)
ρ_ξ	persistence of ξ-shock	0.66	Gertler and Karadi (2011)
ρ_a	persistence of a-shock	0.96	Bi and Traum (2012)
ρ_g	persistence of g-shock	0.84	Bi and Traum (2012)
σ_i	std. of i-shock	0.01	
σ_ξ	std. of ξ-shock	0.01	
σ_g	std. of g-shock	0.01	Bi and Traum (2012)
σ_a	std. of a-shock	0.01	Bi and Traum (2012)

the nonlinear DSGE model be

$$E_t f(y_{t+1}, y_t, y_{t-1}, \epsilon_t) = 0, \tag{3.45}$$

where y_t and ϵ_t represent the vectors of endogenous variables and the vector of exogenous shocks, respectively. Then the solution to this model can be written as a system of policy functions of the form

$$y_t = y(\sigma, \epsilon_t, \epsilon_{t-1}, \epsilon_{t-2}, ...), \tag{3.46}$$

where σ scales the degree of aggregate risk of the model.[15] Under the assumption of normally distributed shocks (i.e., with zero skewness), the third-order Taylor approximation of the policy function takes the form

$$\begin{aligned} y_t = \overline{y} + \frac{1}{2} y_{\sigma^2} \sigma^2 + \sum_{i=0}^{\infty} \left(y_i + \frac{1}{2} y_{\sigma_i^2} \sigma^2 \right) \epsilon_{t-i} + \frac{1}{2} \sum_{i=0}^{\infty} \sum_{j=0}^{\infty} y_{i,j} (\epsilon_{t-i} \otimes \epsilon_{t-j}) \\ + \frac{1}{6} \sum_{i=0}^{\infty} \sum_{j=0}^{\infty} \sum_{k=0}^{\infty} y_{i,j,k} (\epsilon_{t-i} \otimes \epsilon_{t-j} \otimes \epsilon_{t-k}), \end{aligned} \tag{3.47}$$

where $\overline{y}$ denotes the vector of deterministic steady state values of the respective endogenous variables, and the partial derivatives $y_i, y_{i,j}, y_{i,j,k}, y_{\sigma^2}$ and $y_{\sigma_i^2}$ are evaluated at the deterministic steady state. Up to the first order approximation, the policy function is independent of the degree of risk in the model. However, when the model is approximated with a third-order approximation, two terms enter the policy function that adjust it for the risk of future shocks. While y_{σ^2} is constant, $y_{\sigma_i^2}$ varies over time and interacts the linear impulse responses to realized shocks with the risk of future shocks.

In the case at hand, this becomes particularly relevant as leverage constrained banks hold risky government bonds on their balance sheets. To the extent that government spending shocks affect prices and returns of the banks' assets, they imply a time-varying adjustment of the banks' asset holdings to aggregate risk, which alters the reaction of output to the shock. As the economy moves closer to the fiscal limit the default probability becomes more sensitive to the fluctuations in the debt-to-GDP ratio,[16] Therefore, the fiscal stress channel amplifies this time-varying adjustment to risk which, as I will show, affects the dynamic consequences of government spending

[15] $\sigma = 0$ corresponds to the non-stochastic model, whereas $\sigma = 1$ corresponds to the model with the originally assigned distribution of shocks.

[16] This corresponds to the empirical finding of a higher sensitivity of default risk premiums to fundamentals in fiscal crises as found by (Beirne and Fratzscher, 2013). (Beirne and Fratzscher, 2013) label this as an increase in "fundamental awareness".

shocks to output in a quantitatively relevant way, and thus requires a third-order approximation of equilibrium dynamics.[17]

3.4 Dynamic analysis of government spending shocks

This section analyses the effects of a shock to government spending. In order to illustrate the effects of the fiscal stress channel for the output effects of the shock, I compare the full two model described in section 2. with a model in which the fiscal stress channel is shut of. Here, I eliminate equation (4.23) from the model, and set variable Φ_t is to a constant (i.e., $\Phi_t = \Phi \ \ \forall_t$).[18] In all other aspects the two models are identical. I label the latter model: model without fiscal stress .

3.4.1 The linearized model

Let me first focus on the analysis of the impulse responses to a government spending shock in the linearized model. The shock is of the size of 1 percent of steady state GDP. Figure (3.3) depicts the impulse responses. The blue lines show the effect of the shock in the benchmark model with fiscal stress , whereas the black lines show the effect of the shock in a model, which abstracts from the role of fiscal stress for the transmission of the shock. As figure (3.3) illustrates the contribution of fiscal stress is negligible in the linearized case. However, before I turn to the non-linear case, I briefly discuss in this section how the features embedded in the model affect the dynamic consequences of the government spending shock.

As the model contains several features, which affect the transmission of the shock, I start with a brief description of those effects that are independent of financial frictions or fiscal stress. The government spending shock increases government debt and stimulates output. Private activity is crowded out, however. Since households are Ricardian, and preferences are additive separable in consumption and leisure, the increase in government spending induces a wealth effect on the labor supply.[19] As in many models, consumption falls and the labor supply increases after the shock, leading to increasing equilibrium labor hours and a decline in the real wage. With the higher labor input the marginal product of labor decreases. In the presence of sticky prices, the average real marginal cost increase and the average markup declines with the increase in production. As a result of the falling markup, the demand for labor increases for any given real wage, contributing to the increase in equilibrium labor

[17] Note, that while in principle, time varying risk-adjustment affects the dynamic consequences of level shocks in any DSGE model, the risk-adjustment components are in general of negligible size. For the neoclassical growth model, this is illustrated by (Lan and Meyer-Gohde, 2013).

[18] The value of Φ_t in the deterministic steady state, is the same in both models.

[19] For a discussion of the wealth effect on the labor supply, see, e.g., (Christiano and Eichenbaum, 1992) or (Baxter and King, 1993).

hours and output.[20] As highlighted by (Monacelli and Perotti, 2008), the increase in labor hours raises the marginal product of capital. In equilibrium this is accompanied by an increase in the loan rate. This has the effect that investment becomes less attractive, leading to a decline in the capital stock as well as in the price of capital. The firms' demand for loans from banks contracts.

The resulting decline of investment in response to the increase in government spending, that is essential for the link between fiscal stress and the multiplier in my model, is consistent with empirical evidence. For the US, a decline in investment in response to the shock can be found across different approaches to the identification of government spending shocks (see, e.g., (Blanchard and Perotti, 2002), (Mountford and Uhlig, 2009), (Ramey, 2011b)). Evidence from cross-country panels provided by (Corsetti et al., 2012) and by (Ilzetzki et al., 2013) similarly points to a decline in investment in response to an increase in government spending.

As (Kirchner and van Wijnbergen, 2016) show, the crowding-out of investment is amplified through a contraction in the supply of loans, if government bonds are held by leverage constrained as it is the case in this model. Banks reduce the supply of loans for two reasons: First, as they incur capital losses due to the decline in capital prices, their net worth shrinks, tightening their leverage constraints. Additionally, the price of government bonds falls together with the price of capital, due to arbitrage on financial markets, further tightening the leverage constraint. The fall in the prices of capital assets and bonds drive up the spread of the return on bonds over the return on deposits. Lastly, the reduction of the supply of loans increases expected future returns on loans. Hence, the spread of the return on capital assets (loans from the banks to the firms), over the return of deposits increases. As a consequence of the falling asset prices, banks are forced to reduce the size of their balance sheets and sell capital assets, amplifying the fall in the price of capital, and to reduce the supply of loans. A second reason reason for the contraction of the loan supply is that banks change the composition of their asset portfolio. The increase in public debt increases their holdings of government bonds. Given the constraint on the size of banks' balance sheets, the portfolio shift towards government bonds exerts further pressure on the supply of loans to firms. Overall, the financial accelerator mechanism that is implied by constrained banks amplifies the crowding out of investment compared to a situation with unconstrained investors in capital assets, and lowers the government spending multiplier.

[20] For an analysis of the role of markup shifts for the transmission of government spending shocks in the New Keynesian model, see: (Monacelli and Perotti, 2008).

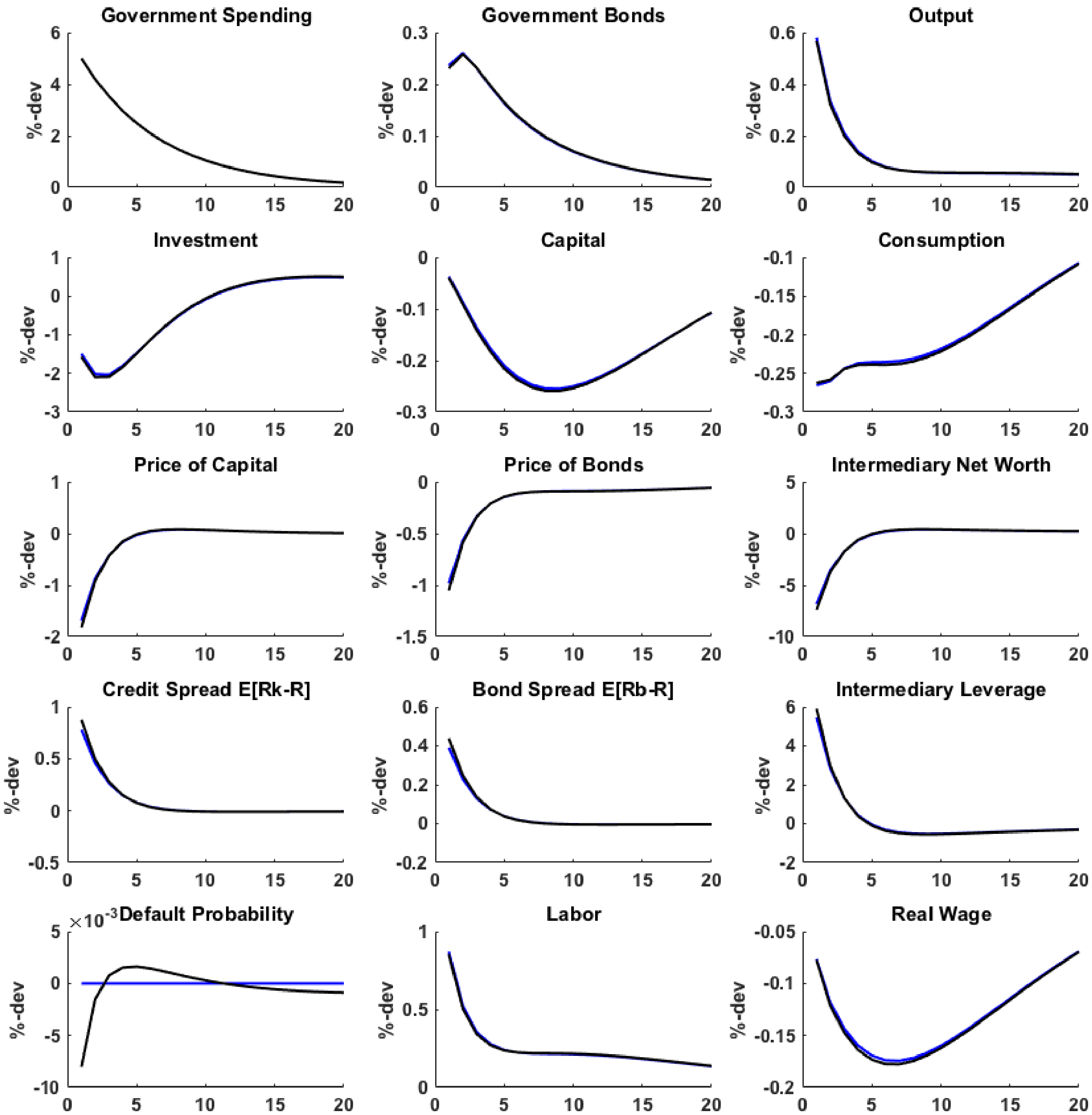

Figure 3.3: Dynamic consequences of a shock in government spending of 1 percent obtained from a first-order approximation to equilibrium dynamics. The blue lines depict the impulse responses of a model without fiscal stress. The black line depicts the impulse responses with fiscal stress.

Now let me turn to the effect of fiscal stress on the government spending multiplier. Most of the literature on the interaction of fiscal multipliers and fiscal stress, theoretical as well as empirical, focusses on the possibility that higher fiscal stress decreases the impact of government spending shocks. Theoretical studies that focus on the effect of fiscal retrenchment suggest that, for instance, an improvement of the expectations of future growth ((Bertola and Drazen, 1993)), or a decrease in risk premiums on government bonds, enhanced financial intermediation and increasing investment (e.g. (Alesina and Perotti, 1997), (Corsetti et al., 2013) or (van der Kwaak and van Wijnbergen, 2013)) counteract the otherwise detrimental effects of fiscal retrenchment on output growth. I follow the authors who focus in their argument on the channel of financial intermediation and changes in risk premiums.

The response to the government spending shock in the linearized model with fiscal stress depicted as black curves in figure (3.3). As one can see, the contribution of the fiscal stress channel to the response of the financial and real variables to the government spending shock is very small. The main difference to the scenario without fiscal stress is that now the default probability responds to the movements in the debt-to-GDP ratio. As the initial increase in GDP is larger in percentage terms than the initial increase in public debt, the debt-to-GDP ratio decreases on impact. This initial fall in the default probability after a fiscal expansion is in line with empirical findings by (Born et al., 2015) and (Strobel, 2016) who find that in periods of a higher of fiscal stress, bond yield spreads increase on impact after contractionary fiscal shocks. Already after the second quarter, the default probability in the model rises above the steady state, since the increase in debt is more persistent than the output response. Through equation (3.41) the variation in the default probability contributes to the fall in price of bonds and the increase in the return on bonds, and as prices and returns of assets move together, it contributes to the fall in the price of capital and the increase in the return on capital as well. The contraction of investment and capital are slightly stronger, and the response of output slightly weaker than in the model without fiscal stress.

The size of this effect is, however, very small. Table 2 shows the difference in the government spending multipliers for the two models. Adding the feature of fiscal stress decreases the impact multiplier from 0.58 to 0.57, and the cumulative multiplier over a time horizon of 20 quarters from 0.37 to 0.36. Thus, the linearized model cannot generate the empirical finding that the presence of fiscal stress lowers the government spending multiplier.

Table 3.2: Government Spending Multipliers

	Impact Multiplier	Cumulative Multiplier*
linear , no fiscal stress	0.581	0.368
linear , with fiscal stress	0.569	0.362

*time horizon of 20 quarters

3.4.2 The role of risk for the fiscal stress channel

This section discusses the role of risk for the transmission of government spending shocks. Figure (3.4) compares the linear impulse responses to the government spending shock in the full model with fiscal stress (dashed line) with the impulse responses to the same shock, obtained by a third-order approximation to equilibrium dynamics (solid line).

The main difference in the two sets of impulse responses lies with the time-varying adjustment for the risk of future shocks.[21] The risk associated with the realization of future shocks matters because agents are risk-averse and their behavior now reflects a precautionary motive. In particular, the behavior of banks matters for the transmission of the shock. As in the linearized model, the increase in government spending crowds out investment and results in a decrease in asset prices and fire sales of assets by banks, who incur losses, and face a shrinking net worth and an increasing leverage ratio. Now, that banks take into account the risk of further, potentially detrimental, shocks in the future, they react more sensitive to changes in asset prices and interest rates, and they reduce their exposure to risky assets to a larger extent in response to the shock. This amplifies the fall in the prices of bonds and capital assets, and leads to a stronger contraction of the net worth of bankers. As the implied increase in banks' leverage is stronger, they further have to increase their fire sales and the contraction in the supply of loans is more pronounced. Hence, the fall in investment is stronger than in the linearized model, up to three percent in the non-linear case, compared to a decline of roughly two percent in the linear case. Both values are well within range of the empirically observed decline after an identified government spending shock.[22]

[21] In the context of the third-order approximation to the policy functions, shown above, the difference between the two sets of impulse responses is almost entirely driven by the risk correction term $\sum_{i=0}^{\infty}\left(\frac{1}{2}y_{\sigma_i^2}\sigma^2\right)\epsilon_{t-i}$. The effects by the second-order and third-order terms, describing actually realized fluctuations are negligible. See appendix A.3.

[22] For instance, (Ramey, 2011b) estimates a fall of non-residential investment of 1% after a shock to defense spending, and a decline of residential investment of 3.5% in response to a government spending identified via professional forecast errors.

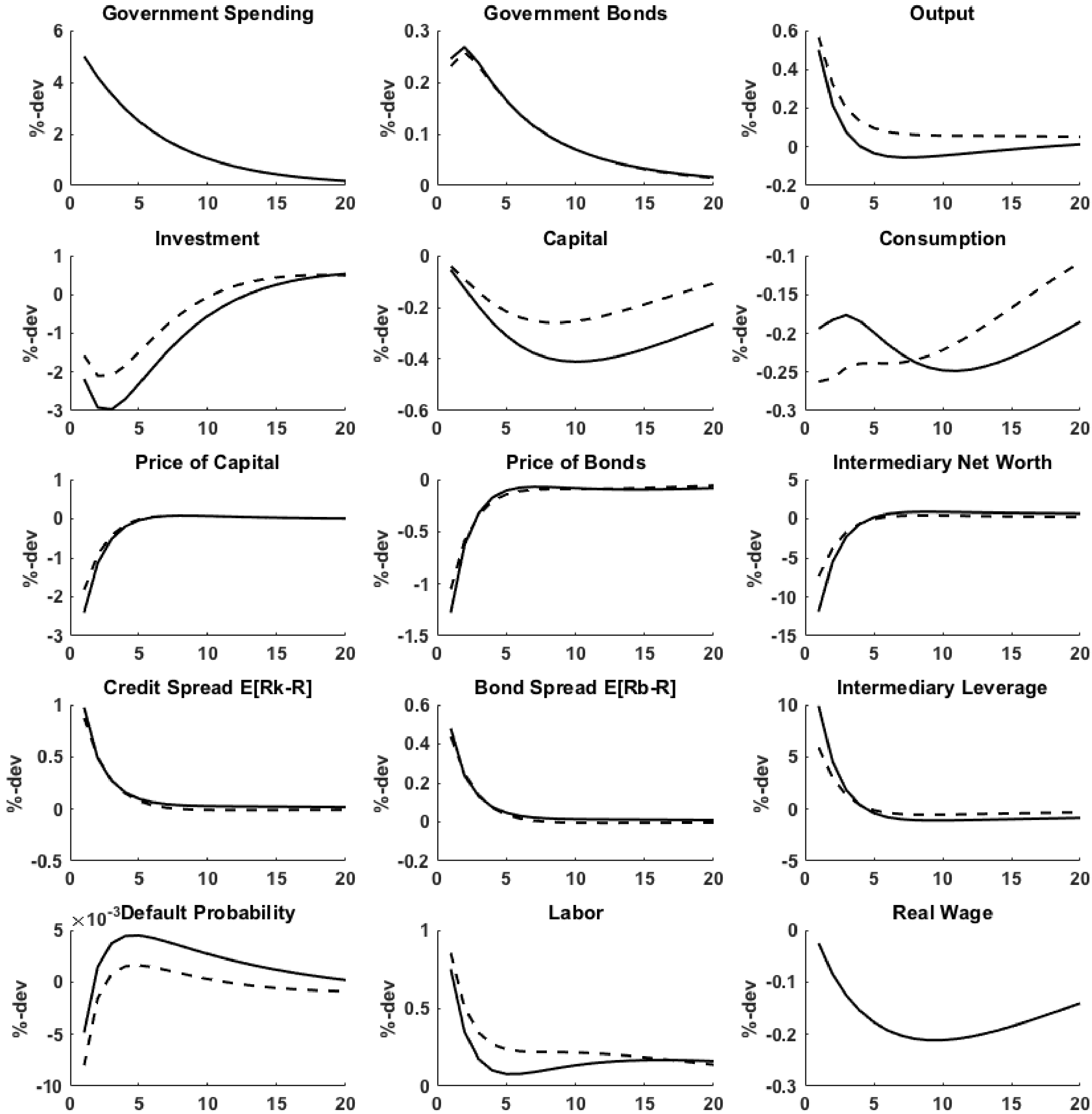

Figure 3.4: Dynamic consequences of a shock in government spending of 1 percent in the model with fiscal stress. The dashed lines depict the impulse responses obtained from a first-order approximation to equilibrium dynamics. The solid lines depicts the impulse responses obtained from a third-order approximation to equilibrium dynamics.

Importantly, risk also increases the role of fiscal stress for the multiplier. The steeper fall in investment leads to a smaller and more short-lived output stimulus in response to the increase in government spending. Four quarters after the shock, output even declines below the initial state, and the economy enters a mild recession. As the response of public debt is hardly altered, the initial fall in the debt-to-GDP ratio is attenuated and it quickly rises above the initial state, increasing the quarterly probability of a sovereign default close to half a percent above its steady state value. Due to the non-linear shape of the fiscal limit function, the increase in the probability of default implies a higher sensitivity of interest rates to fluctuations in economic fundamentals.

While the current increase in the probability of default amplifies current losses, the outlook of a stronger response of the fiscal stress indicator and the economy to future shocks, which move the debt-to-GDP ratio increases the motive of the banks to reduce their exposure to risky assets, contributing to the amplification of fire sales, the stronger contraction in investment, and the dampening of the output stimulus.

The contribution of the fiscal stress channel to the output response to a government spending shock is illustrated by figure (3.5). The black line represents the full model with fiscal stress and the blue line represents the case in which the fiscal stress channel is shut off. The dashed lines represent the linear impulse responses (black - full model, blue - without fiscal stress). This figure shows that taking into account the effects of risk on the transmission of the shock alters the response in both cases with and without fiscal stress. The difference between the solid blue line and solid black line shows the impact of the fiscal stress channel on the reaction of aggregate output. While it is still relatively small, it is substantially larger than in the linear case in which the two curves of the models with and without fiscal stress are virtually undistinguishable.

Table 3 shows that this is reflected by the resulting government spending multipliers. In the non-linear case without the fiscal stress channel, the impact multiplier is 0.54 and the cumulative multiplier is 0.16. Introducing fiscal stress lowers the impact multiplier to 0.50 and the cumulative multiplier to 0.06. Thus, whereas the introduction of the fiscal stress channel reduces the cumulative multiplier in the linearized economy by only 0.006, in the non-linear case, the differences of the cumulative multipliers with and without fiscal stress is roughly 15 times larger.

Risk also influences the behavior of the other agents in the economy. For the risk-averse households it strengthens the motive of consumption smoothing and labor smoothing. Following the shock, households reduce their consumption by less, and, due to the smaller wealth effect, increase labor supply by less than in the

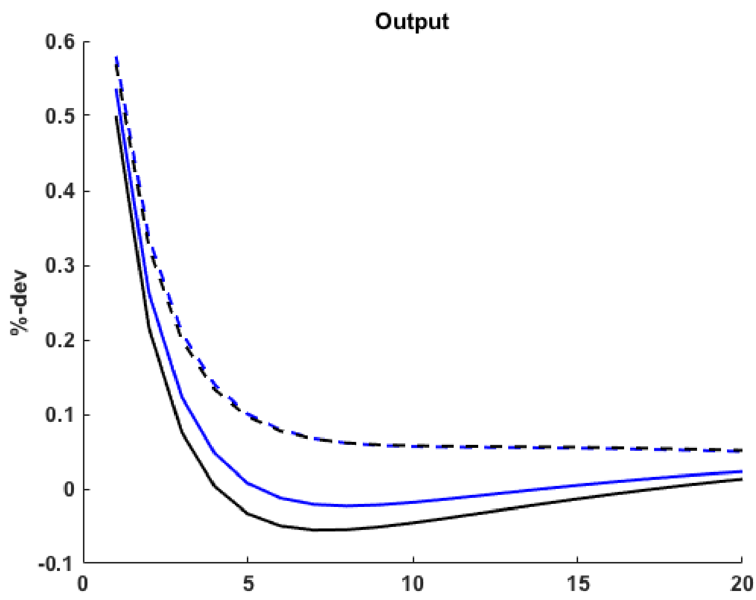

Figure 3.5: Output response to a shock in government spending of 1 percent obtained from a third-order approximation to equilibrium dynamics. The blue line depicts the impulse responses in the model without fiscal stress. The black line depicts the impulse responses obtained in the full model with fiscal stress .

Table 3.3: Government Spending Multipliers

	Impact Multiplier	Cumulative Multiplier*
linear , no fiscal stress	0.581	0.368
linear , with fiscal stress	0.569	0.362
non-linear , no fiscal stress	0.537	0.155
non-linear , with fiscal stress	0.500	0.064

*time horizon of 20 quarters

linear case. Overall however, the steeper fall in investment outweighs the effect of the attenuation of the consumption response on output, enhancing the fall in output as well. A few periods after the shock, when the more pronounced decline in capital becomes effective over time, the response of aggregate consumption follows the fall in production and declines below its linear counterpart as well. (Born and Pfeifer, 2014) give an overview of further channels through which aggregate risk influences the behavior of households and firms in a model with sticky prices. However, as section 5 shows, in the model at hand the link between fiscal stress and the size of the multiplier virtually disappears, when bonds are not held by leverage constrained banks, I omit a detailed discussion of further channels.[23]

[23]Results for a version of the model in which government bonds are held by households are available upon request.

This exercise illustrates two points. Firstly, the transmission of the government spending shock in general is altered, when risk about future shocks matters. This is mainly driven by the presence of financial frictions and fiscal stress. Secondly, the impact of the fiscal stress on the government spending is increased substantially by taking account of risk and precautionary motives of the agents, helping to generate a negative effect of fiscal stress on the government multiplier.

However, while the fiscal stress channel is larger than in the linear case, its effect is still too small to reflect the large effects that fiscal stress can have on the multiplier according to the empirical findings by (Perotti, 1999) or (Ilzetzki et al., 2013). Given the benchmark calibration of the model, the latter result is not surprising. Since the benchmark calibration of the debt-to-GDP ratio and the parameters of the default function, which are taken from (Bi and Traum, 2012a), reflect a period in which Italian sovereign bond markets have been rather calm, the default function is relatively flat at the steady state, implying a low sensitivity of the default probability to changes in the debt-to-GDP ratio. Section 4.3 discusses under which conditions the link between fiscal stress and the government spending multiplier is strong.

3.5 When is the impact of fiscal stress on the multiplier strong?

The moderate role of the fiscal stress channel for the government spending multiplier in section 4 reflects that the parameter values for the benchmark calibration are obtained from a sample of Italian data from 1999.Q1-2010.Q3, a sample period in which for most observations, sovereign yield spreads in Italy were low. This section assesses the role of the fiscal stress channel for the multiplier under conditions that capture some features of a sovereign debt crisis. In each subsection, I adjust the benchmark calibration along one dimension. In particular, I focus on the debt-to-GDP ratio, η_2, which governs the sensitivity of the fiscal stress indicator to the debt-to-GDP ratio, the leverage ratio of banks, the degree of aggregate risk, and κ_g, which determines, to what degree increases in government spending are mirrored by increases in taxes. The figures in this section depict cumulative multipliers for the linear and the non-linear approximation (dashed and solid lines, respectively), both for the full model and the model without the fiscal stress channel (blue and black lines, respectively).

The main result for the multipliers obtained by a first-order approximation is that even for extreme calibrations the role of fiscal stress for the government spending multiplier is very small. This highlights the necessity for accounting for risk, when the aim is to generate a link between fiscal stress and the government spending multiplier.

The results for the multipliers obtained by the non-linear approximation are discussed in their respective sections.

The role of fiscal stress when public debt is high

The benchmark calibration of the debt-to-GDP ratio in the deterministic steady state is 1.19, which is the average Italian debt-to-GDP in the sample by (Bi and Traum, 2012a). In recent years, Italy has experienced debt-to-GDP ratios of roughly 1.3. For the full model it holds that the higher the debt-to-GDP ratio, the smaller the cumulative multiplier, and the stronger is the fiscal stress channel. The solid black line in the upper panel or figure (3.6)) shows that this relationship is monotonous. This exercise points to the possibility that government spending multipliers have even been negative in Italy during recent crisis. As mentioned above, the possibility of negative fiscal multipliers has been discussed controversially following the proposition of the expansionary fiscal contraction hypothesis by (Giavazzi and Pagano, 1990).[24] In the context of the model at hand, negative government spending multipliers are possible, if public finances are sufficiently fragile, and financial intermediation is sufficiently impaired.

Changing the calibration of the debt-to-GDP ratio affects two mechanisms of the model, the portfolio shift of banks towards government bonds that is induced by an increase in government spending, and the effect of variations in the bond price in the necessity for banks to reduce the size of their balance sheets. Increases in the calibration of the debt-to-GDP increase the amount of public debt that banks hold in their portfolio and the strength of the crowding out of loans on the balance sheets through portfolio shifts. Thus for both models, with and without financial stress, the multiplier decreases for lower debt-to-GDP ratios.

In the model in which the effect of fiscal stress on bond prices is eliminated (or very weak, as in the case of the linear approximation of the full model), the price of capital assets falls by more than the price of bonds after an expansionary government spending shock. This reflects that in the model without fiscal stress, the reason for the fall in bond prices is the fall in the price of capital assets, which is induced by the crowding out of investment. As the price of capital falls by more than the price of bonds, the fall in the average price of assets held by the banks is smaller, and therefore the need to delever is less severe, the larger the amounts of government bonds on the balance sheet relative to capital assets. Hence, a higher the debt-to-GDP ratio implies a less severe contraction in the banks' balance sheets after the shock. For debt-to-GDP ratios higher than 1.25, the latter effect dominates in the model without financial stress, and the multiplier increases with further increases in the debt-to-GDP ratio.

In the full model in which government bond prices are affected by fiscal stress, they fall by more, the higher the debt-to-GDP ratio. Hence, the price effect decreases the

[24] see, e.g., (Bertola and Drazen, 1993), (Alesina and Perotti, 1997), (Guajardo et al., 2014).

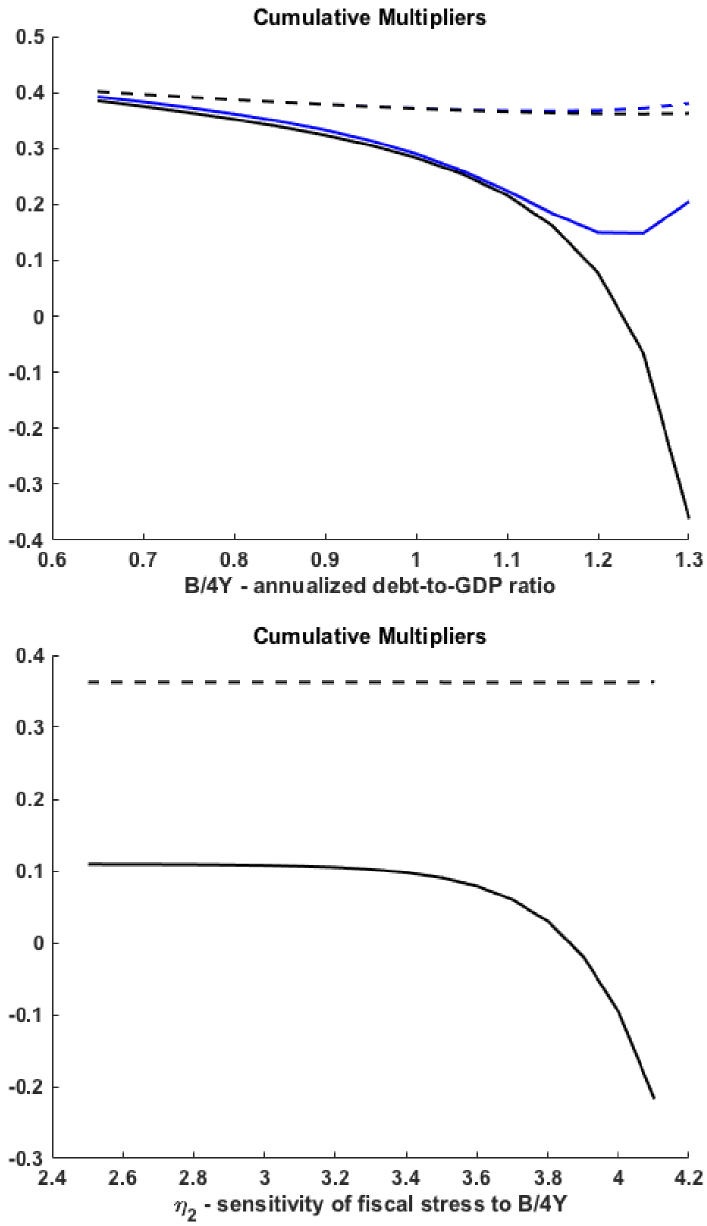

Figure 3.6: Cumulative government spending multipliers for a time-horizon of 20 periods. The x-axis shows the calibration of the parameters in the deterministic steady state. Blue dashed line - model without fiscal stress, linear approximation; Black dashed line - model with fiscal stress, linear approximation; Blue solid line - model without fiscal stress, non-linear approximation; Black solid line - model with fiscal stress, non-linear approximation.

multiplier for high public debt. The multipliers of the model without fiscal stress and the full model diverge for large debt-to-GDP ratios. This illustrates that for large debt-to-GDP ratios, the effect of fiscal stress on the size of the government spending multiplier increases, allowing for a size of this effect that is closer to the what empirical evidence by (Perotti, 1999) and (Ilzetzki et al., 2013) suggest.

The role of fiscal stress when it is very sensitive to the debt-to-GDP ratio

(Beirne and Fratzscher, 2013) suggest that during the recent debt crisis in the Eurozone the sensitivity of default risk premiums on government bonds to fundamentals became stronger for countries with weak public finances. The exercise in this section highlights that, if this sensitivity is increased in the model, fiscal stress can drastically lower cumulative multipliers, and, as in the previous subsection, even lead to negative multipliers. The more sensitive the fiscal stress indicator to variations in the debt-to-GDP ratio, the stronger is the fiscal stress channel, and the smaller is the cumulative multiplier. The lower panel of figure (3.6) shows the sensitivity of the cumulative multiplier to η_2, which governs the sensitivity of fiscal stress to the debt-to-GDP ratio. The benchmark calibration of this parameter value is 3.4015. The changes in the calibration of the debt-to-GDP ratio already entailed changes in the sensitivity of the fiscal stress indicator, as the latter is a convex function of the debt-to-GDP ratio. However, the sensitivity analysis with respect to η_2 isolates the price effects discussed in the previous section from the effects of variations in the steady state quantity of government bonds. As the model without fiscal stress does not feature a fiscal stress indicator, only the results for the full model are plotted. The higher η_2 the stronger are the degree of fiscal stress, bond prices, and the financial accelerator affected by variations in government spending. Thus, the contraction of the loan supply is stronger for higher values of η_2, and the weaker is the output response induced by government spending shocks and the smaller the cumulative multiplier.

The role of fiscal stress when the degree of risk is high

The literature on stochastic volatility suggests macroeconomic and financial variables are higher, when the economy experiences a crisis.[25] In this subsection, I analyze how the degree of aggregate risk affect the government spending multiplier, and in particular, the role of the fiscal stress channel for the multiplier. Increasing the degree of risk does not affect the importance of the fiscal stress channel for the cumulative government spending multiplier. The upper panel of figure (3.7) depicts the relation between the degree of risk, scaled by factor k, and the multiplier in the model without

[25] See, e.g.,(Bloom, 2009), (Basu and Bundick, 2015). (Bloom, 2009) calibrates the standard deviation of second moment shocks to TFP to a hundred percent of the standard deviation of the respective first moment shocks. (Basu and Bundick, 2015) calibrate the volatility of second moment shocks to a preference shock to be one sixths of the volatility of the respective level shock.

and with fiscal stress. The benchmark calibration of k is 1. Concretely, in this exercise the standard deviations of all shocks except the government spending shock are premultiplied with k. Higher level of risk affect the multiplier mostly through a stronger effect of precautionary fire sales by banks, and a stronger financial accelerator. While figure (3.7) shows that for higher degrees of risk, the government multiplier decreases, the contribution of the fiscal stress channel to the size of the multiplier stays fairly stable.

The role of fiscal stress when banks' leverage is high

Another feature of the recent debt crisis in the Eurozone were weakly capitalized banks. When banks are highly levered, fiscal stress has a stronger impact on the government spending multiplier. The middle panel of figure (3.7) depicts the relation between the leverage ratio in the deterministic steady state and the multiplier in the model without and with fiscal stress. The higher banks are levered up, the stronger is the need to delever in the face of adverse shocks to asset prices. As the fiscal stress channel amplifies the fall in the price of government bonds after an increase in government spending, it also amplifies the pressure on banks to delever after the shock. This stronger pressure on banks balance sheets becomes more notable, the higher the leverage ratio. Thus, the difference between the multipliers in the model with and without the fiscal stress channel increases for higher leverage ratios. Hence, the importance of fiscal stress for the government spending multiplier is likely to be higher, in crises such as the recent crisis in the Eurozone in which banks were weakly capitalized, and is likely to decrease when banks' capital buffers are strengthened.

The role of fiscal stress when the share of debt-financing is high

Lastly, the government spending multiplier is lower for smaller shares of tax-financing of variations in government expenditures. The lower panel of figure (3.7) depicts the relation between the response coefficient for lump sum taxes to variations in government spending, κ_g, and the cumulative multiplier in the model without and with fiscal stress. For a value of 1, variations in government spendings are fully mimicked by changes in taxes. For low values, the share of debt-financing is higher. The higher the share of debt-financing, the more the amount of government bonds held by banks increases, and the stronger the crowding out effect of investment. Thus, the multiplier decreases in the share of debt-financing for both models. However, due to the low sensitivity of the bond price to changes in the debt-to-GDP ratio implied by the benchmark calibration, the difference between the multipliers in both models, and hence the importance of the fiscal stress channel for the government spending multiplier, is only weakly altered by variations in the share of debt-financing.

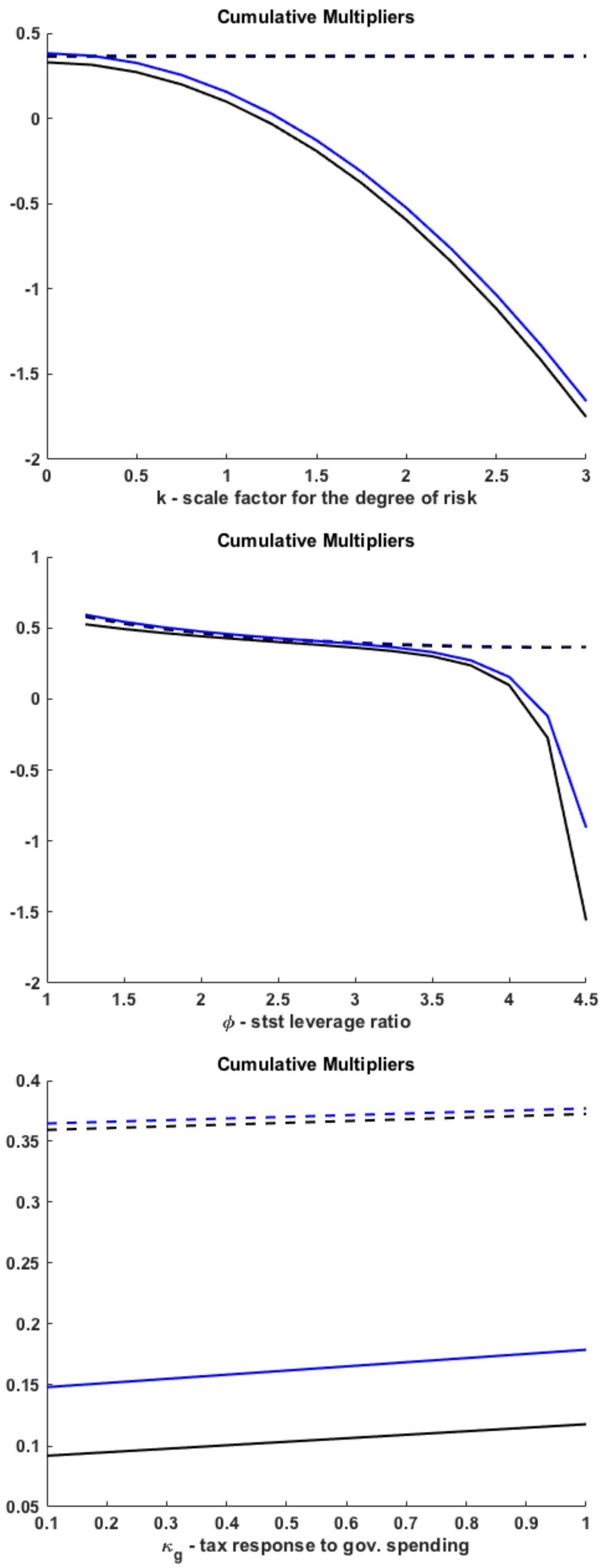

Figure 3.7: Cumulative government spending multipliers for a time-horizon of 20 periods. The x-axis shows the calibration of the parameters in the deterministic steady state. Blue dashed line - model without fiscal stress, linear approximation; Black dashed line - model with fiscal stress, linear approximation; Blue solid line - model without fiscal stress, non-linear approximation; Black solid line - model with fiscal stress, non-linear approximation

3.6 Conclusion

According to a growing empirical literature, the government spending multiplier is smaller for countries that experience fiscal stress, as opposed to countries, which have sound public finances. This paper develops a theoretical model with leverage constrained banks and sovereign default risk to explain the link between fiscal stress and the size of the government spending multiplier suggested by the empirical literature. To the extent that a positive shock to government spending crowds out investment, it lowers the price of capital assets, which induces a downward pressure on the price of bonds as well. Additionally, the government spending shock increases the downward pressure on bond prices to the extent that it increases the debt-to-GDP ratio and raises the degree of fiscal stress. The fall of asset prices exerts an adverse effect on the balance sheets of banks, which are forced to sell assets, and contract the supply of credit to firms. As a consequence, aggregate investment falls and dampens the initial output stimulus of the government spending shock.

I show that whether the contribution of the fiscal stress channel to the response of output, and hence to the government spending multiplier, is quantitatively important depends on the order of approximation that is employed to solve the model. In the linearized model, the effect of the degree of fiscal stress on the government spending multiplier is negligible. In contrast to this, fiscal stress can play a sizable role for the size of the multiplier, if the model is solved using a third-order approximation to equilibrium dynamics. The reason is that aggregate risk affects the transmission of the government spending shock. In particular, it amplifies the reduction of credit and investment, which can be explained by a precautionary motive of banks, who react more sensitive to variation in asset prices following the shock. As a result, the output stimulus induced by the shock, and the government spending multiplier is decreased by the presence of fiscal stress.

Considering the role of aggregate risk for the transmission of the government spending shock is novel in the literature on government spending multipliers. Importantly, accounting for risk allows me to establish the empirically observed link between the degree of fiscal stress and the size of the government spending multiplier. I show that the fiscal stress channel for the multiplier becomes more important, the higher the initial degree of fiscal stress, in which government spending is increased, the higher the sensitivity of fiscal stress to fluctuations in the debt-to-GDP ratio, and the stronger the motive of banks to delever in the face of the shock. For a calibration, that captures some of the key features of the recent debt crisis in Italy, the cumulative government spending multiplier can even become negative.

While this paper offers a theoretical explanation for the empirical link between fiscal stress and the size of the multiplier, it does not attempt a full-fledged analysis of a sovereign risk crisis. Instead it focusses on a key mechanism, and highlights the role of risk for the fiscal stress channel. Additionally, episodes with increased sovereign default risk can be associated with steep recessions, or liquidity problems of the agents in the economy, that may affect the government spending multiplier. Furthermore, aspects such as distortionary taxation, the political economy, unconventional monetary policy, and open economy considerations are omitted from the analysis to focus on the contribution of the fiscal stress channel to the government spending multiplier. The many possible extensions of the analysis yield an interesting field of future research.

Chapter 4

The Government Spending Multiplier, Fiscal Stress, and the Zero Lower Bound

Abstract

The recent sovereign debt crisis in the Eurozone was characterized by a monetary policy, which has been constrained by the zero lower bound (ZLB) on nominal interest rates, and several countries, which faced high risk spreads on their sovereign bonds. How is the government spending multiplier affected by such an economic environment? While prominent results in the academic literature point to high government spending multipliers at the ZLB, higher public indebtedness is often associated with small government spending multipliers. I develop a DSGE model with leverage constrained banks that captures both features of this economic environment, the ZLB and fiscal stress. In this model, I analyze the effects of government spending shocks. I find that not only are multipliers large at the ZLB, the presence of fiscal stress can even increase their size. For longer durations of the ZLB, multipliers in this model can be considerably larger than one.

Keywords: Government spending multiplier; Fiscal stress; Zero lower bound; Financial frictions
JEL Classification: E32, E 44, E62, H30, H60

4.1 Introduction

Following the global financial crisis, which started in 2007, several European countries have experienced deep and persistent recessions as well as spiking sovereign yield spreads. At the same time, the ECB eased its monetary policy until the main refinancing rate hit the zero lower bound (ZLB). In this situation, these countries faced two challenges simultaneously: restoring the sustainability of their public finances while limiting the deep recession. With monetary policy being constrained by the ZLB, fiscal policy came into the focus of the public policy debate. While countries under fiscal stress ran policies of fiscal austerity, which included cuts to government spending, to stabilize their public debt, it is far from clear to what extent the government spending cuts contributed to the contraction of aggregate output in these countries. On the one hand, prominent result point toward large government spending multipliers at the ZLB,[1] on the other hand, higher public indebtedness is often associated with small government spending multipliers.[2] This paper investigates on the size of the government spending multiplier in the context of a DSGE model with leverage constrained banks that captures both features of this economic environment, the ZLB and fiscal stress.

For the analysis, I use the model developed by (Strobel, 2017). The degree of fiscal stress is captured by the probability of a sovereign default, which is modeled as a fiscal limit function. This function maps the debt-to-GDP ratio into the probability of a sovereign default.[3] Thus, to the extent that government spending shocks drive changes in the debt-to-GDP ratio, they affect the degree of fiscal stress. As documented by (Battistini et al., 2014), banks in those eurozone countries, which experienced spiking sovereign yield spreads, increased their exposure to domestic sovereign bonds, making their financial position more vulnerable to variations in the degree of fiscal stress. The link between fiscal and financial fragility is captured in my framework, by leveraged constrained banks à la (Gertler and Karadi, 2011), which hold government bonds next to private capital assets on their balance sheets. Hence, changes in government spending can directly affect the supply of credit by banks to non-financial firms and influence aggregate investment in the economy. Following (Gertler and Karadi, 2011), I simulate a negative capital quality shock to trigger a financial crisis scenario in which the economy is forced to the ZLB on nominal interest rates, and compare government spending multipliers in the state, in which the ZLB constraint is slack, to multipliers in the state, in which the ZLB constraint is binding. To solve the model with the occasionally binding constraint, I employ the piece-wise linear approach by (Guerrieri and Iacoviello, 2015) and their software toolkit OccBin.

In the baseline scenario of the model, the cumulative government spending multiplier over 20 quarters is roughly 0.39 when the ZLB constraint is not binding. When the economy is not at the ZLB, I find that an increase in government spending raises the debt-to-GDP ratio and thereby the degree of fiscal stress, lowering the price of government bonds and capital assets, and raising the loan rate. Hence, the

[1] see, e.g., (Christiano et al., 2011) and (Eggertson and Krugman, 2012)

[2] see, e.g., (Alesina and Perotti, 1997), (Perotti, 1999), (Corsetti et al., 2013)

[3] Fiscal limit functions of various functional forms have been among others by (Leeper and Walker, 2011), (Bi and Traum, 2012a), (Corsetti et al., 2013)

increase in the degree of fiscal stress contributes to a crowding-out of investment and lowers the government spending multiplier. However, as in (Strobel, 2017), the log-linear dynamics of the model imply that the size of the effect of fiscal stress on the government spending multiplier is negligible, when the ZLB constraint is slack.

When the ZLB constraint is binding however, the picture changes drastically. In this state, the output response to a positive shock to government spending is far larger, and an expansionary fiscal policy now manages to improve the financial condition of banks and to crowd in investment. The longer the duration of the ZLB episode, the larger the government spending multiplier. Multipliers in this model can become larger than two. Also the effect of the fiscal stress channel on the multiplier is reversed, when monetary policy is constrained and contributes positively to the multiplier.

As emphasized by (Eggertson, 2011) and (Christiano et al., 2011), the key to the different sizes of multipliers at the ZLB is the reversed effect of government spending shocks on the real interest rate. An expansion of government spending raises aggregate demand and triggers an increase in output and inflation. In normal times, when the central bank follows the Taylor principle for nominal interest rates, this causes the real interest rate to go up as well.
At the ZLB the effect on the real interest rate changes. In the scenario at hand, the capital quality shock that triggers the crisis, causes inflation to drop. With monetary policy constrained and nominal interest rates stuck at zero, the expectations of a persistent deflation translates into a rising real interest rate. An increase in government spending that raises aggregate demand and exerts inflationary pressure therefore leads to a decrease in the real interest rate. Thus, expansionary fiscal policy makes investment more attractive, when the economy is at the ZLB. The presence of the fiscal stress channel in my model does not undo this intuition, but rather strengthens it. Despite the growing public debt after a positive government spending shock, the large output response lowers the debt-to-GDP ratio and the degree of fiscal stress. Particularly, for higher levels of public indebtedness, for which the default probability is more sensitive to movements in underlying fundamentals, the falling degree of fiscal stress raises bond prices and strengthens the balance sheet of banks and their ability to supply credit. Hence, the fiscal stress channel further amplifies the investment boom, and contributes to a large multiplier at the ZLB.

Empirical evidence on the government spending multipliers at the ZLB is scant as ZLB episodes have been rare in industrialized countries. (Miyamoto et al., 2016) analyze the case of Japan in which the policy rate has been close to or at the ZLB since the mid 1990's. Using local projection methods, they estimate the output multiplier in Japan to be 1.5 at the ZLB and 0.6 when the ZLB is not binding. Their results are roughly in line with the multipliers, I obtain in my paper. Empirical papers, that study cases outside of Japan, have to rely either on historical data or on the few years of the Great Recession. (Ramey and Zubairy, 2014) analyze US data reaching back to 1889, including two ZLB episodes. While the government spending multiplier is not significantly different from normal times in an estimation over the entire sample, it becomes significantly larger, when the ZLB episode around World War II is excluded and only the Great Recession remains. For the interwar period in the UK, in which the interest rates were at the lower bound, (Crafts and Mills, 2013) find government spending multipliers below one for different shock identification schemes.

In the theoretical literature on the government spending multiplier, a large multiplier at the ZLB is a recurring result.[4] This result is in almost all cases explained by the non-standard reaction of the real interest rate to government spending shocks explained above. In his careful analysis of the effects of different fiscal policy shocks at the ZLB, (Eggertson, 2011) obtains a government spending multiplier of 2.3. (Christiano et al., 2011) find roughly the same value.

On the other hand, empirical evidence on the role of fiscal stress for the size of the government spending multiplier generally suggests that higher public debt, higher deficits or higher sovereign yield spreads are associated with small government spending multipliers.[5] Some results even point to negative multipliers for countries, which are highly indebted. (Ilzetzki et al., 2013) estimate the long run multiplier to be negative three. Theoretical models that investigate the role of fiscal stress for the government spending multipliers offer different explanations for the observation of 'expansionary fiscal contractions'. (Bertola and Drazen, 1993) argue that, if a fiscal contraction is associated with a shift to a sustainable path of government debt, it can spur expectations of future economic growth and stimulate consumption by households. (Strobel, 2017) focusses on the role of investment dynamics for small multipliers in times of fiscal stress. In his model, the crowding-out of aggregate investment is induced by increasing bank loan rates that co-move with rising sovereign yield spreads. The model in this paper is solved with a third order approximation to equilibrium dynamic. When risk and the precautionary motive by banks are accounted for, banks react very sensitive to increasing degrees of fiscal stress, rapidly reducing their exposure to assets with a stochastic return, and sharply contracting the supply of loans to firms, such that, in this situation, output can contract after the

[4]see, e.g., (Woodford, 2010), (Christiano et al., 2011), (Eggertson, 2011), (Eggertson and Krugman, 2012), (Aloui and Eyquem, 2016). As a caveat, however, one should point out that most of these results are obtained relying on log-linear equilibrium conditions. Recently, (Boneva et al., 2016) showed that in the context of a small New-Keynesian model, which is solved non-linearly, the size of the multiplier is very sensitive to the calibration of the model and can take very different values for plausible calibrations.

[5]see, e.g., (Alesina and Perotti, 1997), (Perotti, 1999) (Alesina and Ardagna, 2010), (Corsetti et al., 2012), (Guajardo et al., 2014)

fiscal expansion. The paper at hand builds on the same model but focusses on the role of the ZLB, instead of the role of risk for the relationship between fiscal stress and the multiplier.

The papers closest to the one presented here are (Corsetti et al., 2013) and (Aloui and Eyquem, 2016). Both analyze the multiplier in a model that takes account of both, fiscal stress and the ZLB. In the context of a small New-Keynesian model with banks à la (Cúrdia and Woodford, 2011) and a fiscal limit function, (Corsetti et al., 2013) find that multipliers can actually be smaller at the ZLB, as in this situation monetary policy cannot counter the recessionary effects of sharply increasing sovereign yield spreads. However, more recently, (Aloui and Eyquem, 2016) extend the model by (Corsetti et al., 2013) with capital formation, investment adjustment costs and distortionary labor taxes, and show that in the extended model, the typical result that multipliers are increased by the ZLB is restored. While my framework differs along various dimensions from theirs, I confirm the finding by (Aloui and Eyquem, 2016). In my model as well, the ZLB dominates the fiscal stress channel as a determinant of the size of the government spending multiplier leading to a multiplier's size that is in the range of values typically found in the related literature.

The remainder of the paper is structured as follows: Section two gives a brief overview of the model. Section three discusses the calibration and the solution method. The fourth section introduces the crisis experiment, analyzes the dynamic consequences of government spending shocks at the ZLB, and discusses government spending multipliers for different lengths of the ZLB period and different levels of indebtedness. Section five concludes.

4.2 The model

For the analysis in this paper, I use the model developed by (Strobel, 2017). It is a New Keynesian model featuring leverage constrained banks as in (Gertler and Karadi, 2011). Households consume, supply labor and save in the form of bank deposits. Period utility is separable in leisure and consumption with internal habit formation. The firm sector consists of three types of firms. Intermediate good producers use labor and capital in their production. They sell their depreciated capital each period to capital good firms, which make their investment decisions taking into account convex investment adjustment costs. The intermediate good producers then repurchase new capital from the capital good producers, financing their purchases with loans from banks. Lastly, retailers, that act under monopolistic competition and price stickiness, buy the output of the intermediate good firms, repackage the goods and sell them as final goods.

Banks fund the extension of loans as well as purchases of government bonds with deposits made by households and with their own net worth. The process of financial intermediation is subject to a friction. Each period, bankers have the option to divert a fixed fraction of their assets and exit the banking sector. They choose to do so, if the value of diverting assets is larger than the expected value of continuing their business in the banking sector. In that case, households loose their deposits. Hence, in equilibrium, depositors will allow banks to acquire assets only up to the point, in which the value of operating bank's business is as large as the value of diverting a fraction of their assets. As a consequence, given their net worth, banks are constrained in their leverage ratio.

Government bonds are long-term bonds, and are subject to default risk. Their default probability is expressed as a function of the debt-to-GDP ratio as in (Bi and Traum, 2012a). Furthermore, the government funds its expenditures with non-distortionary lump sum taxes. Monetary policy is modeled in form of a Taylor rule. Since the details of the model have been discussed in (Strobel, 2017), I turn directly to the equilibrium conditions of the model.

Some equilibrium conditions

The Euler equation of consumption reads

$$1 = E_t \beta \Lambda_{t,t+1} R_t, \tag{4.1}$$

where β is the households discount factor, R_t is the return on bank deposits. $\Lambda_{t,t+1} \equiv \frac{U_{c,t+1}}{U_{c,t}}$, where $U_{c,t}$ is the marginal utility of consumption

$$U_{c,t} = (C_t - hC_{t-1})^{-1} - \beta h E_t (C_{t+1} - hC_t)^{-1}. \tag{4.2}$$

C_t denotes consumption in period t and h is the parameter for internal habit formation. Household supply their labor to intermediate good producers according to the condition

$$W_t = \frac{\chi L_t^{\phi}}{U_{c,t}}, \tag{4.3}$$

where W_t is the real wage and L_t denotes labor hours. Parameter ϕ is the inverse of the Frisch elasticity and χ is the weight of the disutility of labor in the period utility function of the household. The production function of the intermediate good producers reads

$$Y_{m,t} = A_t (\xi_t K_{t-1})^{\alpha} L_t^{1-\alpha}, \tag{4.4}$$

where $Y_{m,t}$, A_t, ξ_t and K_t are intermediate output, total factor productivity, the quality of the employed capital, and capital, respectively. Parameter α is defined to be the output elasticity of capital. The optimal demand for labor and capital can be are written as

$$R_{k,t+1} = \frac{P_{m,t+1}\alpha\frac{Y_{m,t+1}}{K_t} + (1-\delta)Q_{t+1}\xi_{t+1}}{Q_t}, \tag{4.5}$$

$$W_t = P_{m,t}(1-\alpha)\frac{Y_{m,t}}{L_t}. \tag{4.6}$$

R_{kt} denotes the return on capital, $P_{m,t}$ is the price of the intermediate good and Q_t is the price of the capital good. Parameter δ is the depreciation rate of capital. As in (Gertler and Karadi, 2011), the law of motion of capital is affected by the quality of capital

$$K_t = (1-\delta)\xi_t K_{t-1} + I_t \tag{4.7}$$

The optimal decision on investment, I_t, is intertemporal due to the presence of investment adjustment costs, $f\left(\frac{I_t}{I_{t-1}}\right) \equiv \frac{\eta_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$. Parameter η_i denotes the inverse elasticity of investment to the price of capital

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}}f'\left(\frac{I_t}{I_{t-1}}\right) - E_t\beta\Lambda_{t,t+1}\left(\frac{I_t}{I_{t-1}}\right)^2 f'\left(\frac{I_t}{I_{t-1}}\right). \tag{4.8}$$

Due to the assumption of nominal rigidities as in (Calvo, 1983), the price index reads

$$\Pi_t^{1-\epsilon} = (1-\gamma)(\Pi_t^*)^{1-\epsilon} + \gamma\Pi_{t-1}^{\gamma_p(1-\epsilon)}, \tag{4.9}$$

where Π_t is gross inflation and Π_t^* denotes the optimal price from the viewpoint of firms in period t divided by the past price level. Parameter ϵ is the elasticity of substitution between different varieties of final goods, γ is the share of firms that cannot update their price in any given period, and γ_p governs the degree of price indexation. Retailers determine the optimal price, Π_t^*, as a function of their current and future marginal cost, which is equivalent to the price of the intermediate good, $P_{m,t}$, such that

$$\Pi_t^* = \frac{\epsilon}{\epsilon-1}\frac{F_t}{Z_t}\Pi_t, \tag{4.10}$$

where F_t and Z_t are defined as $F_t \equiv Y_{m,t}P_{m,t} + \beta\gamma\Lambda_{t,t+1}\Pi_{t+1}^{\epsilon}\Pi_t^{-\gamma_p\epsilon}F_{t+1}$ and $Z_t \equiv Y_{m,t} + \beta\gamma\Lambda_{t,t+1}\Pi_{t+1}^{\epsilon-1}\Pi_t^{-\gamma_p(\epsilon-1)}Z_{t+1}$. Up to a first order approximation, aggregate final good output Y_t is equivalent to aggregate intermediate good output.

Banks extend loans to the intermediate good producers, and hold government bonds, B_t, on their balance sheets. They fund their operations with deposits from the households, D_t, and their own net worth, N_t. Their balance sheet thus reads

$$Q_t K_t + Q_t^b B_t = D_t + N_t, \tag{4.11}$$

where Q_t^b is the price of government bonds. The banking sector consists of a continuum of banks. Each bank remains in the sector in any given period with probability θ and exits the sector otherwise. Exiting bankers consume out of their accumulated net worth. The accumulation of the aggregate net worth of those banks who remain in the banking sector in any given period, N_{ot}, is governed by the return on capital and bonds, R_{kt} and R_{bt} respectively, as well as by the return they have to pay on their deposits

$$N_{ot} = \theta \left[R_{kt} Q_{t-1} K_{t-1} + R_{bt} Q_{t-1}^b B_{t-1} - R_{t-1} D_{t-1} \right]. \tag{4.12}$$

New bankers that enter the business receive an initial endowment that is a fraction of last periods assets, $N_{nt} = \omega \left[Q_t K_{t-1} + Q_t^b B_{t-1} \right]$. Accordingly, it holds that $N_t = N_{ot} + N_{nt}$. Additionally, each period, bankers have the option to divert a fraction of their assets and close their bank. As a result, bankers aim to maximize the value of their net worth at their expected time of departure from the sector, subject to an incentive constraint that prescribes that the value of remaining in the business, V_t, must be larger or equal than the value of the fractions of capital assets and bonds that they can divert. Thus,

$$V_t \geq \lambda Q_t K_t + \lambda_b Q_t^b B_t \tag{4.13}$$

with $\lambda > 0$ and $\lambda_b > 0$. In this environment, the marginal values of an additional unit of capital or bonds on the bank's asset side, ν_{kt} and ν_{bt} respectively, and the marginal value of an additional unit of net worth, ν_{nt}, are function of the return on the assets and deposits

$$\nu_{kt} = E_t \Omega_{t,t+1} (R_{k,t+1} - R_t), \tag{4.14}$$

$$\nu_{bt} = E_t \Omega_{t,t+1} (R_{b,t+1} - R_t), \tag{4.15}$$

$$\nu_{nt} = E_t \Omega_{t,t+1} R_t. \tag{4.16}$$

The stochastic discount factor of the bank, Ω_t, reflects the stochastic discount factor of the household, and the financial conditions of the bank

$$\Omega_{t,t+1} \equiv \beta \Lambda_{t,t+1} [(1-\theta) + \theta(1+\mu_{t+1})\nu_{n,t+1}]. \tag{4.17}$$

μ_t is the Lagrangian multiplier of the incentive constraint. The banks' demand for loans can be described as a function of government bond holdings and the amount of net worth of the banking sector

$$Q_t K_t = \frac{\nu_{bt} - \lambda_b}{\lambda - \nu_{kt}} Q_t^b B_t + \frac{\nu_{nt}}{\lambda - \nu_{kt}} N_t. \tag{4.18}$$

Two further optimality conditions that result from the banks optimization problem pin down the relationship of the marginal values of holding either asset. These are determined by the fraction of the respective assets that can be diverted, and the Lagrangian multiplier of the incentive constraint, which indicates the banks' capability to hold assets on their balance sheets,

$$\nu_{kt} = \lambda \frac{\mu_t}{1 + \mu_t}, \tag{4.19}$$

$$\nu_{bt} = \lambda_b \frac{\mu_t}{1 + \mu_t}. \tag{4.20}$$

Finally, the leverage ratio of banks is defined as $\phi_t \equiv \frac{Q_t K_t + Q_t^b B_t}{N_t}$.
Government spending, G_t, is exogenous. The government finances its expenditures with lump sum taxes, T_t, that follow a tax rule, $T_t = T + \kappa_b (B_{t-1} - B) + \kappa_g (G_t - G)$, where the parameters $\kappa_b > 0$ and $\kappa_b > 0$ determine the size of the feedback of taxes to changes in public debt and government spending. The government budget constraint reads

$$G_t + Q_t^b B_t = R_{bt} Q_{t-1}^b B_{t-1} + T_t. \tag{4.21}$$

The return of government bonds reflects that the government defaults on its debt with probability Φ_t and that the size of the haircut in case of default is D. Bonds are modeled as geometrically decaying consoles to allow for matching a realistic average maturity of the outstanding bonds. Hence, further determinants of the return are the decay rate, ρ_c, and the coupon, r_c. The return on bonds reads

$$R_{b,t} = (1 - \Delta_t^d * D) \left[\frac{r_c + \rho_c Q_t^b}{Q_{t-1}^b} \right]. \tag{4.22}$$

Key to the fiscal stress channel on the multiplier is the sovereign default probability that is linked to the debt-to-GDP ratio via the logistic distribution function

$$\Delta_t^d = \frac{exp\left(\eta_1 + \eta_2 \frac{B_t}{4Y_t})\right)}{1 + exp\left(\eta_1 + \eta_2 \frac{B_t}{4Y_t}\right)}. \tag{4.23}$$

This function implies that the default probability is more sensitive to fluctuations of the debt-to-GDP ratio, for higher levels of public indebtedness. Monetary policy follows a Taylor rule. The nominal interest rate is non-negative. When the ZLB constraint is not binding, the central bank reacts to fluctuations in the net inflation rate, π_t and of the log deviation of the real marginal cost from the viewpoint of the final good producer, $\hat{P}_{m,t}$

$$i_t = \max(0, [i + \kappa_\pi \pi_t + \kappa_y \hat{P}_{mt}]). \tag{4.24}$$

For the model to render a unique rational expectation equilibrium in the neighborhood of the deterministic steady state, it has to hold that $\kappa_{pi} > 1$. The Fisher equation is $1 + i_t = R_t E_t \Pi_{t+1}$. Closing the good market clearing condition reads

$$Y_t = C_t + I_t + f\left(\frac{I_t}{I_{t-1}}\right) I_t + G_t. \tag{4.25}$$

The stochastic disturbances that drive the dynamics of the model are the capital quality shock, and the government spending shock, which follow the AR(1)-processes

$$g_t = \rho_g g_{t-1} + \epsilon_t^g, \tag{4.26}$$

$$\xi_t = \rho_\xi \xi_{t-1} + \epsilon_t^\xi. \tag{4.27}$$

4.3 Calibration and solution method

Calibration

The calibration of the parameters is chosen to match key features of the Italian economy since its accession to the Eurozone. Parameter β, the discount factor of the household, is set to 0.995, instead of the conventional 0.99. Increasing the discount factor implies a lower interest rate at the steady state of the model moving it closer to the ZLB. As a consequence, the solution method, which is discussed in the next subsection, reliably generates solutions for scenarios, in which the economy remains up to five periods at the ZLB, and across different calibrations for the debt-to-GDP ratio. All other parameters are set in accordance with the calibration of the model in (Strobel, 2017). As in that paper, the main sources for the calibration are (Bi and Traum, 2012a), who estimate a structural model with sovereign default risk on Italian data between 1999Q1 and 2010Q4, and (Gertler and Karadi, 2011), who developed the core structure of the model used in the paper at hand. Table 1 lists the values of the model parameters.

Table 4.1: Calibration of Parameters

β	discount factor	0.995	
h	habit formation	0.14	Bi and Traum (2012)
χ	weight for disutility of labor	4.7125	
φ	inverse of Frisch elasticity	0.276	Gertler and Karadi (2011)
α	effective capital share	0.33	Gertler and Karadi (2011)
δ	depreciation param.	0.025	Gertler and Karadi (2011)
η_i	invest. adjust. param.	1.728	Gertler and Karadi (2011)
ϵ	elasticity of substitution	4,167	Gertler and Karadi (2011)
γ	Calvo param.	0.779	Gertler and Karadi (2011)
γ_p	price indexation param.	0.241	Gertler and Karadi (2011)
$Rk-R$	steady state spread	0.01	Gertler and Karadi (2011)
$Rb-R$	steady state spread	0.005	Bocola (2015)
λ	divertibility of capital assets	0.4479	
λ_b	divertibility of bonds	0.2239	
θ	survival probability of banker	0.975	Gertler and Karadi (2011)
ω	transfer to new bankers	0.0018	
κ_π	interest rate rule	1.5	Gertler and Karadi (2011)
κ_y	interest rate rule	-0.125	Gertler and Karadi (2011)
G/Y	share of gov. spending	0.1966	Bi and Traum (2012)
$B/4Y$	debt-to-GDP ratio.	1.19	Bi and Traum (2012)
κ_b	tax rule param.	0.3	Bi and Traum (2012)
κ_g	tax rule param.	0.53	Bi and Traum (2012)
η_1	fiscal limit parameter	-21.5285	Bi and Traum (2012)
η_2	fiscal limit parameter	3.4015	Bi and Traum (2012)
D	haircut	0.378	Bi and Traum (2012)
r_c	coupon rate	0.04	v.d.Kwaak and v. Wijnbergen (2014)
ρ_c	rate of decay of consol	0.96	v.d.Kwaak and v. Wijnbergen (2014)
ρ_i	intrest rate smoothing	0.0	v.d.Kwaak and v. Wijnbergen (2014)
ρ_ξ	persistence of ξ-shock	0.66	Gertler and Karadi (2011)
ρ_g	persistence of g-shock	0.84	Bi and Traum (2012)
σ_ξ	std. of ξ-shock	0.01	
σ_g	std. of g-shock	0.01	Bi and Traum (2012)

Solution method

To deal with the occasionally binding ZLB constraint, I employ the piecewise-linear approach by (Guerrieri and Iacoviello, 2015). This approach treats models with occasionally binding constraints as models with two different regimes: one in which the constraint is binding and one in which it is slack. The model is linearized around a reference point, here the deterministic steady state. (Guerrieri and Iacoviello, 2015) refer to this state as the reference regime, and other one the alternative regime. Their approach requires two conditions to be fulfilled. First, the conditions for existence of a rational expectation equilibrium laid out by (Blanchard and Kahn, 1980) have to hold in the reference regime. Secondly, if shocks move the economy away from the reference and into the alternative regime, it has to return to the reference regime in finite time. Both conditions hold in the case at hand.
In this paper, the ZLB constraint is slack in the reference regime, and binding in the alternative regime. At the reference regimes, the rational expectation equilibrium of the model can be described as

$$\mathscr{A} E_t X_{t+1} + \mathscr{B} X_t + \mathscr{C} X_{t-1} + \mathscr{E} \epsilon_t = 0, \tag{4.28}$$

where X_t is the vector of n endogenous variables, ϵ_t is the vector of m exogenous disturbances, and the elements of the matrices $\mathscr{A}, \mathscr{B}, \mathscr{C}$, (each of size n×n) and $\mathscr{E}$ (of size n×m) are functions of the structural parameters of the model. At the alternative regime, the rational expectation equilibrium of the model can be described as

$$\mathscr{A}^* E_t X_{t+1} + \mathscr{B}^* X_t + \mathscr{C}^* X_{t-1} + + \mathscr{D}^* + \mathscr{E}^* \epsilon_t = 0. \tag{4.29}$$

$\mathscr{A}^*, \mathscr{B}^*, \mathscr{C}^*$, and $\mathscr{E}^*$ are matrices that are analogous to $\mathscr{A}, \mathscr{B}, \mathscr{C}$, and $\mathscr{E}$. $\mathscr{D}^*$ is a vector of parameters of size n, which corrects for the fact that the linearization is carried out around the deterministic steady state, in which the reference regime applies. Given initial conditions X_0 and a sequence of shocks, the solution to this model is a policy function[6]

$$X_t = \mathscr{P}_t X_{t-1} + \mathscr{R}_t + \mathscr{Q}_t \epsilon_t, \tag{4.30}$$

where matrices $\mathscr{P}_t$ (n×n), $\mathscr{R}_t$ (n×1), and $\mathscr{Q}_t$ (n×m) are regime-dependent and $\mathscr{R}_t = 0$ at the reference regime. The solution algorithm starts with a guess for the period, in which the economy returns to the reference regime, and for the regime in each period up to the final return period. Then it solves for the policy function at the date in which the economy has just returned to the reference regime, plugs the policy function into the equilibrium conditions for the alternative regime, and applies backward induction

[6] In their definition of a solution for the model, (Guerrieri and Iacoviello, 2015) focus at the case, in which there is only a shock in period 1. However, their software package Occbin allows for shocks in subsequent periods as well.

to trace the equilibrium path back to the initial period, applying either system (4.28) or system (4.29) at any given period along the path, depending on whether the economy is at the ZLB or not according to the guess. Finally, the initial guess is either verified or updated until a guess has been verified.

How long the economy remains at the ZLB depends on the model structure and on the size of the shock that pushes the economy to the ZLB. An attractive property of the solution is that the expectation of how long the ZLB regime will last, already affects the decisions by the agents contemporaneously.[7] An advantage of using the piecewise-linear approach is that, at it relies on perturbation methods, it is easily applicable to medium-scale models such as the one being used for the analysis in this paper.

4.4 Crisis scenario and government spending stimulus

To trigger the crisis that moves the economy to the ZLB, I simulate a negative shock, as it is done in (Gertler and Karadi, 2011).[8] I consider different lengths of the duration of the ZLB and compare government spending multipliers across different initial calibration of the debt-to-GDP ratios and different durations of the ZLB period. For each steady state value of the debt-to-GDP ratio, and for each desired duration of the ZLB, I adjust the size of the capital quality shock accordingly.

In order to illustrate the effects of the fiscal stress channel for the output effects of the shock, I compare the full model described in section 2 with a model in which the fiscal stress channel is shut off. Here, I eliminate equation (4.23) from the model, and set variable Φ_t to a constant value (i.e., $\Phi_t = \Phi \;\; \forall_t$).[9] In all other aspects the two models are identical. I refer to the latter model as the model without fiscal stress.

4.4.1 Crisis scenario

Figure (4.1) illustrates the consequences of a fall in capital quality of four percent that pushes the economy to the ZLB for four quarters. In this particular case, the debt-to-GDP ratio is calibrated to 1.19, which is the average debt-to-GDP ratio in the sample considered by (Bi and Traum, 2012a) in the estimation of their structural model. The dashed lines represent the responses of the variables in the linear case, which ignores the ZLB and the solid lines depict the responses of the variables generated by the piecewise linear solution, which takes the ZLB into account. Black

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[7]This stands in contrast to algorithms, in which the model's return to the reference regime, is determined each period anew, according to a stochastic process (see, e.g., (Eggertson and Woodford, 2003)).

[8](Gertler and Karadi, 2011) liken this shock to a sudden economic depreciation or obsolescence of capital. Often, to trigger a zero bound episode, a shock to the discount factor that raises the agents desire to save is used. However, in the model at hand this shock has the undesirable feature that it increases aggregate investment in crisis times. The capital quality shock circumvents this pitfall.

[9]The value of Φ_t in the deterministic steady state, is the same in both models.

lines show the responses of the full model. Blue lines show the model in which the fiscal stress channel is eliminated.

In each scenario in figure (4.1), the exogenous decline in capital quality effectively reduces the productive capital stock on impact. As a consequence, aggregate output falls and so does consumption of households. The lower stock of effective capital reduces the marginal product of labor, and consequently the demand for labor falls, leading to a decline in equilibrium hours worked.
An additional consequence of the lower quality of capital is that the price of capital assets falls. With the subsequent deterioration of the banks' balance sheets, their shrinking net worth forces banks to sell off assets, amplifying the fall in the price of capital. The leverage ratio increases, and so does the spread of the return on capital (loans of the bank to firms) over the return on deposits. The ensuing credit crunch causes aggregate investment to drop. A second reaction by banks to the capital quality shock is to change the composition of their asset holdings. In a flight to the relatively less affected assets, they increase the share of government bonds in their portfolio. Thus, in contrast to the fall in capital assets, the amount of government bonds held by banks increases.

How does the fiscal stress affect the dynamic consequences of the capital quality shock? As the sovereign default probability goes up together with the debt-to-GDP ratio, the price of government bonds falls by more than in the case, in which the fiscal stress channel is inactive. Similarly, the spread on bonds over deposits increases more sharply. With the price of bonds being more sensitive to the shock, bonds lose some attractiveness as a save haven and the portfolio shift towards government bonds is less pronounced. Instead, the banks net worth falls more than in the scenario, in which the fiscal stress channel is inactive, and the leverage ratio as well as the credit spreads increases by more in this case. Hence, the contraction in the supply of credit is stronger than in the case without the fiscal stress channel, deepening the fall in aggregate investment and output. The pro-cyclical amplification of the financial accelerator is therefore stronger, when the fiscal stress channel is active.

What is the role of the ZLB constraint for the equilibrium dynamics after the negative capital quality shock? In response to the shock, the central bank lowers its nominal rate to counter the deflationary push and to stimulate the economy. In the simulation in which the ZLB is neglected, the nominal policy rate is lowered to minus 2 percentage points. In the simulation, in which the ZLB is accounted for, the nominal rate falls to zero and the ZLB binds for 4 periods (solid lines). When the ZLB is binding, the ability of the central bank to stimulate aggregate demand and to offset the downturn is constrained. Thus, while the dynamic consequences of the shock are qualitatively similar to the simulation, in which the ZLB is neglected, the size of the recessionary impact of the shock is larger. At its trough, output decreases in the case with the ZLB and the fiscal stress channel by roughly 4,5 percent compared to 4 percent in the case without the ZLB constraint. With the magnified contraction of real activity, the distress in the banking sector increases, amplifying the rise in the spreads and the leverage ratios and the decline in asset prices, net worth and aggregate investment. As in the scenario without the ZLB, the fiscal stress channel adds to the vulnerability of the banks' balance sheets, and magnifies the financial accelerator in the downturn.

4.4.2 The government spending shock

Against the backdrop of the crisis described in the foregoing subsection, I simulate a government spending stimulus of the size of one percent of steady state output (i.e. five percent of steady state government expenditures) and compare the effects across the four scenarios introduced in the last subsection. The presence of the ZLB has important qualitative effects for the consequences of the government spending stimulus. The dynamic consequences of the government spending shock for the simulation in which the ZLB is ignored, are discussed in detail in (Strobel, 2017). In figure (4.2) they are depicted as the dashed lines (blue - without the fiscal stress channel, black - with an active fiscal stress channel).[10]

The expansion of government spending increases output and government debt alike. The increase in output is stronger on impact, but less persistent, than the growth in public debt. The dynamics of the debt-to-GDP are mirrored by the movements in the default probability. The increase in output raises the inflation rate, triggering a response by the central bank, which raises its policy rate. Government spending crowds out private consumption of Ricardian consumers and equilibrium hours increase, raising the marginal product of capital, and as a consequence, also the return on capital assets. In equilibrium, this is accompanied by an increase in the loan rate. The demand for bank loans contracts and as a consequence, the price of capital assets, as well as aggregate investment and the capital stock fall in response to the government spending shock.[11]

As in the case of the capital quality shock, banks react with both, a change in the size of their balance sheet as well as with a change in the composition. The fall in the equilibrium prices of capital assets and government bonds results in a shrinking

[10]For each of the scenarios, I simulate the equilibrium dynamics once in response to the capital quality shock and the government spending shock, and once with only the capital quality shock. Then, I subtract the results of the latter simulation from the former with both shocks. Figure (4.2) displays the results: the isolated effect of the government spending shock on the equilibrium path.

[11]For empirical evidence on the crowding out of investment by government spending increases, see, e.g., (Blanchard and Perotti, 2002), (Ramey, 2011b), (Ilzetzki et al., 2013)

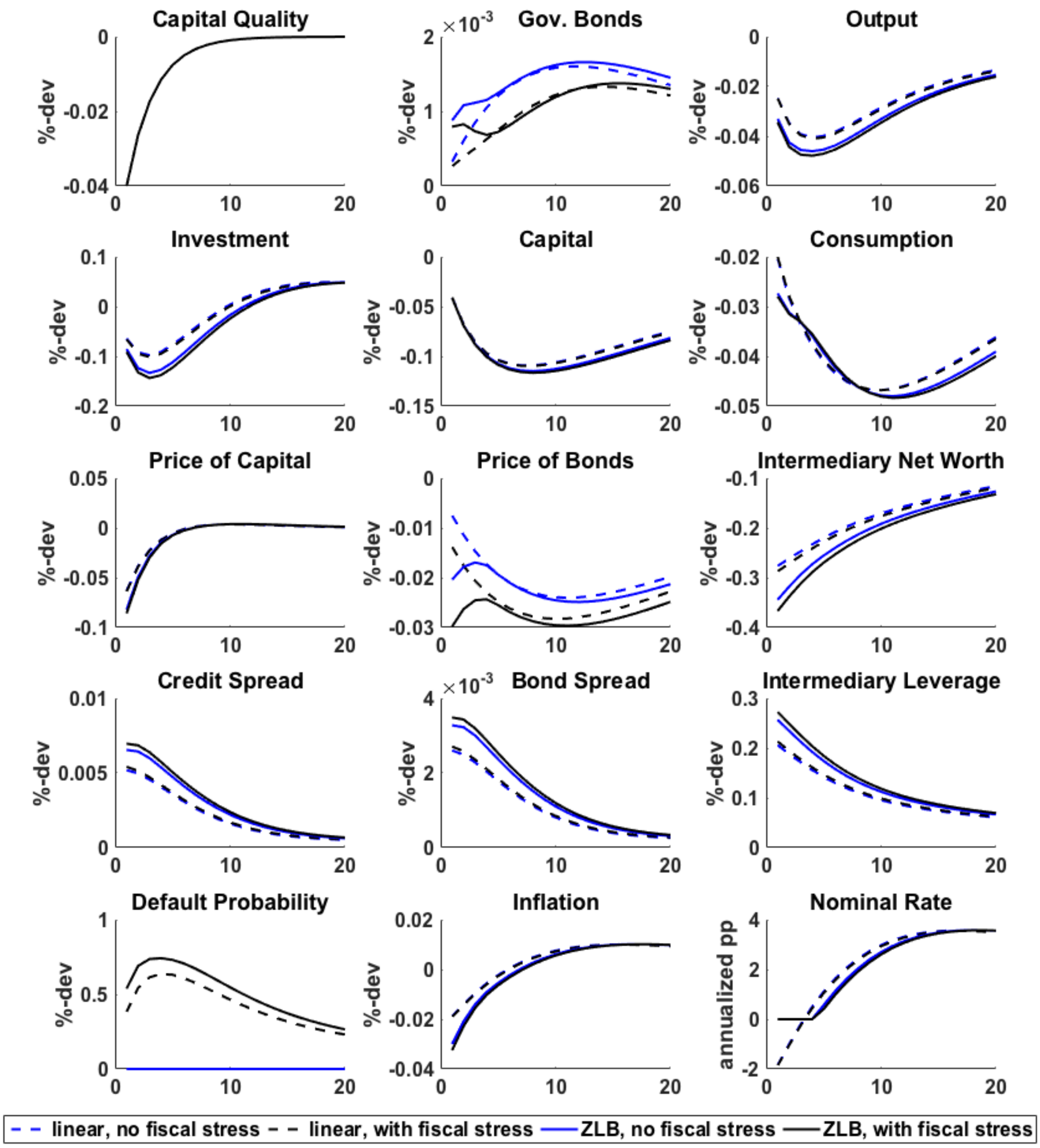

Figure 4.1: Dynamic consequence of a negative capital quality shock. The size of the shock is calibrated to make the zero lower bound binding for 4 periods. The debt-to-GDP ratio is calibrated to 1.19.

net worth of banks, who have to sell assets and reduce the credit supply, in order to satisfy their constraint on the leverage ratio. Hence, the contraction of the balance sheet and of the supply of credit amplifies the crowding-out of investment. Secondly, the increase of public debt through the government spending stimulus leads to a crowding-out of capital assets on the balance sheets of banks, further reducing the loan supply, aggregate investment and the output stimulus by the government spending shock.
Lastly, when the fiscal stress channel is active, variations in the default probability lower the price of government bonds and raise the distress in the banking sector, expressed by higher spreads on credit and bonds, and a lower net worth of banks. However, as emphasized in (Strobel, 2017), the effects of the fiscal stress channel are quantitatively negligible.

At the ZLB, the effects of government spending shocks change drastically. As in (Christiano et al., 2011) and (Eggertson, 2011), the output stimulus of the government spending shock is far stronger at the ZLB. The capital quality shock that triggers the ZLB period, leads to a deep recession associated with strong deflationary tendencies. When the nominal interest rate is constrained to be zero, expected deflation translates into a rise in the real interest rate, which incentivizes households to delay consumption and which makes investment less attractive to firms. In this situation, the increase in government spending dampens the fall in aggregate demand and counters the deflationary tendencies. As figure (4.2) shows, the positive impact of the government shock on inflation is far stronger at the ZLB. As long as nominal rate is at zero, the push in inflation dampens the increase in the real interest rate. As a consequence, it becomes more attractive for firms to invest and aggregate investment is now even crowded-in by the government spending shock. The surge in investment demand results in a growing capital stock and an increasing price of capital assets at the ZLB. Hence, at the ZLB the effect of government spending is to bolster the net worth of banks, to lower their leverage ratio and to expand their ability to hold assets and to supply loans. This further amplifies the investment boom, and contributes to the stronger rise in aggregate output after the government spending shock. The consumption of Ricardian households is still crowded out by the government spending shock, due to the wealth effect on the labor supply, but this effect is much weaker than away from the ZLB.

Similarly, the role of the fiscal stress channel for the effects of the government spending shock is reversed at the ZLB. Here, the expansion of output is strong enough to decrease the debt-to-GDP ratio, and thus the default probability of government bonds. Consequently, the price of bond increases by more than in the simulation without the fiscal stress channel. In equilibrium, this positive effect spills over to the price

of capital. As a result, the net worth of banks is further bolstered, and the leverage ratio is lower than in the scenario with fiscal stress. Whereas the spreads of credit and government bonds over the deposit rate still increase slightly, when the fiscal stress channel is inactive, they fall in the scenario, in which the fiscal stress channel further contributes to a decline in the return on capital and bonds as well as to falling spreads. The crowding-in of investment is more pronounced and the capital accumulation accelerated.
Overall, the fall of the sovereign default probability due to the strong expansion of output after the government spending stimulus further raises the government spending multiplier.

Figure (4.3) displays the cumulative government spending multiplier over a time horizon of 20 quarters for different steady state levels of public indebtedness and different lengths of the ZLB episode. Since its accession to the Eurozone, the stock of Italian public debt fluctuated between 100 and 132 percent of Italy's GDP. The debt-to-GDP ratios in the four panels are chosen accordingly.[12] For each of these calibrations, I conduct simulations with ZLB episodes up to five periods. As one can see, in the linear scenario the fiscal stress channel hardly affects the government spending multiplier. The blue and the black dashed lines are virtually indistinguishable. Again, this is in line with the results by (Strobel, 2017).

For the simulations, in which the ZLB constraint is accounted for, three results stand out. First, at the ZLB government spending multipliers can become much larger than in normal time, regardless of the level of public debt.
Secondly, across different levels of public indebtedness the government spending multiplier increases quickly with the duration of the ZLB period. Longer ZLB periods reflect deeper recessions, which are triggered by larger negative capital quality shocks. The deeper the crisis, the stronger is the deflationary pressure induced by the shock. Consequently, an expansion of government spending dampens a stronger deflation for more periods, until the economy leaves the ZLB. Thus, the spending stimulus lowers the real interest rate for longer and stimulates investment by more, the longer the ZLB period. In these simulations, the government spending multiplier quickly becomes larger than one and reaches up to roughly 2.3. Again, this result is similar to the prominent result by (Christiano et al., 2011) who attain large multipliers at the ZLB.

Thirdly, the positive contribution of the fiscal stress channel to the multiplier is larger for longer ZLB episodes. This result follows naturally as a stronger expansion of aggre-

[12] In a larger sensitivity analysis, I tested debt-to-GDP ratios between 0.6, the threshold requested in the Maastricht treaty, and 1.3. The fiscal stress channel is quantitatively negligible for small values of the debt-to-GDP ratio. The results are qualitatively robust to an extension of the parameter space and are available upon request.

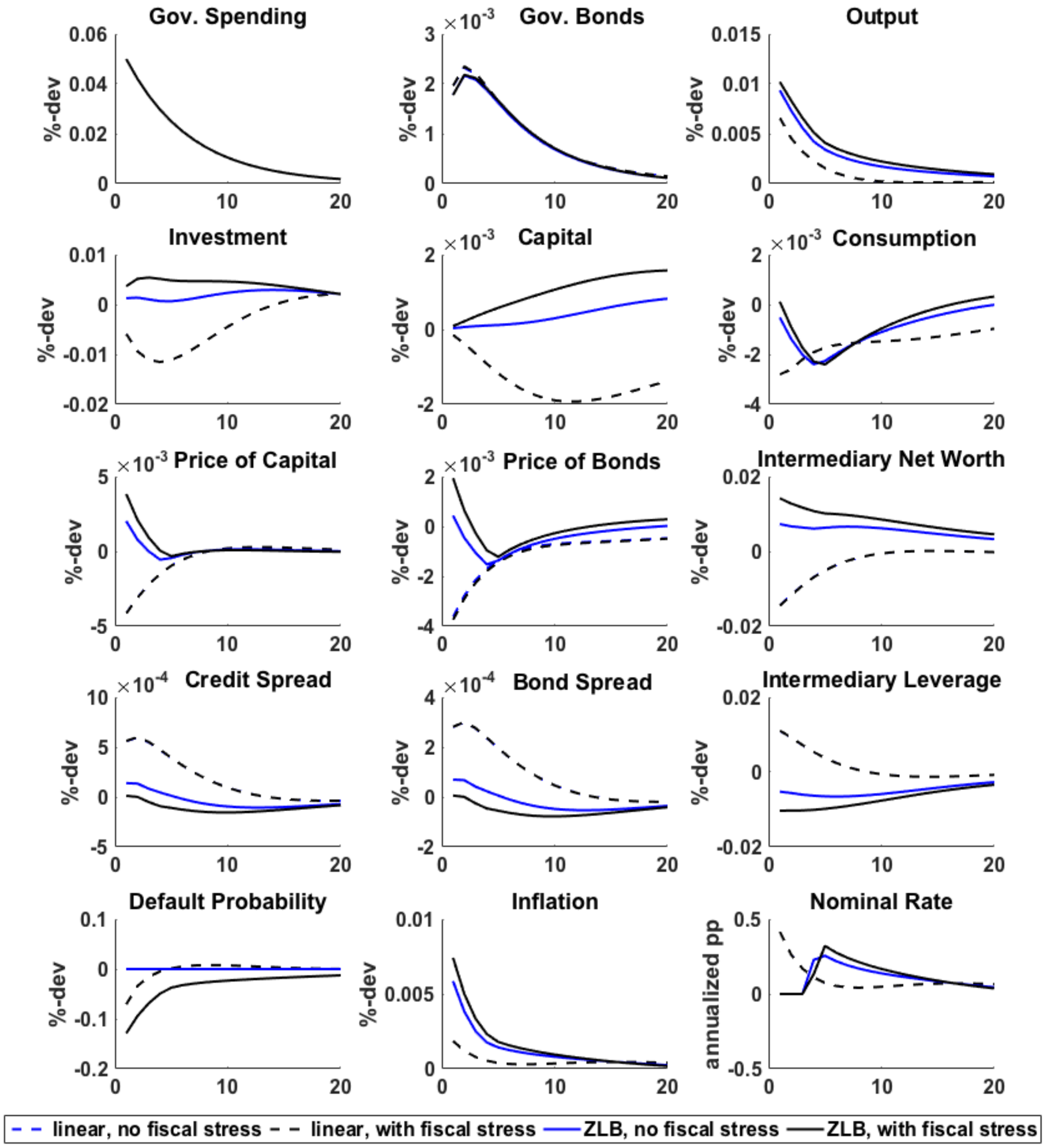

Figure 4.2: Dynamic consequence of a government spending shock of one percent of steady state output. The size of the shock is calibrated to make the zero lower bound binding for 4 periods. The debt-to-GDP ratio is calibrated to 1.19.

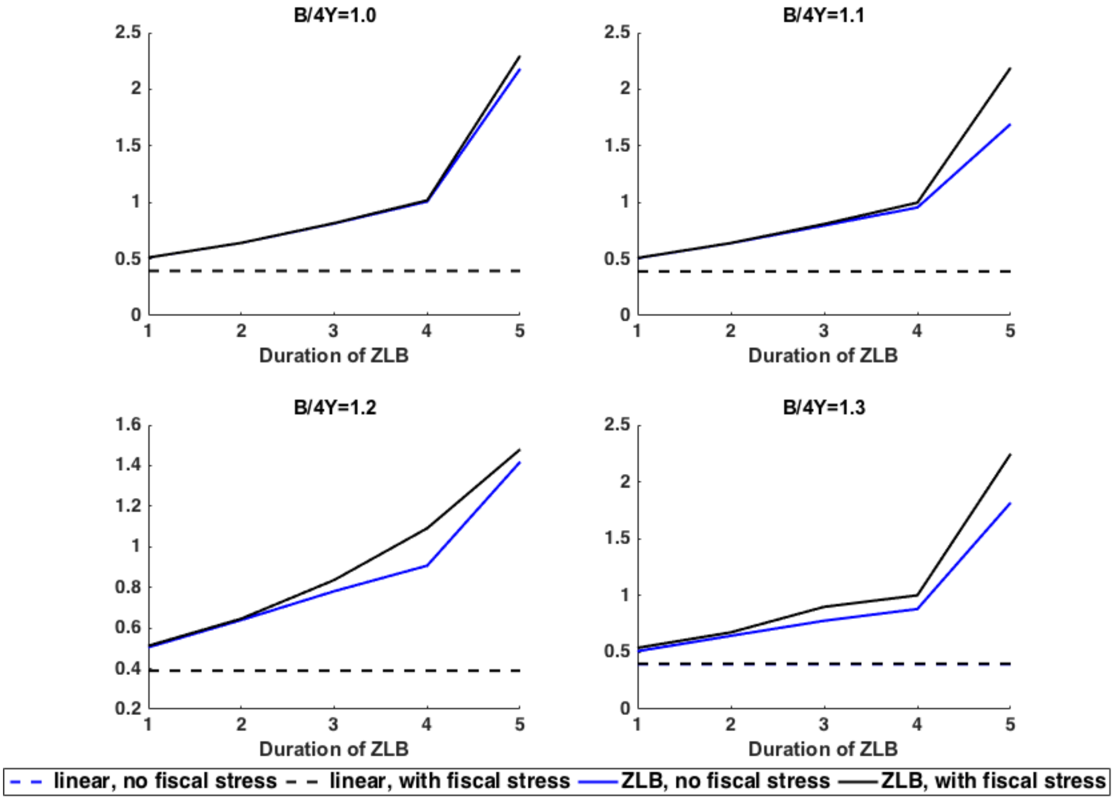

Figure 4.3: Cumulative Government Spending Multipliers over a time horizon of 20 quarters

gate output at longer ZLB periods, leads to a stronger decline in the debt-to-GDP ratio and hence as well the default probability in the model. This improves the financial conditions of banks, and facilitates a larger credit and investment volume.

Also, as is shown in figure (4.4), the contribution of the fiscal stress channel is generally larger, the higher the debt-to-GDP ratio.[13] This is due to the higher sensitivity of the default probability to fluctuations in the debt-to-GDP ratio for higher levels of public debt as implied by equation (4.23).[14] For the case without fiscal stress, the relationship between the debt-to-GDP ratio and the multiplier is generally negative at the ZLB. A higher debt-to-GDP ratio implies a larger share of government bonds in the portfolio of banks, serving as a buffer from the consequences of the recessionary capital quality shock, and dampening the amplification of the crisis by the financial accelerator. Thus, the recession and the deflation triggered by the crisis shock are less severe for higher levels of public debt. The inflationary impulse by the government spending

[13]The panel for a duration of the ZLB of 5 periods is omitted. The size of the capital shock needed to obtain a duration of 5 periods in this model varies irregularly with the calibration of the debt-to-GDP ratio. As the size of the initial crisis shock is itself a determinant of the multiplier, the results are therefore strongly distorted.

[14]The non-linear shape of this function is taken from (Bi and Traum, 2012a) and is in line with results by panel data studies on the drivers of sovereign yield spreads in Europe, which find a stronger sensitivity of the spreads to fundamentals in crisis times (see, e.g., (Manganelli and Wolswijk, 2009), (Beirne and Fratzscher, 2013))

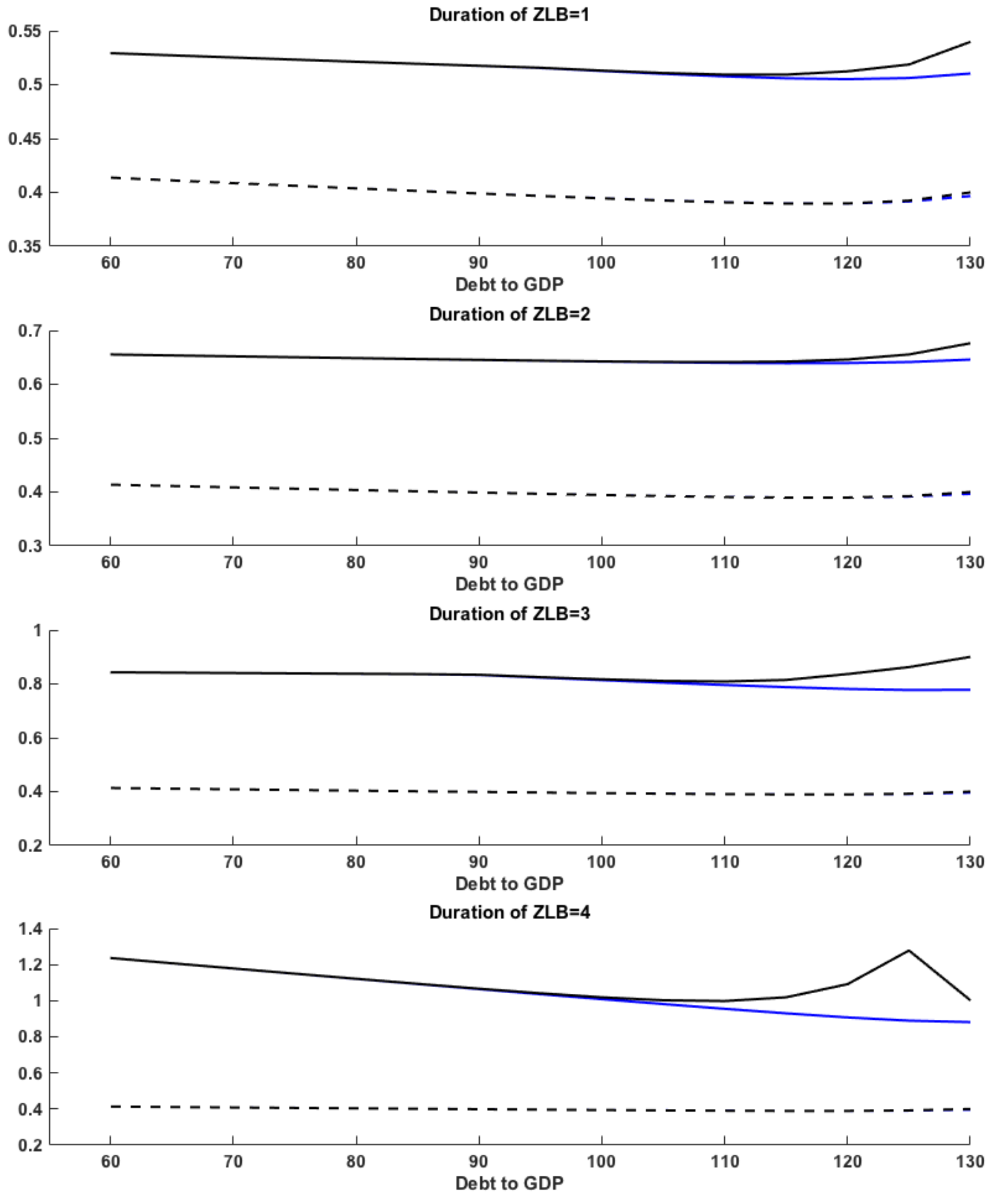

Figure 4.4: Cumulative Government Spending Multipliers over a time horizon of 20 quarters

stimulus counters a less severe deflation and therefore affects the real interest rate by less. Accordingly, when the fiscal stress channel is inactive, the stimulus of government spending to investment and output is weaker, for higher levels of public debt. The same rationale holds for the cases, in which the fiscal stress channel is active, but weak due to low levels of the steady state debt-to-GDP ratio.

When the fiscal stress channels is active and the debt-to-GDP ratio is rather high, the default probability is more sensitive to the fall in the debt-to-GDP ratio. Therefore, in this case fiscal stress amplifies the crisis and implies a deeper fall in output and the inflation rate. This makes the impact of the government spending shock again stronger on the real interest rate. Additionally, an active fiscal stress channel implies, a sharper fall in the default probability after the government spending shock, which itself increases the output stimulus and the multiplier.

The result that the government spending multiplier at the ZLB, can be larger when a country is higher in debt, is in contrast with the finding by (Corsetti et al., 2013), who argue in the context of a small New Keynesian model with banks à la (Cúrdia and Woodford, 2011) that fiscal stress affects the multiplier negatively at the ZLB. However, it is in line with the results by (Aloui and Eyquem, 2016), who find that extending the model by (Corsetti et al., 2013) with capital accumulation and distortionary taxes overturns their result and establishes a positive relationship between the debt-to-GDP ratio and the government spending multiplier at the ZLB. As my analysis differs from theirs not only in the model features, but also in the solution method, a close comparison of the results is, however, not straightforward.

4.5 Conclusion

In the sovereign debt crisis in the Eurozone, several countries have conducted government spending cuts against the backdrop of an economic environment, which featured a high degree of fiscal stress and a monetary policy that was constrained by the ZLB on nominal interest rates. Both features have been found to be potentially important determinants of the size of the government spending multiplier. This paper investigates on the size of the government spending multiplier in a model that takes account of both features. I find that the presence of fiscal stress does not undo the widespread notion that multipliers are large at the ZLB. In fact, the presence of a fiscal stress channel can even increase the multiplier at the ZLB.

To the extent that shocks to government spending change the debt-to-GDP ratio, they affect the degree of fiscal stress, and thus the prices of government bonds and capital assets. As at the ZLB an expansion of government spending prevents a deflationary trap, it raises inflation expectations and lowers the real interest rate. Thereby, it stimulates investment and leads to a large output response. The longer the crisis episode in which the ZLB holds, the stronger the expansionary effect of a positive government spending shock. Since the increase in aggregate output is strong enough to lower the debt-to-GDP ratio despite the increasing amount of outstanding government bonds. A fiscal expansion lowers the degree of fiscal stress, takes pressure of bank's balance sheets, improves their ability to lend and contributes to the investment boom. This holds particularly when the government is highly indebted, and the default probability reaction to variations in the debt-to-GDP ratio is more sensitive. Taking into account variations in fiscal stress, actually increases the government spending multiplier.

With my analysis, I operate at the intersection of two distinct strands of the literature, which either focus on the effects of fiscal stress or the effects of the ZLB on the government spending multiplier. My result is in line with the gist of the theoretical literature on multipliers at the ZLB, which predominantly finds large multipliers. My analysis confirms that this finding is robust to the presence of high government debt and a fiscal stress channel in a medium scale model.
The degree of fiscal stress in the theoretical framework of this paper depends on the reaction of the debt-to-GDP ratio to the government spending shock. (Strobel, 2017) shows that in the same model the increase in the debt-to-GDP after the shock can raise fiscal stress and lower the multiplier. Here, I show that the ZLB has the opposite effect on the fiscal stress channel. The piece-wise solution method prevents me from nesting the analysis by (Strobel, 2017), and investigating on the effects of aggregate risk and the ZLB jointly. However, it has the advantage that it facilitates the incorporation of an occasionally binding constraint into the analysis of a model of this size. Adjusting the size of the model to make it suitable for a global solution to conduct the investigation is a interesting path for future research. Alternatively, for a more complete account of a sovereign debt crisis, the analysis can be extended to include other important aspects that can determine the size of government spending multiplier, and that are omitted from this analysis, such as open economy considerations, the role of private debt, unconventional monetary policy and distortionary taxation. The investigation of the effects of fiscal policy remains a fruitful field for future research.

Appendix A

Appendix

A.1 Bank's optimization problem

The representative bank of the model in chapter three and four maximizes its value function subject to a balance sheet constraint and an incentive constraint

$$V_{jt} = \max_{\{K_{jt}\},\{B_{jt}\},\{D_{jt}\}} \quad E_t \Lambda_{t,t+1}[(1-\theta)N_{jt} + \theta V_{j,t+1}]$$

$$\begin{aligned} s.t. \qquad Q_t K_{jt} + Q_t^b B_{jt} &= D_{jt} + N_{jt} \\ V_{jt} &\geq \lambda Q_t K_{jt} + \lambda_b Q_t^b B_{jt} \end{aligned}$$

In the following, I make the assumption that the incentive constraint is always binding. Additionally, the law of motion of net worth is assumed to be

$$N_{jt} = (R_{kt} - R_{t-1})Q_{t-1}K_{j,t-1} + (R_{bt} - R_{t-1})Q_{t-1}^b B_{j,t-1} + R_t N_{j,t-1}.$$

Guess that the value function is linear in loans, government bonds and net worth

$$V_{jt} = \nu_{kjt} Q_t K_{jt} + \nu_{bjt} Q_t^b B_{jt} + \nu_{njt} N_{jt}.$$

The Lagrangian function for the optimization problem of the bank reads

$$\mathscr{L} = (1+\mu_{jt})(\nu_{kjt} Q_t K_{jt} + \nu_{bjt} Q_t^b B_{jt} + \nu_{njt} N_{jt}) - \mu_{jt}(\lambda Q_t K_{jt} + \lambda_b Q_t^b B_{jt})$$

Hence, the first order conditions for loans, bonds, and the Lagrangian multiplier, μ_t, are

$$\nu_{kjt} = \lambda \frac{\mu_{jt}}{1+\mu_{jt}}$$

$$\nu_{bjt} = \lambda_b \frac{\mu_{jt}}{1+\mu_{jt}}$$

$$\nu_{kjt} Q_t K_{jt} + \nu_{bjt} Q_t^b B_{jt} + \nu_{njt} N_{jt} = \lambda Q_t K_{jt} + \lambda_b Q_t^b B_{jt}$$

The supply of loans can be obtained by rearranging the incentive constraint

$$Q_t K_{jt} = \frac{\nu_{bjt} - \lambda_b}{\lambda - \nu_{kjt}} Q_t^b B_{jt} + \frac{\nu_{njt}}{\lambda - \nu_{kjt}} N_{jt}$$

The Value function can be written solely as a function of N_{jt}. by substituting out private assets using the foregoing equation

$$\begin{aligned}
V_{jt} &= \nu_{kjt} Q_t K_{jt} + \nu_{bjt} Q_t^b B_{jt} + \nu_{njt} N_{jt} \\
\Leftrightarrow V_{jt} &= \left[\nu_{kjt} \frac{\nu_{bjt} - \lambda_b}{\lambda - \nu_{kjt}} + \nu_{bjt} \right] Q_t^b B_{jt} + \left[\nu_{kt} \frac{\nu_{njt}}{\lambda - \nu_{kjt}} + \nu_{njt} \right] N_{jt} \\
\Leftrightarrow V_{jt} &= \left[\nu_{kt} \frac{\nu_{njt}}{\lambda - \nu_{kjt}} + \nu_{njt} \right] N_{jt} \\
\Leftrightarrow V_{jt} &= \left[\frac{\lambda \nu_{njt}}{\lambda - \nu_{kjt}} \right] N_{jt} \\
\Leftrightarrow V_{jt} &= \left[\frac{\lambda \nu_{njt}}{\lambda - \lambda \frac{\mu_{jt}}{1+\mu_{jt}}} \right] N_{jt} \\
\Leftrightarrow V_{jt} &= (\nu_{njt}(1+\mu_{jt})) N_{jt}
\end{aligned}$$

Defining: $\Omega_{j,t} \equiv \Lambda_{t-1,t}((1-\theta) + \theta(1+\mu_{jt})\nu_{njt})$, plugging this expression of the value function into the Bellman equation, and using the law of motion of net worth, yields

$$\begin{aligned}
V_{jt} &= \nu_{kjt} Q_t K_{jt} + \nu_{bjt} Q_t^b B_{jt} + \nu_{njt} N_{jt} \\
&= \beta E_t \Lambda_{t,t+1} [(1-\theta) N_{jt} + \theta V_{j,t+1}] \\
&= \beta E_t \Omega_{t+1} ((R_{k,t+1} - R_t) Q_t K_{j,t} + (R_{b,t+1} - R_t) Q_t^b B_{j,t} + R_t N_{j,t}).
\end{aligned}$$

One can then solve for the coefficients of the value function

$$\begin{aligned} \nu_{kjt} &= \beta E_t \Omega_{jt+1}(R_{k,t+1} - R_t), \\ \nu_{bjt} &= \beta E_t \Omega_{jt+1}(R_{b,t+1} - R_t), \\ \nu_{djt} &= \beta E_t \Omega_{jt+1} R_t. \end{aligned}$$

For aggregation, I assume an equilibrium in which all banks are symmetric (i.e., $\forall j : \nu_{kjt} = \nu_{kt}, \nu_{bjt} = \nu_{bt}, \nu_{njt} = \nu_{nt}, \Omega_{jt+1} = \Omega_{t+1}$). The leverage ratio, ϕ_t, is obtained by defining the ratio of bonds over loans in the portfolio of the bank, $\varsigma_t = \frac{Q_t^b B_t}{Q_t K_t}$ and starting from the incentive constraint

$$\begin{aligned} & (\lambda - \nu_{kt})Q_t K_t + (\lambda_b - \nu_{bt})Q_t^b B_t &= \nu_{nt} N_t \\ \Rightarrow\ & (\lambda - \nu_{kt})Q_t K_t + \left(\tfrac{\lambda \nu_{bt} - \nu_{kt}\nu_{bt}}{\nu_{kt}}\right) Q_t^b B_t &= \nu_{nt} N_t \\ \Rightarrow\ & (\lambda - \nu_{kt})Q_t K_t + \left((\lambda - \nu_{kt})\tfrac{\lambda_b}{\lambda}\right) Q_t^b B_t &= \nu_{nt} N_t \\ \Rightarrow\ & (\lambda - \nu_{kt})Q_t K_t + (\lambda - \nu_{kt})\tfrac{\lambda_b}{\lambda}\varsigma_t Q_t K_t &= \nu_{nt} N_t \\ \Rightarrow\ & Q_t K_t &= \frac{\nu_{nt}}{(\lambda - \nu_{kt})(1 + \frac{\lambda_b}{\lambda}\varsigma_t)} N_t \\ \Rightarrow\ & \tfrac{Q_t K_t + Q_t^b B_t}{N_t} &= \frac{\nu_{nt}(1 + \varsigma_t)}{(\lambda - \nu_{kt})(1 + \frac{\lambda_b}{\lambda}\varsigma_t)} \equiv \phi_t \end{aligned}$$

A.2 Equilibrium equations

Households

$$W_t = \frac{\chi L_t^{\phi}}{U_{c,t}} \tag{A.1}$$

$$U_{c,t} = (C_t - hC_{t-1})^{-1} - \beta h E_t (C_{t+1} - hC_t)^{-1} \tag{A.2}$$

$$1 = E_t \beta \Lambda_{t,t+1} R_t \tag{A.3}$$

$$\Lambda_{t,t+1} = \frac{U_{c,t+1}}{U_{c,t}} \tag{A.4}$$

Intermediate Good Producers

$$Y_{mt} = A_t(\xi_t K_{t-1})^{\alpha} L_t^{1-\alpha} \tag{A.5}$$

$$R_{k,t+1} = \frac{P_{m,t+1}\alpha \frac{Y_{m,t+1}}{K_t} + (1-\delta)Q_{t+1}\xi_{t+1}}{Q_t} \tag{A.6}$$

$$W_t = P_{mt}(1-\alpha)\frac{Y_{mt}}{L_t} \tag{A.7}$$

Capital Good Producers

$$K_t = (1-\delta(U_t))\xi_t K_{t-1} + I_t \tag{A.8}$$

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - E_t \beta \Lambda_{t,t+1}\left(\frac{I_t}{I_{t-1}}\right)^2 f'\left(\frac{I_t}{I_{t-1}}\right) \tag{A.9}$$

$$f\left(\frac{I_t}{I_{t-1}}\right) = \frac{\eta_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{A.10}$$

Retailers

$$\Pi_t^* = \frac{\epsilon}{\epsilon - 1}\frac{F_t}{Z_t}\Pi_t \tag{A.11}$$

$$F_t = Y_t P_{mt} + \beta\gamma\Lambda_{t,t+1}\Pi_{t+1}^{\epsilon}\Pi_t^{-\gamma_p \epsilon} F_{t+1} \tag{A.12}$$

$$Z_t = Y_t + \beta\gamma\Lambda_{t,t+1}\Pi_{t+1}^{\epsilon-1}\Pi_t^{-\gamma_p(\epsilon-1)} Z_{t+1} \tag{A.13}$$

$$Y_{mt} = \Delta_{p,t} Y_t \tag{A.14}$$

$$\Delta_{p,t} = \gamma\Delta_{p,t-1}\Pi_t^{\epsilon}\Pi_{t-1}^{-\gamma_p \epsilon} + (1-\gamma)\left(\frac{1-\gamma\Pi_t^{\epsilon-1}\Pi_{t-1}^{-\gamma_p(\epsilon-1)}}{1-\gamma}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{A.15}$$

$$X_t = \frac{1}{P_{mt}} \tag{A.16}$$

$$\Pi_t^{1-\epsilon} = (1-\gamma)(\Pi_t^*)^{1-\epsilon} + \gamma\Pi_{t-1}^{\gamma_p(1-\epsilon)}, \tag{A.17}$$

Banks

$$\nu_{kjt} = \lambda \frac{\mu_{jt}}{1+\mu_{jt}} \tag{A.18}$$

$$\nu_{bjt} = \lambda_b \frac{\mu_{jt}}{1+\mu_{jt}} \tag{A.19}$$

$$Q_t K_{jt} = \frac{\nu_{bjt} - \lambda_b}{\lambda - \nu_{kjt}} Q_t^b B_{jt} + \frac{\nu_{njt}}{\lambda - \nu_{kjt}} N_{jt} \tag{A.20}$$

$$\Omega_{j,t} \equiv \Lambda_{t-1,t}((1-\theta) + \theta(1+\mu_{jt})\nu_{njt}) \tag{A.21}$$

$$\nu_{kjt} = \beta E_t \Omega_{jt+1}(R_{k,t+1} - R_t) \tag{A.22}$$

$$\nu_{bjt} = \beta E_t \Omega_{jt+1}(R_{b,t+1} - R_t) \tag{A.23}$$

$$\nu_{njt} = \beta E_t \Omega_{jt+1} R_t \tag{A.24}$$

$$\phi_t \equiv \frac{\nu_{nt}(1+\varsigma_t)}{(\lambda - \nu_{kt})(1+\frac{\lambda_b}{\lambda}\varsigma_t)} = \frac{Q_t K_t + Q_t^b B_t}{N_t} \tag{A.25}$$

$$Q_t K_t + Q_t^b B_t = D_t + N_t \tag{A.26}$$

$$\varsigma_t = \frac{Q_t^b B_t}{Q_t K_t} \tag{A.27}$$

$$N_{ot} = \theta \left[R_{kt} Q_{t-1} K_{t-1} + R_{bt} Q_{t-1}^b B_{t-1} - R_{t-1} D_{t-1} \right] \tag{A.28}$$

$$N_{nt} = \omega \left[Q_{t-1} K_{t-1} + Q_{t-1}^b B_{t-1} \right] \tag{A.29}$$

$$\varsigma_t = \frac{Q_t^b B_t}{Q_t K_t} \tag{A.30}$$

$$N_{ot} = \theta \left[R_{kt} Q_{t-1} K_{t-1} + R_{bt} Q_{t-1}^b B_{t-1} - R_{t-1} D_{t-1} \right] \tag{A.31}$$

$$N_{nt} = \omega \left[Q_{t-1} K_{t-1} + Q_{t-1}^b B_{t-1} \right] \tag{A.32}$$

$$N_t = N_{ot} + N_{nt} \tag{A.33}$$

$$prem_t = \frac{E_t R_{kt+1}}{R_t} \tag{A.34}$$

Fiscal Policy

$$G_t = Ge^{g_t} \tag{A.35}$$

$$T_t = T + \kappa_b (B_{t-1} - B) + \kappa_g (G_t - G) \tag{A.36}$$

$$R_{b,t} = (1 - \Delta_t^d * D) \left[\frac{r_c + \rho_c Q_t^b}{Q_{t-1}^b} \right] \tag{A.37}$$

$$G_t + Q_t^b B_t = R_{bt} Q_{t-1}^b B_{t-1} + T_t \tag{A.38}$$

$$\Delta_t^d = \frac{exp\left(\eta_1 + \eta_2 \frac{B_t}{4Y_t})\right)}{1 + exp\left(\eta_1 + \eta_2 \frac{B_t}{4Y_t}\right)} \tag{A.39}$$

$$prem_t^b = \frac{E_t R_{bt+1}}{R_t} \tag{A.40}$$

Monetary Policy and Good Market Clearing

$$i_t = \rho_i i_{t-1} + (1 - \rho)(i + \kappa_\pi \pi_t + \kappa_y \hat{mc}_t) + \epsilon_t^i \tag{A.41}$$

$$1 + i_t = R_t \frac{E_t P_{t+1}}{P_t} \tag{A.42}$$

$$Y_t = C_t + I_t + f\left(\frac{I_t}{I_{t-1}}\right) I_t + G_t \tag{A.43}$$

Shock Processes

$$g_t = \rho_g g_{t-1} + \epsilon_t^g \tag{A.44}$$

$$a_t = \rho_a a_{t-1} + \epsilon_t^a \tag{A.45}$$

$$\xi_t = \rho_\xi \xi_{t-1} + \epsilon_t^\xi \tag{A.46}$$

A.3 Decomposition of the output response to the shock

This section highlights, that the time-varying risk adjustment is indeed the main reason for the difference between the third-order accurate impulse response of output to the government spending shock and the first-order accurate impulse response to the government spending shock. Figure (A.1) illustrates the contributions of the different components of the policy function to the overall response of output to the shock. For convenience, equation (3.47) is restated below

$$y_t = \overline{y} + \frac{1}{2} y_{\sigma^2}\sigma^2 + \sum_{i=0}^{\infty}\left(y_i + \frac{1}{2} y_{\sigma_i^2}\sigma^2\right)\epsilon_{t-i} + \frac{1}{2}\sum_{i=0}^{\infty}\sum_{j=0}^{\infty} y_{i,j}(\epsilon_{t-i}\otimes\epsilon_{t-j}) + \frac{1}{6}\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\sum_{k=0}^{\infty} y_{i,j,k}(\epsilon_{t-i}\otimes\epsilon_{t-j}\otimes\epsilon_{t-k}),$$

where $\overline{y}$ denotes the vector of deterministic steady state values of the respective endogenous variables, and the matrices of partial derivatives, $y_i, y_{i,j}, y_{i,j,k}, y_{\sigma^2}$ and $y_{\sigma_i^2}$, are evaluated at the deterministic steady state. σ is a scale factor for the degree of risk in the model, and ϵ_{t-i}, ϵ_{t-j}, and ϵ_{t-k} are vectors of past realizations of shocks.

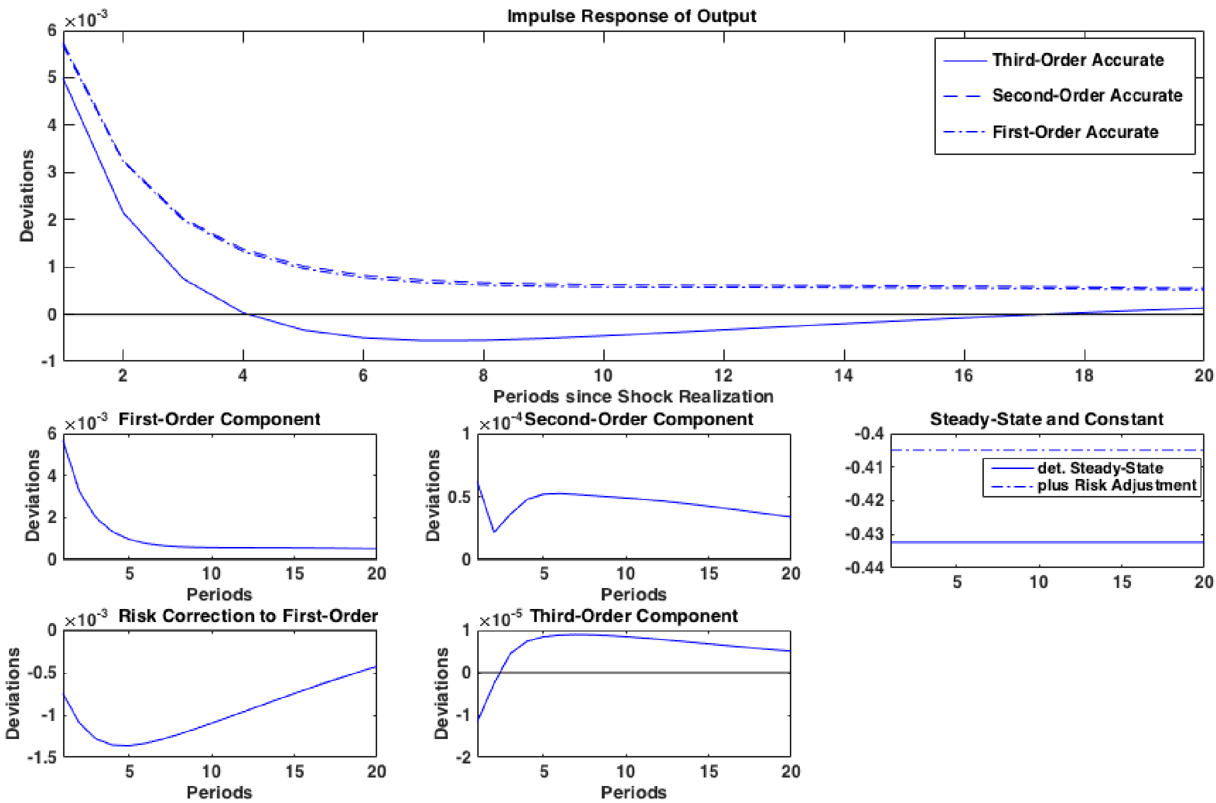

Figure A.1: Components of the output response to a shock in government spending of 1 percent of output.

The left panel of the middle row of figure (A.1) depicts the first-order accurate response to the realized government spending shock, which is captured by the term $\sum_{i=0}^{\infty} y_i \epsilon_{t-i}$ in the policy function. Note, that the contribution of the first-order component is at the scale of 10^{-3}. The lower left panel depicts the contribution of the time-varying risk adjustment term, $\frac{1}{2}\sum_{i=0}^{\infty} y_{\sigma_i^2}\sigma^2\epsilon_{t-i}$. Again, the contribution of this term the third-order accurate impulse response is of the order 10^{-3}. In contrast to these terms, for the same impulse response, the contributions of the second-order component, $\frac{1}{2}\sum_{i=0}^{\infty}\sum_{j=0}^{\infty} y_{i,j}(\epsilon_{t-i}\otimes\epsilon_{t-j})$ (depicted in the center panel), and the third-order component, $\frac{1}{6}\sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\sum_{k=0}^{\infty} y_{i,j,k}(\epsilon_{t-i}\otimes\epsilon_{t-j}\otimes\epsilon_{t-k})$ (depicted in the lower right panel), are of smaller magnitudes (10^{-4} and 10^{-5}, respectively). Thus the first-order component and the risk-adjustment are the dominating terms for the third-order accurate impulse response.

The solid line in the upper panel of figure (A.1) shows the overall impulse response of output to the government spending shock that is obtained with a third-order approximation. Compared to the first-order accurate and the second-order accurate impulse response it displays a weaker impact of the shock on output. The lower left panel of figure (A.1) shows that this difference is due to the negative contribution of the risk correction to first-order to the impact of the government spending shock on output. This reflects the fact that in the face of the shock banks reduce their exposure to the risky assets by more than in the linear setting, decreasing the credit supply, investment and hence, output.

As the state-dependence of impulse responses, and the asymmetry between responses to positive and negative shocks hinge on the second-order terms and the third-order terms associated with realized shocks, they are very small, and I can abstract from them in my analysis.

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Ich versichere, die von mir vorgelegte Dissertation selbständig und ohne unerlaubte Hilfe und Hilfsmittel angefertigt, sowie die benutzten Quellen und Daten anderen Ursprungs als solche kenntlich gemacht zu haben.

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Berlin, 2. Juni 2017

Felix Strobel