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Austerity, Fiscal Volatility, and Economic Growth

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Non-Technical Summary

The persistence of the European sovereign debt crisis since early 2009 has induced all European Union (EU) members to tie themselves with stricter fiscal discipline. Among other measures imposed by the Stability Growth Pact (SGP), some EU members are obliged 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 (i.e. austerity) on long-term growth remains controversial. Some policymakers and economists argue in favor of austerity saying that it might promote both short- and long-run growth. Some argue against by saying that austerity may come at the cost of lower long-run growth.

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, data tell us that austerity measures in countries facing high levels of fiscal deficit, debt and labor taxes did not pay off (in terms of real economic growth).

In such a scenario, these countries might be forced to implement adverse policies, among others, on productive sectors as well (e.g. R&D).

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 European fiscal discipline above mentioned, we assume that public expenditure is hinged on a zero-deficit target and is financed only by taxes, both on labor income and R&D. Letting the government combine different tax sources captures the idea that, although the budget targets are fixed and publicly observed, future fiscal policies remain uncertain. We introduce policy uncertainty by means of a fiscal volatility shock on public expenditure, which in turn determines uncertainty on R&D expenditure. Fiscal volatility shocks generate imbalances of output, consumption and labor hours. In this setup, we study the impact on such variables in the case of both (i) a deterministic R&D tax rate chosen by an ex-ante fiscal policy and (ii) a stochastic R&D tax rate, positively correlated to public spending shocks.

Our analysis shows that uncertainty on future government expenditure undermines households' confidence. In response to a fiscal volatility shock, households increase current labor supply at the expense of current consumption.

Of course, this increases current government revenues coming from labor income taxation. However, because of the strong fiscal consolidation regime, this comes at the cost of a negative long-run growth.

To finance public spending our fiscal authority, due to the zero-deficit target, may be induced to increase taxation in the R&D sector.

If they do so, a significantly worse contraction in the expected growth rate of consumption, output, labor and R&D investments takes place.

Moreover, upon the realization of a positive shock to the stochastic R&D tax rate, both current and expected R&D investment decrease. This, of course, produces a stronger contraction on the long-term prospects of the economy.

Here, uncertainty is simultaneously transmitted through both public expenditure and the R&D tax rate, and households anticipate government's actions by allocating capital in risk-free assets (i.e. increase savings). This mechanism increases the equity returns and decreases the risk free rate as compared to an economy with deterministic tax rates. As a result, fiscal uncertainty commands a premium, of about 2%, over deterministic tax rates.

Our findings 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 (R&D sector), a positive expenditure shock may shrink future consumption and output growth more than it would happen in absence of co-movements between fiscal volatility and R&D taxation.

Austerity, Fiscal Volatility, and Economic Growth

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Abstract

This paper contributes to the ongoing debate on the relationship between austerity measures and economic growth. We propose a general equilibrium model where (i) agents have recursive preferences; (ii) economic growth is endogenously driven by investments in R&D; (iii) the government is committed to a zero-deficit policy and finances public expenditures by means of a combination of labor taxes and R&D taxes. We find that austerity measures that rely on reducing resources available to the R&D sector depress economic growth both in the short- and long-run. High debt EU members are currently implementing austerity measures based on higher taxes and/or lower investments in the R&D sector. This casts some doubts on the real ability of these countries to grow over the next years.

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

JEL Codes: G12, G15

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1 Introduction

“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)

The severity of the recent European sovereign debt crisis has induced European Union (EU) members to sign a new treaty, namely “Fiscal Compact”, with the purpose of strengthening countries’ creditworthiness, previously established in the Stability and Growth Pact (SGP).¹ The aim of the SGP was to steer the fiscal discipline of each EU member according to the following well-known deficit and debt criteria (medium-term budgetary objective): (i) annual deficit-to-GDP ratio of 3%, and (ii) total public debt below 60% of the GDP, or else sufficiently decreasing towards the 60% each year. However, the absence of enforcement mechanisms in the SGP has not led to fiscal compliance of the member states of the EMU to the SGP debt and deficit targets. Accordingly, European policymakers have put forward that such a failure of the SGP budget criteria across EU countries has been one of the reasons of the spread of the sovereign debt crisis in the Euro-zone.²

With the specific purpose to reduce the macroeconomic imbalances, EU countries have tied themselves with a more rigorous “balanced budget rule” by introducing “automatic mechanism to take corrective actions” if significant deviations from the medium-term objectives are observed.³ The new fiscal discipline adopted in the Fiscal Compact,⁴ which reaffirms the budget criteria fixed in the SGP, establishes also for each member state a limit of a structural deficit of 0.5% of GDP at market prices and the obligation to incorporate the new budget rule (also known as “golden rule”) in the domestic legal system by means of a constitutional law or an ordinary law.⁵

¹Officially, 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.

²See *A Blueprint for a Deep and genuine EMU*, European Commission, November 2012.

³See the *Treaty on Stability, Coordination and Governance in the Economic and Monetary Union*.

⁴This includes the so-called “Six-pack” and “Two-pack” measures. We acknowledge that the Six-pack entered into force in December 2011.

⁵For member states with a debt-to-GDP ratio significantly below 60% the deficit-to-GDP ratio has to be equal to 1.0%.

Such stringent rules have induced fiscally weak EU members to strongly increase taxes and cut public spending. We refer to the implementation of these actions as “adverse fiscal policy”.

To study the equilibrium effects of “adverse fiscal policy”, we present a production economy in which (i) growth is endogenously driven by firms’ incentives to innovate (as in Romer (1990); Croce, Nguyen, and Schmid (2013); Kung and Schmid (2014)), (ii) agents have recursive preferences, and (iii) a regime of fiscal consolidation is exogenously imposed by means of R&D taxes. To be consistent with the new European fiscal discipline, we assume that public expenditure is hinged on a zero-deficit target and is financed only by taxes, both on labor income and R&D investments.⁶ Letting fiscal authorities combine different tax sources captures the idea that, although the budget targets are fixed and publicly observed, future fiscal policies might remain uncertain. We account for policy uncertainty by introducing fiscal volatility shock on public expenditure,⁷ which in turn determines uncertainty on R&D expenditure. Upon the realization of a fiscal volatility shock, imbalances on output, output growth, and other macroeconomic aggregates take place. In this setup, we study the impact on such variables in the case of both (i) a deterministic R&D tax rate chosen by an ex-ante fiscal policy and (ii) a stochastic R&D tax rate, positively correlated to public spending.

Our analysis shows that uncertainty on future government expenditure undermines households’ confidence. In response to a fiscal volatility shock, households – which are averse to both consumption and utility risk in our model – increase current labor supply at the expense of current consumption. Of course, this increases current government revenues coming from labor income taxation. However, because of the strong fiscal consolidation regime, this comes at the cost of a negative long-run growth. To finance public spending our fiscal authority, due to the zero-deficit target, may be induced to increase taxation in the R&D sector. If they do so, a significantly worse contraction in the expected growth rate of consumption, output, labor and R&D investments takes place. Moreover, upon the

⁶In our setting, only labor income taxes are endogenously determined. Therefore, both government expenditure and innovation sector taxes are exogenous.

⁷See for instance Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012).

realization of a positive shock to the stochastic R&D tax rate, both current and expected R&D investment decrease. This, of course, produces a stronger contraction on the long-term prospects of the economy. Here, uncertainty is simultaneously transmitted through both public expenditure and the R&D tax rate, and households anticipate government's actions by allocating capital in risk-free assets (i.e. increase savings). This mechanism increases the equity returns and decreases the risk free rate as compared to an economy with deterministic tax rates. As a result, fiscal uncertainty commands a premium, of about 2%, over deterministic tax rates. Our findings 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 (R&D sector), a positive expenditure shock may shrink future consumption and output growth more than it would happen in absence of co-movements between fiscal volatility and R&D taxation.

Our paper adds to the growing body of literature studying the effects of fiscal uncertainty and different government policies on growth and asset prices. Croce, Nguyen, and Schmid (2012) and Croce, Nguyen, and Schmid (2013) find that countercyclical deficit policies aimed at short-run stabilization reduce the price of model uncertainty and increase growth risk resulting in lower average growth rates and welfare, respectively. Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012) show that fiscal volatility shocks have sizable adverse effects on economic activity. Empirically, the effects of fiscal stimuli (i.e. government expenditure shocks) depend on the economic characteristics of the country as laid out in Ilzetzki, Mendoza, and Végh (2013). Furthermore, our paper relates to the endogenous growth literature with expanding varieties as introduced by the seminal work of Romer (1990) and used to study asset prices by Kung and Schmid (2014).

The ongoing debate on austerity measures and growth remains controversial. Some policymakers 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 will reduce output

in both the short-run and the long-run (Romer and Romer (2010), Bilbao-Ubillos and Fernández-Sainz (2014)) as well as increase poverty and income inequality (Ball, Furceri, Leigh, and Loungani (2013); Schaltegger and Weder (2014); Woo, Bova, Kinda, and Zhang (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.

Both fiscal consolidation and economic policy uncertainty are still at the top of the policy agenda, especially across European authorities. However, there is a relatively high degree of heterogeneity in the level of fiscal stabilization urgency across countries showing different debt structures. High-debt/deficit European economies seem to suffer from such a strict fiscal consolidation long-term plan. In particular, countries showing relatively high debt- and deficit-to-GDP ratios and high labor income tax ratios seem to be forced to adjust fiscal balances through cuts on government expenditure or “exotic taxes” (see IMF Fiscal Monitor (2013) and European Commission Annual Growth Survey (2013)). In this scenario, countries might be forced to impose also spending cuts (or special taxes) in highly productive sectors, such as R&D (see Veugelers (2014)). This might affect private investments in R&D as well (see Westmore (2013)). Consequently, the potential for technological spillovers decreases, thus, reducing aggregate productivity growth.

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 these countries are far from promoting economic growth. Can European fiscal authorities tax more fairly? The answer seems to be in the affirmative. However, when countries face high debt/deficit, they already display relatively high corporate and labor income taxes and are less competitive in terms of good prices, a tightening policy may come at the cost of current and expected economic growth.

The rest of the paper is organized as follows. In the next session we report some empirical facts in times of fiscal consolidation. We present our production economy and calibration strategy in in section 3, and discuss the quantitative results in sections 4 and 5. Section 6 concludes.

2 Motivating facts

We present some empirical evidence that supports our contention that an unusual set of fiscal policy actions (i.e. fiscal volatility shock plus strong fiscal consolidation) may be an important component for the current European economic slowdown, and in particular, for the low economic performance of Mediterranean countries (i.e. *PIGS*), as well as for expected European economic growth. First, we report evidence on the presence of an unprecedented fiscal policy scenario (see also (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez, 2012)). Second, we examine the austerity-growth relationship in an ex-post (i.e. 2009-2013) and ex-ante (2014-2018) framework. Last, we compare changes in the total amount of government spending in R&D and gross domestic expenditure in R&D with real economic growth in European countries over the last five years, a period including the Lehman Chapter 11 and the European Sovereign Debt Crisis.

I. AN UNPRECEDENTED FISCAL POLICY SCENARIO

Figure 1 plots the dynamics of the government expenditure-output ratio, G/Y , across European countries over the last two decades. Approximately, we rely on countries showing high-debt/deficit levels (e.g. Italy, Portugal, Spain “*PIS*”) and on countries showing non-high-debt/deficit levels (*GERMANY* and *GERMANY(+)*).⁸ The G/Y patterns confirm the presence of an unusual policymakers behavior in the aftermath of the Lehman collapse (see also Baker, Bloom, and Davis (2013), Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012)). In particular, they suggest that policymakers in all European countries heavily increased government expenditure in the first quarter of 2009 to limit the adverse macroeconomic effects of the Lehman Chapter 11 (2009:1Q). However, after this fiscal volatility shock policymakers in low-debt/deficit (e.g. Finland, Germany, Netherlands, Norway) and high-debt/deficit (e.g. Greece, Italy, Spain, Portugal) countries behaved slightly differently. In fact, over the period 2009:2Q-2012:4Q, cuts in public expenditures of high-debt/deficit countries were significantly higher than in low-debt/deficit countries (i.e. -2.72 (*PIS*) vs. -0.87 (*GERMANY*) and 0.07 (*GERMANY(+)*), on an an-

⁸*GERMANY(+)* includes Belgium, Denmark, Finland, Germany, Netherlands, Norway, Sweden.

nual basis)). This provides evidence for the presence of high-debt/deficit level countries' commitment to reduce fiscal deficit (i.e. austerity), as required by the fiscal compact.

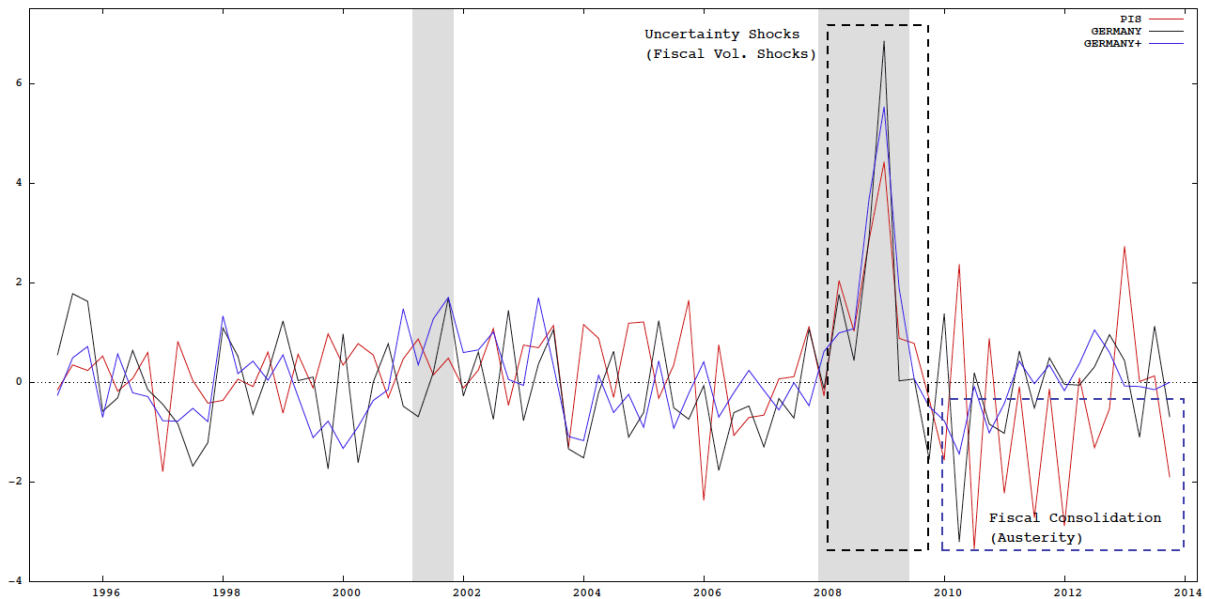


Figure 1: FISCAL POLICY MEASURES DYNAMICS (MOTIVATING FACT I): *Notes:* This figure reports the dynamics of the rate of change of G/Y . G and Y represent **general government final consumption expenditure** and **gross domestic product**, respectively. PIS includes Portugal, Italy and Spain. $GERMANY(+)$ includes Belgium, Denmark, Finland, Germany, Netherlands, Norway, Sweden. Both the G and Y series are from the OECD database. Shaded areas denote NBER-dated recessions. Additional details on the data are given in the appendix.

II. AUSTERITY VS. GROWTH

Is austerity good for economic growth? Does it represent the best remedy? According to ex-post IMF data austerity did not actually work. This is clear from Figure 2 which plots austerity measures (on the horizontal axis) against countries' economic performance (on the vertical). Austerity is measured as the sum of tax increases and government spending cuts (as a percentage of GDP). The real GDP growth proxies countries' economic performance. Both macroeconomic aggregates are averaged over the period 2009-2013 and are taken from the IMF. Our simple scatter plot suggest that highly indebted European countries that simultaneously increased taxes and decreased public spending in order to reduce fiscal deficit (as required by the fiscal compact) also display relatively low real output growth. For example, Greece reduced its fiscal deficit (as share of GDP) by 3 percentage point and displays an average real GDP growth of (roughly) -5%. Similarly, Spain and Portugal reduced their deficit by more than 1 percentage point, and ended up

with output growth of -2%. Overall, this simple analysis suggests that austerity has the unpleasant effect of reducing GDP growth (see also Bilbao-Ubillos and Fernández-Sainz (2014)). We confirm the evidence in Figure 2 using a simple regression analysis, where

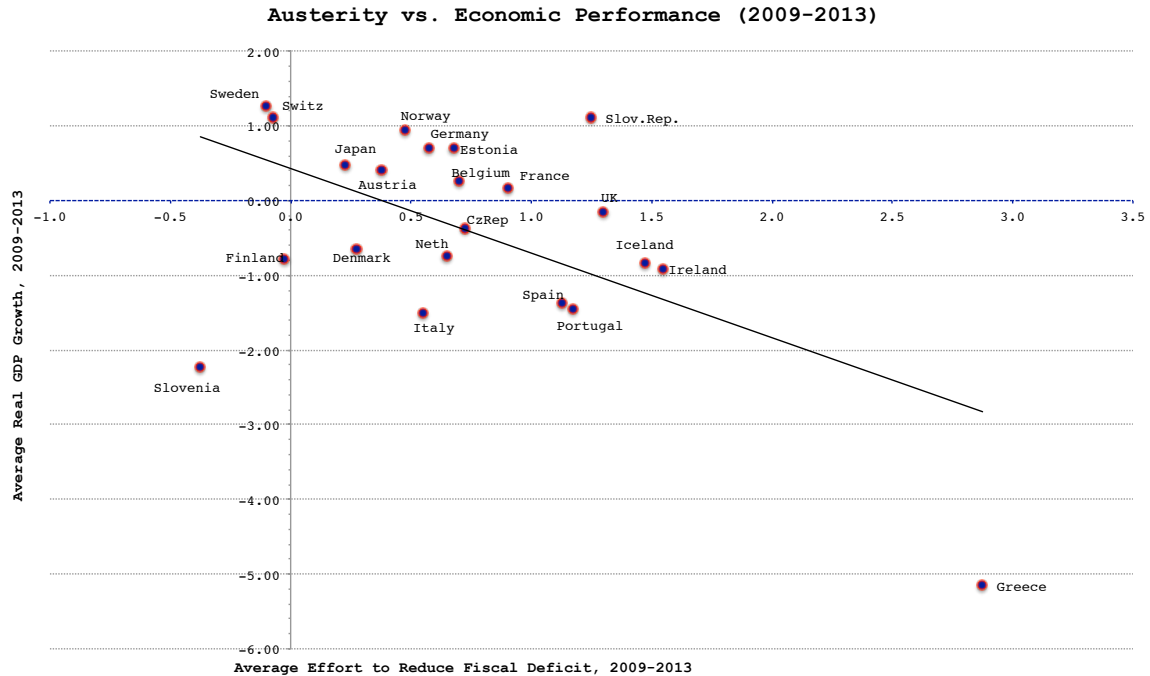


Figure 2: AUSTERITY VS. GROWTH: EVIDENCE FROM EUROPEAN COUNTRIES, 2009-2013 (MOTIVATING FACT II). *Notes:* This figure plots austerity against real GDP growth. Austerity is measured as the average reduction in fiscal deficit (as % of GDP) over the period 2009-2013. Fiscal balance and output data are from the IMF. Additional details on the data are given in the appendix.

countries' real GDP growth is regressed over austerity (A). As in Edison, Levine, Ricci, and Slok (2002), in order to have one observation per country (i.e. pure cross-sectional analysis) data are averaged over the period 2009-2013. Results are reported in Table 1, and provide strong support for our argument that austerity is a significant causal factor in the amplification of the EU sovereign debt crisis. Therefore, as informally suggested by Figure 2, austerity negatively affects economic growth. As a robustness check, we interact our austerity measure with the sovereign credit rating of the economy in 2013 (CR), to capture the idea that austerity is likely to affect more countries with lower creditworthiness (i.e. countries facing serious public finance issues). Based on the S&P sovereign foreign currency credit rating in 2013, 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)).⁹ We obtain similar statistics, i.e. our measure of austerity is statistically significant. In addition, the relatively high adjusted R^2 is supportive of austerity, playing an important role in explaining the European economic downturn. In summary, this evidence suggests that an austerity approach is important for the amplification of the negative economic shocks. The birth of this fiscal policy strategy is due to the over-indebted and unstable nature of

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

Table 1: AUSTERITY VS. ECONOMIC PERFORMANCE (2009-2013). *Notes:* The dependent variable is represented by the 2009-2013 average real GDP growth rate. A denotes austerity and is represented 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-. Robust 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.

sovereign debts, which increases interest rates and inhibit growth. Supportive examples are austerity programs implemented by the IMF in emerging markets and Germany's post-Berlin Wall adjustment. The hope is that countries with high levels of debt and deficit can contain their excessive spending enough to restore credibility. In doing so, they will bring down interest rates and promote economic growth. Based on this premise, the IMF estimates that such austerity will bring all European countries to positive real economic growth. This is clear from Figure 3, which plots the average reduction in fiscal deficit against the real GDP growth over the period 2014-2018 (Source: IMF Fiscal Monitor). Based on these estimates, no country will display negative economic growth. For example, Greece is expected to growth (in real terms) by more than 2.5% (on average).

On the one hand, IMF estimates might proxy existing empirical evidence (Giavazzi and Pagano (1990), Alesina and Perotti (1995), Alesina and Perotti (1996), among others) suggesting that large fiscal deficit cuts might be followed by an increase in private con-

⁹Our sample includes the following OECD countries: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Slov. Republic, Slovenia, Spain, Sweden, Switz, United Kingdom.

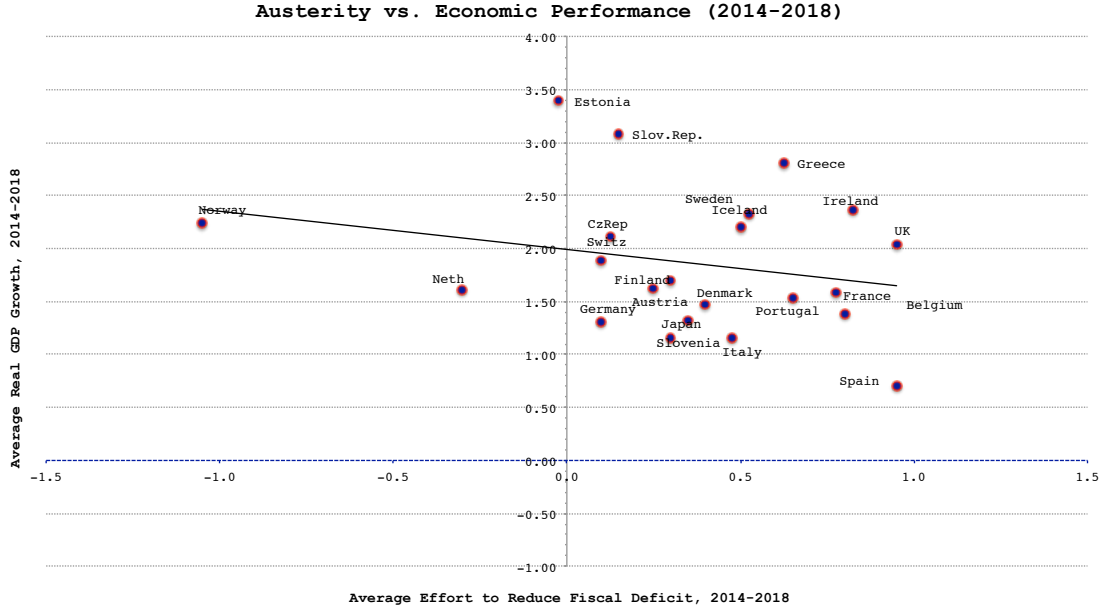


Figure 3: AUSTERITY VS. GROWTH: EVIDENCE FROM EUROPEAN COUNTRIES (2014–2018)^E. *Notes:* This figure plots austerity against real GDP growth. Austerity is measured as the average reduction in fiscal deficit (as % of GDP) over the period 2014-2018. Fiscal balance and output data estimates are from the IMF. Additional details on the data are given in the appendix.

sumption. 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 increased (cumulatively) by 17.7% and 14.5%. Alesina and Perotti (1996) identify similar episodes in Belgium (1984-1987), Italy (1989-1992), Portugal (1984-1986) and Sweden (1983-1989). However, Perotti (1999) observes that fiscal policy shocks might have both positive and negative effects on private consumption. The author shows that this is related to the state of the economy (i.e. good vs. bad times). On the other hand, our simple analysis along with other existing post-Lehman empirical findings cast doubts on these estimates (see also Krugman (2013), Bilbao-Ubillos and Fernández-Sainz (2014)). We stress that, in addition to a negative average real GDP growth, most high fiscal consolidation countries exhibit a negative private consumption growth rate. For example, the PIGS private consumption growth rate over the period 2009-2012 is equal to -2.87%. This has clearly affected the EU private consumption which displays also a negative growth rate (i.e. -0.32%). This scenario is in line with the one depicted by Bilbao-Ubillos and Fernández-Sainz (2014) who argue that the impact of austerity measures within fiscally weak EU members has shrunk economic activity more

than expected.

III. R&D EXPENDITURE VS. GROWTH IN TIMES OF FISCAL CONSOLIDATION

As a consequence of tightening fiscal measures, fiscally weak and innovation-lagging EU economies (i.e. high fiscal consolidation countries) largely cut their R&D expenditure along with all the other public expenses (see also Veugelers (2014)). Differently, fiscally stronger and innovation-leading countries (i.e. low fiscal consolidation countries) continued to sustain public R&D spending. For example, as of 2011, Italy, Portugal and Spain, decreased the percentage of output devoted to R&D by -1.03%, -6.02% and -4.09%, respectively (source: World Economic Indicators). In contrast, most low fiscal consolidation countries (e.g. Belgium, Denmark, Germany and Netherlands) increased the R&D spending (as % of GDP).¹⁰ However, as suggested by both theoretical and empirical studies (Aghion and Howitt (1992); Griffith (2000); Westmore (2013)), public and private R&D investments as well 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. Can a drastic cut in R&D be beneficial? Apparently not. Figure 4 informally shows that high fiscal consolidation countries (i) drastically cut total R&D government expenditure (Panel a); (ii) exhibit a lower gross domestic expenditure on R&D (Panel b) and (iii) display a negative real GDP growth (Panel c), in the aftermath of the Lehman Chapter 11. A fair question to ask is the following: What are the effects of such R&D spending trends on long-term growth?

3 A framework to assess the impact of austerity

We develop a theoretical framework which allows to study a world characterized by an unprecedented fiscal consolidation. In our world, the government is committed to a zero deficit policy and finances public expenditures with a mix of labor and R&D taxes. We explicitly assume that labor taxation is already so high that R&D taxation is the only way

¹⁰See Veugelers (2014) for a more detailed analysis on R&D spending trends in low- and high-fiscal consolidation countries during the post-Lehman era.

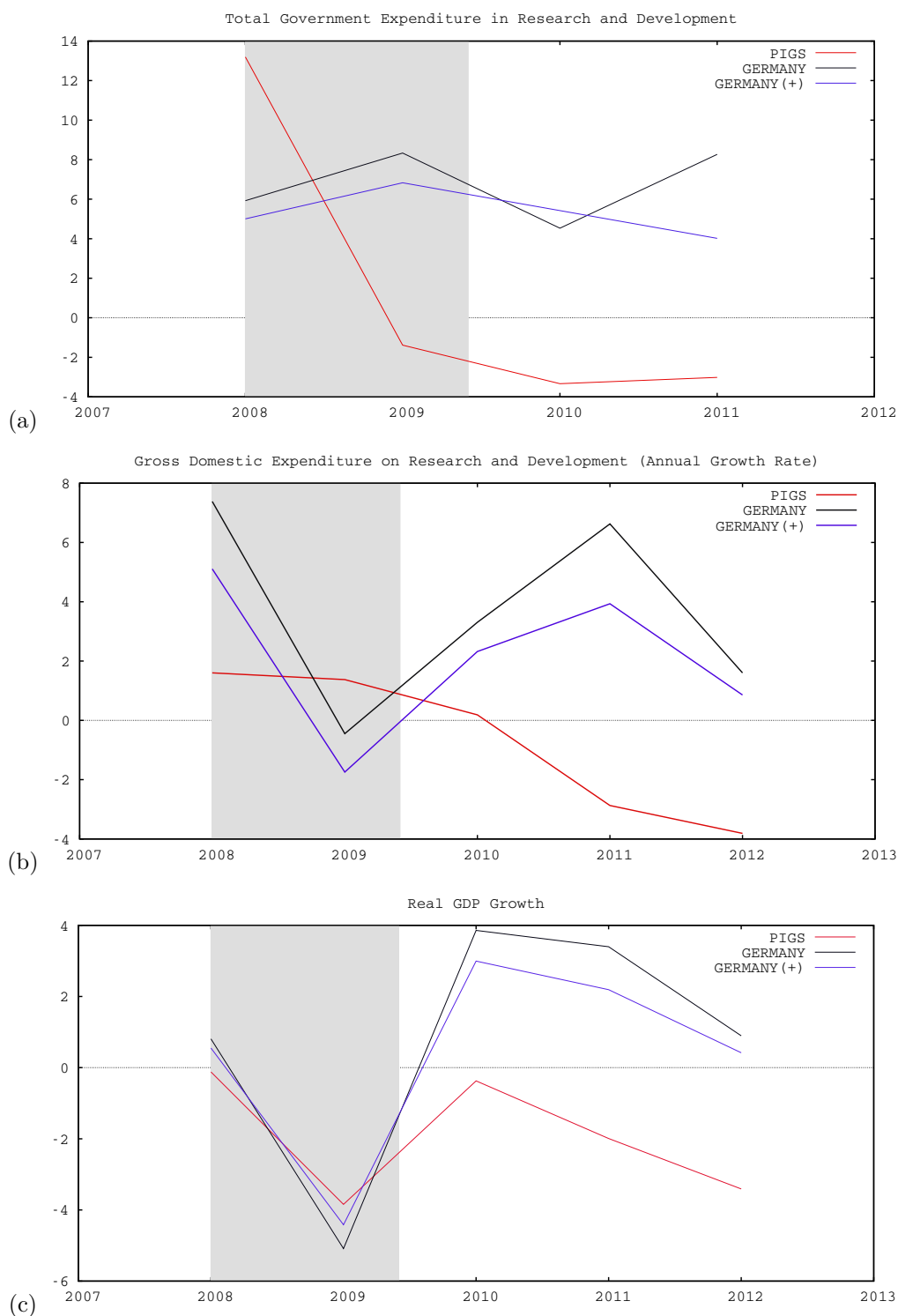


Figure 4: R&D vs. ECONOMIC GROWTH IN EUROPE: POST-SUBPRIME CRISIS (MOTIVATING FACT III). *Notes:* Panel (a) reports the rate of growth of the total government expenditure in R&D. Panel (b) reports the annual compound growth of gross expenditure on R&D. Panel (c) reports the real GDP growth. *PIGS* includes Portugal, Italy, Greece and Spain. *GERMANY(+)* includes Belgium, Finland, Germany, Netherlands, Norway, Sweden. The shaded areas represent periods dated as recessions by the NBER. Details on data sources are given in the Appendix.

to raise money when bad times occur. This is equivalent to assuming that the economy is already at the peak of the labor Laffer curve and that further labor tax increases have adverse effects on fiscal revenue. Mendoza, Tesar, and Zhang (2014) show that this is indeed the case for European countries subject to large shocks on public debt and/or with high labor taxes. We emphasize that this tax rule is consistent with the way high fiscal consolidation countries in Europe are currently implementing austerity measures.¹¹

Our theoretical framework builds on Croce, Nguyen, and Schmid (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 setting. First, we account for stochastic fiscal volatility (i.e. fiscal volatility shocks) in the spirit of Bloom (2009); Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012). Stochastic fiscal volatility is also consistent with the post-Lehman empirical evidence (Bloom (2009); (Baker, Bloom, and Davis, 2013)).¹³ Second, 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. Finally, we study the effects of austerity measures under both the constant and stochastic R&D tax rate.

¹¹Notice 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.

¹²Our theoretical setup is also closely related to Kung and Schmid (2014) 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.

¹³The analysis on the effects of fiscal policy uncertainty on economic activity developed in this paper is related to the one carried out by Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012). However, it differs in two main dimensions. First, it does not rely on a standard New Keynesian model. In contrast, it adopts a stochastic version of Romer (1990) and extend it to allow for uncertainty in fiscal policy. Second, because of recursive preferences, our representative agent dislikes uncertainty of future utility (i.e. $\gamma > 1/\psi$).

3.1 Households

The representative agent has recursive preferences a la Epstein and Zin (1989), defined over consumption C_t and labor L_t :

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

where γ measures the relative risk aversion (RRA), ψ is the intertemporal elasticity of substitution (IES), and $\beta \in (0, 1)$ is the household's subjective discount factor. A standard expected utility model is nested under the assumption $\gamma = \frac{1}{\psi}$. 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

$$u(C_t, L_t) = C_t^{\alpha_c} (A_t(1 - L_t))^{1-\alpha_c} \quad (2)$$

where $\alpha_c \in (0, 1)$ reflects preferences for consumption versus leisure. In line with the long-run risk literature, we assume $\gamma \geq \frac{1}{\psi}$, that is, the 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 IES, and has been widely used in recent asset pricing and RBC/IBC studies (Benigno, Benigno, and Nisticó (2011); Papanikolaou (2011); Caldara, Fernández-Villaverde, Rubio-Ramírez, and Yao (2012); Colacito and Croce (2013); Pancrazi (2013); Kung and Schmid (2014)). Notice also that this class of preference has been recently supported by experimental studies (Brown and Kim (2013)).¹⁴

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

$$C_t + B_{t+1} + \Upsilon_t Q_{t+1} = (1 - \tau_t^l) W_t L_t + B_t R_t^f + (\Upsilon_t + D_t) Q_t \quad (3)$$

where Q_t denotes equity shares, Υ_t is the market value of an equity share, D_t represents

¹⁴In an Epstein and Zin (1989) preferences environment, agents care about when uncertainty is resolved. Brown and Kim (2013), via experiments, show that subjects prefer early resolution of uncertainty and have RRA greater than the reciprocal of the IES, consistent with the predictions by recursive preferences.

aggregate dividends, 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 for M_t

$$M_{t+1} = \beta \left(\frac{C_{t+1}}{C_t} \right)^{-1} \left(\frac{u_{t+1}}{u_t} \right)^{1-\frac{1}{\psi}} \left(\frac{U_{t+1}}{[E_t U_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi}-\gamma}. \quad (4)$$

The usual Euler equations of asset prices can be written as

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

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

$$(1 - \tau_t^l)W_t = \frac{1 - \alpha_c}{\alpha_c} \left(\frac{C_t}{1 - L_t} \right). \quad (5)$$

3.2 Production

Production takes place in three sectors: the consumption good is produced in the consumption sector using labor and intermediate goods as input. The intermediate sector produces intermediate goods using as input the technology developed by the R&D sector.

I. FINAL GOOD PRODUCTION

As in Kung and Schmid (2014), the final consumption good (i.e. final output), Y_t , is produced in a competitive sector using a bundle of intermediate goods, $Z_{i,t}$, and labor, L_t . Formally,

$$Y_t = \Lambda_t L_t^{1-\alpha} \left[\int_0^{A_t} Z_{i,t}^\alpha di \right], \quad (6)$$

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 (stationary) productivity process¹⁵

$$\log(\Lambda_t) = \rho^\Lambda \log(\Lambda_{t-1}) + \epsilon_t^\Lambda, \quad \epsilon_t^\Lambda \sim N(0, \sigma^\Lambda).$$

¹⁵In our economy, Λ_t is a labor augmenting technology and does not represent measured productivity, which is instead measured by newly produced patents.

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 implies the following

$$W_t = (1 - \alpha) \frac{Y_t}{L_t}, \quad Z_{i,t} = L_t \left(\frac{\Lambda_t \alpha}{P_{i,t}} \right)^{\frac{1}{1-\alpha}}. \quad (7)$$

II. 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 (7) as given, and chooses $P_{i,t}$ to maximize profits, $\Pi_{i,t}$:

$$\Pi_{i,t} := \max_{P_{i,t}} [P_{i,t} Z_{i,t} - Z_{i,t}]. \quad (8)$$

Replacing (7) in (8) we find that monopolistic firms charge a markup α by choosing the optimal price

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

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

$$Z_t = L_t (\Lambda_t \alpha^2)^{\frac{1}{1-\alpha}} \quad (9)$$

and makes a profit of

$$\Pi_{i,t} \equiv \Pi_t = \left(\frac{1}{\alpha} - 1 \right) Z_t. \quad (10)$$

Finally, replacing (9) in (6) we have

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

This expression shows that the final output depends on the variety of the intermediate goods, A_t .

III. R&D

The variety of intermediate goods embodies new technologies (i.e. patents).¹⁶ Therefore, in each period, each firm sells its intermediate good to the final good firm to make profits. In the forthcoming periods, new intermediate firms will produce new patents and sell them to make profits and some of the old firms lose their patents. In this setup, the value of existing variety, V_t , is as follows

$$V_t = \Pi_t + (1 - \delta_v)E_t[M_{t+1}V_{t+1}], \quad (11)$$

where δ_v represents the depreciation rate of the new technology. The market value of a new patent must then be equal to the cost of producing a new patent corrected for R&D taxation (i.e. free-entry condition):

$$E_t[M_{t+1}V_{t+1}] = \frac{1}{\Theta_t}(1 + \tau_t^r), \quad (12)$$

where $\frac{1}{\Theta_t}$ is the cost of developing a new patent and τ_t^r is the tax rate on R&D expenditure. The stock of patents evolves as

$$A_{t+1} = \Theta_t S_t + (1 - \delta_v)A_t. \quad (13)$$

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

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

¹⁶See also Santacreu (2012).

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 $\eta \in (0, 1)$ is the elasticity of new patents with respect to total R&D investment.

3.3 Government

We assume that government expenditure is driven by an exogenous stochastic process. In addition, in the spirit of Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012), we account for fiscal volatility shocks. Formally, public expenditures G_t evolve as follows

$$\frac{G_t}{Y_t} = \frac{1}{1 + e^{-g_t}} \quad (14)$$

$$g_t = (1 - \rho_g)\bar{g} + \rho_g g_{t-1} + e^{\nu_t} \epsilon_t^g, \quad \epsilon^g \sim N(0, \sigma_g^2) \quad (15)$$

$$\nu_t = (1 - \rho_\nu)\bar{\nu} + \rho_\nu \nu_{t-1} + \epsilon_t^\nu, \quad \epsilon^\nu \sim N(0, \sigma_\nu^2), \quad (16)$$

where \bar{g} and $\bar{\nu}$ are the long-run averages of the government expenditure-output ratio and government expenditure volatility, respectively. ρ_g and ρ_ν are persistence parameters.

In order to capture austerity measures that rely on R&D cuts (consistently with recent empirical evidences, see Figure 4), we assume that the government finances total public spending by means of labor taxes and R&D taxes τ_t^r , so that the total tax income is $T_t = \tau_t^l W_t L_t + \tau_t^r X_t$, where X_t represents either profits Π_t or the aggregate capital of the R&D sector S_t . The tax rate of the R&D sector follows the process

$$\tau_t^r = \frac{1}{1 + e^{-\chi_t}} \quad (17)$$

$$\chi_t = (1 - \rho_\chi)\bar{\chi} + \rho_\chi \chi_{t-1} + \epsilon_t^\chi, \quad \epsilon^\chi \sim N(0, \sigma_\chi^2). \quad (18)$$

The economic intuition for this fiscal rule is the following: the government has a desired fiscal rule for the R&D sector given by $(1 - \rho_\chi)\bar{\chi} + \rho_\chi \chi_{t-1}$. The shock ϵ^χ captures

unexpected changes in economic or legislative conditions that force the government to deviate from the desired rule. For instance, the request from an external authority to curb and reduce public debt.

Differently from Croce, Nguyen, and Schmid (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 European SGP). Thus, the government sets

$$G_t - T_t = 0. \tag{19}$$

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. The expenditure on debt service is then included in government's expenditure G_t .

3.4 Resource constraint

Finally, we close our economy with the following market clearing conditions:

$$Y_t = C_t + A_t Z_t + S_t + G_t \tag{20}$$

in the final good production, and

$$(1 - \tau_t^l) \frac{(1 - \alpha) Y_t}{L_t} = \frac{1 - \alpha_c}{\alpha_c} \frac{C_t}{1 - L_t} \tag{21}$$

in the labor market.

4 Quantitative analysis

In this section we calibrate our model and explore the implications of fiscal policy for long- and short-run dynamics of macroeconomic variables. As a first exercise, we set taxes on R&D to zero and re-examine the impact of fiscal volatility shocks. Then, we impose different levels of constant R&D taxes and study their effects on macroeconomic aggregates in presence of both TFP and fiscal volatility shocks. Finally, we calibrate our

full model with stochastic fiscal policy (i.e. both government expenditure and R&D taxes are stochastic) and explore its implications for short- and long-run economic growth.

4.1 Calibration

The model presented in this paper involves 21 parameters: three for preferences, eight referring to the technology (final good production) and R&D (new patents development), and ten for government policies and taxes. Notice that our benchmark calibration relies on a zero-deficit policy commitment. All parameter values are reported in Table 2. Preferences' parameters (i.e. subjective discount factor, β , RRA, γ , and IES, 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 $\gamma = 10$ (Kung and Schmid (2014)) and $\psi = 1.7$ (Croce, Nguyen, and Schmid (2013)).

Since the main focus of the paper is on the implications of EU cross-country adverse fiscal policies on current and expected economic growth, the scale parameter ξ is chosen to match the average output growth rate in the Euro Area over the last two decades (around 1.5%). The technology parameters α (i.e. the relative share of labor in the final good production) and η (i.e. the elasticity of new intermediate goods) are set as in Croce, Nguyen, and Schmid (2013). Moreover, we set the technology shock volatility $\sigma^\Lambda = 0.005$ to be below the value used in Croce, Nguyen, and Schmid (2013) who employ $\sigma^\Lambda = 0.006$. As in Kung and Schmid (2014), we set the patent obsolescence rate, ρ_v , equal to 0.0375. Since the main focus of the paper is on the implications of EU cross-country adverse fiscal policies on current and expected economic growth, the scale parameter ξ is chosen to match the average output growth rate in the Euro Area over the last two decades (around 1.5%). The technology parameters α (i.e. the relative share of labor in the final good production) and η (i.e. the elasticity of new intermediate goods) are set as in Croce, Nguyen, and Schmid (2013). Moreover, we set the technology shock volatility $\sigma^\Lambda = 0.005$ to be below the value used in Croce, Nguyen, and Schmid (2013) who employ $\sigma^\Lambda = 0.006$. As in Kung and Schmid (2014), we set the patent obsolescence rate, ρ_v , equal to 0.0375.

Turning to government and taxes parameters, the constant \bar{g} captures the average

logarithmic level of the government expenditure output ratio. To be more consistent with EU data, we set $\bar{g} = -2.0373$, which implies a government expenditure-GDP ratio of 13%. This value is slightly higher than that employed by Croce, Nguyen, and Schmid (2013), who set $G/Y = 11\%$. The persistence parameters of the government expenditure-output ratio and government expenditure volatility, ρ_g and ρ_ν , are taken from Croce, Nguyen, and Schmid (2013) and Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012), respectively. The volatility of the government expenditure shock, σ_g , is equal to $0.5 \cdot \sigma^\Lambda$ as well as to the volatility of the R&D tax shock, σ_χ . In addition, we assume that ε_t^g and ε_t^χ are positively correlated and impose $\text{corr}(\varepsilon^g, \varepsilon^\chi) = 0.3$. We employ this positive correlation to capture the fact that in order to finance higher expenditures, governments likely increase taxes (in this case, R&D taxes).

Our calibration implies a steady state R&D tax rate, τ_t^r , equal to 11.92%. In addition, we impose a steady state labor income tax rate equal to 36.5% (in line with EU average labor market data). The model is calibrated at a quarterly frequency and solved using third-order perturbation methods.¹⁷

4.2 Examining the effect of fiscal volatility shocks

In this section, we examine the implications of the model in presence of an increase in the volatility of government expenditures. More precisely, we study the effect of a positive shock when the R&D tax rate is set to 0. This naturally implies that there is no correlation between fiscal expenditure and R&D taxes, i.e., $\text{corr}(\varepsilon^g, \varepsilon^\chi) = 0$. According to equation (11)-(13) and the zero-deficit rule, a positive shock to volatility of government expenditures generates higher than usual uncertainty about the future fiscal policy.

Figure 5 depicts the impulse responses of macroeconomic aggregates to a fiscal volatility shock. The shock generates a moderate but persistent contraction in the future growth rate of the economy (i.e. the expected growth rate of consumption, output, labor supply and R&D expenditures drop immediately and return to their initial level more than 20

¹⁷We solve our models in DYNARE++4.3.0 using a third-order approximation. 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 quarterly calibration used for the full model presented in Section 3. Parameters' sources: 1=own calibration, 2=Croce, Nguyen, and Schmid (2013), 3=Kung and Schmid (2014), 4=Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012).

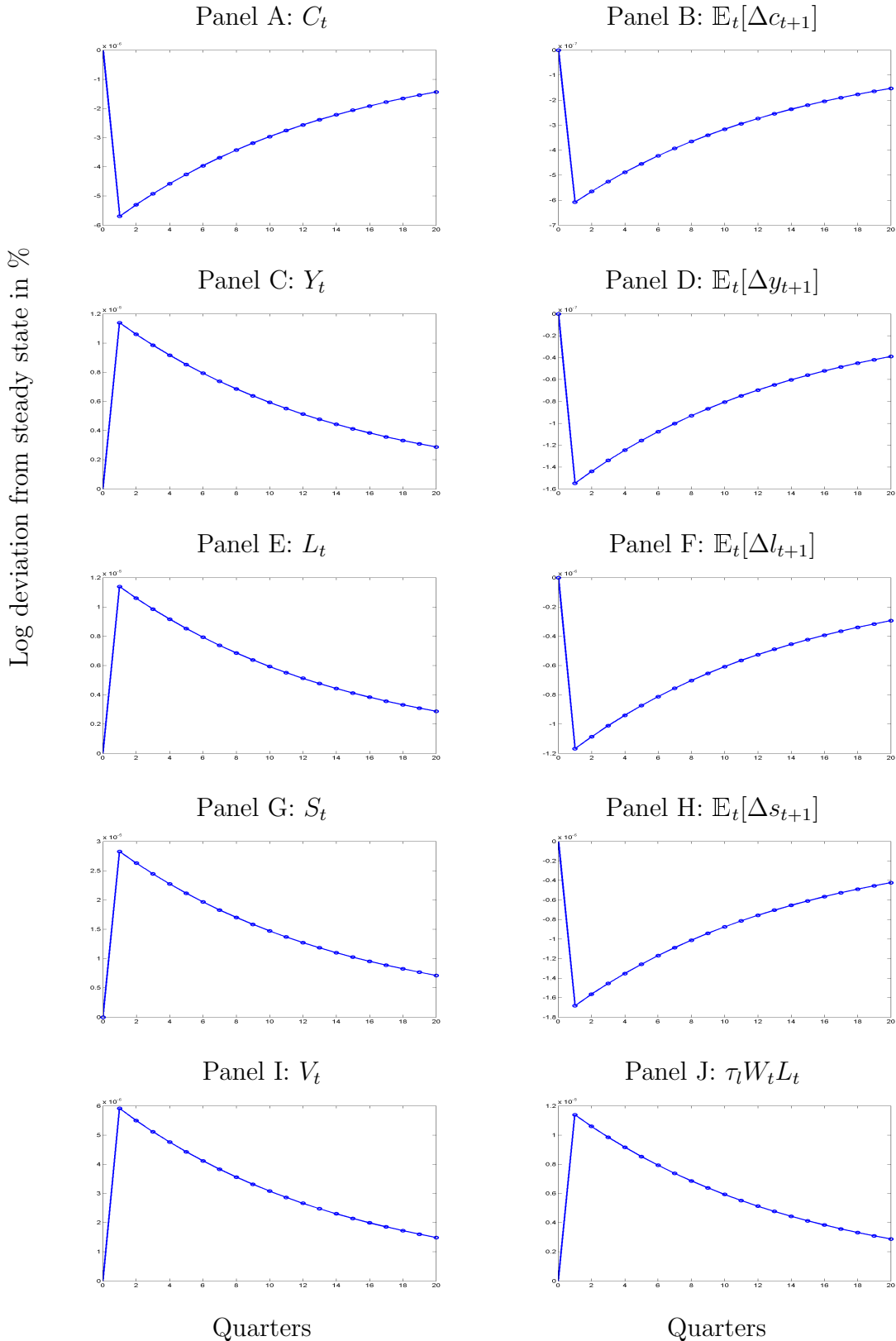
Parameter	Description	Source	Value
β	Subjective discount factor	2	0.996
γ	Risk aversion	3	10
ψ	Elasticity of intertemporal substitution	2	1.7
α	Labor share	2	0.70
α_c	Consumption share in utility bundle	1	0.3496
τ^l	Labor tax rate	1	0.365
ρ^Λ	Autocorrelation of productivity level $\log(\Lambda_t)$	1	0.97
σ^Λ	Volatility of productivity shock ϵ_t^Λ	1	0.005
η	Elasticity of R&D technology	2	0.80
ξ	R&D productivity shift parameter	1	0.6135
δ_v	Patent obsolescence rate	3	0.0375
ρ_g	Autocorrelation of government expenditure ratio g_t	2	0.98
σ_g	Volatility of government expenditure shock ϵ_t^g	1	0.0025
\bar{g}	Long-run mean of government expenditure-output ratio g_t	1	-2.0373
ρ_ν	Autocorrelation of government expenditure volatility ν_t	4	0.93
σ_ν	Volatility of government expenditure volatility shock ϵ_t^ν	1	0.0025
$\bar{\nu}$	Long-run mean of government expenditure volatility ν_t	1	0
ρ_χ	Autocorrelation of R&D tax χ_t	1	0.97
σ_χ	Volatility of R&D tax shock ϵ_t^χ	1	0.0023
$\bar{\chi}$	Long-run mean of R&D tax χ_t	1	-2
$corr(\epsilon^g, \epsilon^\chi)$	Correlation of ϵ_t^g and ϵ_t^χ	1	0.30

quarters after the shock, see Panels B, D, F and H).¹⁸ The current value of new patents increases (see Panel I). The higher uncertainty concerning future fiscal rules decreases the value of households' continuation utility. Because of agents being averse to both consumption and utility risk (i.e. $\psi > 1$), the continuation utility and consumption are substitutes. As a result, households respond to the higher uncertainty by working more today and decreasing current consumption (see Panels A and E). The increase in the labor supply also increases the amount of current labor taxes and the aggregate output which, in turn, boosts expected corporate profits (see Panels C and J). The increase in corporate profits incentives innovations and augments current R&D expenditures (see Panel G).

¹⁸This is due to the level of persistence in the fiscal volatility shock of 0.93 (quarterly).

Note that our policies slightly differ from those of Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012) where a fiscal uncertainty shock decreases current labor supply. The difference is explained by the utility function: households in our paper are equipped with Epstein and Zin recursive utility whereas in Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012) the agents have standard separable consumption-labor power utility with habit formation in consumption. In our setup, the substitution effect generated by Epstein and Zin preferences implies that, households, which are averse to utility risk, increase labor today. This comes at the cost of lower expected labor growth.

Figure 5: FISCAL EXPENDITURE VOLATILITY SHOCKS: ZERO R&D CUTS. *Notes:* This figure plots impulse response functions of consumption C_t , expected consumption growth $\mathbb{E}_t[\Delta c_{t+1}]$, output Y_t , expected 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 , R&D expenditure growth $\mathbb{E}_t[\Delta s_{t+1}]$, value of a new patent V_t and total amount of labor taxes $\tau_l W_t L_t$ with respect to a shock to the volatility of government expenditures ν_t (ε_t^ν). To focus exclusively on fiscal volatility shocks, we impose $\text{corr}(\varepsilon^g, \varepsilon^x) = 0$ and $\tau^r \equiv 0$ and the scale parameter is adjusted to be $\xi = 0.6054$. All the remaining parameters are calibrated to the values reported in Table 2.



4.3 Deterministic R&D taxation

The previous section examines the effect of fiscal volatility shocks in a world where the R&D sector is not taxed. In order to capture the effect of austerity measures that rely on raising R&D taxes we consider now an economy with deterministic R&D tax rates. Figure 6 depicts the effect of a fiscal volatility shock for different R&D tax rates. The main result of this experiment is the following: higher taxes on the R&D sector worsen the effect of an increase in the uncertainty surrounding future fiscal rules, and make the subsequent economic contraction not only more severe but also more long-lasting. (e.g. see the blue and green lines in Figure 6)

R&D taxation also alters the effect of TFP shocks. The impulse response function of a negative TFP shock are presented in Figure 7. First, we observe that a negative TFP shock creates a more prolonged and severe contraction in economic activity than the fiscal volatility shock. Second, R&D taxes act as a cushion to the negative TFP shock in the sense that the drop in macroeconomic variables is less pronounced in case of higher R&D taxes. The explanation for this result is as follows: the negative TFP shock causes the labor income to decrease. In case of higher R&D tax rates, much of the burden of the negative TFP shock is absorbed by the R&D sector. As a result, the labor income drops less than it would have dropped in case of low R&D tax rates (see Panel J). The less pronounced drop in labor income stimulates future labor supply and reduces the impact of the negative TFP shock (see Panel E).

In summary, R&D taxation has a twofold effect on the dynamics of macroeconomic variables: on the one hand, it amplifies the economic contraction after a negative fiscal volatility shock; on the other hand, it mitigates the negative effects produced by negative TFP shocks on the expected growth rates of consumption, output and R&D expenditures (see Panels B, D and H).

We conclude the analysis of the model with deterministic taxes on the R&D sector by reporting the unconditional moments of the most relevant macroeconomic variables for different values of the tax rate τ^r . Table 3 reports that a higher tax rate on the R&D sector depresses the expected growth of output. More precisely, an increase of τ^r from

0% to 15% decreases the expected growth rate of aggregate output from 3.83% to 0.53%. Correspondingly, the risk-free rate decreases from 2.90% to 1.21%. This suggests that, following an increase in the taxation of the R&D sector, capital is reallocated away from the R&D sector and invested in the risk-free asset (i.e. saving increases), thus, decreasing the risk-free rate. This result suggests that, overall, the amplification effect of R&D taxes on fiscal volatility shocks dominates the cushion effect on TFP shocks. We conclude that, in our framework, austerity measures that rely on higher R&D tax rates tend to depress economic growth.

Table 3: DETERMINISTIC R&D TAXATION: 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 for different degrees of R&D taxes. The reported moments are annualized. 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, Ghironi, and Melitz (2012). The aggregate risk premium, $E[r_a^* - r_f]$, is levered following Boldrin, Christiano, and Fisher (2001).

	$\tau^r = 0\%$	$\tau^r = 5\%$	$\tau^r = 10\%$	$\tau^r = 15\%$
First Moments				
$E[\Delta y]$	3.83%	2.64%	1.50%	0.53%
$E[\Delta c]$	3.83%	2.64%	1.50%	0.53%
$E[r_f]$	2.90%	2.29%	1.71%	1.21%
$E[r_c - r_f]$	1.72%	1.58%	1.43%	1.33%
$E[r_a^* - r_f]$	0.91%	0.76%	0.67%	0.62%
Second Moments				
$\sigma_{\Delta y}$	4.34%	4.33%	4.31%	4.30%
$\sigma_{\Delta c}$	3.12%	3.16%	3.19%	3.23%
$\sigma_{\Delta s}$	5.53%	5.60%	5.68%	5.75%
$\sigma_{\Delta c}/\sigma_{\Delta y}$	0.72	0.73	0.74	0.75
$\sigma_{\Delta s}/\sigma_{\Delta y}$	1.27	1.29	1.32	1.34
σ_{r_f}	0.74%	0.70%	0.66%	0.63%
$\sigma_{r_c - r_f}$	2.89%	2.81%	2.75%	2.70%
$\sigma_{r_a^* - r_f}$	2.94%	2.77%	2.67%	2.61%

Figure 6: DIFFERENT DETERMINISTIC R&D TAXES AND FISCAL VOLATILITY SHOCKS. *Notes:* This figure plots impulse response functions of consumption C_t , expected consumption growth $\mathbb{E}_t[\Delta c_{t+1}]$, output Y_t , expected 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 , R&D expenditure growth $\mathbb{E}_t[\Delta s_{t+1}]$, value of a new patent V_t and total amount of labor taxes $\tau_l W_t L_t$ with respect to a shock to the volatility of government expenditures ν_t (ϵ_t^ν). To match the average output growth rate, we adjust the scale parameter and impose $\xi = 0.6054$. All the other parameters are calibrated to the values reported in Table 2.

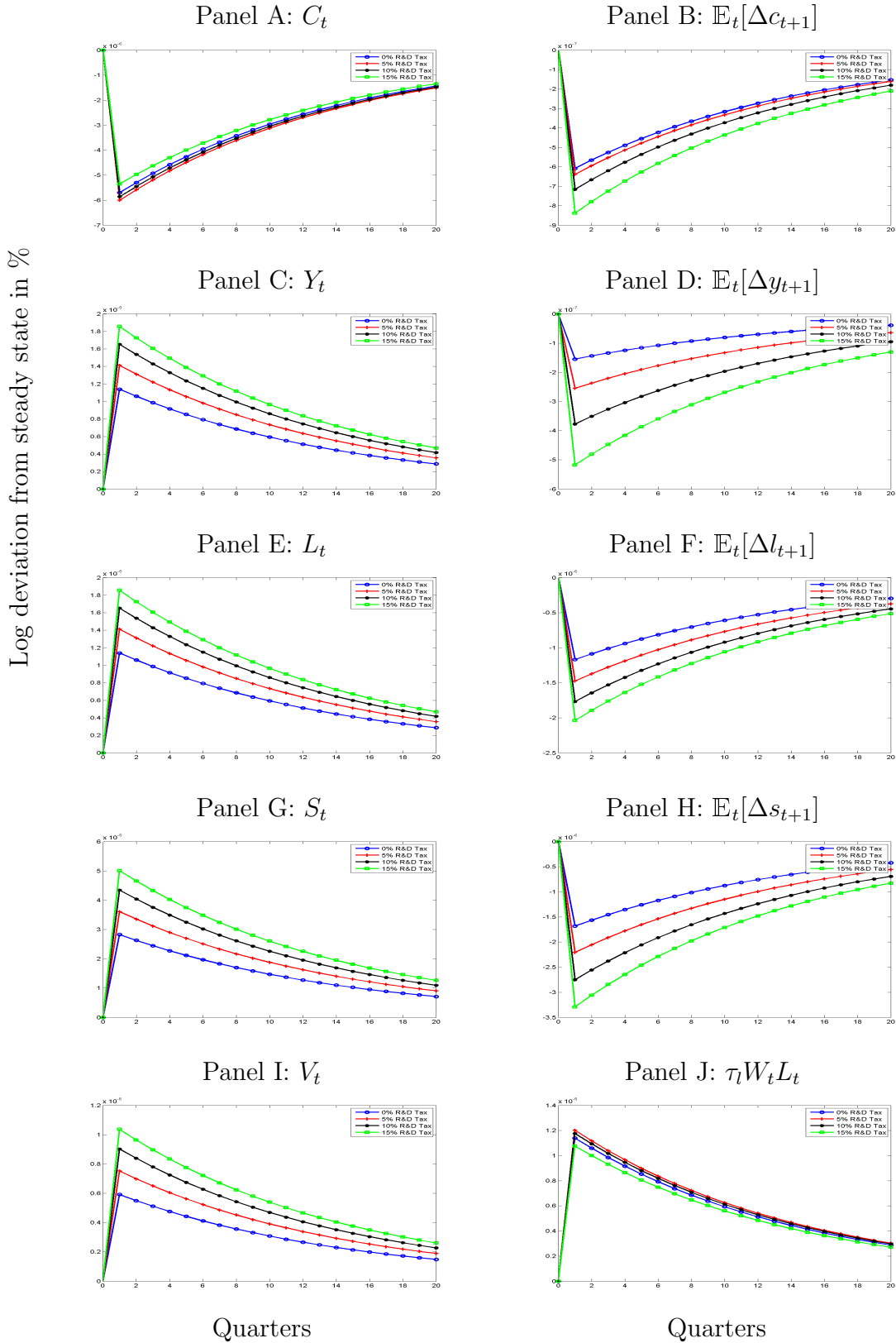
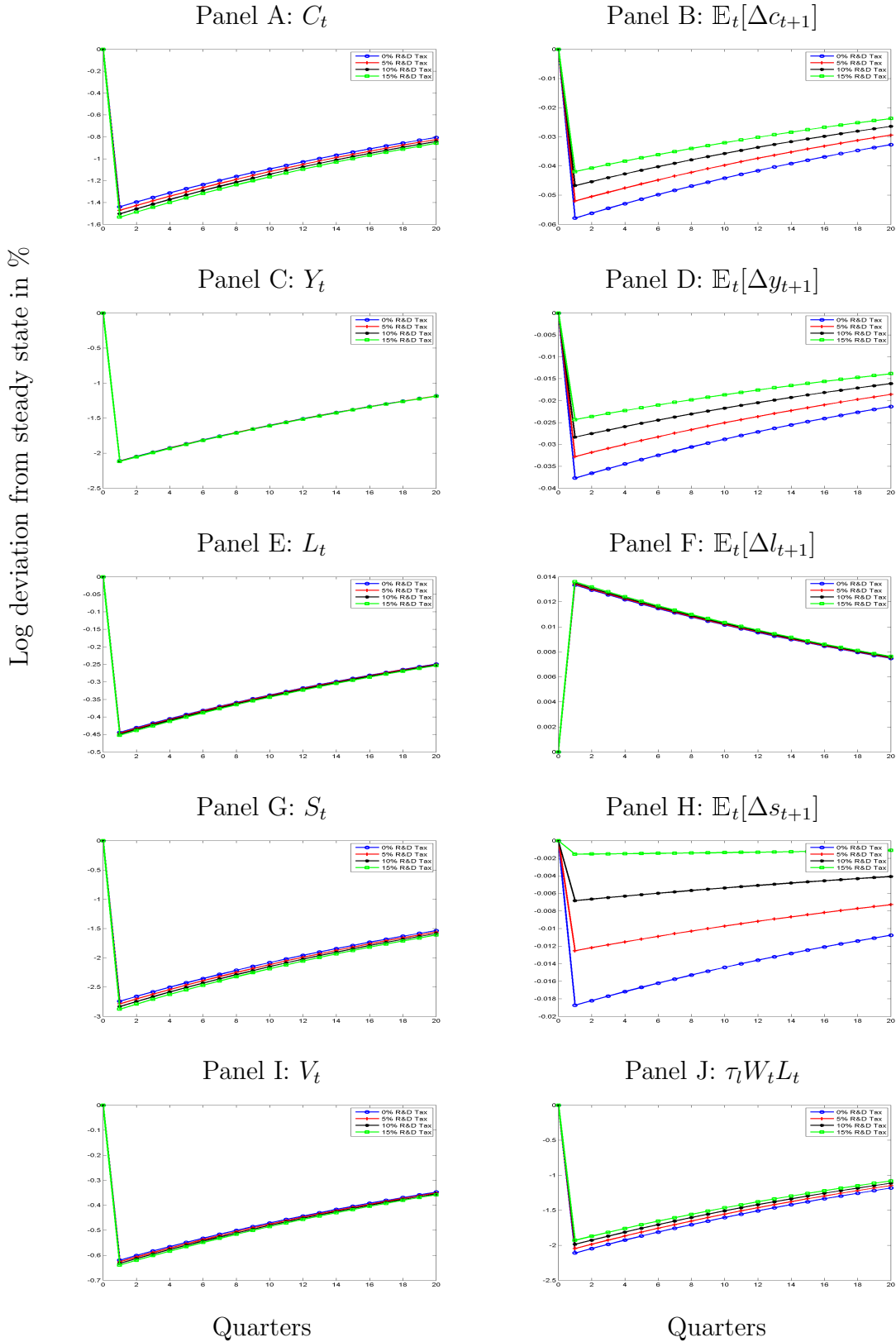


Figure 7: DIFFERENT DETERMINISTIC R&D TAXES AND NEGATIVE TFP SHOCKS. *Notes:* This figure plots impulse response functions of consumption C_t , expected consumption growth $\mathbb{E}_t[\Delta c_{t+1}]$, output Y_t , expected output growth $\mathbb{E}_t[\Delta y_{t+1}]$, labor hours L_t , expected labor hours growth $\mathbb{E}_t[\Delta l_{t+1}]$, R&D expenditure S_t , R&D expenditure growth $\mathbb{E}_t[\Delta s_{t+1}]$, value of a new patent V_t and total amount of labor taxes $\tau_l W_t L_t$ with respect to a negative shock to the Solow residual (ϵ_t^Δ). To match the average output growth rate, we adjust the scale parameter and impose $\xi = 0.6054$. All the other parameters are calibrated to the values reported in Table 2.



4.4 Stochastic R&D taxation

In Figure 8 we consider the complete model with stochastic R&D taxes and analyze the effects of a shock to the stochastic volatility of public expenditures. The effects are qualitatively the same as in the case of zero R&D taxes (see Figure 5) and no tax uncertainty (see Figure 6). However, the uncertainty surrounding tax rules generates a more severe contraction in the expected growth rate of macroeconomic aggregates.

In Figure 9 we analyze the effect of a shock to the R&D tax rate in the complete model. This shock induces a contraction in economic activity. The higher tax rate reduces current and future investment in the R&D sector. The reallocation of resources from the investment to the consumption sector induces the household to work less and consume more today. The higher consumption today comes at the cost of lower consumption tomorrow. More importantly, the drop in R&D investments reduces output both currently and in the future. Finally, in order to judge the plausibility of the economic mechanism proposed in this paper, we compare the model implied moments with those in the data. From the results reported in Table 4, we observe that the model matches the expected values of most relevant macroeconomic quantities. In particular, the model produces realistic values for the expected growth rates of output and consumption and the risk-free rate. The equity premium is a bit lower than in the data (2.75% vs 3.95%). A way to increase the equity premium would be to add stochastic volatility on the process for R&D taxes. In our production economy, we do not consider this extra source of uncertainty because we prefer concentrating our analysis on the link between R&D taxation and economic growth. Admittedly, the absence of this extra source of uncertainty makes the model unable to match the volatility of stock returns. However, the model replicates the excess volatility of output over consumption in a reasonable way. By comparing the unconditional moments of the model with stochastic taxation with those of the model with deterministic tax rates we note that fiscal uncertainty increases the equity premium by about 2%. This result stems from hedging motives: agents react to fiscal uncertainty by increasing savings, thus, lowering the risk free rate and increasing the equity premium.

In summary, the main message arising from our quantitative analysis is the following:

Figure 8: FISCAL EXPENDITURE VOLATILITY SHOCKS: STOCHASTIC R&D TAXES. *Notes:* This figure plots impulse response functions of consumption C_t , expected consumption growth $\mathbb{E}_t[\Delta c_{t+1}]$, output Y_t , expected 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 , R&D expenditure growth $\mathbb{E}_t[\Delta s_{t+1}]$, value of a new patent V_t and total amount of labor taxes $\tau_l W_t L_t$ with respect to a shock to the volatility of government expenditures ν_t (ε_t^ν). All parameters are calibrated to the values reported in Table 2 (i.e. full model benchmark calibration).

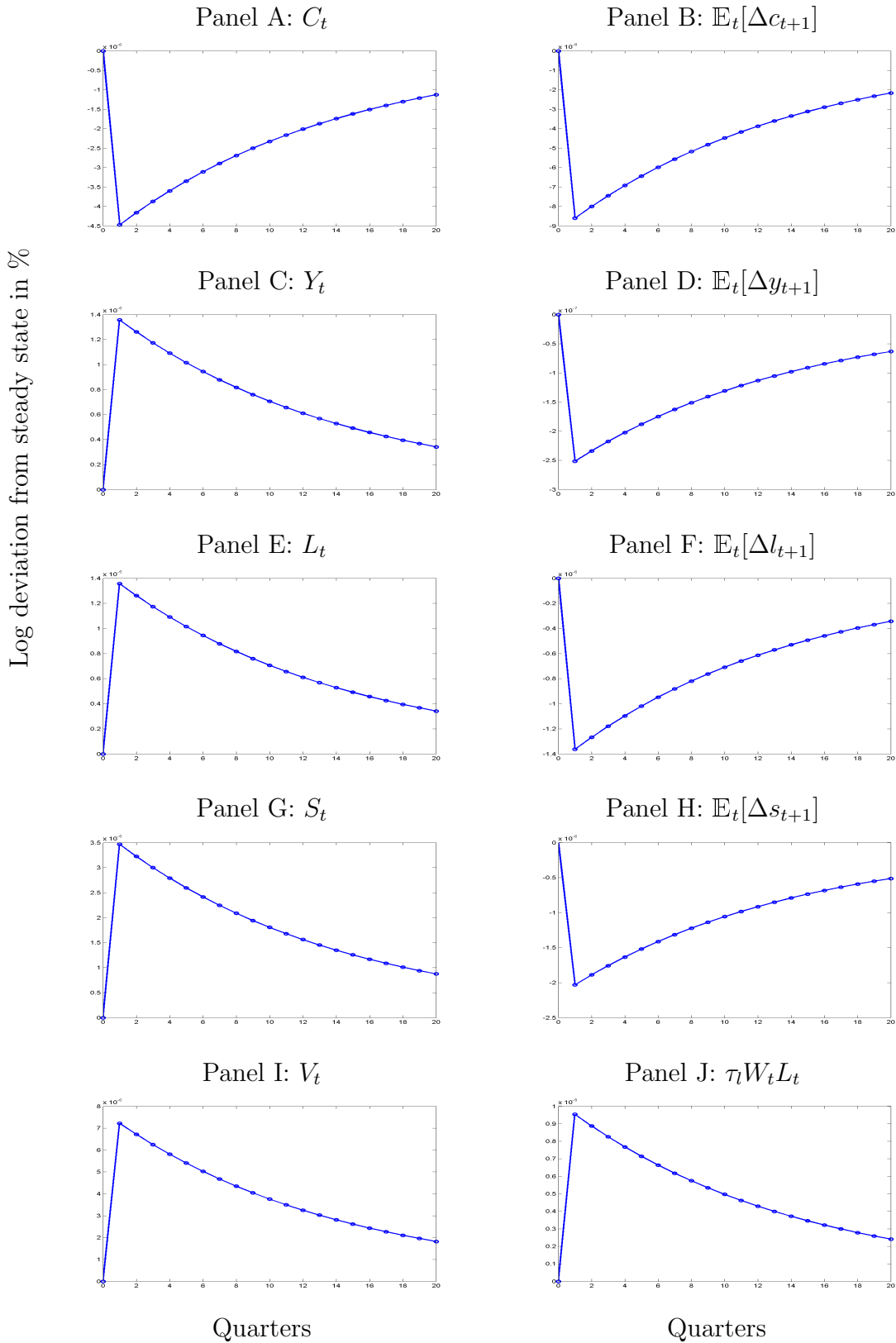


Figure 9: R&D TAX RATE SHOCKS. *Notes:* This figure plots impulse response functions of consumption C_t , expected consumption growth $\mathbb{E}_t[\Delta c_{t+1}]$, output Y_t , expected output growth $\mathbb{E}_t[\Delta y_{t+1}]$, labor hours L_t , expected labor hours growth $\mathbb{E}_t[\Delta l_{t+1}]$, R&D expenditure S_t , R&D expenditure growth $\mathbb{E}_t[\Delta s_{t+1}]$, value of a new patent V_t and total amount of labor taxes $\tau_l W_t L_t$ with respect to a shock to the R&D tax rate τ_t^r (ε_t^X). All parameters are calibrated to the values reported in Table 2 (i.e. full model benchmark calibration).

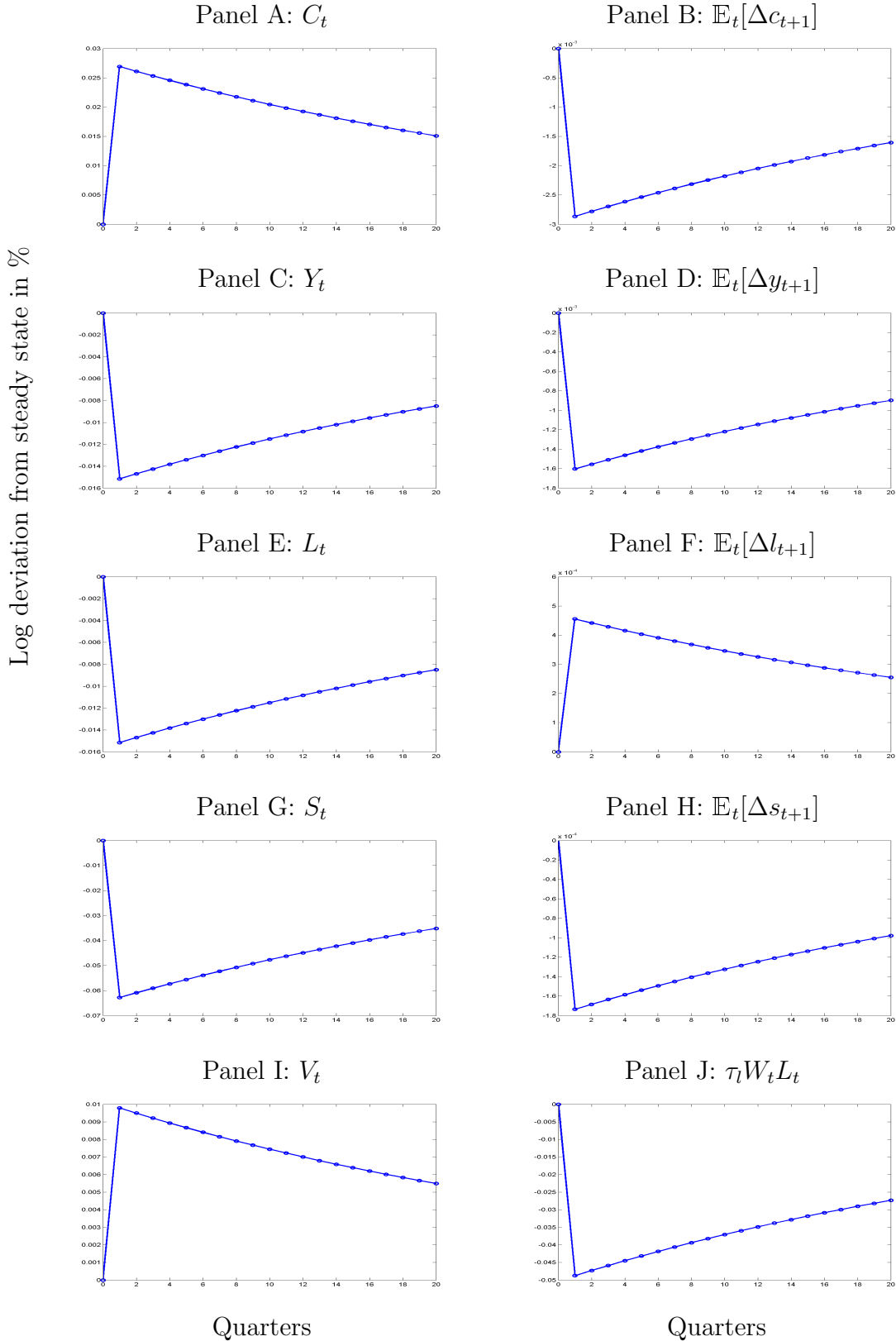


Table 4: BENCHMARK CALIBRATION: SIMULATION RESULTS. *Notes:* This table reports the results of simulating 3,000 economies for 75 years, i.e., 300 quarters, and then throwing away the first 10 years. The reported moments are annualized. From the model simulations, we report the means and volatilities 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, Ghironi, and Melitz (2012). The aggregate risk premium, $E[r_a^* - r_f]$, is levered following Boldrin, Christiano, and Fisher (2001). Macro and asset pricing data are from the OECD and run from 1996 to 2013. Annualized empirical moments are represented by cross-country averages. Our sample includes the following EU countries: France, Germany, Italy, Spain and United Kingdom. R&D expenditure growth in each country, Δs , is represented by the Gross Domestic Expenditure on R&D Compound annual growth rate. Countries' equity returns are computed from "OECD Share Price Indexes". The volatilities have been calculated using this average growth rates and return series. The "OECD EU18 Immediate interest rates, Call Money, Interbank Rate" proxies our risk-free rate. Additional details on the data are given in the Appendix A.

	Model	Data
First Moments		
$E[\Delta y]$	1.50%	1.49%
$E[\Delta c]$	1.50%	1.50%
$E[r_f]$	1.71%	2.41%
$E[r_c - r_f]$	1.45%	-
$E[r_a^* - r_f]$	2.75%	3.95%
Second Moments		
$\sigma_{\Delta y}$	4.35%	1.21%
$\sigma_{\Delta c}$	3.20%	0.97%
$\sigma_{\Delta s}$	5.72%	3.05%
$\sigma_{\Delta c} / \sigma_{\Delta y}$	0.74	0.80
$\sigma_{\Delta s} / \sigma_{\Delta y}$	1.31	2.52
σ_{r_f}	0.67%	1.46%
$\sigma_{r_c - r_f}$	2.90%	-
$\sigma_{r_a^* - r_f}$	4.83%	18.32%

Austerity measures that include an increase in the taxation of R&D sector can, at best, provide a temporary increase in consumption but harm future economic growth. The temporary increase in consumption comes from the reallocation of resources from the R&D sector to the consumption sector produced by the higher tax rates in conjunction with the substitution effect of Epstein and Zin preferences. However, the reallocation of capital away from the R&D sector decreases the incentive of firms to innovate and reduces economic growth (see Panels D and H in Figure 8). We emphasize that in our framework economic growth is only driven by investment in R&D. As a result, any kind of fiscal policy that depresses investment in R&D, as for instance a cut in the government R&D expenditures, also has a negative effect on economic growth. These results may cast some doubts on the effective economic growth of countries with high-debt/deficit levels. A similar statement can be found in Ilzetzki, Mendoza, and Végh (2013). These countries are currently under austerity measures and, according to Figure 4, also implement substantial cuts in their R&D expenditures, which, of course, decreases private R&D investment. A legitimate question to ask is then the following: Can these countries achieve, in the next years, a stable and positive GDP growth consistent with estimation by the IMF in Figure 3?¹⁹

5 Robustness: Taxes on R&D profits

In this section we explore the robustness of our quantitative results. We address whether our results are driven exclusively by the assumption that the government raises revenues by taxing R&D investments directly. To do so, we assume that our government raises money by means of taxing R&D profits rather than R&D capital expenditure. The new equations defining the value of the variety (i.e. value of owning rights to produce a new patent), V_t , and government's exogenous tax on profits, τ_t^π , are described in Appendix (B). Impulse responses to a fiscal volatility shock and to a shock on profits taxes are illustrated in Figures B.1 and B.2, respectively. Simulated moments are then reported in

¹⁹(Bilbao-Ubillos and Fernández-Sainz, 2014), for example, find that fiscal uncertainty and wild austerity measures can lead to incorrect forecasts.

Table B.2.

We stress that results are qualitatively similar: raising taxes on the R&D sectors produces adverse effects on future growth prospects (compare Panels B, D and H in Figures 8-9 vs. Figures B.1-B.2). However, when the government taxes R&D profits rather than R&D expenditure, the drop in economic activity following an adverse economic shock is less severe. This is so because, taxes on R&D investments have a direct negative effect on the marginal cost of new R&D expenditures which, in turn, decreases both the incentive of firms to innovate and aggregate expenditures on R&D. Differently, taxes on profits do not alter the marginal cost of new R&D but only final profits. As a result, the drop in the R&D expenditures and the consequent contraction of economic activity is less pronounced under the profit-taxation policy than under the investment-taxation policy. Moreover, current output and labor now slightly increase and the value of patents slightly decrease following in response to a positive R&D profit tax rate shock (see Panels C, E and I of Figure B.2).

Overall, our results suggest that the adverse effects produced by our fiscal policy scheme, which reduces resources allocated to the sector driving economic growth, are quite general and do not depend on the R&D taxation implemented.

6 Concluding remarks

In this paper we propose a unified general equilibrium framework to study jointly 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 increasing taxes or spending cuts in the R&D sector seriously harm economic growth. While this result is not surprising in light of the standard economic growth theory, the behavior of fiscal authorities in European countries with relatively high debt/deficit levels (e.g. PIGS) 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 opinion, this scenario casts doubts on their ability to gain a stable growth path in the next future. To conclude, we are not

arguing that austerity measures are bad *per se*. Instead, we argue that implementing austerity measures by means of R&D cuts might have sizable adverse effects on current and future economic performance. Of course, a smarter fiscal consolidation which supports investments in R&D is needed.

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A Data

FIGURE 1

- *Y*: Gross Domestic Product - Expenditure Approach (*Measure*: Millions of national currency, current prices, quarterly levels, seasonally adjusted; *Sample*: 1995:1Q-2013:4Q; *Source*: OECD)
- *G*: General Government Final Consumption Expenditure (*Measure*: Millions of national currency, current prices, quarterly levels, seasonally adjusted; *Sample*: 1995:1Q-2013:4Q; *Source*: OECD)

FIGURES 2-3, TABLE 1

- Effort to Reduce Fiscal Deficit: Yearly Reduction (as share of GDP) in General Government Overall Balance (*Sample*: 2009-2013 and 2014-2018; *Source*: IMF Fiscal Monitor (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

- Total government expenditure in R&D: Sum of government R&D expenditure in the following sectors: General public services; Defence; Public order and safety; Economic affairs; Environmental protection; Housing and community amenities; Health; Recreation, culture and religion; Education; Social protection (*Measure*: National currency, current prices, millions; *Sample*: 2008-2011; *Source*: OECD)
- R&D Investment: Gross Domestic Expenditure on R&D (*Measure*: Compound annual growth rate, constant prices; *Sample*: 2008-2012; *Source*: OECD Main Science and Technology Indicators Database)
- Real Gross Domestic Product: Gross domestic product - constant prices (*Sample*: 2008-2012; *Source*: IMF)

TABLE 3

- Δy : Gross domestic product - expenditure approach (*Measure*: Growth rate compared to previous quarter, seasonally adjusted; *Sample*: 1996:1Q-2013:4Q; *Source*: OECD)
- Δc : Private final consumption expenditure (*Measure*: Growth rate compared to previous quarter, seasonally adjusted; *Sample*: 1996:1Q-2013:4Q; *Source*: OECD)
- Δs : R&D expenditures growth (*Measure*: Compound annual growth rate, constant prices; *Sample*: 1996-2012; *Source*: OECD Main Science and Technology Indicators Database)
- R_c : Country Share Prices, Index 2010=100 (*Sample*: 1996-2013; *Source*: Monthly Monetary and Financial Statistics, OECD)
- R_f : Euro area (18 countries) Immediate interest rates, Call Money, Interbank Rate (*Sample*: 1996-2013; *Source*: Monthly Monetary and Financial Statistics, OECD)

B Robustness Check - Taxes on Profit

In this setup, the value of existing variety, V_t , is as follows

$$V_t = (1 - \tau_t^\pi)\Pi_t + (1 - \delta_v)E_t[M_{t+1}V_{t+1}], \quad (\text{B.1})$$

where δ_v represents the depreciation rate of the new technology and τ_t^π takes the following form

$$\tau_t^\pi = \frac{1}{1 + e^{-\kappa_t}} \quad (\text{B.2})$$

$$\kappa_t = (1 - \rho_\kappa)\bar{\kappa} + \rho_\kappa\kappa_{t-1} + \epsilon_t^\kappa, \quad \epsilon_t^\kappa \sim N(0, \sigma_\kappa^2). \quad (\text{B.3})$$

The market value of a new patent must then be equal to the cost of producing a new patent (i.e. free-entry condition):

$$E_t[M_{t+1}V_{t+1}] = \frac{1}{\Theta_t}, \quad (\text{B.4})$$

where $\frac{1}{\Theta_t}$ is the cost of developing a new patent. Notice that in this scenario our government finances total public spending by means of public debt, labor and capital income taxes, $T_t = \tau_t^l W_t L_t + \tau_t^\pi \Pi_t$. Parameter values are reported B.1. As an exercise, we set values for the parameters related to taxes on R&D profits equal to R&D taxes parameter values (see Table 2). To match the 1.5% average output growth rate, we impose $\xi = 0.6209$. Our calibration implies a steady state tax rate on R&D profits equal to 11.92%. As in Section 4.4, we assume that government expenditure and profit taxes shocks are correlated (i.e. $\text{corr}(\epsilon^g, \epsilon^\kappa) > 0$). Impulse responses to a fiscal volatility shock and to a shock on profits taxes are reported in Figures B.1 and B.2, respectively. Simulated moments are reported in Table B.2.

Table B.1: PARAMETERS: BENCHMARK CALIBRATION (TAXES ON R&D PROFITS). *Notes:* This table reports the benchmark quarterly calibration used for the full model presented in Section 3. Parameters' sources: 1=own calibration, 2=Croce, Nguyen, and Schmid (2013), 3=Kung and Schmid (2014), 4=Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012).

Parameter	Description	Source	Value
β	Subjective discount factor	2	0.996
γ	Risk aversion	3	10
ψ	Elasticity of intertemporal substitution	2	1.7
α	Labor share	2	0.70
α_c	Consumption share in utility bundle	1	0.3496
τ^l	Labor tax rate	1	0.365
ρ^Λ	Autocorrelation of productivity level $\log(\Lambda_t)$	1	0.97
σ^Λ	Volatility of productivity shock ε_t^Λ	1	0.005
η	Elasticity of R&D technology	2	0.80
ξ	R&D productivity shift parameter	1	0.6209
δ_v	Patent obsolescence rate	3	0.0375
ρ_g	Autocorrelation of government expenditure ratio g_t	2	0.98
σ_g	Volatility of government expenditure shock ε_t^g	1	0.0025
\bar{g}	Long-run mean of government expenditure-output ratio g_t	1	-2.0373
ρ_ν	Autocorrelation of government expenditure volatility ν_t	4	0.93
σ_ν	Volatility of government expenditure volatility shock ε_t^ν	1	0.0025
$\bar{\nu}$	Long-run mean of government expenditure volatility ν_t	1	0
ρ_κ	Autocorrelation of Profits tax κ_t	1	0.97
σ_κ	Volatility of profits tax shock ε_t^κ	1	0.0025
$\bar{\kappa}$	Long-run mean of Profits tax κ_t	1	-2
$corr(\varepsilon_t^g, \varepsilon_t^\kappa)$	Correlation of ε_t^g and ε_t^κ	1	0.30

Figure B.1: FISCAL EXPENDITURE VOLATILITY SHOCKS: STOCHASTIC PROFIT TAXES. *Notes:* This figure plots impulse response functions of consumption C_t , expected consumption growth $\mathbb{E}_t[\Delta c_{t+1}]$, output Y_t , expected 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 , R&D expenditure growth $\mathbb{E}_t[\Delta s_{t+1}]$, value of a new patent V_t and total amount of labor taxes $\tau_l W_t L_t$ with respect to a shock to the volatility of government expenditures ν_t (ε_t^ν). All parameters are calibrated to the values reported in Table B.1.

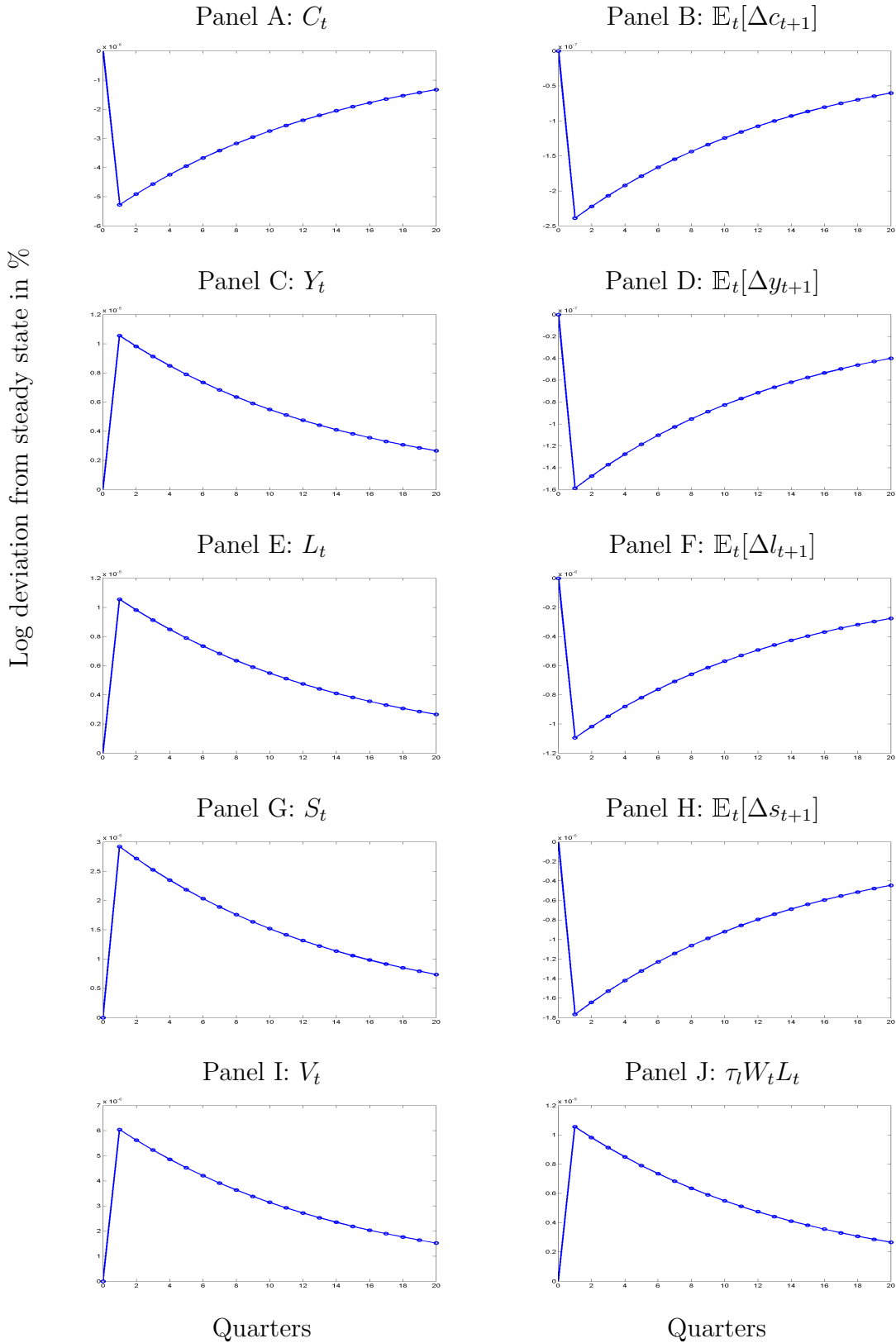


Figure B.2: PROFIT TAX RATE SHOCKS. *Notes:* This figure plots impulse response functions of consumption C_t , expected consumption growth $\mathbb{E}_t[\Delta c_{t+1}]$, output Y_t , expected output growth $\mathbb{E}_t[\Delta y_{t+1}]$, labor hours L_t , expected labor hours growth $\mathbb{E}_t[\Delta l_{t+1}]$, R&D expenditure S_t , R&D expenditure growth $\mathbb{E}_t[\Delta s_{t+1}]$, value of a new patent V_t and total amount of labor taxes $\tau_l W_t L_t$ with respect to a shock to the profit tax rate τ_t^π (ε_t^π). All parameters are calibrated to the values reported in Table B.1.

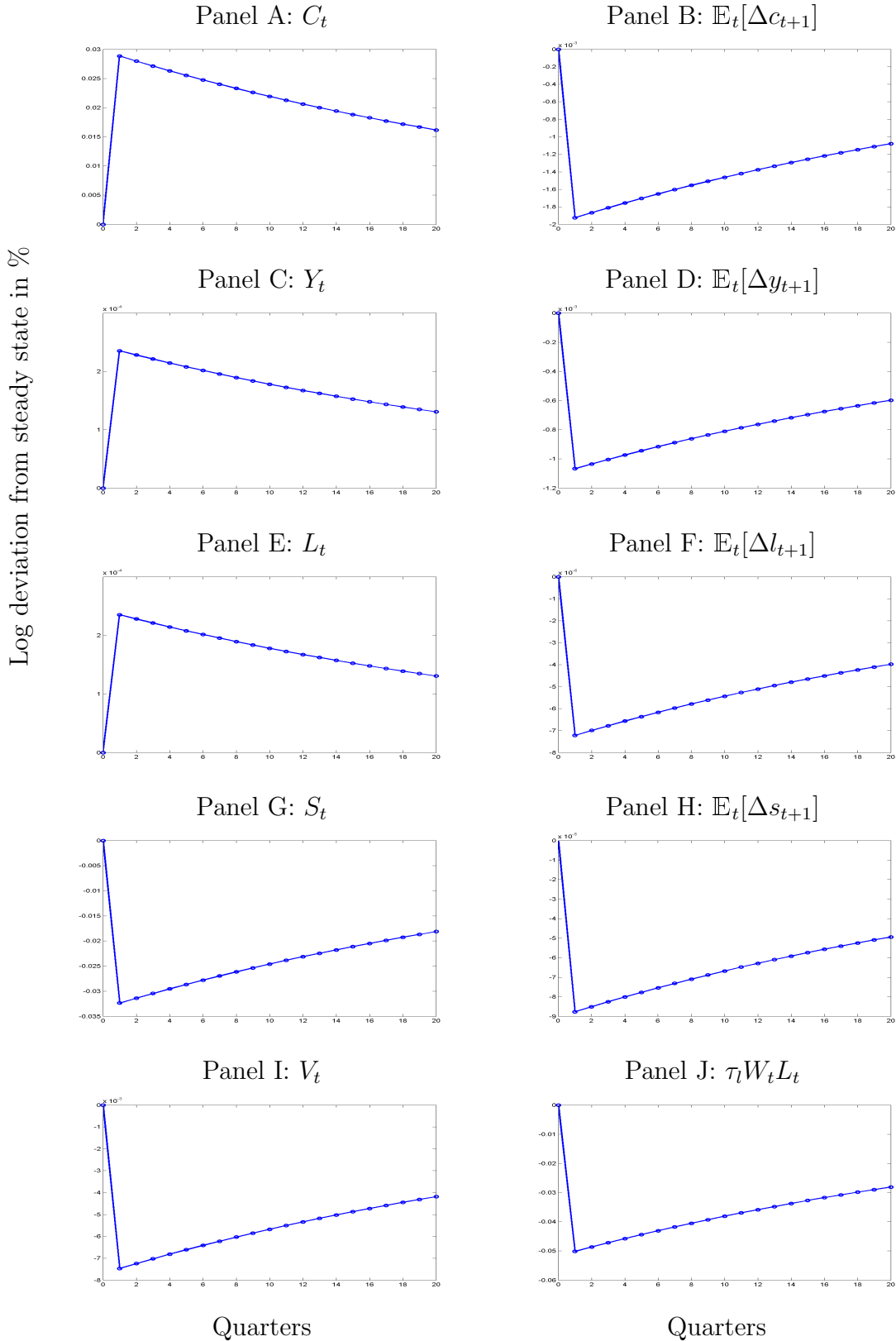


Table B.2: BENCHMARK CALIBRATION: SIMULATION RESULTS. *Notes:* This table reports the results of simulating 3,000 economies for 75 years, i.e., 300 quarters, and then throwing away the first 10 years. The reported moments are annualized. From the model simulations, we report the means and volatilities 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 $D_{a,t} = Y_t - W_t L_t - A_t P Z_t + (1 - \tau_t^r) \Pi_t$. Aggregate dividends are defined as in Bilbiie, Ghironi, and Melitz (2012). The aggregate risk premium, $E[r_a^* - r_f]$, is levered following Boldrin, Christiano, and Fisher (2001). Macro and asset pricing data are from the OECD and run from 1996 to 2013. Annualized empirical moments are represented by cross-country averages. Our sample includes the following EU countries: France, Germany, Italy, Spain and United Kingdom. R&D expenditure growth in each country, Δs , is represented by the Gross Domestic Expenditure on R&D Compound annual growth rate. Countries' equity returns are computed from "OECD Share Price Indexes". The volatilities have been calculated using this average growth rates and return series. The "OECD EU18 Immediate interest rates, Call Money, Interbank Rate" proxies our risk-free rate. Additional details on the data are given in the Appendix A.

	Model	Data
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$E[\Delta y]$	1.49%	1.49%
$E[\Delta c]$	1.49%	1.50%
$E[r_f]$	1.72%	2.41%
$E[r_c - r_f]$	1.39%	-
$E[r_a^* - r_f]$	2.62%	3.95%
Second Moments		
$\sigma_{\Delta y}$	4.22%	1.21%
$\sigma_{\Delta c}$	3.10%	0.97%
$\sigma_{\Delta s}$	5.56%	3.05%
$\sigma_{\Delta c} / \sigma_{\Delta y}$	0.73	0.80
$\sigma_{\Delta s} / \sigma_{\Delta y}$	1.32	2.52
σ_{r_f}	0.65%	1.46%
$\sigma_{r_c - r_f}$	2.69%	-
$\sigma_{r_a^* - r_f}$	4.72%	18.32%

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