HOUSE OF FINANCE

WORKING PAPER SERIES

Giuliano Curatola - Michael Donadelli - Alessandro Gioffré - Patrick Grüning

Austerity, Fiscal Uncertainty, and Economic Growth: Insights from Fiscally Weak EU Countries

SAFE Working Paper No. 56

SAFE I Sustainable Architecture for Finance in Europe
A cooperation of the Center for Financial Studies and Goethe University Frankfurt

House of Finance | Goethe University
Theodor-W.-Adorno-Platz 3 | 60323 Frankfurt am Main

Tel. +49 69 798 34006 | Fax +49 69 798 33910
info@safe-frankfurt.de | www.safe-frankfurt.de

Non-Technical Summary

The persistence of the European sovereign debt crisis since early 2009 has induced European Union members to tie themselves with a stricter fiscal discipline. Among other measures imposed by the current treaties, EU members are constrained to a limit to the structural deficit of 0.5% of GDP at market prices.

The ongoing debate on the effects of a strong fiscal consolidation on long-term growth remains controversial. Some policymakers and economists argue in favor of austerity, saying that it may promote both short- and long-run growth. Others argue against austerity measures, warning that these measures may come at the cost of lower long-run growth.

In this paper we present a production economy in which agents have recursive preferences, growth is driven by firms' incentives to innovate, and a regime of fiscal consolidation is exogenously imposed. In order to be consistent with the current European fiscal discipline, we assume that public expenditure is hinged on a zero-deficit target and is financed only by labor and corporate taxes. In this setup, we study the impact on macroeconomic variables in the case of *(i)* a negative productivity shock, *(ii)* a positive shock on total government expenditure, and *(iii)* a negative shock on R&D spending.

Our analysis shows that the zero-deficit rule is highly detrimental for long- and short-run dynamics of macroeconomic variables after either a productivity drop or a spending stimulus. Moreover, austerity measures that reduce resources available to the R&D sector undermine economic growth in both the short and the long run.

Our findings suggest that fiscal policy uncertainty plays a key role in economic consolidation. In particular, household reacts to a sudden reduction in R&D spending by increasing savings. This mechanism generates an equity premium, which, although lower than the one observed in the GIPS countries, is higher than the premium produced by standard consumption-based asset pricing models.

Austerity, Fiscal Uncertainty, and Economic Growth: Insights from Fiscally Weak EU Countries

Giuliano Curatola Michael Donadelli

Alessandro Gioffré Patrick Grüning*

Abstract

Recent empirical evidence suggests that during the last years fiscally weak European countries significantly cut their R&D budgets in an effort to reduce their deficit, according to the spirit of the Fiscal Compact. We propose a general equilibrium model that endogenously captures the trade-off between costs and benefits of austerity measures driven by a zero-deficit policy. Our analysis suggests that cuts in R&D spending undermine economic growth both in the short and the long run. We use our model to estimate the reduction of economic growth due to R&D cuts implemented by fiscally weak European countries during the period 2010-2012. The model predicts a reduction in real growth by 0.63%, 2.93%, and 4.46%, in the next 1, 5, and 10 years, respectively. Moreover, we show that the zero-deficit constraint hampers economic growth in the presence of either a productivity drop or a spending stimulus.

Keywords: Austerity Measures, Fiscal Policy, Endogenous Growth, R&D

JEL Codes: E21, E23, E62, G18

*All authors are at the Research Center SAFE, Goethe University Frankfurt, Grüneburgplatz 1, 60323 Frankfurt, Germany. Corresponding author: Giuliano Curatola, curatola@safe.uni-frankfurt.de, +49 (0) 69-798-30096. Remaining authors' e-mails and phone numbers: donadelli@safe.uni-frankfurt.de, +49 (0) 69-798-33882; gioffre@safe.uni-frankfurt.de, +49 (0) 69-798-33855; gruening@safe.uni-frankfurt.de, +49 (0) 69-798-30086.

"*Investments in education, research, innovation and energy should be prioritized and strengthened where possible, while ensuring the efficiency of such expenditure*"

European Commission (Annual Growth Survey, 2013)

1 Introduction

The severity of the recent European sovereign debt crisis pushed EU members to sign a new treaty, namely "Fiscal Compact",[2] with the purpose of strengthening countries' creditworthiness, previously established in the Stability and Growth Pact (SGP). The SGP had aimed to steer the fiscal discipline of EU members according to the following medium-term objectives: (*i*) annual deficit-to-GDP ratio of 3%, and (*ii*) total public debt below 60% of the GDP, or else sufficiently decreasing towards 60% each year. However, the absence of enforcement mechanisms led EU countries to breach the commitments undertaken in the SGP, reinforcing the view that the failure of the medium-term objectives has been one of the reasons behind the outbreak of the sovereign debt crisis in the Eurozone.[3]

The entry into force of the Fiscal Compact has tied EU countries to a more rigorous "balanced budget rule", by introducing automatic mechanisms to take corrective actions if significant deviations from the medium-term objectives are observed.[4] The new fiscal discipline adopted in the Fiscal Compact[5] reaffirms the budget criteria contained in the SGP and establishes also – for each member state – a limit of structural deficit equal to 0.5% of GDP at market prices.[6] These stringent rules have induced fiscally weak European countries to implement an overall reduction of the general government spending and/or an increase of taxes, which in turn affect investments and taxes in the R&D sector. (see

[2]Officially, the *Treaty on Stability, Coordination and Governance in the Economic and Monetary Union*. The treaty was signed by all the member states of the EU in March 2012, but the United Kingdom, Czech Republic, and Croatia, which joined EU, in July 2013.

[3]See *A Blueprint for a Deep and genuine EMU*, European Commission, November 2012.

[4]See the *Treaty on Stability, Coordination and Governance in the Economic and Monetary Union*.

[5]This includes the so-called "Six-pack" and "Two-pack" measures. We acknowledge that the Six-pack entered into force in December 2011.

[6]The treaty includes also the obligation to incorporate the new budget rule (known as "golden rule") in the domestic legal system by means of a constitutional law or an ordinary law. For member states with a debt-to-GDP ratio significantly below 60% the deficit-to-GDP ratio has to be equal to 1.0%.

Veugelers [2014]).

In this paper we study the short- and long-run macroeconomic effects of austerity measures on R&D in an economy where the government is subject to a zero-deficit rule. To do so, we propose a production economy characterized as follows. First, economic growth is endogenously driven by firms' incentives to innovate (as in Romer [1990]; Comin and Gertler [2006]; Croce et al. [2013]; Kung and Schmid [2015]). Second, a regime of fiscal consolidation is exogenously imposed by means of a reduction in R&D spending, which affects firms' incentives to innovate and, in turn, alters log-run growth. More specifically, in our framework, cutting R&D spending plays the role of an unexpected and exogenous corrective action, as imposed by the Fiscal Compact. Third, a fraction of public expenditure is productive. As a result, an increase of public spending produces two opposing effects on economic growth: on the one hand, due to the zero-deficit constraint, the government can finance public expenditure only through taxes, whose distortive effects hamper growth; on the other hand, by virtue of the productive fraction of public expenditure, an overall increase of public spending directly stimulates growth. The final effect, clearly, depends on which of these two impulses dominates. Fourth, households have recursive preferences so that they care about the inter-temporal distribution of both consumption and fiscal policy risk.

Our analysis shows that austerity measures that reduce resources available to the R&D sector undermine economic growth in both the short and the long run. A negative shock on R&D spending, indeed, reduces the incentive of firms to invest in new technology and induces capital reallocation from the R&D to the consumption sector. The reallocation of capital away from the R&D sector can, at best, generate a short-time increase in consumption at the cost of lowering future consumption and output growth, both in the short and the long run. We also observe that the zero-deficit constraint is highly detrimental for long- and short-run dynamics of macroeconomic variables if the aggregate productivity drops or, conversely, if it is stimulated by an expansionary fiscal policy. In both circumstances, our findings are in consonance with those observed in Croce et al. [2013].

Fiscal uncertainty also alters the dynamics of the stock market. In our model, uncertainty is transmitted through a sudden reduction in R&D spending, and, accordingly, households react by allocating capital in risk-free assets (i.e. increase savings). This mechanism increases equity returns and decreases the risk free rate, generating an equity premium of 1.56%, which, although lower than the one observed in the GIPS countries, is higher than the premium produced by standard consumption-based asset pricing models (see, among others, Mehra and Prescott [1985], Mehra [2003]).

These results suggest that fiscal policy uncertainty plays a key role in economic consolidation. In particular, if uncertainty undermines household confidence in the expected fiscal investment stimulus, a positive expenditure shock may shrink future consumption and output growth. However, the ongoing debate on austerity measures and growth remains controversial. Some policy-makers and economists argue that the observed effort to reduce deficits in high-debt levels European countries would stimulate the economy in the short run as well as promote long-run growth (see for instance Alesina and Ardagna [2009], or the dispute on Reinhart and Rogoff [2010]). Others argue that austerity measures would reduce output in both the short run and the long run (Romer and Romer [2010], Bilbao-Ubillos and Fernàndez-Sainz [2014]) as well as increase poverty and income inequality (Ball et al. [2013]; Schaltegger and Weder [2014]; Woo et al. [2013]). The general idea is that adverse effects of fiscal consolidations take place because simultaneous public spending cuts and tax increases tend to leave no room for both public and private investments in physical capital and new technologies.

Our work is related to Croce et al. [2012] and Croce et al. [2013] who examine the welfare implications of long-run tax uncertainty by focusing on two different fiscal policy rules. We differ from them because, first, in order to capture a direct stimulus of public spending on growth, we introduce a fraction of public expenditure that is productive, and, second, we explicitly focus on the effects of austerity measures – meant as a reduction of R&D spending under a zero-deficit regime – on economic growth.

The rest of the paper is organized as follows. In the next section, we report some empirical facts in times of fiscal consolidation. In Section 3, we present our production economy. In Section 4, we discuss the calibration strategy and quantitative results. Section 5 concludes.

2 Motivating Facts

In this section, we present several reasons motivating our research questions and the theoretical framework of this paper. First, we examine the austerity-growth relationship for European (especially fiscally weak) countries for the period 2009-2013 (realized values) and the period 2014-2018 (projected values). This analysis is not meant to establish a causal link between austerity and growth but, more generally, to push forward the existence of a potential negative relationship between the two variables. In Section 3 we propose a theoretical model to study the nature and the direction of this relationship. Second, we compare variations in the total amount of government spending devoted to R&D investments with output growth of fiscally weak and fiscally strong countries over the last eight years. In line with other recent empirical evidence (see [Veugelers, 2014]), we find that fiscally weak countries have cut their R&D budgets during the last years. This empirical evidence motivates the construction of our theoretical model and, in particular, our quantitative analysis.

2.1 Austerity vs. Growth

In Figure 1 we report the realized economic growth of European and non-European countries and the strength of their austerity measures. Austerity (x-axis) is measured as the sum of tax increases and government spending cuts (as a percentage of GDP). The real GDP growth (y-axis) proxies for the country's economic performance. We observe that European countries with most severe austerity measures also show relatively low or negative output growth. For example, Greece has reduced its overall balance (as share of GDP) by 2.88% and displays an average decrease in GDP growth of 5.15%. Similarly, Spain and Portugal reduced (on average) their overall balance by 1.15%, and show an average output growth rate of -1.41%.[7]

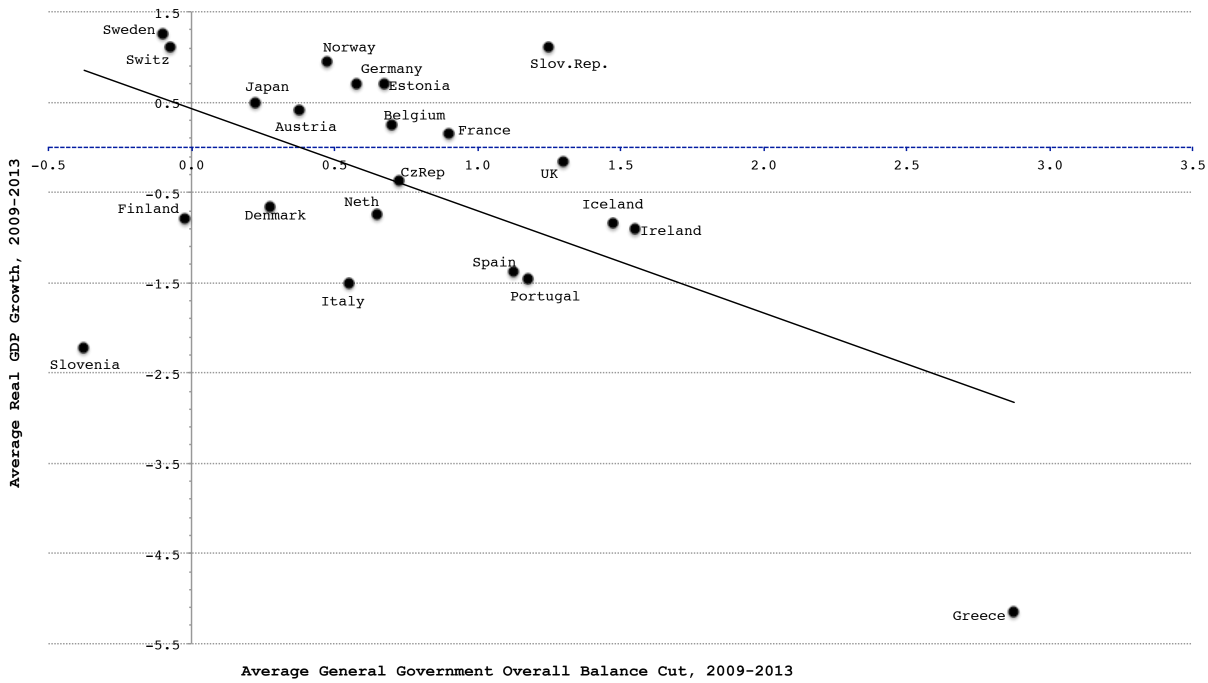


Figure 1: Fiscal Consolidation vs. Growth: Evidence from European Countries, 2009-2013 (Motivating Fact I). *Notes*: This figure plots the average reduction in the General Government Overall Balance (on the horizontal axis) against the real GDP growth (on the vertical axis). Fiscal balance and output data are from the IMF. Additional details on the data are given in the Appendix.

To provide additional support to the evidence in Figure 1 we regress real GDP growth on the average reduction in General Government Overall Balance.[8] The estimation reported in Table 1 suggests that the negative slope observed in Figure 1 is also significant. In addition, to capture the idea that the effect of austerity measures is likely to be more severe for fiscally weak countries, we interact our austerity measure with the sovereign credit rating of the economy in 2013.[9]. The estimated coefficient confirms the intuition that austerity measures may be particularly severe for fiscally weak countries.

[7]Notice that the use of the primary balance – defined as the overall balance excluding net interest payments – gives rise to a similar scatter plot.

[8]In order to have one observation per country we follow Edison et al. [2002] and average data over the period 2009-2013.

[9]Based on the S&P sovereign foreign currency credit rating, we convert the credit rating to a numerical scale, where a value of 0 corresponds to a AAA rating, 1 to a AA+ rating, and so on, down to 15 for a B rating, the lowest in our sample (see also Devereux and Yetman [2010]) Our sample includes the following OECD countries: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom.

	"(1)"	"(2)"
A	-1.132*	
	[0.623]	
ACR		-0.114***
		[0.014]
$\bar{R}^2$	0.277	0.565
Obs.	22	22

Table 1: Fiscal Consolidation vs. Economic Performance (2009-2013): OLS Regression. *Notes*: The dependent variable is represented by the 2009-2013 average real GDP growth rate. A denotes austerity, which here is captured by the average reduction in countries' fiscal deficit (i.e. $G \downarrow$-$T \uparrow$). ACR is an interactive variable given by $A * CR$, where CR is the S&P sovereign credit rating in 2013. $CR = 0$ corresponds to a AAA rating, , and $CR = 15$ to a B-. HAC standard errors are reported in square brackets. ***, **, * denote significance at 1%, 5% and 10%, respectively. GDP and government data are from the IMF. Additional details on the data are given in the Appendix.

This simple analysis is worthwhile but only gives a partial view of the possible effects of austerity measures. In fact austerity measures embody long term goals despite their potential short-term negative effects. More precisely, the main idea behind austerity measures is that fiscally weak countries should contain their excessive spending to restore credibility. Doing so, they would bring down interest rates and promote long-term economic growth. Based on this idea, the IMF estimates the long-term effect of austerity measures on economic growth. We report these estimates in Figure 2, which shows the average reduction in fiscal deficit against the real GDP growth over the period 2014-2018. Based on these estimates, fiscally weak European countries will have positive economic growth in the next years. For example, Greece is expected to grow (on average) by 2.81%.

A number of studies support the beneficial effects of austerity measures (Giavazzi and Pagano [1990], Alesina and Perotti [1995], Alesina and Perotti [1996], among others) and suggest that large fiscal deficit cuts might be followed by an increase in private consumption. For example, Giavazzi and Pagano [1990] show that in Denmark (1983-1996) and Ireland (1987-1989) the fiscal deficit fell by 9.5 and 7.2 percent of GDP, respectively, and private consumption cumulatively increased by 17.7% and 14.5%, respectively. Alesina and Perotti [1996] identify similar episodes in Belgium (1984-1987), Italy (1989-1992), Portugal (1984-1986) and Sweden (1983-1989). On the other hand, Perotti [1999] observes that fiscal policy shocks might have both positive and negative effects on private consumption, and the sign of such effects is related to the state of the economy, i.e. expansionary vs. recessionary periods, respectively. Krugman [2013], Bilbao-Ubillos and

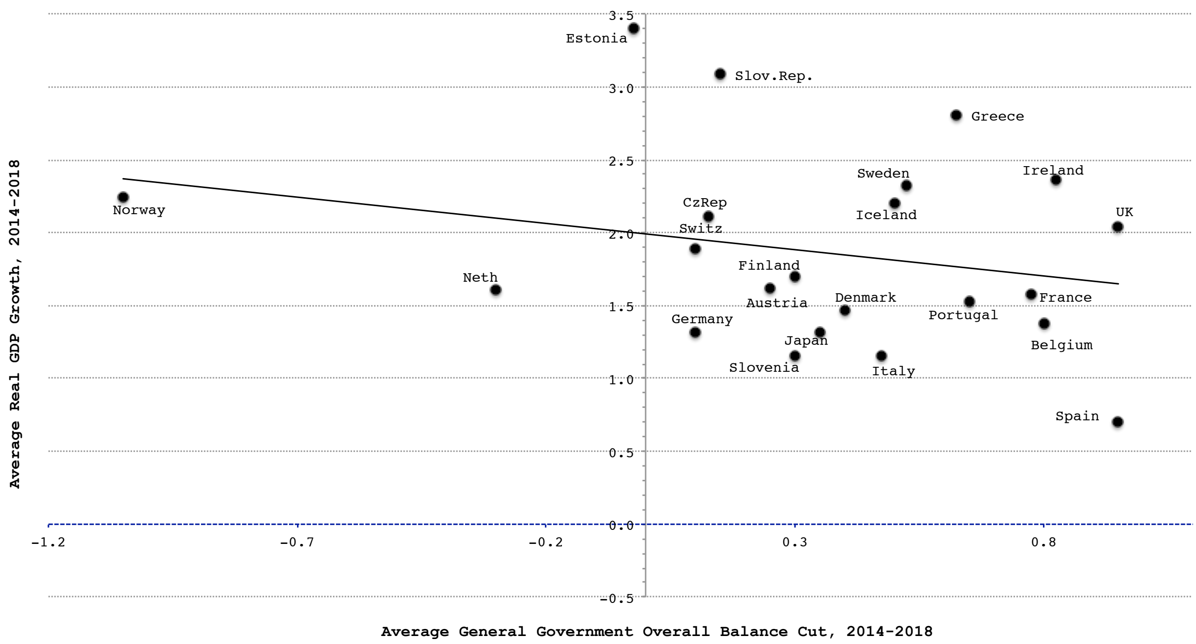


Figure 2: Fiscal Consolidation vs. Growth: Evidence from European Countries (2014 – 2018)^E. *Notes*: This figure plots the average expected reduction in the General Government Overall Balance (on the horizontal axis) against the expected real GDP growth (on the vertical axis). Fiscal balance and output data are from the IMF. Additional details on the data are given in the Appendix.

Fernàndez-Sainz [2014] argue that austerity measures within fiscally weak EU members have decreased economic activity more than expected and cast several doubts on the effective ability of such countries to grow in the next years. In addition, several fiscally weak European countries also exhibit a negative private consumption growth rate. For example, the private consumption growth rate of the GIPS countries (Greece, Italy, Portugal, and Spain) over the period 2009-2012 is equal to -2.87%.

Overall these results leave two questions open: what is the short-term effect of austerity measures? And, most importantly, what is their long-term effect on economic growth? These questions will be addressed in the next sections.

2.2 R&D Expenditure vs. Growth in Times of Fiscal Consolidation

In order to provide a realistic description of the effect of austerity measures, we need to describe how the austerity programs have been implemented by fiscally weak countries so far. Veugelers [2014] reports that, as a consequence of tightening fiscal measures, fiscally weak and innovation-lagging EU economies largely cut their R&D expenditure along with all other public expenses. Differently, fiscally stronger and innovation-leading countries continued to sustain public R&D spending.

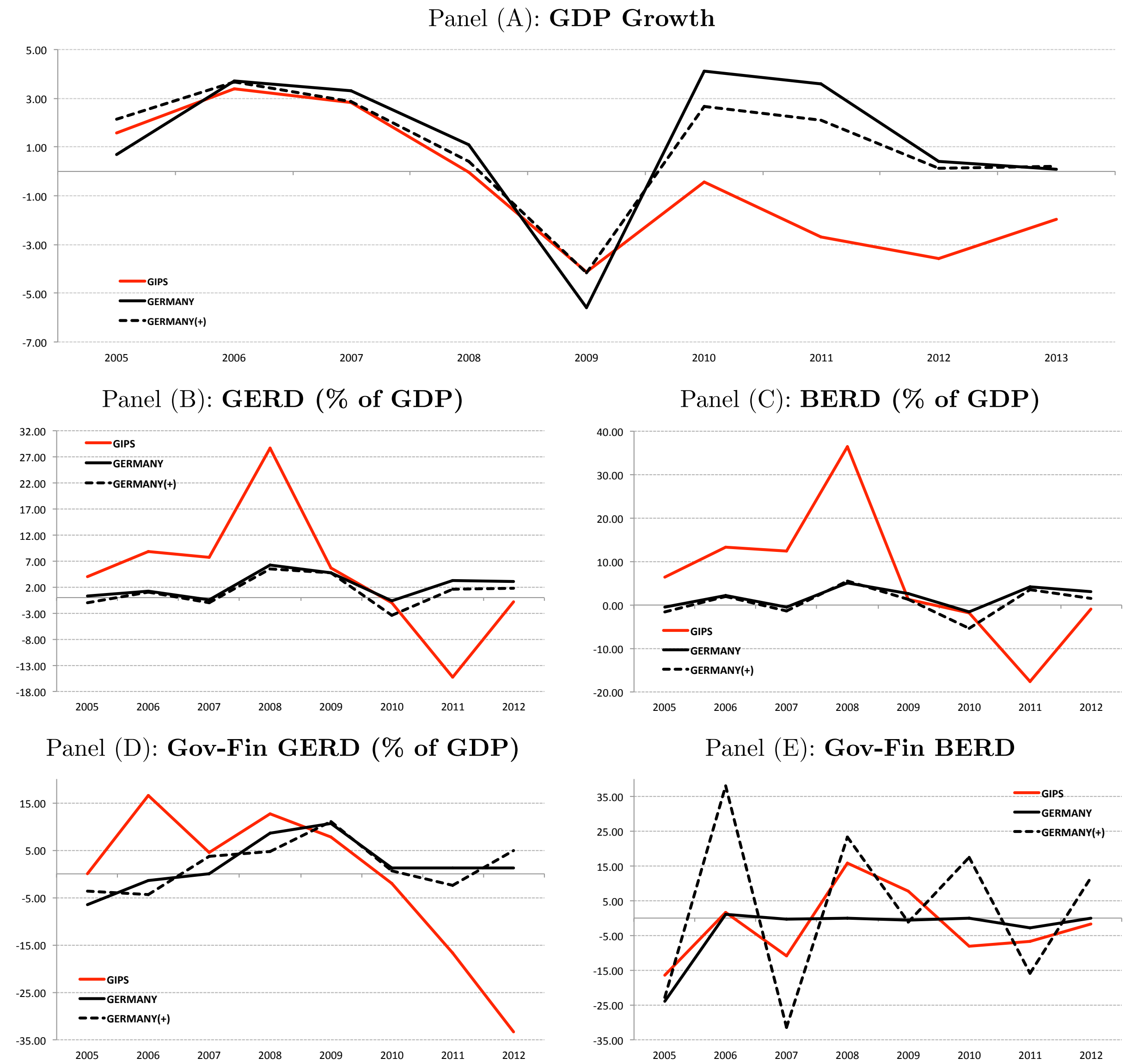


Figure 3: R&D Investments vs. Economic Growth in Europe (Motivating Fact II). *Notes*: Panel (A) reports the rate of growth of the GDP. Panels (B) and (C) report the rate of change of gross domestic and business enterprise expenditure on R&D (both measured as % of GDP), respectively. Panels (D) reports the rate of change of government-financed gross domestic expenditure on R&D (measured as % of GDP). Panel (E) reports the percentage change of business enterprise expenditure on R&D (BERD) financed by government. *GIPS* includes Greece, Italy, Portugal and Spain. *GERMANY*(+) includes Denmark, Germany, the Netherlands, Norway, Sweden. Details on data sources are given in the Appendix.

For example, the GIPS's governments cut their support to gross R&D expenditure (as % of GDP, on average across countries) by 2.07%, 16.67% and 33.33%, respectively in

2010, 2011 and 2012 (see Figure 3, Panel D). These numbers are remarkable, especially if compared with the changes in R&D expenditure of fiscally strong countries. For instance, the percentage of GDP devoted to R&D expenditure in Germany increased (on average) by 2.61% over the same period. More generally, fiscally strong countries (Denmark, Germany, Netherlands, Norway and Sweden) increased their R&D budget by 1.19%.[10]

The observed spending strategy of fiscally weak European countries seems to be in contrast with theoretical and empirical studies (Aghion and Howitt [1992]; Griffith [2000]; Westmore [2013]), suggesting that public and private R&D investments as well as innovation specific policies (e.g. R&D tax incentives, direct government support to innovation, patent rights) are fundamental in driving both short- and long-run economic growth. A fair question to ask is then the following: Can a severe cut in R&D expenditure, especially when implemented in conjunction with other tight fiscal measures, be beneficial? What are the effects of these R&D spending trends on short-and long-term growth of fiscally weak European countries?

3 A Framework to Assess the Impact of Austerity

In this section we develop a theoretical framework that allows us to study a world characterized by an unprecedented fiscal consolidation. In our model, austerity refers to the measures taken by the government to reduce expenditures in an attempt to keep the public budget balance tied to a zero-deficit policy. Here, public expenditure is financed by the government with a mix of labor and corporate taxes. Moreover, the labor income tax rate is set to satisfy the zero-deficit rule, whereas the corporate tax rate is assumed to be constant (consistent with EU tax data).[11]

[10]For a more detailed analysis on R&D spending trends in low- and high-fiscal consolidation countries during the post-Lehman era see Veugelers [2014] In addition, the World Bank provides similar data on R&D expenditure trends. According to the World Development Indicators, the R&D expenditure (measured as % of GDP) in the GIPS displays a fall of around 20% over the period 2009-2012.

[11]Notice that the European Commission states in its 2013 Annual Growth Survey that "*the tax burden on labor should be substantially reduced in countries where it is comparatively high and hampers job creation [...] and to ensure that reforms are revenue-neutral, taxes such as consumption tax, recurrent property tax and environmental taxes could be increased [...] and additional revenue should be raised preferably by broadening tax bases rather than by increasing tax rates or creating new taxes*". However, this is a very hard task for those countries where (*i*) the average annual per worker income is rather low; (*ii*) taxes on capital income are very high; and (*iii*) consumer confidence is extremely low.

Our theoretical framework builds on Croce et al. [2013] who employ a production economy in which (i) agents have recursive preferences, and (ii) growth is determined by patent accumulation (as in Romer [1990]) to study the effects of different fiscal policy schemes on the composition of intertemporal consumption risk.[12] We consider several departures from their benchmark setting. First, we assume that the government is committed to a unique fiscal strategy, namely the zero-deficit rule, which is consistent with the rules imposed by the fiscal compact recently signed by EU members. Second, we consider R&D subsidies from the government to the R&D sector which are stochastic to account for sudden cuts when the pressure for fiscal consolidation is high (as, e.g., in the European sovereign debt crisis). Third, we assume that a fraction of government spending is productive, in the sense that it increases output by being one input in final good production together with labor and intermediate goods, while the remaining fraction is unproductive. Finally, in order to consider a more consistent fiscal policy scenario, we also account for corporate taxation.

3.1 Households

The representative agent has recursive Epstein and Zin [1989] preferences, defined over consumption C_t and labor L_t:

$$U_t = \left[(1-\beta) u_t^{1-\frac{1}{\psi}} + \beta \left(E_t \left[U_{t+1}^{1-\gamma} \right] \right)^{\frac{1-1/\psi}{1-\gamma}} \right]^{\frac{1}{1-1/\psi}}, \tag{1}$$

where γ measures the relative risk aversion (RRA), ψ is the elasticity of intertemporal substitution (EIS), and $\beta \in (0,1)$ is the household's subjective discount factor. The standard expected utility arises as a special case when $\gamma = \frac{1}{\psi}$. The utility flow, $u_t := u(C_t, L_t)$, is a Cobb-Douglas index of aggregate consumption and leisure, $1 - L_t$, given by

$$u(C_t, L_t) = C_t^{\alpha_c} \left(A_t (1 - L_t) \right)^{1-\alpha_c},$$

[12] Our theoretical setup is also closely related to Kung and Schmid [2015] who employ a stochastic version of Romer [1990]) where agents have recursive preferences and long-run growth prospects are endogenously determined by innovation and R&D to match asset prices. However, there are several differences between their work and ours: (i) we assume that the government plays a role; (ii) we do not account for physical capital accumulation.

where $\alpha_c \in (0,1)$ reflects preferences for consumption versus leisure. In line with the long-run risk literature, we assume $\gamma \geq \frac{1}{\psi}$, i.e. the representative agent is averse to both consumption and volatility risk. In other words, our agent dislikes uncertainty on future utility levels. Notice that this preference specification allows to separate the RRA parameter from the EIS, and has been widely used in recent asset pricing and RBC/IBC studies (Benigno et al. [2011]; Papanikolaou [2011]; Caldara et al. [2012]; Colacito and Croce [2013]; Pancrazi [2014]; Kung and Schmid [2015]). Notice also that this class of preferences has been recently supported by experimental studies (Brown and Kim [2014]).[13]

In each period, the representative agent chooses consumption C_t and labor L_t to maximize (1) subject to the following budget constraint

$$C_t + \theta_{B,t+1} + Q_t\,\theta_{Q,t+1} = (1-\tau_t^l)W_t L_t + \theta_{B,t} R_t^f + (Q_t + D_t)\theta_{Q,t}, \tag{2}$$

where $\theta_{Q,t}$ denotes equity shares, Q_t is the market value of an equity share, D_t represents aggregate dividends, $\theta_{B,t}$ denotes public debt holdings, R_t^f is the risk-free rate and W_t represents the level of wages taxed at the rate τ_t^l. The first order conditions of the maximization problem lead to the following expression for the stochastic discount factor

$$M_{t+1} = \beta \left(\frac{C_{t+1}}{C_t}\right)^{-1} \left(\frac{u_{t+1}}{u_t}\right)^{1-\frac{1}{\psi}} \left(\frac{U_{t+1}}{[E_t U_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma}. \tag{3}$$

The usual Euler equations of asset prices can be written as

$$\Upsilon_t = E_t[M_{t+1}(\Upsilon_{t+1} + D_{t+1})], \qquad \frac{1}{R_t^f} = E_t[M_{t+1}].$$

Finally, the agent's optimal labor condition takes the following form

$$(1-\tau_t^l)W_t = \frac{1-\alpha_c}{\alpha_c}\left(\frac{C_t}{1-L_t}\right). \tag{4}$$

[13] In an Epstein and Zin [1989] preferences environment, agents care about the timing of the resolution of uncertainty. Brown and Kim [2014], via experiments, show that subjects prefer early resolution of uncertainty and have RRA greater than the reciprocal of the EIS, consistent with the predictions by recursive preferences.

3.2 Firms

Three types of firms are present in our economy: the consumption good is produced in the final good sector by a representative firm using labor and intermediate goods as input. The firms in the intermediate sector produce intermediate goods using as input the technology developed by the patent developing firms in the R&D sector, which are granted subsidies by the government.

3.2.1 Final Good Production

As in Kung and Schmid [2015], the amount Y_t of the final consumption good is produced in a competitive sector using a bundle of intermediate goods, $Z_{i,t}$, and labor, L_t. Formally,

$$Y_t = \Lambda_t L_t^{1-\alpha} \left[\int_0^{A_t} Z_{i,t}^{\alpha} di \right], \tag{5}$$

where α is the intermediate goods bundle share, A_t represents the number of intermediate goods at time t, and Λ_t is an exogenous stochastic total factor productivity (TFP) process[14]

$$\log(\Lambda_t) = \rho_\Lambda \log(\Lambda_{t-1}) + \epsilon_t^\Lambda, \qquad \epsilon^\Lambda \sim N(0, \sigma_\Lambda).$$

The final good firm chooses labor and intermediate goods to maximize profits. Formally,

$$\max_{[L_t, Z_{i,t}]} \left[Y_t - W_t L_t - \int_0^{A_t} P_{i,t} Z_{i,t} di \right],$$

where $P_{i,t}$ represents the price of the intermediate good i at time t. The maximization problem implies the following optimality conditions:

$$W_t = (1-\alpha)\frac{Y_t}{L_t}, \qquad Z_{i,t} = \left(\frac{\Lambda_t \alpha L_t^{1-\alpha}}{P_{i,t}} \right)^{\frac{1}{1-\alpha}}. \tag{6}$$

[14] In our economy, Λ_t is a labor augmenting technology and does not represent measured productivity, which is instead measured by the number of patents.

3.2.2 Intermediate Good Production

Intermediate goods are produced by monopolistic firms, i.e. firm i produces good i. In order to produce $Z_{i,t}$ units of the intermediate good i, each firm needs $Z_{i,t}$ units of the final good. The intermediate producer takes the demand schedule $Z_{i,t}$ obtained in (6) as given, and chooses $P_{i,t}$ to maximize profits $\Pi_{i,t}$:

$$\Pi_{i,t} := \max_{P_{i,t}} [P_{i,t} Z_{i,t} - Z_{i,t}]. \tag{7}$$

By replacing (6) in (7), we find that monopolistic firms charge a markup α by choosing the optimal price

$$P_{i,t} \equiv P = \frac{1}{\alpha} > 1.$$

Since firms are identical, a generic firm i produces $Z_t \equiv Z_{i,t}$ units of good i given by

$$Z_t = (\Lambda_t \alpha^2 L_t^{1-\alpha})^{\frac{1}{1-\alpha}} \tag{8}$$

and makes a profit of

$$\Pi_{i,t} \equiv \Pi_t = \left(\frac{1}{\alpha} - 1\right) Z_t. \tag{9}$$

Finally, by replacing (8) in (5) we obtain

$$Y_t = \Lambda_t L_t^{1-\alpha} \left[\int_0^{A_t} (\Lambda_t L_t^{1-\alpha} \alpha^2)^{\frac{\alpha}{1-\alpha}} di \right] = A_t \, L_t \, \alpha^{\frac{2\alpha}{1-\alpha}} \, \Lambda_t^{\frac{1}{1-\alpha}}.$$

This expression shows that the final good firm's production Y_t is linear in the variety of the intermediate goods A_t.

3.2.3 Research and Development (R&D)

The variety of intermediate goods embodies new technologies (i.e. patents).[15] Therefore, in each period, firms sell intermediate goods to final good firms to make profits. In the forthcoming periods, new intermediate firms will produce new patents and sell them to

[15] See also Santacreu [2014].

make profits and some of the old firms lose their patents. In this setup, the value of existing variety, V_t, is specified as follows

$$V_t = (1 - \tau^{\pi})\Pi_t + (1 - \delta_v)E_t[M_{t+1}V_{t+1}], \tag{10}$$

where δ_v represents the depreciation rate of the new technology and τ^{π} the corporate tax rate so that total corporate taxes are proportional to profit Π_t. Hence, the market value of a new patent must be equal to the cost of producing a new patent corrected for R&D subsidies (i.e. free-entry condition):

$$E_t[M_{t+1}V_{t+1}] = \frac{1}{\Theta_t}(1 - \tau_t^r), \tag{11}$$

where $\frac{1}{\Theta_t}$ is the cost of developing a new patent and τ_t^r is the R&D subsidy supplied by the government. The stock of patents evolves as

$$A_{t+1} = \Theta_t S_t + (1 - \delta_v)A_t, \tag{12}$$

where S_t is the total amount of investment in R&D. Thus, the growth rate of newly produced technology is given by

$$\frac{A_{t+1}}{A_t} = \Theta_t \frac{S_t}{A_t} + 1 - \delta_v.$$

Notice that Θ_t represents the productivity of the innovation sector and, as in Comin and Gertler [2006], is defined as follows:

$$\Theta_t = \xi \left(\frac{S_t}{A_t} \right)^{\eta - 1},$$

where $[A_t^{\eta-1} \cdot S_t^{1-\eta}]^{-1}$ represents a congestion externality,[16] $\eta \in (0, 1)$ is the elasticity of new patents with respect to total R&D investment and ξ is a scale parameter.

[16] This ensures that the elastic response of a newly developed technology to R&D differs from one.

3.3 Government

The framework described so far is quite similar to Croce et al. [2013]. From now on, we describe the main departures from their setting. Let G represent the total public expenditure of the government. We assume that a fraction c of public expenditure is productive and it is added to the output produced by the representative firm to determine the total output of the economy Y^*. More formally,

$$Y_t^* = Y_t + cG_t. \tag{13}$$

The remaining fraction of total public expenditure is divided into R&D subsidies, $\tau_t^r S_t$, and the residual, B_t, that represents wasteful government spending:

$$G_t = cG_t + \tau_t^r S_t + B_t.$$

The R&D subsidy rate is determined by the following exogenous stochastic process

$$\begin{aligned} \tau_t^r &= \frac{1}{1+e^{-\nu_t}} \\ \nu_t &= (1-\rho_\nu)\bar{\nu} + \rho_\nu \nu_{t-1} + \epsilon_t^\nu, \qquad \epsilon^\nu \sim N(0, \sigma_\nu^2), \end{aligned}$$

where $\bar{\nu}$ is the long-run average of government's R&D subsidies and ρ_ν is the persistence of shocks to R&D subsidies.

Finally, we assume that public expenditures are stochastic and satisfy

$$\begin{aligned} \frac{G_t}{Y_t^*} &= \frac{1}{1+e^{-g_t}} \\ g_t &= (1-\rho_g)\bar{g} + \rho_g g_{t-1} + \epsilon_t^g, \qquad \epsilon^g \sim N(0, \sigma_g^2), \end{aligned}$$

where $\bar{g}$ is the long-run average of the government expenditure-output ratio, ρ_g is the persistence of government expenditure shocks, and Y_t^* is the total final output specified above.

The government finances total public spending by means of labor and corporate taxes, so that the total tax income is

$$T_t = \tau_t^l W_t L_t + \tau^\pi \Pi_t, \tag{14}$$

where the corporate tax rate τ^π is constant and thus intermediate good producers needs to pay a constant fraction of their profits Π_t to the government. Differently from Croce et al. [2013], we focus exclusively on a tax regime where the government is committed to finance all its expenditures via current taxes (i.e. a zero-deficit regime consistent with rules imposed by the Fiscal Compact). Thus, the government sets

$$G_t - T_t = 0. \tag{15}$$

The labor tax rate is set so that the zero-deficit constraint is satisfied. This implies that the labor tax rate τ_t^l is determined as[17]

$$\tau_t^l = \frac{G_t - \tau^\pi \Pi_t}{W_t L_t}.$$

Intuitively, our economy is consistent with a hypothetical high-debt country which is committed to a zero-deficit rule and thus holding its debt-to-GDP ratio constant over time. In this hypothetical setup, the country's debt service is a part of wasteful public expenditure B_t.

We stress that our model generates a trade-off between benefits and financing costs of R&D expenditures. On the one hand, due to the zero-deficit constraint, the government can finance an increase in the public expenditures only through tax increases. The distorting effect of taxes has a negative impact on consumption and output and, more generally, on economic growth. On the other hand, the productive fraction of public expenditure increases output via Equation (13) and has a positive effect on economic growth. Naturally, the final effect of this policy depends on the interaction between these two forces. This trade-off, which is not present in Croce et al. [2013] because in their

[17] We stress that our tax scheme is consistent with tax data showing that corporate tax rates across countries tend to be stable over time (*Source*: KPMG).

model the total amount of public expenditure is non-productive, is important to assess the impact of austerity measures. In principle, a fiscally weak country may cut its R&D budget and, at the same time, reduce taxation of labor income to respect the zero-deficit constraint. Thus, a realistic and comprehensive evaluation of the effect of R&D cuts has to account for these two countervailing effects.

3.4 Resource Constraint

We close our economy with the following market clearing conditions:

$$Y_t^* = C_t + A_t Z_t + S_t + G_t \tag{16}$$

in the final good production, and

$$(1 - \tau_t^l)\frac{(1-\alpha)Y_t}{L_t} = \frac{1-\alpha_c}{\alpha_c}\frac{C_t}{1-L_t} \tag{17}$$

in the labor market.

4 Quantitative Analysis

In this section we examine the quantitative implications of austerity for aggregate macroeconomic quantities. First, recent research (for instance, Born et al. [2014]) suggests that austerity measures may fail to restore market confidence in bad times. In line with their findings, we use our model to analyze short- and long-run implications of a negative TFP shock under the zero-deficit regime (Section 4.2). Second, empirical evidence shows that European countries increased the fraction of GDP devoted to public expenditures in reaction to the recent economic crises.[18] Therefore, we also study the impact of positive public spending shock in the presence of the zero-deficit constraint (Section 4.3). Finally, Veugelers [2014] shows that several European countries (especially fiscally weak countries)

[18]For instance, between 2009-2012 fiscally-week European countries increased the GDP share of public expenditure (on average) by 0.163%. Taking into account the post-Lehman era (i.e. the period 2008-2009) the increase in public expenditures was even higher (i.e. 5.75%).

cut their R&D budgets in an attempt to implement austerity measures. Thus, we calibrate our model on the recent (2010-2012) R&D cuts of fiscally weak European countries and estimate the short- and long-run implications of such a fiscal policy (Section 4.5).

4.1 Calibration

The model presented in this paper involves 18 parameters: four for preferences, seven referring to the technology (final good production) and R&D (new patents development), and seven for government policies and taxes. In order to capture the trade-off between benefits and costs of R&D cuts in a realistic way, we pay particular attention to parameter values which are chosen to reproduce key macroeconomic quantities of GIPS countries and stylized facts about their fiscal policy.[19] All parameter values are reported in Table 2.

Preference parameters (i.e. subjective discount factor β, RRA γ, and EIS ψ) are in line with the long-run risk literature which imposes $\gamma > \frac{1}{\psi}$ (i.e. agents are risk averse in future utility as well as future consumption). In particular, we set $\gamma = 10, \beta = 0.984$ (Kung and Schmid [2015]) and $\psi = 1.7$ (Croce et al. [2013]). The consumption share in the utility bundle is set so that the steady state labor endowment is one third of the total time endowment.

Since we focus on the implications of EU cross-country adverse fiscal policies on current and expected economic growth in the GIPS countries, we calibrate the model to match key tax and government statistics of the GIPS countries in 2009 and to match as closely as possible the means and volatilities of growth rates over a long horizon in those countries. To this end, we set the relative share of labor in the final good production to $\alpha = 0.599$. The scale parameter ξ is then chosen to match the average output growth rate in the GIPS countries from 1981 and 2012, which is 1.71%, i.e. we set $\xi = 2.2095$. $\eta = 0.80$ (i.e. the elasticity of new intermediate goods) is set as in Croce et al. [2013]. As in Kung and Schmid [2015], we set the patent obsolescence rate δ_v equal to 0.15. Moreover, we set the technology shock volatility and persistence to $\sigma_\Lambda = 0.01$ and to $\rho_\Lambda = 0.89$, respectively.

[19] The model is calibrated at annual frequency and solved in DYNARE++4.3.0 using third-order perturbation methods. Policies are computed as annual log deviations from the steady state (DYN.SS vector generated by DYNARE++). All variables in our models are stationarized and expressed in log-units in the DYNARE++ code.

Table 2: PARAMETERS: BENCHMARK CALIBRATION. *Notes*: This table reports the benchmark calibration (annual frequency) used for the model presented in Section 3. Parameters' sources: 1=own calibration, 2=Croce et al. [2013], 3=Kung and Schmid [2015].

Parameter	Description	Source	Value
β	Subjective discount factor	3	0.984
γ	Risk aversion	3	10
ψ	Elasticity of intertemporal substitution	2	1.7
α_c	Consumption share in utility bundle	1	0.4154
α	Labor share	1	0.599
c	Share of productive government spending	1	0.4485
ρ_Λ	Autocorrelation of productivity level $\log(\Lambda_t)$	1	0.89
σ_Λ	Volatility of productivity shock ϵ_t^Λ	1	0.01
η	Elasticity of R&D technology	2	0.80
ξ	R&D productivity shift parameter	1	2.2095
δ_v	Patent obsolescence rate	3	0.15
τ^π	Corporate tax rate	1	0.2785
ρ_g	Autocorrelation of government expenditure ratio g_t	2	0.93
σ_g	Volatility of government expenditure shock ϵ_t^g	1	0.005
$\bar{g}$	Long-run mean of government expenditure-output ratio g_t	1	-1.3078
ρ_ν	Autocorrelation of R&D subsidy rate ν_t	1	0.89
σ_ν	Volatility of R&D subsidy rate shock ϵ_t^ν	1	0.005
$\bar{\nu}$	Long-run mean of R&D subsidy rate ν_t	1	-2.2287

Turning to government and tax parameters, the constant $\bar{g}$ captures the average logarithmic level of the government expenditure output ratio. It is set to $\bar{g} = -1.3078$, which implies a government expenditure-GDP ratio of 21.30%, i.e. the average ratio in the GIPS countries in 2009. This value is much higher than that one employed by Croce et al. [2013], who set $G/Y = 11\%$.[20] The persistence parameter of the government expenditure-output ratio, $\rho_g = 0.93$, is taken from Croce et al. [2013]. The volatility of the government expenditure shock σ_g and the volatility of the R&D subsidy rate shock σ_χ are equal to $0.5 \cdot \sigma_\Lambda$.

The R&D subsidy rate τ_t^r in the GIPS countries (i.e. the percentage of total business R&D expenditures financed by the government) was 9.72% in 2009, and thus we set $\bar{\nu} = -2.2287$. The persistence of R&D subsidy rates is chosen to be rather low at $\rho_\nu = 0.89$

[20]Notice that this value relies on US data.

as the governments change the budget for subsidies rather quickly, as apparent in the data. In addition, we impose a steady state labor income tax rate equal to 42% (average value in the GIPS countries in 2009). Since corporate tax rates do not change often in the data, we use a constant corporate tax rate of 27.85% (average value in GIPS countries in 2009). Finally, the share of productive government spending is set to $c = 0.4485$, as indicated by data on the percentage of total gross R&D expenditures financed by the government.

4.2 Austerity and Productivity Shocks

Figure 4 describes the impact of a negative productivity shock (i.e., $\varepsilon_t^{\Lambda} < 0$) when the government is forced to follow a zero-deficit rule, as imposed by the Fiscal Compact. Panels A, C, E and G describes the response of the levels of consumption, total output, labor supply, and R&D investment, whereas Panels B, D, F and H reports the impact on the related expected growth rates. After the negative TFP shock the current output drops immediately, causing in turn a fall in consumption and labor supply. As a consequence of the consumption fall, R&D investments become less profitable (patents' value V_t drops).[21] As a result, we observe a drop in R&D investments of about 3.5%,[22] while consumption and total output display a rapid decline of around 2.5% within 2 quarters with a subsequent slow recovery from 3 quarters after the shock. The decline in consumption and output is less severe than the decline in investment and reflects the households' desire for consumption smoothing. Due to the recursive preferences, agents care about continuation utility smoothing and not only about current consumption smoothing. Thus, after a negative TFP shock, it is optimal for agents to increase labor supply tomorrow in order to counteract the expected drop in future output and consumption (Panels B, D and F).

The responses of the growth rate of consumption, total output and R&D investment suggest that a standard negative productivity shock – in times of austerity – may have sizeable long-run adverse effects (Panels B, D and H) on the real economic activity, which is exacerbated by the zero-deficit constraint. In fact the use of deficits may reduce the adverse effect of negative TFP shocks on current output and consumption and restore

[21] An increase in marginal utility lowers the current patent value.

[22] This also generates a fall in the quantity of produced intermediate goods.

future economic growth. Differently, under austerity measures, the negative effects on future economic growth are quite persistent: the expected growth rates of consumption, output, and R&D investment drop immediately and return to their initial levels more than 20 quarters after the shock (see also Croce et al. [2013]).

4.3 Austerity and Government Spending

In this section we analyze the response of macroeconomic quantities after a positive shock to government expenditures. While the short-run effects of a change in public expenditures have been largely explored in the literature, their long-run implications are less clear. In order to fill part of this gap, we analyze the impulse response functions of the main macroeconomic variables with respect to a positive government expenditure shock (i.e., $\varepsilon_t^g > 0$). The results are reported in Figure 5. An increase in government expenditures has two countervailing effects on macroeconomic quantities. On the one hand, the fraction c of public expenditures that is productive increases the total output. On the other hand, due to the zero-deficit rule, the government is forced to raise labor taxes. Panel F shows that τ_t^l moves from 42% to 42.25% within a quarter, and slowly goes back to its steady state value. As a result, households have less of an incentive to work, and the labor supply decreases. Panel A and B show that the distorting effects of the labor tax dominates and, accordingly, consumption and output decline immediately by 0.3% and 0.2%, respectively, and start recovering from 2 quarters after the shock.

Figure 4: The Effects of a Negative Productivity Shock. *Notes*: This figure depicts impulse response functions of consumption, C_t, expected consumption growth, $\mathbb{E}_t[\Delta c_{t+1}]$, total output, Y_t^*, expected total output growth, $\mathbb{E}_t[\Delta y_{t+1}^*]$, labor hours, L_t, expected labor hours growth, $\mathbb{E}_t[\Delta l_{t+1}]$, R&D expenditure, S_t, and R&D expenditure growth, $\mathbb{E}_t[\Delta s_{t+1}]$ with respect to a negative one standard deviation shock to TFP, Λ_t (ε_t^{Λ}). Panels A, C, E, and G show log-deviations from the steady state in %, Panels B, D, F, and H show deviations from the steady state in %. Parameters are set as in Table 2.

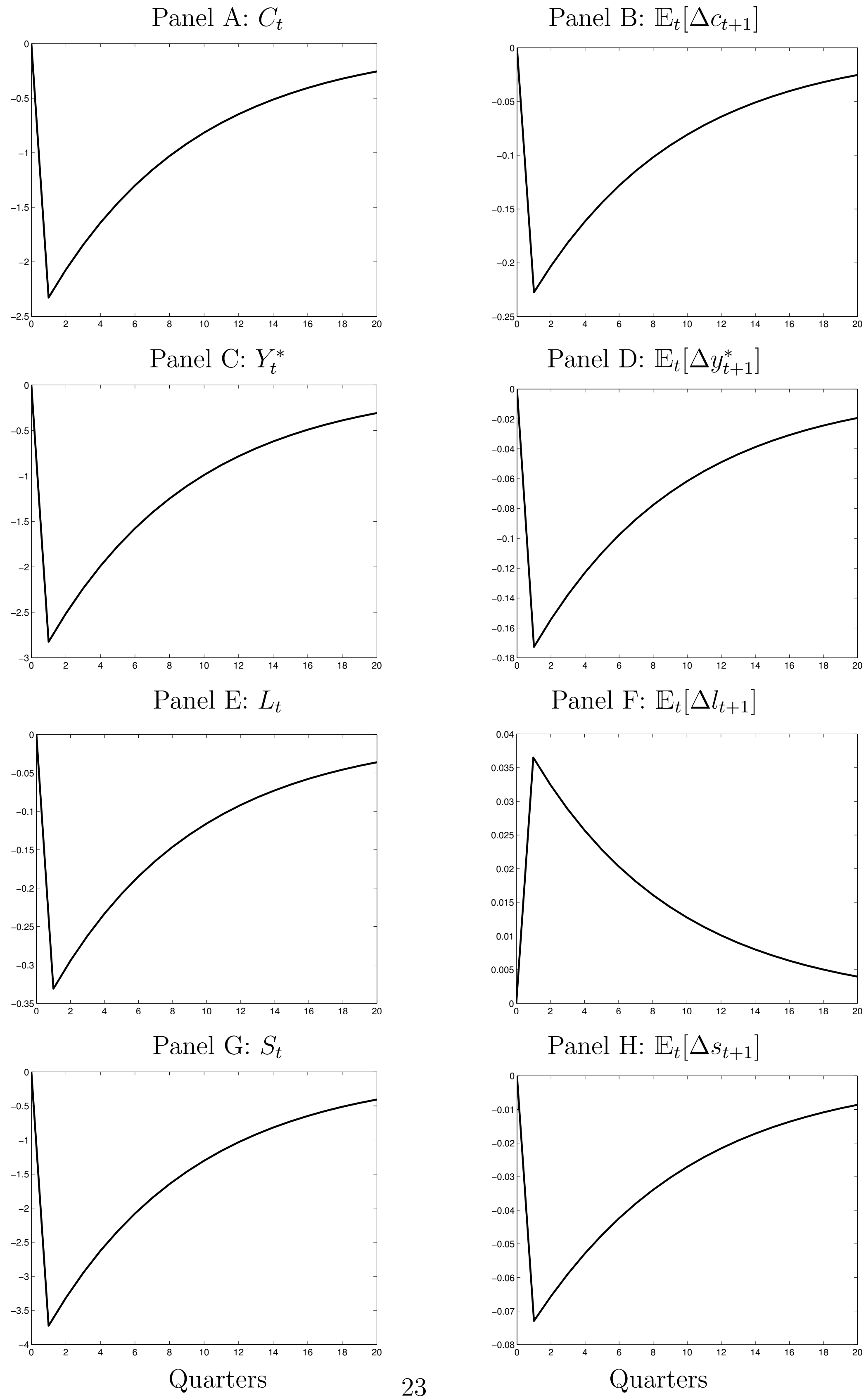
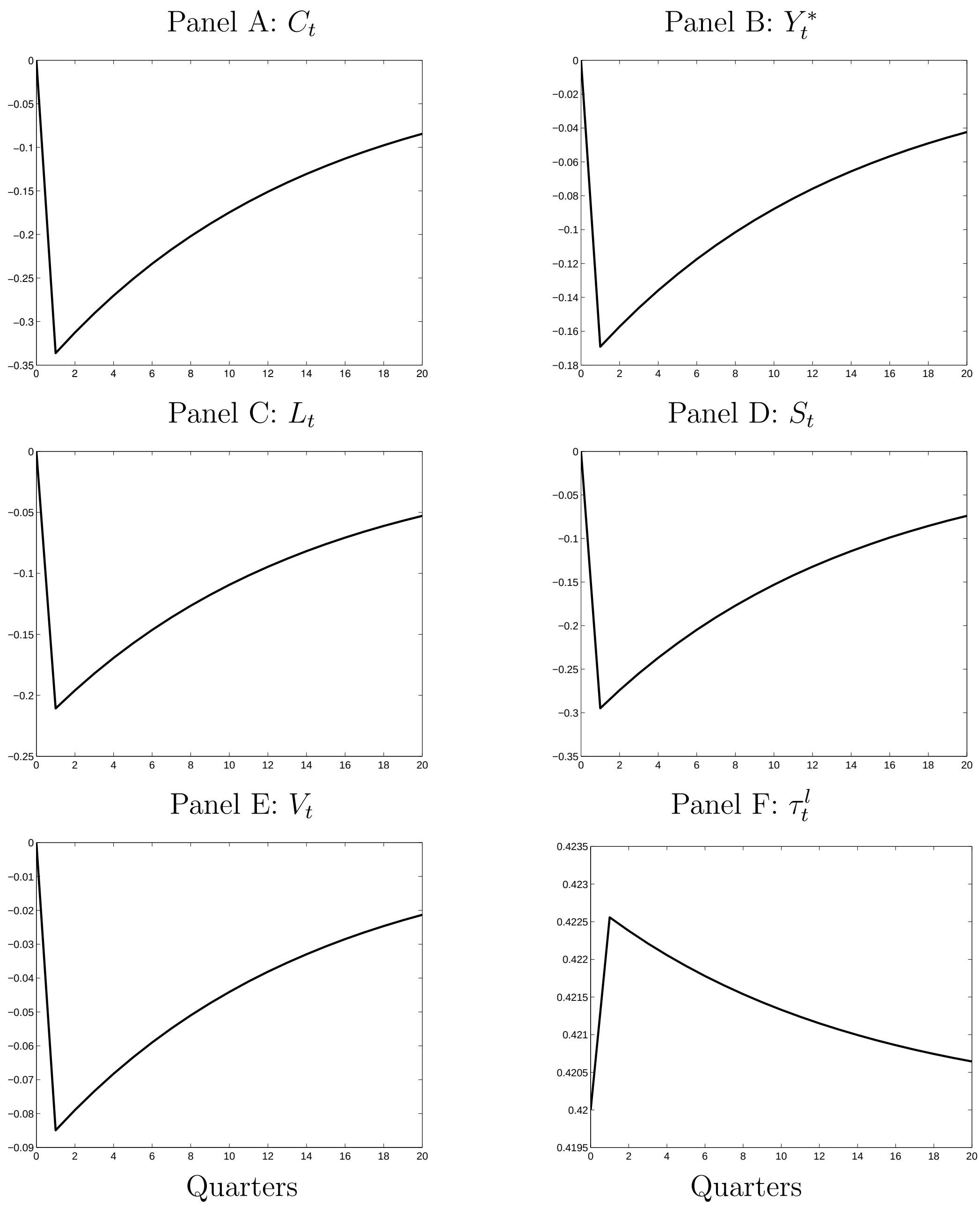
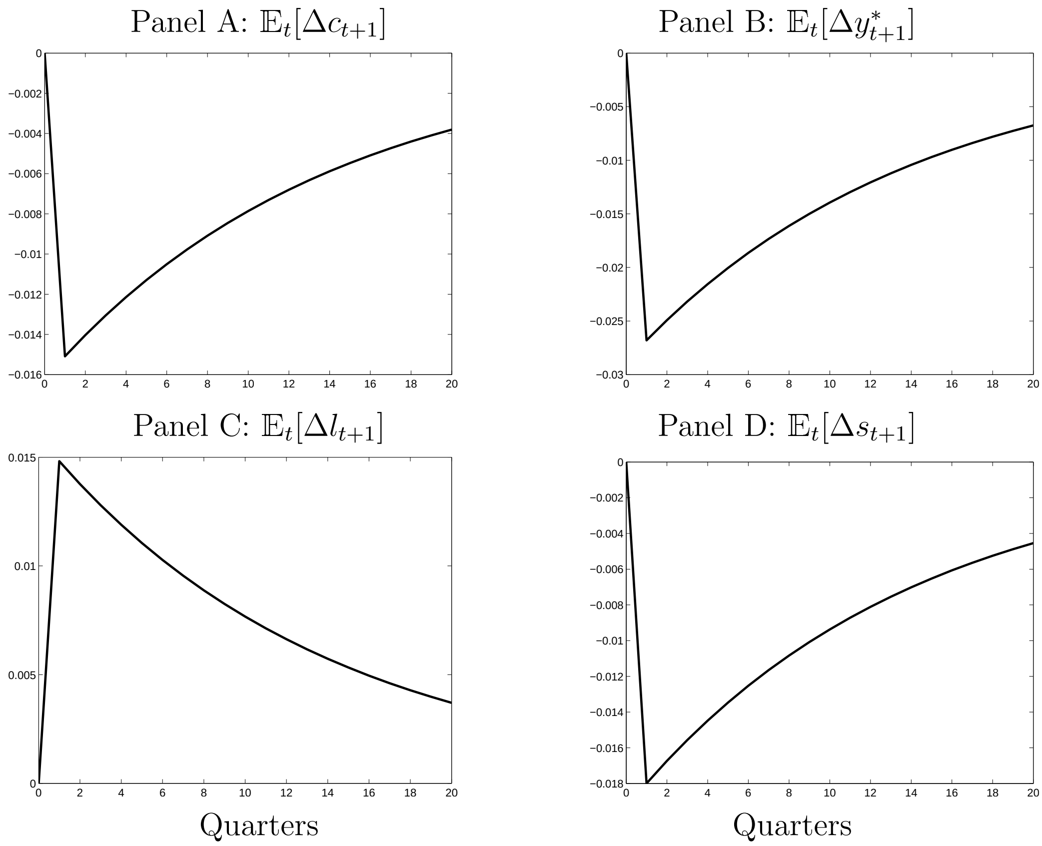


Figure 5: Macro Quantities: Positive Government Expenditure Shock. *Notes*: This figure depicts impulse response functions (measured as log-deviations from the steady state in %) of consumption C_t, total output Y_t^*, labor hours L_t, R&D expenditure S_t, patent value V_t, and labor tax rate τ_t^l with respect to a positive one standard deviation shock to government expenditures g_t (ε_t^g). Parameters are set as in Table 2.



The drop in consumption and output does not only reflect changes in the labor supply but also a decline in the rate of capital accumulation. After an increase in government expenditures, the zero-deficit rule implies a reduction of the resources allocated to the R&D sector and the value of new patents decline (Panel E). However, as public expenditure moves back toward their pre-shock level, the government can alleviate tax burden by decreasing τ_t^l. Consequently, households are willing to increase their labor supply (see Figure 6, Panel C) which stimulates long-term recovery.

Figure 6: Expected Growth Rates: Positive Government Expenditure Shock. *Notes*: This figure depicts impulse response functions (measured as deviations from the steady state in %) of expected consumption growth $\mathbb{E}_t[\Delta c_{t+1}]$, expected total output growth $\mathbb{E}_t[\Delta y^*_{t+1}]$, expected labor hours growth $\mathbb{E}_t[\Delta l_{t+1}]$, and expected R&D expenditure growth $\mathbb{E}_t[\Delta s_{t+1}]$ with respect to a positive one standard deviation shock to government expenditures g_t (ε_t^g). Parameters are set as in Table 2.



4.4 Unconditional Moments

Table 3 reports the unconditional moments of the model under the assumption that that fiscally weak countries in the EU are subject to a zero-deficit policy (as defined in Eq. 15). The model is calibrated to match the 2009 values of the government spending/output ratio, R&D subsidy rate, corporate tax and personal income tax rates in the GIPS countries. Moreover, the model reproduces the average consumption growth observed in the data as well as the volatility of both output growth and consumption growth. In addition, we obtain a good replication of well known macroeconomic stylized facts: (i) consumption is less volatile than output; (ii) R&D investment is much more volatile than output.

Concerning financial markets, the implied equity premium is about 1.56%. This number is lower than the average equity premium of GIPS countries (i.e., 4.70%) but is remarkably high especially if compared with standard consumption-based asset pricing models (see Mehra and Prescott [1985], Mehra [2003]). The model generates also a realistic risk-free rate but cannot reproduce the observed stock market volatility.[23]

4.5 Austerity and R&D Subsidies: Insights from GIPS countries

As discussed in Veugelers [2014] and suggested by our R&D spending trends in Figure 3, fiscally weak countries have cut their R&D spending in the last years. To estimate the macroeconomic implications of such a fiscal policy, we calibrate the shock to τ_t^r in order to replicate exactly the observed reductions in R&D subsidies of GIPS countries over the period 2009-2012. GIPS countries decreased the percentage of publicly financed BERD by 8.06%, 6.70% and 1.65% in 2010, 2011 and 2012, respectively. This sequence of observed R&D spending cuts can be replicated by the shock sequence $\epsilon_{2010}^{\nu} = -0.0922$, $\epsilon_{2011}^{\nu} = -0.0863$, $\epsilon_{2012}^{\nu} = -0.0370$. Other shocks are set to zero.

The model predicts that cuts in R&D expenditures reduce aggregate output by 1.2%. This value is slightly lower but still comparable with the reduction observed in the data

[23] Notice that the inclusion of fiscal volatility shocks in the spirit of Fernández-Villaverde et al. [2012] and risk for the long run as in Bansal and Yaron [2004]) would probably help to match the average equity premium and stock return volatility observed in the GIPS asset pricing data.

Table 3: Benchmark Calibration: Simulation Results. *Notes*: This table reports the results of simulating 3,000 economies for 75 years, i.e. 300 quarters, and then throwing away the first 10 years, by drawing sequences of normally distributed random numbers for all three shocks involved in the model. The reported moments are annualized. From the model simulations, we report the means and volatilities of output and consumption growth, of the risk-free rate, of the risk premium on the claim on consumption C_t and of the risk premium on the claim on aggregate dividends $D_{a,t} = Y_t^* - W_t L_t - A_t P Z_t + \Pi_t$. Aggregate dividends are defined as in Bilbiie et al. [2012]. The aggregate risk premium, $E[r_a^* - r_f]$, is levered following Boldrin et al. [2001]. Annualized empirical moments are represented by cross-country averages. Our sample includes the following fiscally weak EU countries: Greece, Italy, Portugal, and Spain (GIPS). The growth rate of R&D investments in each country, Δs, is represented by the Business Enterprise Expenditure on R&D (compound annual growth rate). Countries' equity returns are computed from "Share Price Indexes". The "EU18 Immediate interest rates, Call Money, Interbank Rate" is used as risk-free rate proxy. Macro and R&D data are from the OECD and run from 1981 to 2013. Asset pricing data are from the OECD and run from 1994 to 2013. Data on income and corporate tax rates are from KPMG. The government spending output ratio, G/Y^*, the R&D rate subsidy, τ^{rd}, and the income and corporate tax rates, τ^l and τ^π, rely on 2009 GIPS' values (i.e., pre-sovereign debt crisis). Additional details on the data are given in the Appendix.

	Model	Data (GIPS)
First Moments		
$E[\Delta y^*]$	1.71%	1.71%
$E[\Delta c]$	1.71%	1.89%
$E[r_f]$	2.11%	2.71%
$E[r_c - r_f]$	0.87%	-
$E[r_a^* - r_f]$	1.56%	4.70%
$E[G/Y^*]$	21.30%	21.30%
τ^π	27.85%	27.85%
$E[\tau^{rd}]$	9.72%	9.72%
$E[\tau^l]$	42.00%	42.00%
Second Moments		
$\sigma_{\Delta y^*}$	2.85%	2.25%
$\sigma_{\Delta c}$	2.40%	2.21%
$\sigma_{\Delta s}$	3.74%	6.62%
$\sigma_{\Delta c}/\sigma_{\Delta y^*}$	0.84	0.98
$\sigma_{\Delta s}/\sigma_{\Delta y^*}$	1.31	2.94
σ_{r_f}	0.49%	1.70%
$\sigma_{r_c - r_f}$	2.24%	-
$\sigma_{r_a^* - r_f}$	3.82%	24.73%

which is about 3%. The model also replicates the drop in labor supply observed during the same period. The unexpected drop in public expenditure reallocates resources from the investment sector to the consumption sector that, in turn, produces a counterfactual increase in current consumption which comes at the cost of a poor long-run economic performance. This suggests that the severe contraction in economy activity experienced by fiscally weak countries in the last years, is unlikely to be explained by R&D cuts only. However, our analysis shows that the zero-deficit rule in conjunction with R&D cuts may exacerbate the impact of adverse macroeconomic shocks (TFP shocks for instance) and undermine future economic growth.

To gain more insights on the long-run effects of observed R&D cuts we report the expected growth rates of macroeconomic variables in Figure 8. The expected growth rates of consumption and total output display a fall of around 0.5% in the first quarter. It is important to note that these effects are qualitatively similar to those generated by a negative TFP shock and by a positive government spending shock, but they differ quantitatively: the fall in $\mathbb{E}_t[\Delta y^*_{t+1}]$ produced by the observed sequence of shocks in the R&D subsidy rate is almost three times larger than the one produced by a standard aggregate productivity shock (see Figure 4, Panel D vs. Figure 8, Panel B).

As a final exercise, we quantify the expected loss in total output growth caused by restrictive R&D policies. Specifically, we compare the loss generated at 1, 5, 10 and 20 years horizon by a 5 standard deviation shock in τ^r_t with those generated by the observed sequence of falls in τ^r_t in the GIPS over the period 2009-2012. Entries in Table 4 confirm that innovation-specific policies may be crucial for promoting long-run growth. A fall in the R&D subsidy tax rate causes a consistent loss in expected output growth at both short and long horizons. It is worth noting that the sequence of reduction in publicly financed BERD implemented by the GIPS during the sovereign debt crisis produces a loss of 0.63% and 5.81% at 1 year and 20 years horizon, respectively. We stress that the produced loss, at 20-year horizon, is eight times larger than the one produced by the 5 standard deviation R&D subsidy rate shock.

Figure 7: Macro Quantities: Observed Shocks in R&D Subsidies in GIPS Countries 2009-2012. *Notes*: This figure depicts impulse response functions (measured as log-deviations from the steady state in %) of consumption C_t, total output Y_t^*, labor hours L_t, R&D expenditure S_t, patent value V_t, and R&D subsidy rate τ_t^r with respect to negative shocks to the R&D subsidy rate ν_t (ε_t^ν). The 2009 is assumed to the initial year where the economy is in the steady state (i.e., pre-sovereign debt crisis). Then, we use the shock sequence $\varepsilon_{2010}^\nu = -0.0922$, $\varepsilon_{2011}^\nu = -0.0863$, $\varepsilon_{2012}^\nu = -0.0370$ to match the empirically observed decrease in R&D subsidies in the GIPS countries from 9.72% to 8.94% in 2010, to 8.34% in 2011, and to 8.20% in 2012. Afterwards, there is mean reversion to the steady state subsidy rate. Parameters are set as in Table 2 except for the following restrictions: $\epsilon_t^\Lambda = 0$, $\epsilon_t^g = 0$.

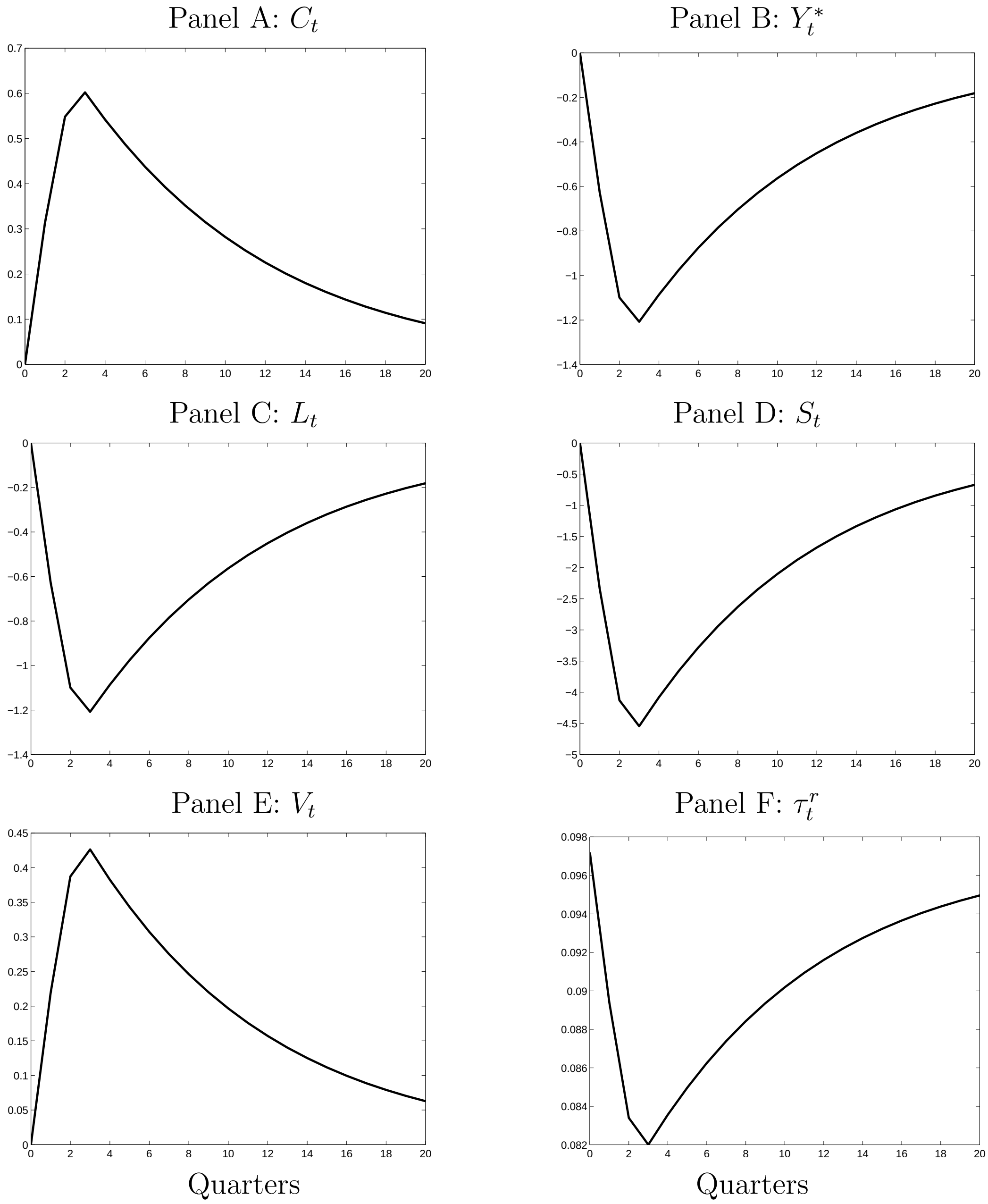


Figure 8: Expected Growth Rates: Observed Shocks in R&D Subsidies in GIPS Countries over the Period 2009-2012. *Notes*: This figure depicts impulse response functions (measured as deviations from the steady state in %) of expected consumption growth $\mathbb{E}_t[\Delta c_{t+1}]$, expected total output growth $\mathbb{E}_t[\Delta y^*_{t+1}]$, expected labor hours growth $\mathbb{E}_t[\Delta l_{t+1}]$, and expected R&D expenditure growth $\mathbb{E}_t[\Delta s_{t+1}]$ with respect to negative shocks to the R&D subsidy rate ν_t (ε^{ν}_t). The 2009 is assumed to the initial year where the economy is in the steady state (i.e., pre-sovereign debt crisis). Then, we use the shock sequence $\varepsilon^{\nu}_{2010} = -0.0922$, $\varepsilon^{\nu}_{2011} = -0.0863$, $\varepsilon^{\nu}_{2012} = -0.0370$ to match the empirically observed decrease in R&D subsidies in the GIPS countries from 9.72% to 8.94% in 2010, to 8.34% in 2011, and to 8.20% in 2012. Afterwards, there is mean reversion to the steady state subsidy rate. Parameter are set as in Table 2 except for the following restrictions: $\epsilon^{\Lambda}_t = 0$, $\epsilon^{g}_t = 0$.

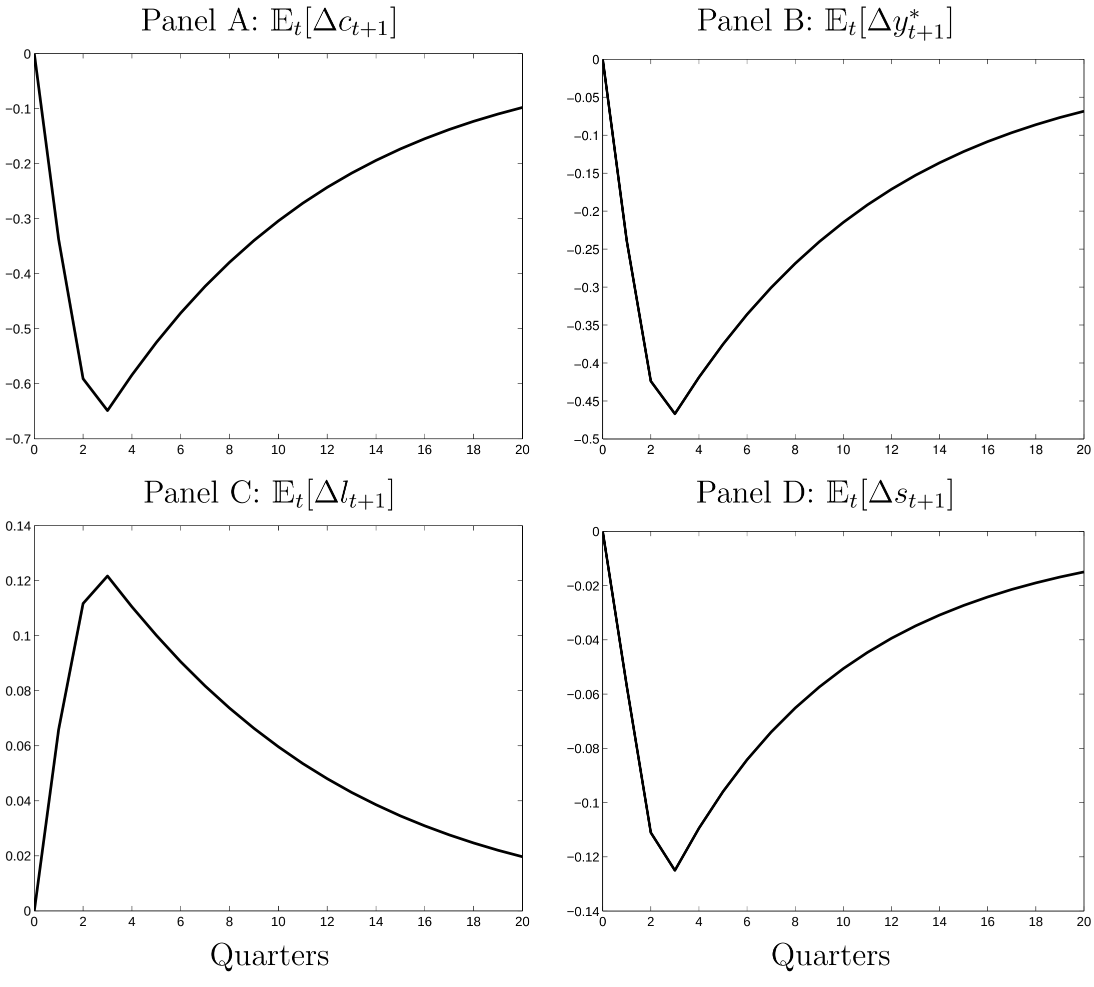


Table 4: The Long-run Effect of an Adverse R&D Policy. *Notes*: This table reports the reduction of growth over 1, 5, 10 and 20 years after negative shocks to the R&D subsidy rate. The compound growth in an economy with no shock occurring in 20 years is compared to the compound growth in an economy with a shock to the R&D subsidy rate τ_t^r in the initial year. Panel A reports the amount of lost output growth after a negative 5 standard deviation shock to the R&D subsidy rate, i.e. $\varepsilon_0^\nu = 0.025$ (this is equivalent to a decrease in the R&D subsidy rate τ_t^r from 9.72% to 9.50% in the initial year; afterwards the R&D subsidy rate reverts back to its long-run mean). Panel B reports the amount of lost output growth due to the empirically observed falls in the R&D subsidy rate in the GIPS countries, i.e. $\varepsilon_0^\nu = -0.0922$, $\varepsilon_1^\nu = -0.0863$, $\varepsilon_2^\nu = -0.0370$ (this is equivalent to a decrease in the R&D subsidy rate τ_t^r from 9.72% to 8.94% in the initial year, to 8.34% in the year afterwards, and to 8.20% in the following year; afterwards the R&D subsidy rate reverts back to its long-run mean).

Panel A:				
Difference in growth after a 5-σ shock to τ_t^r				
	1 Year	5 Years	10 Years	20 Years
$\Delta y_{t+j}^* - \Delta y^*$	-0.18%	-0.40%	-0.57%	-0.72%
Panel B:				
Difference in growth after empirically observed decrease of τ_t^r				
	1 Year	5 Years	10 Years	20 Years
$\Delta y_{t+j}^* - \Delta y^*$	-0.63%	-2.93%	-4.46%	-5.81%

5 Concluding Remarks

In this paper we propose a unified general equilibrium framework to jointly study the sharp increase in government expenditures in the aftermath of the Lehman default and the subsequent strengthening in austerity measures following the EU sovereign debt crisis. Our results suggest that austerity measures based on spending cuts in the R&D sector seriously harm economic growth of fiscally weak countries.

While this result is not surprising in light of standard economic growth theory, the behavior of fiscal authorities in European countries with relatively high debt/deficit levels (e.g. Greece, Italy, Portugal and Spain) which are currently implementing austerity measures by means of cuts in the R&D sector (i.e. adverse R&D expenditure shocks) might be questioned. In our view, this scenario casts doubts on their ability to gain a stable growth path in the next future.

Our analysis suggests that the best strategy for fiscal consolidation may differ across countries, depending on their fiscal robustness. Even if the idea of a fiscal consolidation should be anchored in credible medium term plans, and thus it is too early to draw conclusions, post-Lehman data tell us that austerity measures in fiscally weak countries are far from promoting economic growth. Indeed, we argue that implementing austerity measures by means of R&D cuts might have sizable adverse effects on current and future economic performance.

Overall, these results support the recent debate on the possibility to exclude public investments (R&D expenditures, investments in human capital or development of new technologies) from the country's total deficit.

Acknowledgements

We are grateful to comments from seminar participants at 2014 Frankfurt-Mannheim Macro Workshop, XXII Finance Forum, Macroeconomic Policy Institute (IMK) as well as Francesco Bianchi, Mariano Massimiliano Croce, Holger Kraft, Alex Ludwig, Marco Pagano, Lorenzo Prosperi, Christian Schlag, Lukas Schmid, Ctirad Slavík and Thomas Theobald for helpful discussions. We gratefully acknowledge financial support from the Research Center SAFE, funded by the State of Hessen initiative for research LOEWE. All remaining errors are our own.

References

Philippe Aghion and Peter Howitt. A model of growth through creative destruction. Econometrica, 60(2):323–351, March 1992.

Alberto Alesina and Silvia Ardagna. Large changes in fiscal policy: Taxes versus spending. NBER Working Paper n. 15438, October 2009.

Alberto Alesina and Roberto Perotti. Fiscal expansions and fiscal adjustments in oecd countries. Economic Policy, XXI:205–248, 1995.

Alberto Alesina and Roberto Perotti. Reducing budget deficits. Swedish Economic Policy Review, 3:13–34, 1996.

Laurence Ball, Davide Furceri, Daniel Leigh, and Prakash Loungani. The distributional effects of fiscal consolidation. IMF Working Paper No. 1518, 2013.

Ravi Bansal and Amir Yaron. Risks for the long run: A potential resolution of asset pricing puzzles. The Journal of Finance, 59:1481–1509, August 2004.

Gianluca Benigno, Pierpaolo Benigno, and Salvatore Nisticó. Risk, monetary policy and the exchange rate. NBER Working Paper 17133, June 2011.

Javier Bilbao-Ubillos and Ana-Isabel Fernàndez-Sainz. The impact of austerity policies in the eurozone: Fiscal multipliers and adjustment fatigue. Applied Economics Letters, 21:955–959, 2014.

Florin O. Bilbiie, Fabio Ghironi, and Marc J. Melitz. Endogenous entry, product variety and business cycles. Journal of Political Economy, 120(2):304–345, 2012.

Michele Boldrin, Lawrence J. Christiano, and Jonas D.M. Fisher. Habit Persistence, Asset Returns and the Business Cycle. American Economic Review, 91(1):149–166, March 2001.

Benjamin Born, Gernot Mller, and Johannes Pfeifer. Does austerity pay off? Working Paper, 2014.

Alexander L. Brown and Hwagyun Kim. Do individuals have preferences used in macro-finance models? an experimental investigation. Management Science, 60:939–958, 2014.

Dario Caldara, Jesús Fernández-Villaverde, Juan Rubio-Ramírez, and Wen Yao. Computing dsge models with recursive preferences and stochastic volatility. Review of Economic Dynamics, 15(2):188–206, 2012.

Riccardo Colacito and Mariano M. Croce. International asset pricing with recursive preferences. Journal of Finance, 68(6):2651–2686, 2013.

Diego Comin and Mark Gertler. Medium-term business cycles. American Economic Review, 96(3):523–551, June 2006.

Mariano M. Croce, Thien T. Nguyen, and Lukas Schmid. The market price of fiscal uncertainty. Journal of Monetary Economics, 59:401–416, 2012.

Mariano M. Croce, Thien T. Nguyen, and Lukas Schmid. Fiscal policy and the distribution of consumption risk. Working Paper, 2013.

Michael B. Devereux and James Yetman. Leverage constraints and the international transmission of shocks. Journal of Money, Credit and Banking, 42(1):71–105, September 2010.

H. Edison, R. Levine, L. Ricci, and T. Slok. International financial integration and economic growth. NBER Working Paper 9164, September 2002.

L. Epstein and S. Zin. Substitution, risk aversion, and the temporal behavior of consumption growth and asset returns i: A theoretical framework. Econometrica, 57(4): 937–969, 1989.

Jesús Fernández-Villaverde, Pablo Guerrón-Quintana, Keith Kuester, and Juan Rubio-Ramírez. Fiscal volatility shocks and economic activity. Federal Reserve Bank of Philadelphia, Working Paper No. 11-32/R, 2012.

Francesco Giavazzi and Marco Pagano. Can severe fiscal adjustments be expansionary? NBER Macroeconomics Annual 1990, 1990. Olivier Blanchard and Stanley Fischer, eds. (Cambridge, MA: MIT Press, 1990).

Rachel Griffith. How important is business r&d for economic growth and should the government subsidise it? The Institute for Fiscal Studies, 2000. Briefing Note No. 12.

Paul Krugman. How the case for austerity has crumbled. The New York Review of Books, June 2013.

Howard Kung and Lukas Schmid. Innovation, growth, and asset prices. Journal of Finance, 2015. Forthcoming.

Rajnish Mehra. The equity premium: Why is it a puzzle? Financial Analysts Journal, pages 54–69, 2003.

Rajnish Mehra and Edward Prescott. The equity premium: A puzzle. Journal of Monetary Economics, 15:145–161, 1985.

Roberto Pancrazi. How beneficial was the great moderation after all? Journal of Economic Dynamics and Control, 46:73–90, 2014.

Dimitris Papanikolaou. Investment shocks and asset prices. Journal of Political Economy, 119(4):639–685, 2011.

Roberto Perotti. Fiscal policy in good times and bad. Quarterly Journal of conomics, 114 (4):1399–1436, 1999.

Carmen M. Reinhart and Kenneth S. Rogoff. Growth in a time of debt. American Economic Review, 100(2):573–578, 2010.

Christina D. Romer and David H. Romer. The macroeconomic effects of tax changes: Estimates based on a new measure of fiscal shocks. American Economic Review, 100 (3):763–801, 2010.

Paul M. Romer. Endogenous technological change. Journal of Political Economy, 98(5): 71–102, 1990.

Ana Maria Santacreu. Innovation, diffusion, and trade: Theory and measurement. Working Paper, May 2014.

Christoph A. Schaltegger and Martin Weder. Austerity, inequality and politics. European Journal of Political Economy, 35(1):1–22, 2014.

Reinhilde Veugelers. Undercutting the future? european research spending in times of fiscal consolidation. Bruegel Policy Contribution 2014/06, June 2014.

Ben Westmore. R&d, patenting and growth: The role of public policy. OECD Working Paper No. 1047, May 2013.

Jaejoon Woo, Elva Bova, Tidiane Kinda, and Y. Sophia Zhang. Distributional consequences of fiscal consolidation and the role of fiscal policy: what do the data say? IMF Working Paper No. 195., 2013.

A Data

FIGURES 1-2, TABLE 1

- Fiscal Consolidation: Yearly Average Reduction in the General Government Overall Balance, measure as % of GDP (*Sample*: 2009-2013 and 2014-2018; *Source*: IMF Fiscal Monitor - IMF Staff Estimates and Projections (October 2013))
- Real Gross Domestic Product: Gross domestic product - constant prices (*Sample*: 2009-2013 and 2014-2018; *Source*: IMF)
- CR: S&P Country Ratings Report (*Source*: Thomson Reuters)

FIGURE 4

- PANEL (A): GDP Growth (*Sample*: 2005-2013: Source: OECD)
- PANEL (B): Gross Domestic Expenditure on R&D - GERD (*Measure*: % of GDP; *Sample*: 2005-2012: Source: OECD Main Science and Technology Indicators Database)
- PANEL (C): Business Enterprise Expenditure on R&D - BERD (*Measure*: % of GDP; *Sample*: 2005-2012: Source: OECD Main Science and Technology Indicators Database)
- PANEL (D): Government-financed GERD (*Measure*: percentage of GDP; *Sample*: 2005-2012: Source: OECD Main Science and Technology Indicators Database)
- PANEL (E): % of BERD financed by Government (*Sample*: 2008-2012; *Source*: IMF)

TABLE 3

- $\Delta y \rightarrow$ Gross domestic product - output approach (*Measure*: Growth rate; *Sample*: 1981-2013; *Source*: OECD)
- $\Delta c \rightarrow$ Final consumption expenditure (*Measure*: Growth rate; *Sample*: 1981-2013; *Source*: OECD)
- $\Delta s \rightarrow$ BERD growth (*Measure*: Growth rate; *Sample*: 1981-2012: Source: OECD Main Science and Technology Indicators Database)

- R_a $\rightarrow$ Country Share Prices, Index 2010=100 (*Sample*: 1994-2013; *Source*: Monthly Monetary and Financial Statistics, OECD)

- R_f $\rightarrow$ Euro area (18 countries) Immediate interest rates, Call Money, Interbank Rate (*Sample*: 1994-2013; *Source*: Monthly Monetary and Financial Statistics, OECD)

- G/Y $\rightarrow$ Gross Domestic Product / Financial Consumption Expenditure of General Government (*Measure*: Current Prices; *Sample*: 1981-2013; *Source*: OECD)

- τ^{rd} $\rightarrow$ % of BERD financed by Government (*Sample*: 2006-2014; *Source*: OECD Main Science and Technology Indicators Database)

- τ^{l} $\rightarrow$ Individual Income Tax Rates (*Sample*: 2006-2014; *Source*: KPMG)

- τ^{π} $\rightarrow$ Corporate Tax Rates (*Sample*: 2006-2014; *Source*: KPMG)

Recent Issues

No. 55	Jan Pieter Krahnen, Peter Ockenfels, Christian Wilde	**Measuring Ambiguity Aversion: A Systematic Experimental Approach**
No. 54	Sascha Baghestanian, Todd B. Walker	**Anchoring in Experimental Asset Markets**
No. 53	Holger Kraft, Claus Munk, Frank Thomas Seifried, Morgens Steffensen	**Consumption and Wage Humps in a Life-Cycle Model with Education**
No. 52	Holger Kraft, Thomas Seiferling, Frank Thomas Seifried	**Asset Pricing and Consumption-Portfolio Choice with Recursive Utility and Unspanned Risk**
No. 51	Yacine Aït-Sahalia, Roger J. A. Laeven, Loriana Pelizzon	**Mutual Excitation in Eurozone Sovereign CDS**
No. 50	Ignazio Angeloni, Ester Faia, Roland Winkler	**Exit Strategies**
No. 49	Gabriele Camera, Marco Casari, Stefania Bortolotti	**An Experiment on Retail Payments Systems**
No. 48	Marcel Bluhm, Jan Pieter Krahnen	**Systemic Risk in an Interconnected Banking System with Endogenous Asset Markets**
No. 47	Michael Kosfeld, Ulrich Schüwer	**Add-On Pricing in Retail Financial Markets and the Fallacies of Consumer Education**
No. 46	Marcel Bluhm, Ester Faia, Jan Pieter Krahnen	**Monetary Policy Implementation in an Interbank Network: Effects on Systemic Risk**
No. 45	Fabio Castiglionesi, Fabio Ferozzi, Gyongyi Loranth, Loriana Pelizzon	**Liquidity Coinsurance and Bank Capital**
No. 44	Lorenz S. Schendel	**Critical Illness Insurance in Life Cycle Portfolio Problems**
No. 43	Lorenz S. Schendel	**Consumption-Investment Problems with Stochastic Mortality Risk**
No. 42	Reint Gropp, John Krainer, Elizabeth Laderman	**Did Consumers Want Less Debt? Consumer Credit Demand versus Supply in the Wake of the 2008-2009 Financial Crisis**