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

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). The aim of the SGP was to steer the fiscal discipline of each EU member according to the following deficit and debt criteria (medium-term budgetary objective): (i) annual deficit below the ratio of 3% of the GDP 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.

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. The new fiscal discipline adopted in the Fiscal Compact, 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 know as “golden rule”) in the domestic legal system by means of a constitutional law or an ordinary law.

On the one side, the spirit of the Fiscal Compact and in general of the European austerity policy reflects the idea that EU countries have to transfer fiscal sovereignty to supranational institutions as a cost to safeguard the Euro Area economic and financial

\footnotetext{1}{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.}  
\footnotetext{2}{See A Blueprint for a Deep and genuine EMU, European Commission, November 2012.}  
\footnotetext{3}{See the Treaty on Stability, Coordination and Governance in the Economic and Monetary Union.}  
\footnotetext{4}{This includes the so-called “Six-pack” and “Two-pack” measures. We acknowledge that the Six-pack entered into force in December 2011.}  
\footnotetext{5}{For member states with a debt-to-GDP ratio significantly below 60% the deficit-to-GDP ratio has to be equal to 1.0%.}
stability. On the other side, it is not clear whether the adopted fiscal measures represent a right response to the crisis, or if instead they had adverse effects on the economic recovery.

The ongoing debate on austerity measures and growth remains controversial. Some policymakers and economists argue that the observed effort to reduce fiscal 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)) 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 trough cuts on government expenditure or “exotic taxes” (see, for instance, IMF Fiscal Monitor 2013). In this scenario, countries might be forced to impose also spending cuts (or special taxes) in highly productive sectors, such as R&D. This might affect private investments in R&D as well (Westmore (2013)). Consequently, the probability of developing a new good embodying a technology with long-lasting positive welfare effects decreases.

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.

To study the effects of “adverse fiscal policies”, we present a standard production economy model in which (i) growth is endogenously driven by patents accumulation (as in Romer (1990); Croce, Nguyen, and Schmid (2013); Kung and Schmid (2014)); (ii) agents have recursive preferences (as in Croce, Nguyen, and Schmid (2013) and Kung and Schmid (2014)); and (iii) a regime of fiscal consolidation is exogenously imposed (e.g. 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.\footnote{In our setting, only labor income taxes are endogenously determined. Therefore, both government expenditure and innovation sector taxes are exogenous.} 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 introduce policy uncertainty by means of a fiscal volatility shock on public expenditure,\footnote{See for instance Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012).} 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 fiscal expenditures.

Our analysis shows that uncertainty on future government expenditure undermines households confidence. In response to higher fiscal uncertainty, households – which are averse to both consumption and utility risk in our model – increase current labor supply at the expense of consumption. Such a drop of consumption, in turn, triggers a contraction of output and R&D investments. To face this scenario the government, due to the zero-deficit target, may be induced to increase taxation on the R&D sector. We find that an increase in the R&D tax rate induces a significantly worse contraction in the main macroeconomic variables including expected output growth and expected consumption.

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

\textsuperscript{7}See for instance Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012).
growth. Moreover, we also observe that in the presence of a stochastic R&D tax rate – positively correlated to fiscal expenditures – the expected R&D growth decreases as well. 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 return on equity and decreases the risk free rate as compared to an economy with deterministic tax rates. This mechanism implies that 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 shrinks future consumption and growth rate more than it would happen in absence of co-movements between fiscal volatility and policy on innovations.

We proceed as follows. Section 2 provides some recent empirical evidence on fiscal consolidation. Section 3 presents the model. Section 4 reports the quantitative results. Section 5 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 $GERMANY(+)$). 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 level (e.g. Greece, Italy, Spain, Portugal) countries behaved slightly differently. In fact, over the period 2009:2Q-2012:4Q, cuts in public purchases in high-debt/deficit level governments were significantly higher than in low-debt/deficit level governments (i.e. -2.72 (PIS) vs. -0.87 (GERMANY) and 0.07 (GERMANY(+), on an annual 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.

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 that reduced its fiscal deficit (as share of GDP) by 3 percentage point displays an average real GDP growth of (roughly) -5%. Similarly, Spain and Portugal (two highly indebted countries) reduced their deficit by more than 1 percentage point, and ended up with output growth of -2%. Overall, our simple analysis suggests that austerity is not a good remedy for all those countries with high debt levels. We confirm the evidence in Figure 2 using a simple regression analysis, where 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.
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.

(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)).\footnote{Our 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.} 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 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 high-debt level countries can contain their excessive spending enough to restore credibility. In doing so, they will bring down in-
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 \( A \ast CR \), where \( CR \) is the S&P sovereign credit rating in 2013. \( CR = 0 \) corresponds to a AAA rating, \( CR = 15 \) 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.

![Austerity vs. Economic Performance (2014-2018)](image)

Figure 3: Austerity vs. Growth: Evidence from European Countries (2014 – 2018). 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.
While 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 consumption, empirical evidence from the post-Lehman world tells us another story (see also Krugman (2013)). For example, Giavazzi and Pagano (1990) show that in Denmark (1983-1986) 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). This time it is different. On top of a negative average real GDP growth, several European countries, as a result of the strong fiscal consolidation, also display 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%).

III. R&D vs. Growth

As a consequence of tightening fiscal measures, weaker European countries largely cut R&D expenditure along with all the other public expenses. 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). However, let us remind ourselves that 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, as suggested by both theoretical and empirical studies (Aghion and Howitt (1992); Griffith (2000); Westmore (2013)). Can a drastic cut in R&D be beneficial? Apparently not. Figure 4 informally shows that those countries that put more effort in reducing fiscal deficit in the aftermath of the Lehman Chapter 11 i) drastically cut total 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).

![Graphs showing total government expenditure in research and development, gross domestic expenditure on research and development (annual growth rate), and real GDP growth.](image)

**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.
3 A framework to assess the impact of austerity

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. However, we consider several departures from their theoretical setup. First, we account for stochastic volatility (i.e. fiscal volatility shocks). This is in line with recent empirical and theoretical work aimed at examining the impact of fiscal, technology and monetary volatility shocks on macroeconomic and financial aggregates (Bloom (2009); Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2012)), as well as consistent with post-Lehman empirical evidence (Bloom (2009); Baker, Bloom, and Davis (2013)).

Second, our government is committed to a unique fiscal strategy. Specifically, we focus exclusively on a zero-deficit target policy (consistently with the rules imposed by the fiscal compact and recently signed by EU members). Third, we introduce “ad hoc” austerity measures by means of taxation on R&D expenditure, and for robustness purposes, on R&D profits. It turns out that our government can use both taxes on labor income and R&D (or R&D profits) to finance public expenditures. We first assume a fixed R&D tax, and then, turn our attention to a one following an exogenous stochastic process. Last, for parsimony purposes, we assume a standard Cobb-Douglas consumption-leisure aggregator.

Our 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.

The 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 à la Epstein and Zin (1989),

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

where \( \gamma \) measures relative risk aversion (RRA), \( \psi \) 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, \( C_t \), and leisure, \( 1 - L_t \), given by

\[ u(C_t, L_t) = C_t^{\alpha_c} (A_t(1 - L_t))^{1 - \alpha_c} \]

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 Nisticò (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)).

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

\[ C_t + B_{t+1} + \Upsilon_tQ_{t+1} = (1 - \tau_t)W_tL_t + B_tR_t^f + (\Upsilon_t + D_t)Q_t \]

where \( Q_t \) denotes equity shares, \( \Upsilon_t \) is the market value of an equity share, \( D_t \) represents aggregate dividends, \( B_t \) denotes public debt holdings, and \( R_t^f \) is the risk-free rate. The 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.
representative agent chooses consumption, labor, equity shares and debt holdings, and his wages $W_t$ are taxed at a rate $\tau^t_l$. The stochastic discount factor for this economy can be written as follows

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

The first order conditions of the maximization problem give rise to the following standard asset pricing conditions:

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

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

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 $\alpha$ is the intermediate goods bundle share, $A_t$ represents the number of intermediate goods at time $t$, and $\Lambda_t$ is an exogenous stochastic (stationary) productivity process$^{13}$

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

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$^{13}$In our economy, $\Lambda_t$ 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 the following objective function (profit):

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

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

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

Since firms are identical, by solving the profit maximization problem, 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

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

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

$$Y_t = \Lambda_t L_t^{1-\alpha} \left[ \int_0^{A_t} L_t^\alpha (\Lambda_t \alpha^2)^{\frac{\alpha}{1-\alpha}} di \right] = \frac{1}{\alpha^2} \Lambda_t L_t (\Lambda_t \alpha^2)^{\frac{1}{1-\alpha}}.$$
This expression shows that the final output depends on the variety of the intermediate goods, $A_t$.

### 3.3 Government

In line with [Croce, Nguyen, and Schmid (2013)], 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, $G_t$ evolves as follows

$$
\frac{G_t}{Y_t} = \frac{1}{1 + e^{-g_t}}
$$

$$
g_t = (1 - \rho_g)\bar{g} + \rho_g g_{t-1} + e^g_t, \quad e^g_t \sim N(0, \sigma^2_g)
$$

$$
\nu_t = (1 - \rho_\nu)\bar{\nu} + \rho_\nu \nu_{t-1} + \epsilon_\nu_t, \quad \epsilon_\nu_t \sim N(0, \sigma^2_\nu),
$$

where $\bar{g}$ and $\bar{\nu}$ are the long-run averages of the government expenditure-output ratio and government expenditure volatility, respectively. $\rho_g$ and $\rho_\nu$ 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 public debt, labor and R&D taxes, $T_t = \tau^l_t W_t L_t + \tau^r_t S_t$, where $S_t$ is the total amount of investment in R&D, and

$$
\tau^r_t = \frac{1}{1 + e^{-\chi_t}}
$$

$$
\chi_t = (1 - \rho_\chi)\bar{\chi} + \rho_\chi \chi_{t-1} + \epsilon_\chi_t, \quad \epsilon_\chi_t \sim N(0, \sigma^2_\chi)
$$

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 $\epsilon_\chi$ 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.
The government faces the following budget constraint

\[ B_t = B_{t-1} R_t^f + G_t - T_t. \]  

(16)

Differently from Croce, Nguyen, and Schmid (2013), we focus exclusively on a tax regime where the government is committed to set \( G_t - T_t = 0 \) (consistent with rules imposed by the European SGP).

### 3.4 R&D

In the spirit of Kung and Schmid (2014) and Croce, Nguyen, and Schmid (2013), we assume that each produced intermediate good (i.e. variety) embodies new technology (i.e. patent). Therefore, in each period, each firm develops a new technology and sells it to other intermediate-good firms. In the forthcoming periods, new intermediate firms will produce new patents and sell them to make profits. In this setup, the value of existing variety, \( V_t \), is as follows

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

(17)

where \( \delta_v \) 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):

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

(18)

where \( \frac{1}{\Theta_t} \) is the cost of developing a new patent. Following Kung and Schmid (2014), the stock of patents in this economy evolves as follows

\[ A_{t+1} = \Theta_t S_t + (1 - \delta_v) A_t. \]

(19)

\footnote{See also Santacreu (2012).}
Hence the growth rate of newly produced technology is

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

Notice that \(\Theta_t\) 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.

### 3.5 Resource constraint

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

\[
Y_t = C_t + A_t Z_t + S_t + G_t
\]

in the final good production, and

\[
(1 - \tau_t)(1 - \alpha)Y_t = \frac{1 - \alpha_c}{\alpha_c} \frac{C_t}{1 - L_t}
\]

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, $\beta$, RRA, $\gamma$, and IES, $\psi$) 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 $\xi$ is chosen to match the average output growth rate in the Euro Area over the last two decades (around 1.5%). The technology parameters $\alpha$ (i.e. relative share of labor in the final good production) and $\eta$ (i.e. 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, $\rho_v$, 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, $\rho_g$ and $\rho_v$, 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, $\sigma_g$, is equal to $0.5 \cdot \sigma^\Lambda$ as well as to the volatility of the R&D tax shock, $\sigma_\chi$. In addition, we assume that $\varepsilon^g_t$ and $\varepsilon^\chi_t$ are positively correlated and impose $\text{corr}(\varepsilon^g_t, \varepsilon^\chi_t) = 0.3$. 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, $\tau_r^*$, 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.\footnote{We solve our models in DYNARE++4.3.0 using a third-order approximation. Policies are computed as annual log deviations from the steady state (\texttt{dyn.ss} vector generated by DYNARE++). All variables in our models are stationarized and expressed in log-units in the DYNARE++ code.}


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<th>Parameter</th>
<th>Description</th>
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<td>Elasticity of intertemporal substitution</td>
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</tr>
<tr>
<td>$\alpha$</td>
<td>Labor share</td>
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</tr>
<tr>
<td>$\alpha_c$</td>
<td>Consumption share in utility bundle</td>
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<td>Labor tax rate</td>
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<td>R&amp;D productivity shift parameter</td>
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<td>$\delta_v$</td>
<td>Patent obsolescence rate</td>
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<tr>
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<td>0</td>
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<tr>
<td>$\rho_\chi$</td>
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<td>0.97</td>
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<td>Correlation of $\epsilon^g_t$ and $\epsilon^\chi_t$</td>
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<td>0.30</td>
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### 4.2 Re-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., $\text{corr}(\epsilon^g, \epsilon^\chi) = 0$. 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 quarters after the shock, see Panels B, D, F and H). The current value of new patents increases (see Panel I). The higher uncertainty concerning future fiscal rules decreases the value the 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).

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.

\footnote{This is due to the level of persistence in the fiscal volatility shock of 0.93 (quarterly).}
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 $\tau_t W_t L_t$ with respect to a shock to the volatility of government expenditures $\nu_t (\varepsilon_{\nu_t})$. To focus exclusively on fiscal volatility shocks, we impose $\text{corr}(\epsilon^g, \epsilon^\chi) = 0$ 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: Policy implications

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 shows 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.

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, we point out a trade-off between taxes on R&D and taxes on the labor income. Higher taxes on R&D cause a less pronounced drop in macroeconomic variables. The economic mechanism behind this result can be summarized as follows: higher taxes on the R&D sector imply that the government budget constraint can be satisfied with lower taxes on labor income (see Panel J); the decrease in the labor income tax rate stimulates labor supply and reduces the impact of the negative TFP shocks (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 shocks; 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 $\tau^r$. Table 3 reports that a higher tax rate on the R&D sector depresses the expected growth of output. More precisely, an increase of $\tau^r$ 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 $D_{a,t} = Y_t - W_tL_t - A_tPZ_t + \Pi_t$. 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).

<table>
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<tr>
<th></th>
<th>$\tau^r = 0%$</th>
<th>$\tau^r = 5%$</th>
<th>$\tau^r = 10%$</th>
<th>$\tau^r = 15%$</th>
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<tr>
<td>$E[\Delta y]$</td>
<td>3.83%</td>
<td>2.64%</td>
<td>1.50%</td>
<td>0.53%</td>
</tr>
<tr>
<td>$E[\Delta c]$</td>
<td>3.83%</td>
<td>2.64%</td>
<td>1.50%</td>
<td>0.53%</td>
</tr>
<tr>
<td>$E[r_f]$</td>
<td>2.90%</td>
<td>2.29%</td>
<td>1.71%</td>
<td>1.21%</td>
</tr>
<tr>
<td>$E[r_c - r_f]$</td>
<td>1.72%</td>
<td>1.58%</td>
<td>1.43%</td>
<td>1.33%</td>
</tr>
<tr>
<td>$E[r^*_a - r_f]$</td>
<td>0.91%</td>
<td>0.76%</td>
<td>0.67%</td>
<td>0.62%</td>
</tr>
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**First Moments**

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<th>$\sigma_{\Delta y}$</th>
<th>$\sigma_{\Delta c}$</th>
<th>$\sigma_{\Delta s}$</th>
<th>$\sigma_{\Delta c}/\sigma_{\Delta y}$</th>
<th>$\sigma_{\Delta s}/\sigma_{\Delta y}$</th>
<th>$\sigma_{r_f}$</th>
<th>$\sigma_{r_c-r_f}$</th>
<th>$\sigma_{r^*_a-r_f}$</th>
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<tr>
<td></td>
<td>4.34%</td>
<td>3.12%</td>
<td>5.53%</td>
<td>0.72</td>
<td>1.27</td>
<td>0.74%</td>
<td>2.89%</td>
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<td>2.81%</td>
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<tr>
<td>$\sigma_{\Delta s}$</td>
<td>4.31%</td>
<td>3.19%</td>
<td>5.68%</td>
<td>0.74</td>
<td>1.32</td>
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<td>$\sigma_{\Delta c}/\sigma_{\Delta y}$</td>
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<td>3.23%</td>
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<td>1.34</td>
<td>0.63%</td>
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<td>2.61%</td>
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<td>$\sigma_{\Delta s}/\sigma_{\Delta y}$</td>
<td>1.27</td>
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<tr>
<td>$\sigma_{r_f}$</td>
<td>0.74%</td>
<td>0.70%</td>
<td>0.66%</td>
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<tr>
<td>$\sigma_{r_c-r_f}$</td>
<td>2.89%</td>
<td>2.81%</td>
<td>2.75%</td>
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<tr>
<td>$\sigma_{r^*_a-r_f}$</td>
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<td>2.77%</td>
<td>2.67%</td>
<td>2.61%</td>
<td>2.61%</td>
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24
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 $E_t[\Delta c_{t+1}]$, output $Y_t$, expected output growth $E_t[\Delta y_{t+1}]$, labor hours $L_t$, expected labor hours growth $E_t[\Delta l_{t+1}]$, R&D expenditure $S_t$, R&D expenditure growth $E_t[\Delta s_{t+1}]$, value of a new patent $V_t$ and total amount of labor taxes $\tau_t W_t L_t$ with respect to a shock to the volatility of government expenditures $\nu_t (\epsilon^\nu_t)$. 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.

Panel A: $C_t$  
Panel B: $E_t[\Delta c_{t+1}]$  
Panel C: $Y_t$  
Panel D: $E_t[\Delta y_{t+1}]$  
Panel E: $L_t$  
Panel F: $E_t[\Delta l_{t+1}]$  
Panel G: $S_t$  
Panel H: $E_t[\Delta s_{t+1}]$  
Panel I: $V_t$  
Panel J: $\tau_t W_t L_t$
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 ($\epsilon^s_t$). 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 effect of a shock to the stochastic volatility of fiscal expenditures.

The effects are qualitatively the same as in the case of no tax uncertainty. However, the uncertainty surrounding tax rules generates a more severe contraction in the expected growth rate of macroeconomic variables.

In Figure 9, we analyze the effect of a shock to the R&D tax rate in the complete model. Even in this case, the shock induces a contraction in economic activity. The trade-off between different sources of taxation is still at work: the higher fiscal revenue from the R&D sector allows for a temporary decrease of revenue coming from labor taxes (see Panel J of Figure 9). However, in order to pay back public debt, the government needs to increase future labor taxes which, in turn, depresses future consumption and aggregate output (see Panels B, D, and J). In other words, following a positive shock to $\tau_r^t$, the government is trading off current labor taxes for future labor taxes and this trade-off exacerbates the impacts of a cut in the R&D sector and makes it more long-lasting. The negative effect of this trade-off is evident from the comparison of Figure 8 and Figure 9. At all horizons, the drop in macroeconomic quantities, as output and labor, is more severe and their expected recovery rate lower after a negative shock to $\tau_r^t$ than after a fiscal volatility shock.

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
Figure 8: Fiscal Expenditure Volatility Shocks: Stochastic R&D Taxes. Notes: This figure plots impulse response functions of consumption $C_t$, expected consumption growth $E_t[\Delta c_{t+1}]$, output $Y_t$, expected output growth $E_t[\Delta y_{t+1}]$, labor hours $L_t$, expected labor hours growth $E_t[\Delta l_{t+1}]$, R&D expenditure $S_t$, R&D expenditure growth $E_t[\Delta s_{t+1}]$, value of a new patent $V_t$ and total amount of labor taxes $\tau_t W_t L_t$ with respect to a shock to the volatility of government expenditures $\nu_t (\varepsilon^\nu_n)$. 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 $E_t[\Delta c_{t+1}]$, output $Y_t$, expected output growth $E_t[\Delta y_{t+1}]$, labor hours $L_t$, expected labor hours growth $E_t[\Delta l_{t+1}]$, R&D expenditure $S_t$, R&D expenditure growth $E_t[\Delta s_{t+1}]$, 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 $\tau^r_t (\varepsilon^r_t)$. All parameters are calibrated to the values reported in Table 2 (i.e. full model benchmark calibration).
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 of 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.

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, $\Delta s$, 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.

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<th>Model</th>
<th>Data</th>
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<td>$E[\Delta y]$</td>
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<td>1.49%</td>
</tr>
<tr>
<td>$E[\Delta c]$</td>
<td>1.50%</td>
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<td>1.45%</td>
<td>-</td>
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<tr>
<td>$E[r^*_a - r_f]$</td>
<td>2.75%</td>
<td>3.95%</td>
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<tr>
<td><strong>Second Moments</strong></td>
<td></td>
<td></td>
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<tr>
<td>$\sigma_{\Delta y}$</td>
<td>4.35%</td>
<td>1.21%</td>
</tr>
<tr>
<td>$\sigma_{\Delta c}$</td>
<td>3.20%</td>
<td>0.97%</td>
</tr>
<tr>
<td>$\sigma_{\Delta s}$</td>
<td>5.72%</td>
<td>3.05%</td>
</tr>
<tr>
<td>$\sigma_{\Delta c/\Delta y}$</td>
<td>0.74</td>
<td>0.80</td>
</tr>
<tr>
<td>$\sigma_{\Delta s/\Delta y}$</td>
<td>1.31</td>
<td>2.52</td>
</tr>
<tr>
<td>$\sigma_{r_f}$</td>
<td>0.67%</td>
<td>1.46%</td>
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<tr>
<td>$\sigma_{r_c-r_f}$</td>
<td>2.90%</td>
<td>-</td>
</tr>
<tr>
<td>$\sigma_{r^*_a-r_f}$</td>
<td>4.83%</td>
<td>18.32%</td>
</tr>
</tbody>
</table>
In summary, the main message arising from our quantitative analysis is the following: Austerity measures that include an increase in the taxation of R&D sector can, at best, provide a temporary increase in labor supply but harm future economic growth. The temporary increase in labor supply comes from the reallocation of resources from the R&D sector to the labor market 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. Furthermore, 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?

5 A robustness check: 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 increases revenues by means of taxing R&D profits rather than R&D 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, $\tau^\pi_t$, 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 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 an “ad hoc” R&D taxation.

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 sé. Instead, we argue that implementing austerity measures by means of R&D cuts might have sizable adverse effects on current and future economic performance.
References

AGHION, P., and P. HOWITT (1992): “A Model of Growth Through Creative Destruc-


BENIGNO, G., P. BENIGNO, and S. NISTICÓ (2011): “Risk, Monetary Policy and the


BROWN, A. L., and H. KIM (2013): “Do Individuals Have Preferences Used in Macro-

“Computing DSGE Models with Recursive Preferences and Stochastic Volatility,” *Re-


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)


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

- $\Delta y$: Gross domestic product - expenditure approach (Measure: Growth rate compared to previous quarter, seasonally adjusted; Sample: 1996:1Q-2013:4Q; Source: OECD)

- $\Delta c$: Private final consumption expenditure (Measure: Growth rate compared to previous quarter, seasonally adjusted; Sample: 1996:1Q-2013:4Q; Source: OECD)

- $\Delta s$: 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

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

(B.1)

where $\delta_v$ represents the depreciation rate of the new technology and $\tau^r_t$ takes the following form

$$\tau^r_t = \frac{1}{1 + e^{-\kappa_t}}$$

(B.2)

$$\kappa_t = (1 - \rho_\kappa)\bar{\kappa} + \rho_\kappa \kappa_{t-1} + \epsilon^\kappa_t, \quad \epsilon^\kappa_t \sim N(0, \sigma^2_\kappa).$$

(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):

$$E_t[M_{t+1}V_{t+1}] = \frac{1}{\Theta_t},$$

(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, $T_t = \tau^l_t W_t L_t + \tau^\pi_t \Pi_t$. 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. $corr(\epsilon^g, \epsilon^\kappa) > 0$). 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>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Source</th>
<th>Value</th>
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<tr>
<td>$\beta$</td>
<td>Subjective discount factor</td>
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<td>0.996</td>
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<tr>
<td>$\gamma$</td>
<td>Risk aversion</td>
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<td>10</td>
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<td>Elasticity of intertemporal substitution</td>
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<td>1.7</td>
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<td>$\alpha$</td>
<td>Labor share</td>
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<td>$\alpha_c$</td>
<td>Consumption share in utility bundle</td>
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<td>$\sigma^A$</td>
<td>Volatility of productivity shock $\epsilon^A_t$</td>
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<td>0.005</td>
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<tr>
<td>$\eta$</td>
<td>Elasticity of R&amp;D technology</td>
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<tr>
<td>$\xi$</td>
<td>R&amp;D productivity shift parameter</td>
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<tr>
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<td>Patent obsolescence rate</td>
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<td>$\rho_g$</td>
<td>Autocorrelation of government expenditure ratio $g_t$</td>
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<td>0.98</td>
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<td>Volatility of government expenditure shock $\epsilon^g_t$</td>
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<td>$\bar{g}$</td>
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<td>$\rho_{\nu}$</td>
<td>Autocorrelation of government expenditure volatility $\nu_t$</td>
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<td>0.93</td>
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<tr>
<td>$\sigma_{\nu}$</td>
<td>Volatility of government expenditure volatility shock $\epsilon^\nu_t$</td>
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<td>0.0025</td>
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<tr>
<td>$\bar{\nu}$</td>
<td>Long-run mean of government expenditure volatility $\nu_t$</td>
<td>1</td>
<td>0</td>
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<tr>
<td>$\rho_\kappa$</td>
<td>Autocorrelation of Profits tax $\kappa_t$</td>
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<td>$\sigma_\kappa$</td>
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<td>0.0025</td>
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<tr>
<td>$\bar{\kappa}$</td>
<td>Long-run mean of Profits tax $\kappa_t$</td>
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<td>$corr(\epsilon^g, \epsilon^\kappa)$</td>
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<td>0.30</td>
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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 $\tau_t W_t L_t$ with respect to a shock to the volatility of government expenditures $\nu_t (\varepsilon'_t)$. 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 $E_t[\Delta c_{t+1}]$, output $Y_t$, expected output growth $E_t[\Delta y_{t+1}]$, labor hours $L_t$, expected labor hours growth $E_t[\Delta l_{t+1}]$, R&D expenditure $S_t$, R&D expenditure growth $E_t[\Delta s_{t+1}]$, 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 $\tau_t^\pi (\varepsilon_t^\pi)$. All parameters are calibrated to the values reported in Table B.1.

Panel A: $C_t$  
Panel B: $E_t[\Delta c_{t+1}]$

Panel C: $Y_t$  
Panel D: $E_t[\Delta y_{t+1}]$

Panel E: $L_t$  
Panel F: $E_t[\Delta l_{t+1}]$

Panel G: $S_t$  
Panel H: $E_t[\Delta s_{t+1}]$

Panel I: $V_t$  
Panel J: $\tau_l W_t L_t$

Quarters Quarters
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 $D_{a,t} = Y_t - W_tL_t - A_tPZ_t + (1 - \tau_t)\Pi_t$. 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, $\Delta s$, 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.

<table>
<thead>
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<th>Model</th>
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<tr>
<td>$E[\Delta y]$</td>
<td>1.49%</td>
<td>1.49%</td>
</tr>
<tr>
<td>$E[\Delta c]$</td>
<td>1.49%</td>
<td>1.50%</td>
</tr>
<tr>
<td>$E[r_f]$</td>
<td>1.72%</td>
<td>2.41%</td>
</tr>
<tr>
<td>$E[r_c - r_f]$</td>
<td>1.39%</td>
<td>-</td>
</tr>
<tr>
<td>$E[r^*_a - r_f]$</td>
<td>2.62%</td>
<td>3.95%</td>
</tr>
<tr>
<td>Second Moments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_{\Delta y}$</td>
<td>4.22%</td>
<td>1.21%</td>
</tr>
<tr>
<td>$\sigma_{\Delta c}$</td>
<td>3.10%</td>
<td>0.97%</td>
</tr>
<tr>
<td>$\sigma_{\Delta s}$</td>
<td>5.56%</td>
<td>3.05%</td>
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<tr>
<td>$\sigma_{\Delta c}/\sigma_{\Delta y}$</td>
<td>0.73</td>
<td>0.80</td>
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<tr>
<td>$\sigma_{\Delta s}/\sigma_{\Delta y}$</td>
<td>1.32</td>
<td>2.52</td>
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<tr>
<td>$\sigma_{r_f}$</td>
<td>0.65%</td>
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<tr>
<td>$\sigma_{r_c - r_f}$</td>
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<td>$\sigma_{r^*_a - r_f}$</td>
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<td>18.32%</td>
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