Labor Market Distortions under Sovereign Debt Default Crises

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July 18, 2019

Abstract

Risk of sovereign debt default has frequently affected both emerging market and developed economies. Such financial crises are often followed by severe declines of employment that are hard to justify using standard economic models. This paper documents that labor market distortions deteriorate substantially around debt default episodes. Two different explanations for such dynamics are evaluated by linking these distortions to changes in labor taxes and costs of financing working capital. When added into a dynamic model of equilibrium default, these features are able to replicate the behavior of the observed labor distortion around a period of financial crisis and can also account for substantial declines of employment. In the model, higher interest rates are propagated into larger costs of hiring labor through the presence of working capital. Then, as an economy is hit with a stream of bad productivity shocks, the incentives to default become stronger, thus increasing the cost of debt. This reduces firm demand for labor and generates a labor wedge. A similar effect is obtained with an endogenously generated counter-cyclical income tax rate policy that also rationalizes why austerity is applied during deep recessions. The model is used to shed light on the recent events of the Euro Area debt crisis, in particular, the Greek sovereign debt default.

JEL classification: F32, F34, F41, E62

Keywords: Sovereign default, labor markets, distortionary taxation, austerity, external debt, working capital

*Email: tiago.gomes@itam.mx. I would like to thank Yan Bai, George Alessandria, Dan Lu, Yongsung Chang, Mark Bils, and all participants of the student seminar at the University of Rochester, as well as participants of the 2015 PEJ and 2015 CEF conferences for helpful comments and suggestions. I thank anonymous referees whose insightful comments and suggestions have greatly improved this paper. All errors and omissions are of my own responsibility.

1 Introduction

Sovereign default crises are events usually associated with large economic costs. In particular, countries that experience such events typically face large drops in both output and employment. Mendoza and Yue (2012) document, using at a set of emerging economies, that default events are associated with deep recessions where employment falls on average about 15% relative to pre-crises levels. More recently, the same kind of patterns have been observed for some advanced economies that were at the epicenter of the Euro Area sovereign debt crisis such as Greece, Portugal, and Ireland. One natural question to ask is if the observed fall in employment during these events is unusual given an equally large fall in output at the light of standard economic theory (*e.g.* Chari, Kehoe, and McGrattan, 2007). By showing evidence suggesting that the answer to this question is positive, alternative explanations are advanced where labor markets distortions arise endogenously as a consequence of limited government access to credit markets at the onset of a sovereign debt crisis.

In this paper, labor market frictions are introduced in a standard Eaton and Gersovitz (1981) sovereign default model via two channels. On the one hand, an economy's government relies on distortionary taxation to finance public expenditure, therefore affecting labor supply. On the other hand, firms must borrow a fraction of the wage bill at an interest rate that is itself increasing with the interest rate faced by the government, implying that debt crises also affect directly the production sector. As in other studies (Cuadra et al., 2010), the model can generate an endogenous increase in both tax and interest rates when productivity falls. More new is the conclusion that, combined, both channels generate a deterioration of labor market distortions, also contributing to understanding larger declines of employment associated with default events. Moreover, the inclusion of such distortions partially endogenizes the cost of a debt crises, which helps evaluate policies during and on the path to default. Thus, an important contribution consists in quantifying the extent to which these mechanisms explain employment dynamics during default crises.

To motivate the claim that labor market distortions are increasing during episodes of sovereign default, the Euro Area sovereign debt crisis is used as a main source of empirical evidence. One main advantage of using this set of countries resides on the availability of high frequency data for series such as output, consumption, and employment. Using the Chari, Kehoe, and McGrattan (2007) accounting methodology, it is shown that measured labor wedges, often associated with market distortions, deteriorated much faster for European countries that were close to or defaulted during the crisis. When regressed against a set of controls, worse labor wedges are statistically associated with higher government interest rate spreads, thus suggesting a channel over which adverse government credit conditions spillover into labor market distortions. Additionally, it is shown that both labor tax rates and corporate interest rates started to increase around the year of 2009 for the set of countries that were more severely affected by the European debt crisis. This fact, coupled with evidence that shows that labor wedges are strongly correlated with both tax and corporate interest rates, motivates the focus on specific channels that generate labor market distortions.

These empirical observations are rationalized in a dynamic stochastic model of default with endogenous labor supply. As standard in sovereign default models of the Eaton and Gersovitz (1981) type, the government has limited commitment in honoring its debt contracts, implying that interest rates on external borrowing include a premium over the risk-free rate demanded by international investors to compensate for the risk of default. Because the government is assumed to be impatient and debt is non-contingent, the interest rate spread displays a counter-cyclical pattern as the debt burden becomes more onerous when an economy is in recession and government revenues fall. Given these interest rate dynamics, a financial crisis is then associated with a sharp tightness of credit market access triggered by a sequence of negative productivity shocks. To link such type of financial crises with the labor market, the model adds two additional frictions. First, the government only has access to distortionary taxation and debt to finance public consumption. This implies that taxes have to be raised when access to credit markets becomes constrained thus distorting the household labor supply decision. Second, the model also assumes that firms are required to keep working capital to finance their salary payments and, in line with the literature (Neumeyer and Perri, 2005; Uribe and Yue, 2006; Arellano and Kocherlakota, 2014), it is assumed that high government interest rates spill over to high corporate interest rates. This creates an additional source of labor market distortions from the demand side. To summarize, both distortionary taxation and working capital requirements affect further labor markets when the government is close to default. As a result, the fall in employment is larger than what would have been without these frictions. Under the model framework, default entails direct costs in terms of lower productivity and exclusion of financial markets. However, since repudiating debt repayments releases resources to support both public and private consumption and relaxes the fiscal constraint that prevents further tax increases, the government has to evaluate the cost and benefit of defaulting every period.

A simulated version of this model is computed to match the Greek economy, where several features of its business cycle moments are replicated. In particular, the model can generate counter-cyclical interest spreads and labor tax rates, a characteristic usually associated to emerging market economies (Cuadra et al., 2010; Vegh and Vuletin, 2015). In the model, counter-cyclical tax rates arise due to imperfect credit market access. Such dynamics of both interest rates and tax rates also explain the main results of the simulation: on the path to default employment falls substantially and is followed by increased distortions in labor markets. The model accounts for a typical 15% decline of employment relative to pre-crisis levels (against an observation of 17% for the Greek default) of which 4 percentage points (pp) are accounted from distortionary taxes and some additional 2pp from working capital constraints. That is, without the labor frictions included in the model, employment would have fallen by 9% only.

This paper builds on the literature of endogenous sovereign default risk. Eaton and Gersovitz (1981), Aguiar and Gopinath (2006), or Arellano (2008) developed sovereign default models where the probability of default increases when debt is high or income low. However, these papers assume that the government is able to transfer resources to households in a non-distortionary fashion, thus abstracting from fiscal constraints. In Cuadra, Sanchez, and Sapriza (2010), the authors also use a model of sovereign default extended to include endogenous labor and distortionary taxation to conclude that, under imperfect credit access, tax rates become counter-cyclical. Arellano and Bai (2017) use a similar model to obtain the result that exogenously raising labor taxes may be self-defeating to generate debt sustainability in the sense that the impact of distortions may reduce the revenue base used by the government to repay debt. Despite these important conclusions, neither paper attempts to quantitatively account for the labor market implications of a pro-cyclical tax policy. Also, within the context of sovereign default models, Na, Schmitt-Grohé, Uribe, and Yue (2017) add downward nominal rigidity that translates in involuntary unemployment in order to generate large employment effects during crises. Similarly, Bianchi, Ottonello, and Presno (2018) study optimal fiscal policy in a model with the same kind of wage frictions, identifying that a government's inability to access external finance during recessions induces large increases in involuntary unemployment. However, the kind of severe employment drop generated in both papers relies heavily in the degree of downward wage rigidity, which may have not been experienced in some southern European countries during the crisis[1]. In that sense, this paper provides an alternative explanation for the severe labor market dynamics around sovereign default crises in an environment where wages are fully flexible.

Also related is the literature that uses interest rate shocks as a main source of fluctua-

[1]For example, greek nominal wages fell by more than 12% in 2013 while the unemployment rate stayed at a level of 27% (source: Eurostat).

tions in emerging economies such as Neumeyer and Perri (2005) or Uribe and Yue (2006). These authors present models where firms require working capital, financed by external debt, to pay salaries in advance. This implies that labor demand is reduced when interest rates are high. An important setback of these models relies on the fact that interest rates are completely exogenous and, for that reason, disconnected from the level of government indebtedness. Using a model of sovereign default, Mendoza and Yue (2012), assume that some imported inputs require working capital financing, thus providing a channel over which endogenous interest rate fluctuations affect firm decisions. However, that paper also abstracts from fiscal constraints and the model cannot generate falls in employment at default episodes of the same magnitude as in the data. More recently, Balke (2018) presents a sovereign default model, augmented with labor search, that micro-founds the link between government and corporate interest rates through balance sheet effects of bank intermediation. In that framework, if some government debt is held by domestic banks, then a default reduces the domestic credit supply, implying higher firms' interest rates, lower vacancies posted, and more job separations. An important difference is that wages don't adjust when firms' borrowing costs increase (inducing to potentially large job destruction), while in this paper wages are perfectly flexible thus providing a complementary view of employment dynamics during default crises.

Finally, the literature that uses the accounting methodology developed by Chari, Kehoe, and McGrattan (2007) to study labor market distortions as measured by labor wedges is also relevant to this paper. For example, Karabarbounis (2014a), using a set of developed and emerging market economies, points out that the labor wedge is in general pro-cyclical, that is, it deteriorates when countries are in recession. Similarly, Ohanian et al. (2007) regress labor wedges against a set of regressors and conclude that labor taxes affect negatively this wedge. Neither of these authors relates their wedges with financial crises. An exception comes from Pratap and Quintin (2011) that associate distortions in labor markets to increases in interest rates and tax rates during the Mexican crisis of 1994 but, in their model, neither interest or tax rates are endogenously determined.

The rest of this paper is organized in the following way. Section 2 presents empirical evidence on labor market distortions arising from the Euro Area debt crisis; section 3 describes a model that rationalizes the evidence previously shown; section 4 calibrates the model for the Greek economy and runs counterfactual evaluations; and section 5 concludes.

2 Empirical Evidence

The Euro Area crisis that erupted in 2008 was marked by large heterogeneity in the macroeconomic outcomes of different member countries[2] as evidenced in table 1 that shows the length and depth of the recession for this group of countries. It is quite evident that some countries experienced large and prolonged recessions while others did not. In the case of Greece, the recession is even comparable to the US great depression with a length of more that 6 years followed by a 27% fall in output and an 20pp increase in unemployment (as shown in figure 1). This was also the pattern observed for the other Euro Area countries that experienced prolonged recessions. Given that Greece, Portugal, Ireland, and Spain all received official financial assistance, a natural question to ask is if in their respective recessions the observed increase in the unemployment rate was particularly unusual relative to previous, and otherwise standard, recessions.

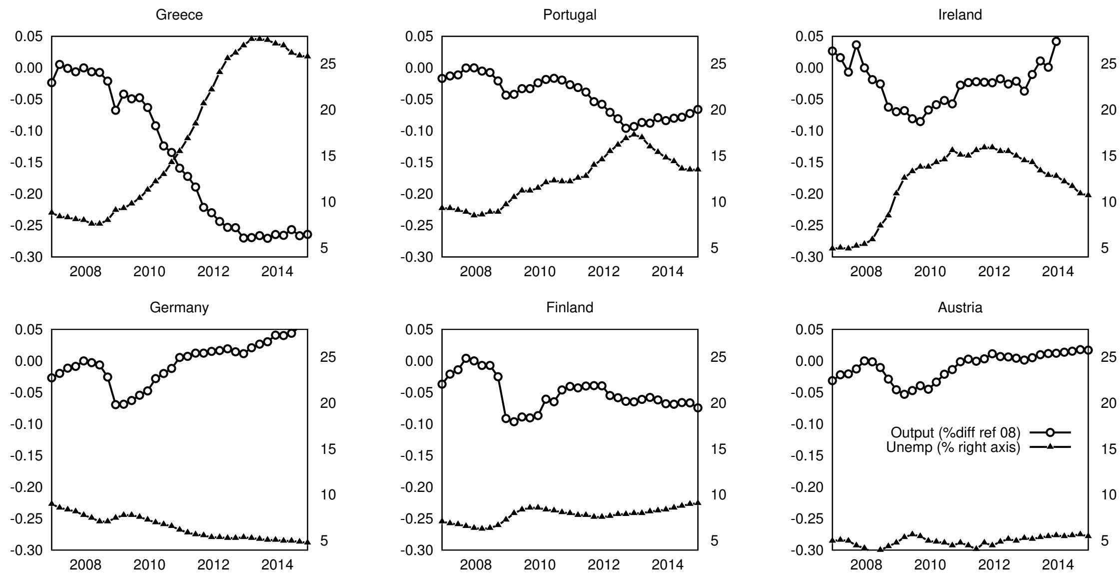
Table 1: Macroeconomic trends for Euro Area countries: percentage change of output (Y), consumption (C), unemployment rate (U), and employment rate (E)

	Peak	Trough	Diff	ΔY (%)	ΔC (%)	ΔU (pp)	ΔE (pp)
Austria	2008q1	2009q2	5	-5.8	1.7	1.2	-0.5
Belgium	2008q2	2009q1	3	-4.2	-0.6	1.1	-0.3
Germany	2008q1	2009q1	4	-6.9	1.3	-0.2	0.3
Spain	2008q2	2013q2	20	-8.0	-8.6	15.8	-9.4
Finland	2007q4	2009q2	6	-9.6	-0.4	1.9	-2.0
France	2008q1	2009q2	5	-4.0	0.8	2.0	-0.7
Greece	2007q2	2013q4	26	-27.4	-22.2	19.2	-11.0
Ireland	2007q4	2012q2	18	-9.7	-9.9	10.0	-9.9
Italy	2008q1	2014q4	27	-9.6	-5.9	6.4	-3.0
Netherlands	2008q1	2009q2	5	-4.2	0.5	0.4	0.1
Portugal	2008q1	2013q1	20	-9.6	-10.4	9.5	-8.3
Slovenia	2008q2	2012q4	18	-11.2	-2.7	5.3	-4.3

Data source: OECD. Output (Y) and consumption (C) are OECD volume estimates. Unemployment (U) and employment (E) rates are the corresponding number of persons relative to the active population. The numbers shown in the table are percentage changes from peak to trough for output and consumption and percentage points changes for unemployment and employment. As in Harding and Pagan (2002), peak and trough turning points are determined using the following methodology: (1) output is measured in logs at quarterly frequency; (2) peaks are selected when $y_t = \max\{y_{t-2}, y_{t-1}, y_t, y_{t+1}, y_{t+2}\}$ and troughs when $y_t = \min\{y_{t-2}, y_{t-1}, y_t, y_{t+1}, y_{t+2}\}$; (3) censoring rules apply where peaks and troughs have to alternate and the minimum phase is 2 quarters with a 5 quarters minimum cycle.

[2] At the beginning of 2008, the set of countries in the Euro Area included: Austria, Belgium, Germany, Spain, Finland, France, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Slovenia. Because Luxembourg is very small with a population of only 0.5 millions, it is not included in the analysis sample. This sample is used for all subsequent results presented in the current section.

Figure 1: Output (% change relative to 2008 - left axis) and unemployment (% of active population - right axis) around the Euro Area debt crisis for selected countries



Data source: Eurostat

Notes: Output refers to the percentage change relative to the beginning of 2008 (left axis), measured at constant 2010 prices. Unemployment corresponds to the percentage of unemployed persons with respect to the active population (right axis). Both variables are seasonally adjusted at the quarterly frequency. Both axis used are fixed for all countries to increase comparability. The replication of this figure for the complete set of Euro Area countries can be found in figure 11 of the Online Appendix.

2.1 Labor wedge

A standard approach in the literature to inspect labor market conditions makes use of the accounting methodology developed by Chari et al. (2007). In this methodology, a wedge is measured as the difference of what is observed in the data relative to the correspondent prediction of a stylized neoclassical model.[3] Essentially, such wedges account for unknown factors that are unaccounted by a frictionless standard economic model. If one focuses only on the labor market, the methodology implies that equilibrium is consistent with the following equation:

$$u_{lt}/u_{ct} = \omega_t \cdot y_t/h_t, \tag{1}$$

[3]An alternative approach that highlights labor market distortions relies on identifying unusual declines of aggregate employment conditional on the recession size. This can be done using an analysis that searches for breaks of the employment/output Okun (1962) relationship. The Online Appendix B.1 provides some suggestive evidence showing that those European countries that were mostly affected by the debt crisis (Greece, Ireland, or Portugal) are also the ones where there is statistical evidence that the relationship breaks, implying that employment is falling faster during the crisis relative to a standard recession.

where u_{lt} and u_{ct} are, respectively, the marginal utility of labor and consumption at time t; y_t and h_t are the aggregate level of output and employment; and ω_t represents a labor wedge, that is, a distortion affecting the labor market that is used to rationalize the data. Following the literature (*eg.* Shimer, 2009; or Karabarbounis, 2014b) a utility function with separable preferences between consumption and leisure is used to account for the labor wedge:

$$u(c,h) = \frac{c^{1-\sigma}}{1-\sigma} - \Gamma \cdot \frac{h^{1+\gamma}}{1+\gamma},$$

where c and h stand for aggregate consumption and aggregate employment; and the parameters σ, γ, and Γ regulate preferences for consumption and hours of work. Linearizing the equilibrium condition in (1), implies the following labor wedge measurement:

$$\hat{\omega}_t = (1+\gamma)\,\hat{h}_t - \hat{y}_t + \sigma \hat{c}_t, \tag{2}$$

where a hat variable represents a log deviation relative to the steady state[4]. That is, an estimate of the labor wedge can be computed by making a choice over the parameters that determine the utility function and by plugging in data observations for the cyclical components of the aggregate output, consumption, and employment.

Figure 2 shows the cyclical component of the labor wedge for a selection of Euro Area countries given a particular choice of the parameter values[5]. It is clear that different countries in the Euro Area were differently affected by the crisis along the labor market. One should note that the labor wedges deteriorated substantially for countries such as Greece, Portugal, or Ireland, while remaining relatively stable for countries such as Germany, Finland, or Austria. This observation seems to suggest that the severity of the financial crisis may be responsible for the adverse labor market behavior in the former set of countries.

To better understand what are the main correlates associated with this labor wedge, the following panel data regression is estimated using all countries of the Euro Area:

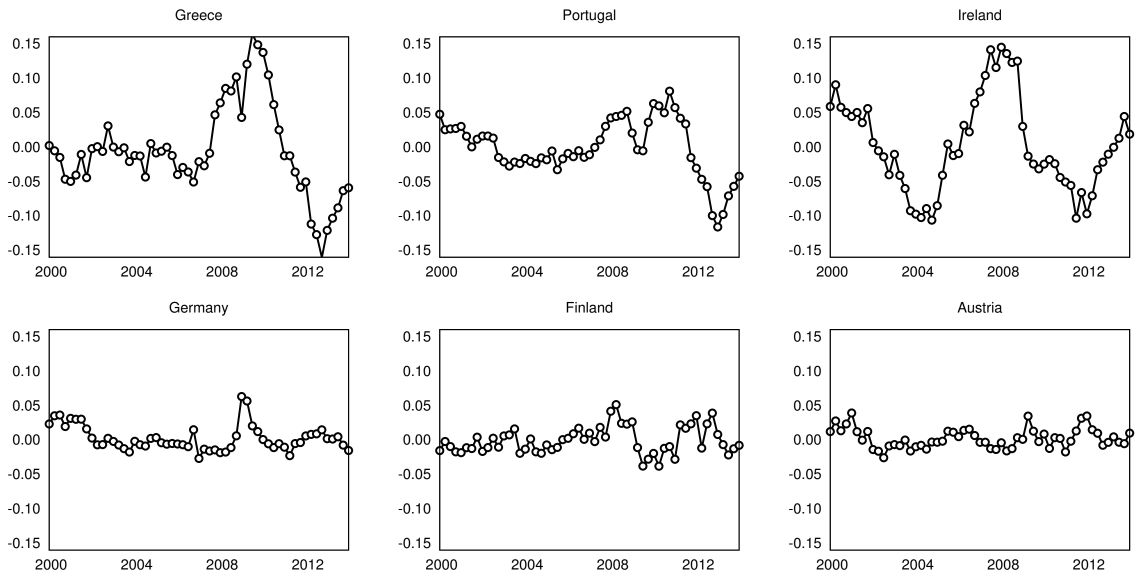
$$\hat{\omega}_{it} = \beta_i + \beta_t + \beta_1 \hat{y}_{it-1} + \beta_2 spread_{it-1} + u_{it}, \tag{3}$$

where $spread_{it}$ is the difference between the 10 year government yield of country i and Germany for the quarter t. The regression uses the interest rate spread as a proxy for the

[4]Specifically, for a level variable x, $\hat{x}_t = \log x_t - \log \bar{x}_t$ and $\bar{x}_t$ is trend component of x_t at time t.

[5]The parameter values are $\sigma = 2$ and $\gamma = 0.5$, which are exactly the same as the ones used in section 4, and close to the ones used, for example, in Neumeyer and Perri (2005).

Figure 2: Cyclical components of the aggregate labor wedge for selected Euro Area countries



Data source: Eurostat
Notes: The variables used to compute the wedges include quarterly seasonal adjusted real output, real consumption, and employment, while the parameters used are the ones referred in footnote 5. Both axes used are fixed for all countries to increase comparability. The line plots correspond to the computation of the wedge using a CRRA utility function accordingly to equations (2). All series are de-trended using an HP-filter with a 1600 smooth parameter. The replication of this figure for the complete set of Euro Area countries can be found in figure 13 of the Online Appendix.

country specific severity of the financial crisis and all regressors are lagged one period to avoid simultaneity bias. Table 2 shows the results of these regressions for different specifications, where the first two columns restricts the sample to countries affected more severely by the crisis while the last two columns include all Euro Area countries.[6] Across specifications, the results indicate that the labor wedge tends to deteriorate during recessions, albeit the negative coefficient is not always significant, a result consistent with previous studies stating that the labor wedge is pro-cyclical (Ohanian and Raffo, 2012; and Karabarbounis, 2014a). The results also show a negative correlation between the labor wedge and the domestic financial conditions as captured by the interest rate spread, that is, a 1 percentage point increase in the interest rate spread is on average associated with a deterioration of the wedge of between 0.41 to 0.54pp. These estimates suggest that times of large spreads are associated with labor markets that are more distorted (consistent with the evidence presented in table 1). That is, the unusual drop in employment, observed mainly in southern European countries and Ireland, may be related with the sharp increase in interest rate

[6]These include Greece, Spain, Ireland, and Portugal, all countries that were bailed out by international institutions during the crisis.

Table 2: Labor wedge panel data regressions for all Euro Area countries (2002-2018)

dependent var: labor wedge ($\hat{\omega}_{it}$)

Sample selection	Crisis countries		All Euro Area countries	
interest rate spread ($spread_{it-1}$)	-0.41^{*}	-0.41^{*}	-0.46^{***}	-0.54^{***}
	(0.16)	(0.16)	(0.08)	(0.16)
output gap ($\hat{y}_{it-1}$)	1.07	0.44	0.71^{***}	0.56
	(0.49)	(0.37)	(0.21)	(.37)
time fixed effects	no	yes	no	yes
country fixed effects	yes	yes	yes	yes
R^2	0.36	0.60	0.26	0.38
N	346	346	794	794

Sources: Eurostat and ECB

Notes: The table shows coefficient estimates for the model summarized in equation (3) for the period of 2002 to 2018. All regressions are estimated using country fixed effects and the standard errors, presented in parenthesis, are heteroskedastic robust. All variables are measured at the quarterly frequency. The results in the first two numerical columns restrict the sample to include only countries that received international bailouts: Greece, Spain, Ireland, and Portugal. In the last two columns, all Euro Area countries are included in the regressions as described in footnote 2.

*** corresponds to a significance level of 1%; ** significance level of 5%; * significance level of 10%

motivated by a sovereign debt crisis.

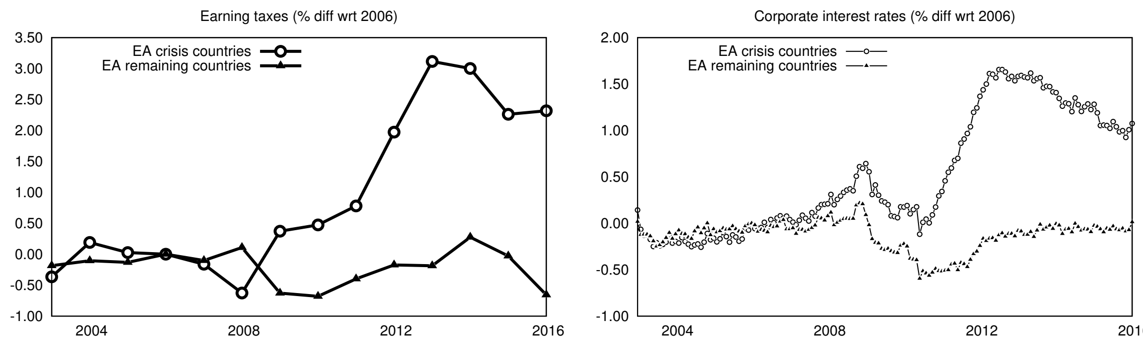
2.2 Dynamics of earning tax rates and corporate interest rates

Given the results presented in the previous subsections, an open question remains on what may be distorting labor markets in countries affected during debt financial crises. In this paper, two different explanations are used to understand such distortions: counter-cyclical, austerity like, taxation on earnings; and an increase of corporate interest rates due to spillover from government interest rates.[7]

Figure 3 shows how proxies for these two variables changed during the Euro Area debt crisis, where the sample is divided between countries that were affected by the crisis (Greece, Spain, Portugal, and Ireland) and all the remaining non-affected countries. It is evident that both the tax rates and the corporate interest rates started to diverge for the two set of countries around the year of 2009 that set the beginning of the European debt crisis. In particular, for the set of crisis countries, earning taxes jumped 3pp relative to pre-crisis values and corporate interest rate spreads 2pp, while remaining more or less constant for

[7]Greece presents as a notable case of such tax dynamics during the crisis. For example, in 2010 maximum statutory personal income tax increased from 40% to 49% and standard value added taxes increased from 19% to 23%, plus many special and solidarity additional taxes levied on specific income brackets (source: European Commission).

Figure 3: Dynamics of earning taxes and corporate interest rates for Euro Area countries during the debt crisis



Data source: Eurostat and ECB
Notes: Tax rates on earnings refer to Eurostat data computed for a typical household with average income and two children. The corporate interest rates refer to ECB data on the average interest rate new loans made to non-financial corporations with maturity less than one year. Spreads are computed as the difference of the country average corporate interest rate with respect to the German average corporate interest rate. 'Euro Area crisis countries' correspond to the average of these two measures for Greece, Spain, Ireland, and Portugal; while 'Euro Area remaining countries' correspond to the average for Austria, Belgium, Germany, Finland, France, Italy, and Netherlands.

the other countries[8]. Note that since crisis countries also experience declines in corporate credit to output, higher interest rates are consistent with a decline in domestic credit supply that may impair the production sector decisions.[9]

Table 3 also shows how both interest rate spreads and earning taxes correlate with the observed labor wedges in Euro Area countries for the period of 2002 and 2018. The results support the idea that lower (or more distorted) labor wedges are associated with higher government or corporate interest rates as well as with higher earning taxes. Interestingly, it is in the set of countries affected by the debt crisis that these effects are stronger and more evident.

These trends, coupled with the evidence presented in tables 2 and 3, suggest that distortions in labor markets associated with financial crises may be caused by the application of austerity policies and disruptions in firm-level credit access. The following section presents

[8]Regarding fiscal policies, Vegh and Vuletin (2015) document that emerging market economies display pro-cyclical tax policies in contrast to developed economies that use counter-cyclical tax policies. Also, Pratap and Quintin (2011) found that in response to the Mexican 1994 debt crisis, the government increased some tax rates. As for corporate interest rates during financial crisis, Arellano and Kocherlakota (2014) and Augustin et al. (2018) document that sovereign risk of default is usually associated with higher corporate interest rates, while Almeida et al. (2017) found that during the European sovereign debt crisis corporate credit ratings were closely linked with sovereign credit ratings. Arteta and Hale (2008), using micro-level data, also identify that firm's access to credit declines substantially during debt crises.

[9]For example, in the case of Greece, corporate interest rate spreads increased to a maximum of 3pp in 2013, while aggregate debt to non-financial corporations decreased about 20% relative to pre-crisis levels (see figures 14 and 15 of the Online Appendix B.2; sources Eurostat and ECB).

Table 3: Simple correlations between cyclical components of labor wedges with government and corporate interest rate spreads, and earnings taxes

corr labor wedge with:	ir spread gov	ir spread corp	earning taxes	earning taxes (alt)	obs
Austria	0.52	-0.43	-0.36	-0.37	17
Belgium	0.53	-0.15	0.23	0.24	17
Germany			0.08	0.02	17
Greece	-0.50	-0.51	-0.57	-0.65	17
Spain	-0.47	-0.39	-0.36	-0.43	17
Finland	0.12	0.21	0.14	-0.02	17
France	-0.15	0.08	-0.31	-0.28	17
Ireland	-0.33	0.26	-0.64	-0.61	17
Italy	-0.07	-0.79	0.11	-0.21	17
Netherlands	0.24	-0.27	-0.38	-0.42	17
Portugal	-0.29	-0.48	-0.47	-0.52	17
Mean crisis countries	-0.40	-0.28	-0.51	-0.55	
Mean remaining countries	0.20	-0.23	-0.10	-0.18	

Sources: Eurostat, ECB, and European Commission
Notes: The table shows coefficients of correlations of different variables and Euro Area countries for the period of 2002 to 2018. Tax rates on earnings refer to Eurostat data computed for a typical household with average income and two children. "Earning taxes" (5th column) uses those rates, while "earning taxes (alt)" (6th column) uses those rates weighted by value added taxes using $(1-\tau_l)/(1-\tau_c)$, where τ_l are earning taxes and τ_c value added taxes. The corporate interest rates refer to ECB data on the average interest rate new loans made to non-financial corporations with maturity less than one year. Spreads are computed as the difference of the country average corporate interest rate with respect to the German average corporate interest rate. 'crisis countries' correspond to the average of these two measures for Greece, Spain, Ireland, and Portugal; while 'remaining countries' correspond to the average for Austria, Belgium, Germany, Finland, France, Italy, and Netherlands. All variables are converted into annual series and de-trended using an HP-filter with a 10 smooth parameter.

a model where the lack of access to international credit markets by a sovereign in risk of default generates such reactions that explain the increased distortions in labor markets and the unusual fall in employment associated with default episodes.

3 Model Economy

The previous section suggests that labor markets and credit access are closely related. In this section, a typical sovereign default model is presented to account for that relationship. The model economy is one based on Eaton and Gersovitz (1981) where a sovereign government borrows or saves from international markets in order to maximize consumers welfare. Because the government cannot commit to honor its debts contracts, international investors demand an interest rate premium over the risk free rate to account for default probability. The main departure from the Eaton and Gersovitz (1981) model resides on the labor market. On the one hand the households supply of labor in the market is subjected to an income tax rate determined endogenously by the government. On the other hand, firms demand labor from the market facing a working capital constrain, implying that part of the inputs of production must be payed in advanced. The first feature links labor supply to credit conditions, as a debt constrained government in need to finance public expenditure has to increase taxes that distorts consumers decisions. As for the second feature, under the assumption that higher government interest rates spillover to corporate higher interest rates, then, due to the working capital constrain, harsher credit conditions affects firms inducing them to hire less labor. The details of this model are outlined in the following subsections.

3.1 Household

The representative household in this economy is assumed to be infinitely lived, valuing consumption and labor accordingly to:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(C_t, H_t), \tag{4}$$

where $\mathbb{E}$ is the expectation operator, β denotes the discount factor, and the period utility $u\left(C_t, H_t\right)$ is: continuous, differentiable, and concave in both arguments; increasing in consumption C and decreasing in hours H. Maximization of lifetime utility (4) is subjected to the following budget constraint:

$$C_t = (1-\tau_t) \cdot \left(w_t H_t + \pi_t + e_t\right). \tag{5}$$

That is, consumption C_t equals total earnings provided by wage income derived from supplying H_t hours at a wage rate of w_t, firms' profits π_t and interest earnings e_t, all income taxed at rate τ_t. The interest earnings, described below, result from intra-period loans intermediated by the government between consumers and firms and is used to introduce a working capital constraint friction on firms. Optimality from the maximization of (4) subjected to (5) implies the following first order condition:

$$\frac{\partial u(C_t, H_t)/\partial H_t}{\partial u(C_t, H_t)/\partial C_t} = (1-\tau_t) w_t. \tag{6}$$

This implies that the marginal rate of substitution of hours to consumption equals the wage rate net of taxes. Equation (6) together with (5) characterize simultaneously this household labor supply and demand for consumption goods. Similar optimality conditions were used within the framework of sovereign default models, for example, in Cuadra, Sanchez, and Sapriza (2010) or Arellano and Bai (2017). Implicitly in this environment is the restriction that the household cannot directly access external borrowing, that is, all external borrowing is made by the government on behalf of consumers[10].

3.2 Firm

Final consumption goods are produced by firms using labor services as inputs[11]. The production function $f(H)$ (continuous, differentiable, concave, and satisfying Inada's conditions) is also subjected to a multiplicative stochastic productivity shock Z_t that follows a Markov process. As in Neumeyer and Perri (2005) or Uribe and Yue (2006), profits equal the difference between revenues and costs that include both the wage bill and working capital costs. This means that in order to pay wages to workers, firms need to set aside a fraction $\theta \in [0, 1]$ of the wage bill immediately at the beginning of the period in order to pay workers before production takes place. However, because production is only available at the end of the period, firms need to borrow an amount equal to $\theta w_t H_t$ from households at a gross interest rate of $\tilde{r}_t \geq 0$[12]. The assumed working capital constraint is meant to capture, in a reduced form, financial frictions faced by firms, where such frictions may aggravate accordingly to the overall credit standing of the government, consistent with the idea that sovereign defaults may generate a sovereign-bank doom loop and ultimately a decrease in the domestic credit supply (Brunnermeier et al., 2016). Taken together, at the end of time t, profits are given by:

$$\pi_t = Z_t f\left(H_t\right) - w_t H_t - \theta \tilde{r}_t w_t H_t. \tag{7}$$

It follows that profit maximization implies the following equation that characterizes

[10] Note that in a decentralized borrowing environment, agents would not internalize the fact that the interest rate depends on debt. However, if the government imposes debt taxes, the outcome of a fully internalized centralized borrowing can be replicated (see Na et al., 2017).

[11] The production side of this economy excludes capital mostly for simplifying purposes. Adding capital makes the solution of a recursive problem with default option significantly harder since it adds an additional endogenous state variable. For a sovereign default model that includes capital and investment dynamics see Gordon and Guerron-Quintana (2018) that show that most business cycle properties of the model, excluding investment related moments, remain relatively unchanged with respect to standard models that disregard capital accumulation.

[12] A different way to interpret working capital requirements is that, due to some friction in the technology for transferring resources, workers demand a fraction θ of the wage payment before production takes place. For that reason, firms need to borrow in advance.

demand for labor:

$$w_t = \frac{1}{1+\theta \tilde{r}_t} \cdot Z_t \frac{\partial f(H_t)}{\partial H_t}. \tag{8}$$

Note that the wage rate is equated to the marginal product of labor times an additional term bounded between 0 and 1 that captures the cost of finance. It follows that, from the firm's perspective, an increase in its cost of finance is equivalent to a negative productivity shock.

3.3 Government

The sovereign government finances public consumption G_t using income taxes or by issuing non-contingent new long-term debt at international markets price of q_t[13]. In order to introduce long-term debt, a similar approach to Chatterjee and Eyigungor (2012) or Hatchondo, Martinez, and Sosa-Padilla (2016) is followed by assuming that the debt stock matures at any given period with probability λ and, for the share of debt that doesn't mature, pays a coupon equal to x. Such modeling choice allows the problem to include long-term debt without having to track more state variables than just the total debt outstanding D_t. This implies that given new issuances I_t, debt accumulates accordingly to:

$$D_{t+1} = (1-\lambda)\, D_t + I_t. \tag{9}$$

Because international investors cannot enforce contracts, the government has the ability to repudiate its debt liabilities. However, under the case of default, the government acquires a bad credit history and becomes excluded from borrowing for a random number of periods. At the end of that period the government has the option of restructuring its debt by paying a fraction φ of what is due. If that is the case, a good credit standing status is regained. Also, while in financially exclusion, firms productivity is negatively affected becoming $\tilde{Z} = Z - l(Z)$ where $l(Z)$ is an increasing loss function[14]. Given these elements, the government budget constrain can be characterized by:

$$\tau_t \cdot (w_t H_t + \pi_t + e_t) = G_t + q_t \left[D_{t+1} - (1-\lambda)\, D_t\right] - D_t \left[\lambda + (1-\lambda)\, x\right] \quad if\ repay \tag{10}$$

$$\tau_t \cdot (w_t H_t + \pi_t + e_t) = G_t \quad if\ default, \tag{11}$$

[13] The main results of the paper regarding the dynamics of labor markets during sovereign default episodes are robust to the inclusion of one-period short-term debt instead.

[14] The loss function $l\,(Z)$ allows the model to deliver default probabilities consistent with data observations (Arellano, 2008).

It follows that the problem for the government, when the credit history is good, resides on choosing the tax rate τ_t, next period debt D_{t+1}, and whether or not to repay current debt in order to maximize the household's lifetime utility (4) subjected to equations (10) and (11), together with (5), (6), and (8). The last three constraints emerge due to the fact that the government has no access to *lump sum* tax instruments and has to operate under a competitive labor market equilibrium. That is, the government internalizes how its tax choices affect labor supply in the economy.

3.4 International Investors

If the government has a good credit history, then it can issue debt in international markets where risk neutral investors charge a debt price q_t that compensates them for the opportunity cost of alternative investments with a certain rate of return of $1/\bar{q}-1$. Under default, debt grows at the risk free rate, so $D_{t+1}=D_t/\bar{q}$. Also under default, the government receives a restructuring shock with probability ζ that allows for a debt reduction of a fraction $\varphi \in [0,1]$ and regained access to credit markets[15]. Letting $\mathbb{I}(D,z)$ be an indicator function taking 1 whenever the government decides to default, then international investors price new issuances of debt, $q_t \equiv q\left(D_{t+1}, Z_t\right)$, accordingly to:

$$q_t = \bar{q} \int \left\{ \left(1-\mathbb{I}_{t+1}\right)\left(\lambda + (1-\lambda)\left(x+q_{t+1}\right)\right) + \mathbb{I}_{t+1} q_{t+1}^{def} \right\} dF(Z_{t+1}|Z_t), \tag{12}$$

where $F(Z_{t+1},|Z_t)$ is the stochastic process governing productivity; $q_{t+1} \equiv q\left(D_{t+2}, Z_{t+1}\right)$ is the bond price in the following period without default; and $q_{t+1}^{def} \equiv q^{def}\left(D_{t+1}/\bar{q}, Z_{t+1}\right)$ is the bond price under default, defined recursively as:

$$q_t^{def} = \bar{q} \int \left\{ (1-\zeta)\, q_{t+1}^{def} + \zeta\varphi \Big(\left(1-\mathbb{I}_{t+1}\right)\left[\lambda + (1-\lambda)\left(x+\tilde{q}_{t+1}\right)\right] + \mathbb{I}_{t+1}\tilde{q}_{t+1}^{def} \Big) \right\} dF(Z_{t+1}|Z_t), \tag{13}$$

and $\tilde{q}_{t+1} \equiv q\left[\varphi D_{t+1}/\bar{q}, Z_{t+1}\right]$ is the price of restructured debt under repayment, while $\tilde{q}_{t+1}^{def} \equiv q^{def}\left[\varphi D_{t+1}/\bar{q}, Z_{t+1}\right]$ is the price of restructured debt under default.

The debt price schedule (12) is composed of 3 main elements: the first one, $\bar{q}$, is the price for risk-free investments; the second, $\int \left[1-\mathbb{I}_{t+1}\right] dF(Z_{t+1},|Z_t)$, is the probability that the government honors the debt contract; and the last, $\int \left[\mathbb{I}_{t+1} q_{t+1}^{def}\right] dF(Z_{t+1},|Z_t)$, reflects

[15] Similarly to footnote 13, the results presented in this paper are robust to different choices of φ, including one where the recovery rate is $\varphi=0$.

the expected recovery rate of an international investor whenever the government defaults. That recovery depends on the parameter φ.

Finally, as pointed by Hatchondo et al. (2016), models with long-term debt and positive recovery rate can give the government incentives to issue large amounts of debt just before defaulting, which could allow for a large increase in consumption. These authors solve this issue by preventing the government from issuing debt at certain low prices. In this model, the same kind of restriction is used where the government cannot issue new debt at a price lower than $\underline{q}$. In the calibration section, a value of $\underline{q}$ is chosen such that this constraint never binds while the government does not default and has a good credit history, and still allows for debt issuances at the sovereign spreads consistent to what is observed in the data[16].

3.5 Recursive Formulation

Given the specification of the problem, the timing of events for a government with good credit history is summarized as follows:

- the government enters a period t with debt D_t; productivity Z_t is realized and observed.

- if the government decides to repay maturing debt λD_t and the coupons on non-maturing debt $(1-\lambda)\,xD_t$, it then chooses current tax rate τ_t, and new debt issuances I_t to finance public consumption G_t.

  - at the beginning of the period, households decide on labor supply and firms on labor demand; labor market equilibrium implies that for a wage rate w_t, H_t hours are supplied; simultaneously, households also decide on their consumption schedules.
  - production follows and, towards the end of the period, profits π_t and interest earnings $e_t = \tilde{r}_t w_t H_t \theta$ are transferred to the household and consumption follows.
  - next period $t+1$ the government keeps its good credit history and starts the period with D_{t+1}.

[16] In the calibration of the model described in section 4, the minimum long-term debt price issuance is set to $\underline{q} = 0.5$, which corresponds to a maximum equivalent zero-coupon yearly interest rate of 18.6%. In the simulations, the maximum yearly interest rate over which the government still decides to issue debt is 11.1%.

- if the government decides to default then credit history becomes bad, productivity suffers a loss equal to $l(Z_t)$ and the government chooses taxes τ_t to finance G_t.
  - a similar chain of events as above determines consumption and labor, C_t and H_t respectively.
  - while in default the government's debt accumulates interests at the risk-free rate: $D_{t+1} = D_t/\bar{q}$.
  - with probability ζ the government receives a debt restructuring shock and its current debt is reduced by φ; the government can decide to repay that new amount of debt, thus regaining a good credit history, or to remain in default.

The remaining object to be defined is the interest rate firms face regarding their working capital requirements. As typical in existing models of business cycles for small open economies with working capital (Neumeyer and Perri, 2005, Uribe and Yue, 2006, or Mendoza and Yue, 2012), the model assumes that the firm (one period) interest rate is given by:

$$\tilde{r} = m\left(1/q\right), \tag{14}$$

where m is an increasing function[17].[18] Because the firm loan is one period only, the function m also converts the long term yield of a government bond $1/q$ into an equivalent one period zero-coupon interest rate[19].

The structure described above implies that the government's problem admits a recursive formulation, where (4) is maximized subjected to equations (6)-(12). Letting $v(D, z)$ be the value of the government with a good credit history, then the problem can be represented as:

$$v(D, Z) = \max_{\mathbb{I}\in\{1,0\}} \left\{(1-\mathbb{I})\cdot v^{rep}(D, Z) + \mathbb{I}\cdot v^{def}(D, Z)\right\}. \tag{15}$$

[17]An increasing function $m(.)$ is also consistent with the empirical evidence stating that higher government interest rates are associated with higher corporate interest rates (Augustin et al., 2018, or Almeida et al., 2017) or lower disbursement of private credit (Arteta and Hale, 2008).

[18]Interest rate spillovers associated with debt risk can flow both ways between government and corporations, a feature usually referred as the diabolic loop (Brunnermeier et al., 2016). For example, Arellano and Kocherlakota (2014) present a model where higher corporate interest rates due to increasing default translates into lower government tax collection and higher default risk and spreads, while Balke (2018) shows a theory where higher government interest rates due to increasing default risk translates into lower domestic credit and higher corporate interest rates.

[19]The model simulation described in section 4 generates an average government bond price of $q = 0.87$, which corresponds to a zero-coupon quarterly yield of 1.04%.

Within the specification of (15), the value of repayment is defined as[20]:

$$v^{rep}(D,Z) = \max_{D',\tau} \left\{ u(C,H) + \beta \mathbb{E}_Z \left[v(D',Z') \right] \right\} \tag{16}$$

$$st$$

$$\begin{aligned}
&C = (1-\tau) \cdot (H + \pi + e) \\
&\pi = Zf(H) - wH - \theta \tilde{r} wH \\
&e = \theta \tilde{r} wH \\
&\frac{u_H(C,H)}{u_C(C,H)} = (1-\tau) w \\
&w = \frac{1}{1+\tilde{r}\theta} \cdot Z f_H(H) \\
&\tau \cdot (wH + \pi + e) = G + D\left[\lambda + (1-\lambda)x\right] - q(D',Z) \cdot \left[D' - (1-\lambda)D\right] \\
&\tilde{r} = m\left(1/q(D',Z)\right).
\end{aligned}$$

Note that, because the government decides on debt and taxes under a labor market equilibrium[21], once new debt is chosen, taxes become determined by (10). Also, the set constraints from (16) can be simplified with the following representation:

$$v^{rep}(D,Z) = \max_{D'} \left\{ uC, H) + \beta \mathbb{E}_Z \left[v(D',Z') \right] \right\} \tag{17}$$

$$st$$

$$C = Zf(H) - G + \Psi' \tag{18}$$

$$\frac{u_H(C,H)}{u_C(C,H)} = Z f_H(H) \cdot \frac{1 - \frac{G-\Psi'}{Zf(H)}}{1 + \theta m\left(1/q(D',Z)\right)} \tag{19}$$

where $\Psi' = q(D',Z) \cdot \left[D' - (1-\lambda)D\right] - D\left[\lambda + (1-\lambda)x\right]$ are net current external inflows into the economy. Equation (18) can be interpreted as a usual resource constraint, and equation (19) as an implementability constraint.

[20]In the equations, $u_C(C,H)$, $u_H(C,H)$, and $f_H(H)$ stand for $\frac{\partial u(C,H)}{\partial C}$, $\frac{\partial u(C,H)}{\partial H}$, and $\frac{\partial f(H)}{\partial H}$, respectively.

[21]Labor market equilibrium represents the set of competitive allocations (C,H) such that both consumers and firms are optimizing given prices and taxes.

Similarly, the value of default specified in (15) is defined as:

$$v^{def}\left(D,Z\right)=u(C,H)+\beta\mathbb{E}_{Z}\left[\zeta\cdot v(\varphi D/\bar{q},Z')+(1-\zeta)\,v^{def}\left(D/\bar{q},Z'\right)\right] \tag{20}$$

st

$$C=\left[Z-l(Z)\right]f\left(H\right)-G \tag{21}$$

$$\frac{u_H(C,H)}{u_C(C,H)}=\left[Z-l(Z)\right]f_H(H)\cdot\frac{1-\frac{G}{[Z-l(Z)]f(H)}}{1+\theta m\left(1/q^{def}(D/\bar{q},Z)\right)} \tag{22}$$

3.6 Recursive Equilibrium

Given the above description for the model economy, a Markov Perfect Equilibrium can be defined. This equilibrium requires that, at every possible state, agents' beliefs over other agents are specified. For such beliefs, each agent must choose actions that are the best response to other agents' strategies. In the current setting both the government and international investors only use stationary Markov strategies.

Definition 1. A recursive equilibrium is a set of:

i) Value function: $v(D,Z)$;

ii) Debt price functions: $q(D',Z)$ and $q^{def}(D',Z)$;

such that:

a) Given debt price functions, $q(D',Z)$ and $q^{def}(D',Z)$, the value function $v(D,Z)$ solves the government problem (15);

b) Given the value function $v(D,Z)$, debt price functions $q(D',Z)$ and $q^{def}(D',Z)$ are consistent with the lenders zero profit condition in (12).

Condition (a) requires that the government default and borrowing decisions are optimal given the debt price schedule. Condition (b) requires that the equilibrium debt prices determining the country's risk premium are consistent with optimal lender behavior. Moreover, given that allocations satisfy equations (6) to (12), then these are are consistent with a competitive equilibrium in the labor market and satisfy the economy's resource constraint. A solution to this recursive equilibrium includes policy functions for debt issuance $I(D,Z)$, consumption $c(D,Z)$, hours $h(D,Z)$, taxes $\tau(D,Z)$, and default sets $\mathbb{I}(D,Z)$.

4 Calibration and Quantitative Analysis

The quantitative implications of the model outlined are studied using numerical simulations at a quarterly frequency following a baseline calibration strategy. In order to proceed, different functional forms are first selected.

4.1 Functional Forms

The choice for the household utility function follows Greenwood, Hercowitz, and Huffman (1988) which suggest a functional form that has a long tradition in the literature studying business cycles in small open economies (Mendoza, 1991; Neumeyer and Perri, 2005; Aguiar and Gopinath, 2007). This utility function has the advantage of shutting down the wealth effect on labor supply and, therefore, shocks in the productivity process have an output response of the same signal. This is of particular relevance for the present exercise that focuses on labor response to a sovereign default crisis. For example, with a common CRRA utility function[22], a strong negative income shock, without a change in the tax structure, would generate a counter-factual increase in labor supply due to wealth effects. For that reason, instead, the following utility function is used:

$$u(C,H) = \frac{1}{1-\sigma} \cdot \left(C - \Gamma \frac{H^{1+\gamma}}{1+\gamma} \right)^{1-\sigma}. \tag{23}$$

Firm's production function, standard in the literature of sovereign default (Mendoza and Yue, 2012, or Arellano and Bai, 2017), is assumed to be given by:

$$\tilde{Z} f(H) = \tilde{Z} H^{\alpha},$$

where α is the labor share parameter and $\tilde{Z} = Z$, if the government doesn't default, or $\tilde{Z} = Z - l(Z)$ if the government is under default. As for the productivity loss function under default $l(z)$, a non-linear specification that is increasing with the level of productivity:

$$l(Z) = \max\{0, Z - d_1\}, \tag{24}$$

implying that for defaults that occur with $Z > d_1$, the loss penalty becomes proportional to productivity. This functional form is similar to the one used in Chatterjee and Eyigungor

[22] A constant relative risk aversion (CRRA) utility function has the following functional form: $u(c,h) = c^{1-\sigma}/(1-\sigma) - \Gamma h^{1+\gamma}/(1+\gamma)$.

(2012) or in Arellano (2008). These authors showed that an increasing loss function in productivity is important to generate realistic default frequencies[23]. Such loss function enables some additional contingency to the government by penalizing it less severely if a default occurs in a low productivity state of the world[24].

As for the gross interest rate on working capital, a simple identity function is used for the equivalent zero coupon rate $\tilde{r}$ associated with the long-term bond with price q, namely:

$$\tilde{r} = m\left(1/q\right) \equiv \left[\lambda + (1-\lambda)\left(x+q\right)\right]/q - 1. \tag{25}$$

To understand the idea of the corporate interest rate function $m\left(1/q\right)$, first note that because the firm only borrows for one period, the government long-term debt price has to be converted into a one-period bond yield[25]. Second, the function implies that firms pay a premium for current loans despite that they never default. This feature, commonly used in the literature (Neumeyer and Perri, 2005; Uribe and Yue, 2006), is meant to capture in a reduced form how the credit risk of a sovereign implies lower credit supply for firms, through either weaker banks (Brunnermeier et al., 2016) or higher risk of confiscation (Mendoza and Yue, 2012). This positive relationship has been also documented by, for example, Arellano and Kocherlakota (2014) who find evidence of positive co-movement between private and sovereign interest rates, or Almeida et al. (2017) who document for the European debt crisis that sovereign and corporate credit ratings move together.[26]

Finally, as usual in these type of models, the productivity process is modeled as a log-normal $AR(1)$, with:

$$\log Z' = \rho_z \log Z + \epsilon' , \quad \epsilon' \sim N(0, \sigma_z).$$

The numerical computation of the model uses value function iteration with a finite element method where the value and debt price functions are approximated using interpolation

[23]This is in contrast with a proportional one as, for example, in Aguiar and Gopinath (2006).

[24]The model proposed by Mendoza and Yue (2012) endogenizes this loss function using a model of trade credit where, under default, high productivity firms face larger costs due to inability to import certain inputs.

[25]Similarly to Chatterjee and Eyigungor (2012), the one-period equivalent interest rate for a long-term bond with price q can be found with $1+\tilde{r} = \left[\lambda + (1-\lambda)\left(x+q\right)\right]/q$.

[26]In the Appendix A.1, some evidence for Euro Area countries is provided where, using the interest rates for new loans to non-financial corporations as a proxy of corporate interest rates, it is shown that the correlation with respect to sovereign yields can be as large as 0.82 for the case of Greece or 0.86 in the case of Portugal. Additional evidence is shown in Mendoza and Yue, 2012, Augustin et al., 2018, or Arteta and Hale, 2008 where this last paper shows that government default risk also implies lower access to firm credit. See also explanations in footnote 18.

techniques. Details of the algorithm used can be found in the appendix A.3.

4.2 Model Calibration

The model is computed at a quarterly frequency targeting the Greek economy for some key data moments. As already mentioned, Greece provides a recent example of the dramatic impact of a financial crisis on labor markets. Greece announced its default in the last quarter of 2011 and, between 2009 and 2012, the unemployment rate jumped from 7.96% to 22.1%, a 14.2pp increase while, during the same period, real GDP fell by 16.3%. Mendoza and Yue (2012) shows that these observations are not uncommon for previous default episodes on emerging economies. High frequency data readily available provides an additional advantage of focusing this study on Greece.

With the numerical solution at hand, the model is then used to interpret the macroeconomic dynamics of variables of interest around default, such as output, consumption, and employment, while maintaining certain simulated statistics close to the observed data counterparts. Data for output, consumption, employment, and trade balance are seasonally adjusted quarterly real series obtained from OECD from 1990 to 2015. Government debt and interest rates are taken from the Eurostat. The tax series, also taken from the Eurostat, refers the annual average income tax of a single person with no children and 100% of the average income received by a worker in Greece. Output and consumption are transformed into logs while trade balance is presented as a percentage of GDP. All series are filtered using a Hodrick–Prescott filter with a 1600 smooth parameter with the exception of the yearly tax series that uses a smooth parameter of 100.

The fixed parameters used in the calibration can be found in table 4. The risk aversion on consumption, $\sigma = 2$, is adopted from Uribe and Yue (2006). The Frisch elasticity of $1/\gamma = 2$ is standard in the literature (for example, Uribe and Yue, 2006 or Arellano and Bai, 2017 use similar values) and is not uncommon to see even larger values being used by some authors[27]. One should note that in the model, a large Frisch elasticity can enable a strong response of labor supply to shocks affecting the marginal product of labor[28]. Since the results may be sensitive to different choices of this parameter, the appendix A.2 also shows the model outcomes for different choices of the Frisch elasticity without substantial implications in the results. The labor income share of $\alpha = 0.5$ is taken directly from the

[27] Shimer (2009), uses a Frisch elasticity of 4 in his model in order to justify some large labor movements in some European countries.

[28] Note that with a Frisch elasticity of 0, changes in the marginal product of labor would imply no change in hours supplied.

average labor compensation to output computed by AMECO. The parameter $\zeta = 0.083$, as used in Richmond and Dias (2009), implies an average market exclusion of 3 years and is consistent with evidence presented in Gelos, Sahay, and Sandleris (2011) finding that debt restructurings have become faster in recent decades. Given that evidence is scarce on the importance of working capital, the strategy suggested by Schmitt-Grohé and Uribe (2007) is followed, where working capital is approximated as the fraction of M1 held by firms, using an estimate for the United States showing that firms own about two-thirds of that aggregate. Using M1 data for Greece (from the Central Bank of Greece), the estimate for working capital held by firms is about 33.5% of yearly GDP. Given that the model generates a working capital to GDP given by $WC/Y = \theta\alpha/\left(1+\tilde{r}\right)$, this implies a $\theta = 0.69$ for an average corporate interest rate of $\tilde{r} = 5.3\%$. Note that $\theta = 0.69$, implying that firms hold 2.8 months of wages in working capital, is consistent with other studies that also assume working capital constraints (Neumeyer and Perri, 2005 use a value of 1; Mendoza and Yue, 2012 use 0.7; and Schmitt-Grohé and Uribe, 2007 use 0.64). The parameter φ, governing the international lenders recovery rate in case of default, is set to 0.5, which is in accordance with the restructuring observed in the Greek default as documented by Zettelmeyer et al. (2013). The parameter Γ is calibrated to deliver a mean labor supply in the model of 1 (normalized) and the government consumption G is set to generate a relative government consumption to GDP of 20%, the average observed in Greece. Finally, the parameters governing debt issuance are set in the following way: Germany's yield is used to set the risk-free debt price to $\bar{q}$ to 0.995, targeting an annual rate of 2%; the parameter λ captures an average 7.4 years debt maturity as reported by the Eurostat; the debt coupon x is normalized to be $1-\bar{q}$ so as to deliver a maximum debt price of $\bar{q}$[29]; and the minimum issuance debt price is set to 0.5 which prevents the government from issuing debt at interest rates larger than 18.6%[30], where this constraint never binds for a government with good credit history in the simulations.

All the remaining 4 parameters $\{\beta, \sigma_z, \rho_z, d_1\}$ are jointly estimated using simulated method of moments where the following data statistics are targeted: standard deviation and autocorrelation of output; the ratio of the standard deviation of trade balance with respect to the standard deviation of output; and the interest rate spread standard deviation. The results of this estimation process can be found in tables 5 and 6.

[29] The maximum debt price, that is, when the probability of repayment is certain, is given by $q^{max} = \bar{q}\left(\lambda + (1-\lambda)\,x\right)/\left(1-\bar{q}\,(1-\lambda)\right)$. Therefore, when $x = 1-\bar{q}$, then $q^{max} = \bar{q}$.

[30] The conversion of a debt price q to an annual interest rate r^{annual} is given by the following expression: $r^{annual} = \left[1 + (\lambda + (1-\lambda)x - \lambda q)/q\right]^4 - 1$.

Table 4: Calibrated parameter values for the model simulations

Parameter		Value	Target
Risk aversion on consumption	σ	2	(standard in the literature)
Inverse Frisch elasticity	γ	0.5	(standard in the literature)
Risk free debt price	$\bar{q}$	1/1.005	Germany's government interest rate
Minimum issuance debt price	$\underline{q}$	0.5	Maximum annual issuance interest rate of 18.6%
Output elasticity of labor	α	0.5	Labour income share in GDP
Redemption probability	ζ	0.083	12 quarters of market exclusion
Share of working capital	θ	0.69	Estimate of working capital to GDP of 33.5%
Recovery parameter	φ	0.5	Greek 50% debt restructuring
Debt maturity	λ	0.034	Greek debt maturity of 7.4 years
Government consumption	g	0.2	Greek 20% government consumption to GDP
Labor disutility	Γ	0.4	Mean labor supply of 1

Notes: The Appendix A.2 shows robustness of the simulation results when the inverse Frisch elasticity is set to $\gamma = 0.33$ and $\gamma = 1$.

Table 5: Estimated parameter values from SMM procedure

Parameter		Value	Joint targets
Discount rate	β	0.973	std deviation of trade balance wrt std deviation of output
Standard deviation of error	σ_z	0.0053	std deviation of Greek output
Persistency of productivity	ρ_z	0.95	persistency of Greek output
Productivity loss	d_1	0.92	std deviation of the interest rate spread

Some comments are in order. First, the choice for these moments attempts to bring some discipline to the model in the sense that the simulated economy resembles Greece. Second, the specific Greek default event is being targeted with the choice of some targeted moments, namely the 50% recovery rate offered to Greek bondholders, and some un-targeted moments such as the fall in employment[31]. Finally, as can be seen in the top panel of table 6, the simulated moments are quite close to the data targets.

Table 6 presents the simulation results for both targeted and non-targeted moments. The model maintains most of the discipline imposed by the targeted moments. Within the non-targeted moments, it should be underlined that the model is able to generate a fall in employment of the same magnitude as observed in the data. A large degree of proximity with the observed data is also achieved along the typical moments that are usually studied

[31]This choice for the recovery rate and the evaluation of the employment fall are not that far from the ones observed in the history of sovereign default. Benjamin and Wright (2009) document that on average recovery rates amount to about 60% and Mendoza and Yue (2012) present evidence showing that, on average, employment fall to a level that is 15% lower relative to the observed three years prior default events.

Table 6: Targeted and non-targeted moments: simulation and data

Targeted moments		Data	Model
standard deviation of output	$stdev(Y)$	1.9%	1.9%
autocorrelation of output	$corr(Y_t, Y_{t-1})$	0.80	0.79
standard deviation of the spread	$stdev(i^{spread})$	1.6%	1.6%
relative volatility of trade balance to output	$stdev(TB/Y)/stdev(Y)$	0.4	0.4
Non-targeted moments			
relative volatility of consumption to output	$stdev(C+G)/stdev(Y)$	1.2	1.3
correlation of output with trade balance	$corr(TB/Y, Y)$	-0.45	-0.73
mean spread	$mean(i^{spread})$	3.2%	2.2%
correlation of output with spread	$corr(Y, i^{spread})$	-0.58	-0.78
correlation of trade balance with spread	$corr(TB/Y, i^{spread})$	0.44	0.63
correlation of employment with spread	$corr(H, i^{spread})$	-0.74	-0.76
correlation of employment with tax rate (annual)	$corr(H, \tau)$	-0.58	-0.89
correlation of output with tax rate (annual)	$corr(Y, \tau)$	-0.47	-0.79
mean tax rate (annual)	$mean\,(\tau)$	37%	21%
relative volatility of tax rate to output (annual)	$stdev(\tau)/stdev(Y)$	0.47	0.46
employment drop from 3 years before default	$mean(H_t/H_{t-12}) - 1$	-17%	-15%
Mean debt to output (annual)	$mean(D/Y)$	110%	43%
Default rate (annual)	$default\,rate$	1-4%	2.5%

Notes: data from OECD, ECB, and Eurostat and refers to Greece. The quarterly data spans from 1994 to 2012 in order to exclude the default period. All data series are log-detrended using the Hodrick-Prescott filter with a smoothing parameter of 1600 for quarterly data and of 100 for yearly data (the trade balance is detrended in levels). The interest spread is computed using the yield long-term government bonds in Greece and Germany. The computation of taxes take into consideration variations in consumption and income taxes. The model statistics are calculated using 50 simulation samples, each with 3000 periods (quarters).

in the literature. In particular, volatility of consumption is larger than the volatility of output and both spreads and trade balance are negatively correlated with output. Given the focus of the model on other features, such as employment and taxes, moments regarding these dimensions, usually not analyzed in previous literatures, can also be computed[32]. The results show that, at least qualitatively, the model mimics well the data observations. In particular, tax rates are counter-cyclical and also negatively associated with employment. The default rate is in line with other studies of sovereign default, with a non-targeted annual frequency of 2.5%. The main discrepancy in this calibration is related with the

[32]Regarding taxes, one should note that because the model abstracts from capital, income and consumption taxes are equivalent. Correcting the income tax by including consumption taxes has some impact in the business cycle statistics from the fact that Greece changed these taxes during the sample period, in particular standard VAT rates changed in 2005 (from 18% to 19%) and 2010 (from 19% to 23%). The Online Appendix B.3 shows how business cycle statistics change if such correction is not applied.

average debt to output where, in the model, one generates a magnitude of 42% while the data shows that Greece has a level of government debt of more that 100% of output. With this respect, Aguiar and Gopinath (2006) extend the Lucas example to show that financial autarky is not a harsh punishment enough to sustain large amounts of debt in equilibrium, so the results from the simulation are not inconsistent with those findings.

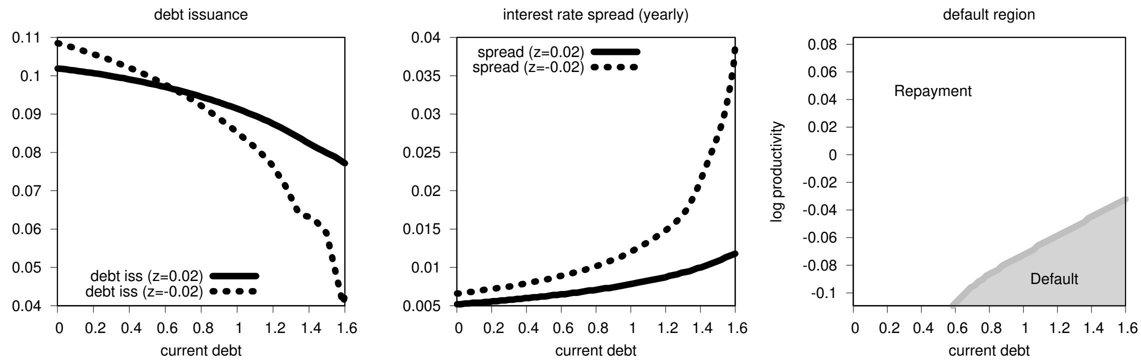
These results indicate that austerity policies, that is, tax policies that tend to aggravate output fluctuations, are a reaction rather than an active policy choice of governments. When an economy is hit by a recession, harder credit conditions force a government to increase tax rates under the impossibility of reducing public consumption. Such increase affects negatively consumers that respond by lowering their market supply of labor. Since firms are also exposed to similar credit conditions as the government, they also reduce labor demand when facing higher interest rates. Note that these adverse effects would not be present under an alternative economy without working capital constraints and where *lump sum* fiscal policies are available to be used by the government. Thus, such movements in hours can be interpreted as a labor wedge that deteriorates when the economy is in recession. Under a default event, the effects previously described become even more pronounced.

4.3 Policy and Impulse Response Functions

To facilitate the understanding of the mechanism underlying the results presented in the previous subsection, figure 4 plots the model policy functions for debt issuances, debt price functions, as well as the default set. The figure shows that new debt issuances, as defined in equation (9), is a decreasing function of current debt but increasing in productivity; the debt price schedule is downward sloping in current debt and increasing with productivity. This reflects the fact that indebted governments have higher probability of default, and this probability is smaller when the economy is growing (as depicted in the right panel of figure 4).

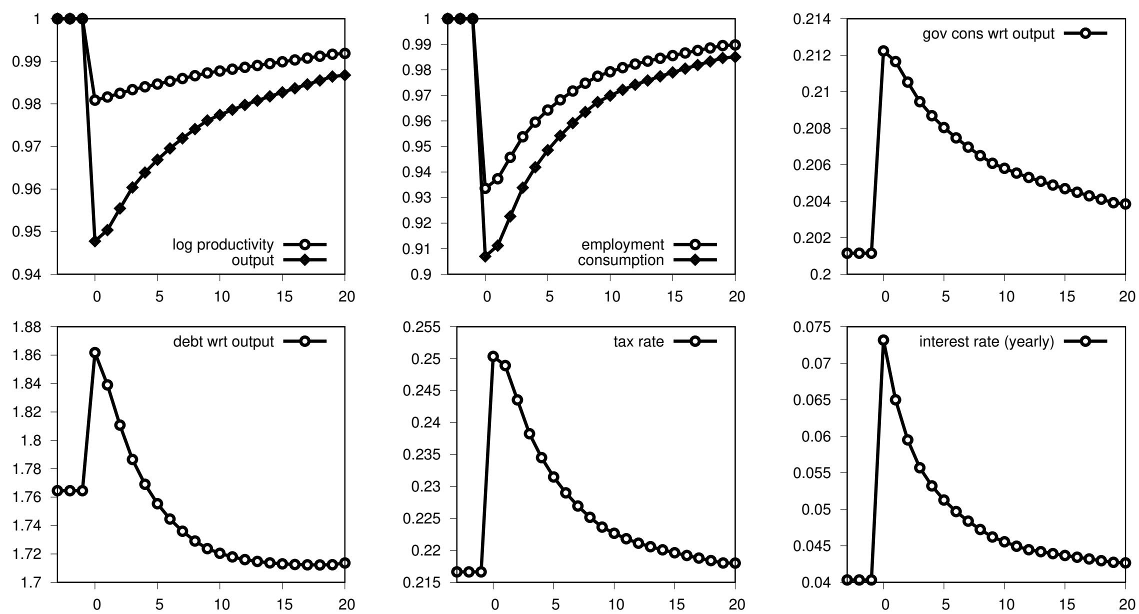
Alternatively, impulse response functions can be plotted to analyze the optimal policies when the economy is hit by external shocks. Figure 5 shows the economy's response when the productivity Z_t suddenly drops by 1.5% relative to its unconditional mean.

Figure 4: Model implied policy functions for debt issuances, yearly interest rate spreads, and default set



Notes: In the figure, debt issuance corresponds to the policy function of $I(D, Z) = D'(D, Z) - (1-\lambda)D$ for initial productivity levels of $\log Z = 0.022$ and $\log Z = -0.022$, deviations of a factor of 1.3 relative to the unconditional standard deviation of the productivity stochastic process. The panel for the yearly interest rate spread corresponds to $spread = (1 + (\lambda + (1-\lambda)x - \lambda q)/q)^4 - (1/\bar{q})^4$ where q is the government bond price. The parameters of the model are summarized in tables 4 and 5.

Figure 5: Model implied impulse response functions when productivity Z falls by 1.5%



Notes: To generate the impulse response functions in this figure, the model is simulated for 150 periods for a productivity realization of $\log Z = 0$ and, for the next period, a productivity realization of $\log Z = -0.015$ that mean reverts in the following periods. The keys in the figure correspond to: log productivity ($\log Z_t$ normalized to 1); output (Y_t normalized to 1); employment (H_t normalized to 1); consumption (C_t normalized to 1); government consumption with respect to output (G_t/Y_t); debt with respect to output (D_t/Y_t); tax rate (τ_t); and the yearly interest rate ($r_t = (1+(\lambda+(1-\lambda)x-\lambda q)/q)^4-1$). The parameters of the model are summarized in tables 4 and 5.

One first observation is that, although productivity falls by 1.5%, output falls by about 5%. This happens due to an endogenous response of labor that retraces by about 6%. The figure also shows that, in response to the fall in productivity, the government increases the tax rate from 21.5% to 25%. Additionally, on impact, the interest rate increases substantially and that is due to the fact that, given the current debt level, the government is more likely to enter in default. Because of this price increase, the government tries to reduce its debt exposure allowing for a normalization of the interest rates during the subsequent periods. The gradual reduction in interest rates, lowers the working capital costs for firms, allowing them to increase production. This expansion increases the taxation base which also allows the government to reduce tax rates even further.

To better understand the effect of taxes and the interest rate spreads on labor dynamics, note that equation (6) and (8) can be combined into the following expression:

$$\frac{\partial u(C_t, H_t)/\partial H_t}{\partial u(C_t, H_t)/\partial C_t} = (1 - \tau_t)\frac{1}{1 + \tilde{r}_t \cdot \theta} \cdot Z_t \frac{\partial f(H_t)}{\partial H_t},$$

which can be re-written as:

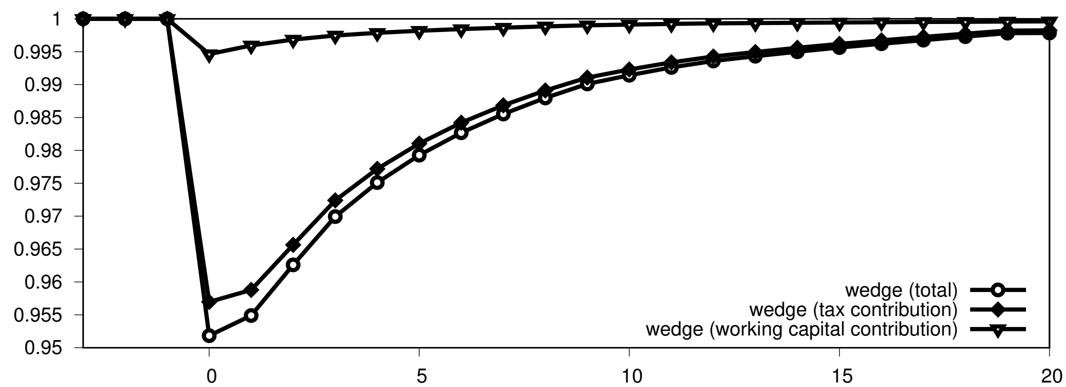
$$\frac{\partial u(C_t, H_t)/\partial H_t}{\partial u(C_t, H_t)/\partial C_t} = \omega_t \cdot Z_t \frac{\partial f(H_t)}{\partial H_t}. \tag{26}$$

Here, ω_t is a labor wedge, that is, the combined distortion of income taxes and working capital constraints on the labor market equilibrium. Applying a log-linearization to (26) near the values $(\bar{\tau}, \bar{\tilde{r}})$ implies:

$$\hat{\omega}_t = -\frac{\bar{\tau}}{1 - \bar{\tau}}\hat{\tau}_t - \frac{\theta \bar{\tilde{r}}}{1 + (\bar{\tilde{r}} - 1)\,\theta}\hat{\tilde{r}}_t, \tag{27}$$

where the first term in the right hand side is the contribution of the income tax to changes in the wedge and the second term is contribution of the interest rate. Such decomposition is depicted in figure 6 when productivity Z drops 1.5%. One can see that from the almost 5% deterioration in the labor wedge, 4% can be accounted due to an increase in the income tax while 1% is due to an increase of interest rates through working capital constraints. One can conclude that both channels play an important role to explain the magnitude of the labor wedge.

Figure 6: Labor wedge and contributions when productivity falls by 1.5%



Notes: The impulse response function in this figure is being generated as explained in figure 5. The wedge (total) line depicted in the figure corresponds to the variable ω_t in equation (26). The wedges for the tax contribution and working capital contribution decompose the total wedge ω_t into the variation due to taxes $(1 - \tau_t)$ and due to working capital $(1/(1 + \tilde{r}_t \cdot \theta))$, respectively.

4.4 Event Analysis - the Greek crisis

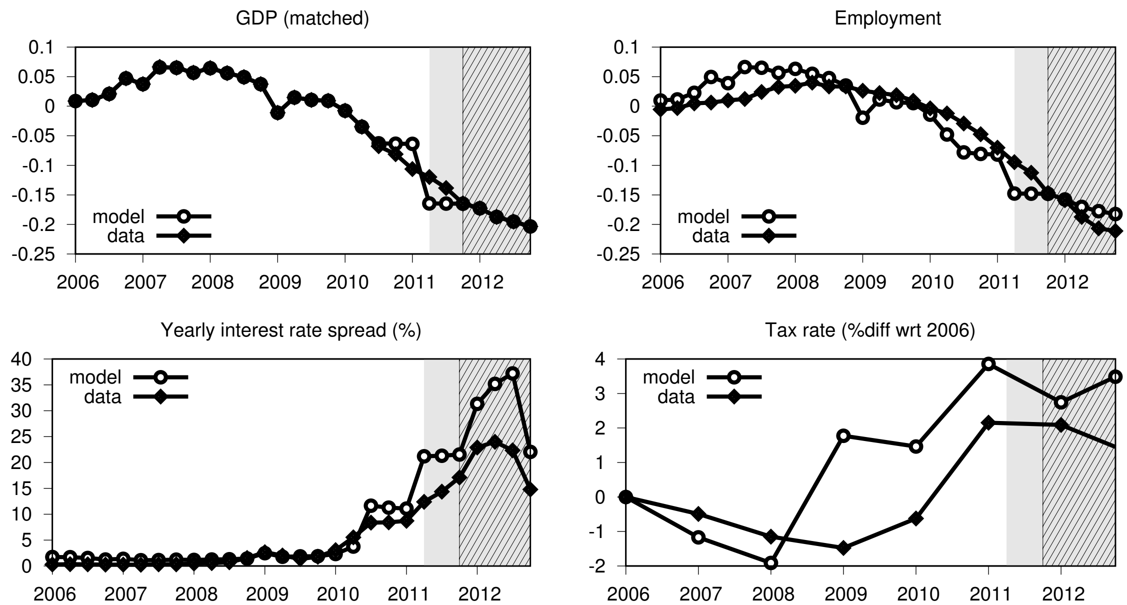
To evaluate the performance of the model, the Greek recent crisis is studied in an event analysis. To this end, the Greek GDP path between 2006-2012 is used as a source to feed a model simulation with a sequence of productivity shocks $\{Z_t\}$, such that the difference between the simulated and observed path of output is minimized. In this sense, the GDP path generated in the model is matched, as much as possible, to the observed Greek data counterpart. Two main purposes are achieved in this exercise. On the one hand, by not targeting interest rate spreads, tax rates, or labor wedges, the exercise allows for a general evaluation of how the model internal dynamics are consistent with data observations of an effective default episode. On the other hand, after finding a path of productivity (the only shock source in the model) that generates the observed output path, the model can be used to assess how the labor wedge or employment deteriorate in counterfactual experiments where certain features of the model are shutdown, such as working capital constraints or distortionary taxation. Figure 7 shows the results of the matching exercise.

The figure plots, for both data and model, time series for GDP, employment, the interest rate spread for government bonds, and the tax rate[33]. In the model, a default is triggered on the 1st quarter of 2011 which is two quarters earlier from the default event observed

[33]The tax series is taken from the Eurostat and refers the annual average income tax of a single person with no children and 100% of the average income received by a worker in Greece. To increase comparability the model counterpart averages the generated tax rate for the same years.

during the Greek crisis[34].

Figure 7: Event analysis for model generated and data time series for the Greek crisis (2006-2012)



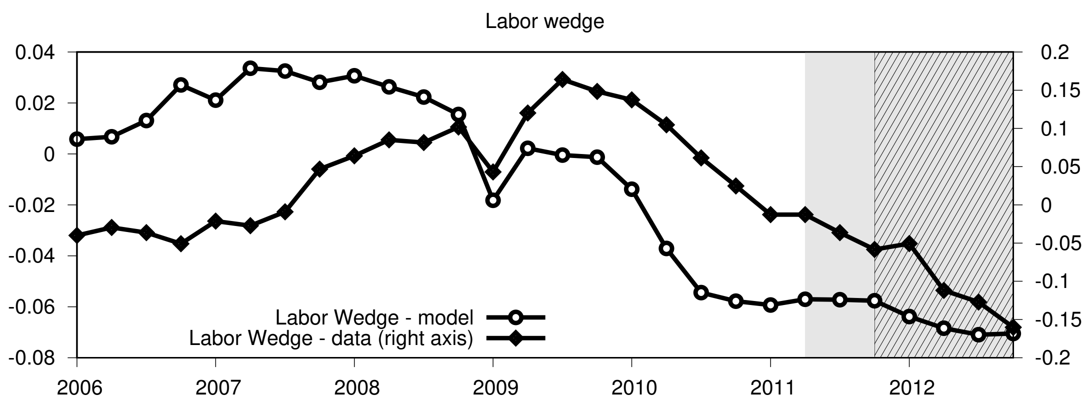
Notes: Data sources are from the OECD and Eurostat. The top left panel in this figure shows output path for both data and model during 2006-2012. Observed data for the output path are generated as the difference of the observed log output with respect to the log output realization in the 1st quarter of 2009: $y_t^{data} = \log(Y_t) - \log(Y_{2009q1})$. The model generated output is computed by simulating the model with a path of productivity shocks $\{Z_t\}$ such that the distance between model and data output for the period of 2006q1-2012q3 is minimized. All remaining panels (non-targeted) are generated from the derived sequence of $\{Z_t\}$. Due to data limitations, the path for the model tax rate is converted into an annual series by averaging the year 4 quarters. The shaded area in gray corresponds to a default period generated in the model, while the pattern shaded area corresponds to the Greek economy default period.

The top left panel of the figure shows that the model can capture well the evolution of GDP during the Greek crisis with the exception of a few periods around the default decision. This is because of the productivity loss function (24) that is used. With that kind of loss function, when a default occurs, productivity drops immediately to d_1, reducing the flexibility of the model to match the output path. That is also why employment, the interest rate spread, and the tax rate jump at the precise default quarter. The second panel in the figure shows that the employment time series path of the model captures the same dynamics that are observed in the data. The last two panels show the main drivers of such dynamics. Both the interest rate spread and the tax rate are increasing in the

[34]It should be noted however that before its default event, Greece negotiated a bailout rescue loan with the IMF and the European Union institutions in the 2nd quarter of 2010. Without such loan it is uncertain if the government would have been able to honor its debt obligations.

model as well in as in the data. In the model, the government has to raise taxes to finance an inelastic public expenditure thus affecting the household supply of labor. At the same time, the prevalence of negative productivity shocks affects the sovereign ability to fulfill its debt obligations, implying that interest rates continue to increase and that, in turn, affects firms given their working capital requirements. These combined movements add pressure on labor markets that subsequently collapse at default with a 15% fall in employment when compared with pre-crisis values.

Figure 8: Model implied (left axis) and data (right axis) labor wedge for the Greek crisis (2006-2012)



Notes: This figure shows the path of the labor wedge ω_t as defined in equation (26) given productivity shocks that generate a path of GDP similar to the one observed in Greece between 2006 and 2012 (see figure 7 for a description). The labor wedge observed in the data is computed as in footnote of figure 2. The shaded area in gray corresponds to a default period generated in the model, while the pattern shaded area corresponds to the Greek economy default period.

As mentioned before, both the effects of the interest rate spread and income taxes affect negatively the labour market. It should be noted that such impact is on top of an already adverse path of successive negative productivity shocks. Contrary to a situation where, with full access to credit markets, a government facing a recession would lower distortionary taxes (Lucas and Stokey, 1983), tax rates are countercyclical in this model. Limited commitment in debt contracts implies that the interest rate is increasing when the economy is in recession, and since credit market access becomes more restricted, the government is forced to raise taxes. This provides a channel between the possibility of government default and labor market distortions induced by countercyclical tax and interest rates as shown in the bottom panels of figure 7. Using the measure of labor market distortion introduced in equations (26) and (27), figure 8 plots the labor wedge that this event analysis produces. As it should be clear, the labor wedge is decreasing, implying larger market distortions as the Greek economy moves into default, consistent with the evidence presented in section 2. It should be noted that the figure also shows that the model implied labor wedge displays a similar dynamic as the observed labor wedge for Greece. An important difference relies on the volatility of the data labor wedge that is larger than the one implied by the model. This may be a reflection of the excessive simplicity of the model presented in this paper that is used mostly for tractability within the context of endogenous default.[35]

4.5 Robustness and Experiments

In order to isolate the non-standard features of the baseline model outlined above, this subsection re-evaluates the baseline model under different specifications. Five alternative versions of the model are computed under the same calibration summarized in tables 4 and 5.

Lump sum taxation The model is recomputed assuming that the government has access to non-distortionary tax policies. That is, the new consumer budget constraint is now given by:

$$C_t = (1-\bar{\tau}) \cdot (w_t H_t + \pi_t + e_t) - T_t,$$

where T_t is a non-distortionary tax (which can be positive or negative) and $\bar{\tau}$ is the average distortionary income tax rate generated in the baseline model[36]. The inclusion of $\bar{\tau}$ attempts to increase comparability between this version and the baseline model by imposing the same level of average distortions in the labor markets. Given the new consumer budget constraint, the counterparts of (18) and (19) simplify to:

$$\begin{aligned}
C &= Zf\left(H\right) + q(D', Z) \cdot \left[D' - (1-\lambda)\, D\right] - D\left[\lambda + (1-\lambda)\, x\right] - G \\
\frac{u_H(C,H)}{u_C(C,H)} &= \frac{(1-\bar{\tau})}{1+\theta m\left(1/q(D',Z)\right)} \cdot Zf_H(H).
\end{aligned}$$

Hence, the recursive problem of the government becomes defined in the same way as before with the only difference in the above 2 equations.

Lump sum taxation with no working capital This formulation is exactly defined as the previous one imposing that $\theta = 0$, that is, firms have no working capital requirements and the government can use *lump sum* taxes.

[35] Gourinchas et al. (2017) or Chodorow-Reich et al. (2019) present rich dynamic general equilibrium models to better account for the Greek depression at the expense of including multiple exogenous shocks such as: productivity, government spending, disaster risk, interest rate shocks, and many others.

[36] In this exercise $\bar{\tau}$ is calibrated to be 0.217.

External impact of working capital In the formulation of the baseline model, the impact of the government policy choices on the working capital requirements of firms through $\tilde{r}$ is properly internalized. That is, the government understands that different prices for debt q affect firms decisions through different corporate interest rates $\tilde{r}$ under the function $m(1/q)$. Under this experiment, instead, such impact is external (non-internalized) by the government. The recursive problem for the government becomes (letting $\Psi' = q(D', Z, \tilde{r}) \cdot [D' - (1-\lambda) D] - D [\lambda + (1-\lambda) x]$):

$$v^{rep}(D, Z, \tilde{r}) = \max_{D'} \{u(CH) + \beta \mathbb{E}_Z [v(D', Z', \tilde{r}')]\} \tag{28}$$

st

$$C = Zf(H) + q(D', Z, \tilde{r}) \cdot [D' - (1-\lambda) D] - D [\lambda + (1-\lambda) x] - G$$

$$\frac{u_H(C,H)}{u_C(C,H)} = Zf_H(H) \cdot \frac{1 - \frac{G-\Psi'}{Zf(H)}}{1+\theta\tilde{r}}$$

$$\tilde{r}' = \Psi(D', Z'),$$

and the consistency condition $\tilde{r}' = \Psi(D', Z')$ is such that $\Psi(D', Z') = m(1/q(D'', Z', \tilde{r}'))$ where $D'' = D'(D', Z', \tilde{r}')$ comes from the optimal debt policy of the decision-maker given the state variables. The formulation of this problem is analogous to the one of Kim and Zhang (2012) who study government default decisions when borrowing is decentralized. It should be noted that because the government's problem changes, so does the computational method to solve it[37].

Endogenous government expenditure This experiment endogenizes government consumption. To implement it, the following utility function is used[38]:

$$u(C, G, H) = \frac{1}{1-\sigma} \cdot \left(C - \Gamma \frac{H^{1+\gamma}}{1+\gamma}\right)^{1-\sigma} + \Upsilon \cdot \frac{G^{1-\sigma}}{1-\sigma}.$$

It follows that, after some algebra, the recursive problem for the government can be

[37]The formal definition of the problem and algorithm used can be found in the appendix A.4

[38]When this model is computed, the parameter Υ is calibrated to generate an average government to output similar to the observed in the data.

summarized by (letting $\Psi' = q(D', Z) \cdot [D' - (1-\lambda) D] - D[\lambda + (1-\lambda) x]$):

$$
\begin{aligned}
& v^{rep}(D, Z) = \max_{D'} \{u(C, G, H) + \beta \mathbb{E}_Z [v(D', Z')]\} \\
st & \\
& C = Zf(H) + q(D', Z) \cdot [D' - (1-\lambda) D] - D[\lambda + (1-\lambda) x] - G \\
& \frac{u_H(C, G, H)}{u_C(C, G, H)} = Zf_H(H) \cdot \frac{1 - \frac{G - \Psi'}{Zf(H)}}{1 + \theta m (1/q(D', Z))} \\
& u_C(C, G, H) = u_G(C, G, H),
\end{aligned} \tag{29}
$$

and a similar formulation is used for the value of default v^{def}. The only difference with respect to the baseline model resides in equation (29) that states that in equilibrium the marginal utility of private consumption equals the marginal utility of public consumption.

Downward real wage rigidity Similarly to Schmitt-Grohé and Uribe (2016) and Na et al. (2017), downward real rigidity in wages is introduced in the model assuming that the real wage rate cannot fall more than a fraction ϕ of the previous period wage. Therefore, this friction in the labor market can generate large increases in involuntary unemployment during periods in which wages are binding and labor demand determines the level of employment. Allowing the government to use lump-sum taxation and eliminating working capital constraints to isolate the effect of wage rigidity, the following equations characterize this specification:

$$
\begin{aligned}
& v^{rep}(D, w_{-1}, Z) = \max_{D'} \{u(C, H) + \beta \mathbb{E}_Z [v(D', w, Z')]\} \\
st & \\
& C = Zf(H) + q(D', w, Z) \cdot [D' - (1-\lambda) D] - D[\lambda + (1-\lambda) x] - G \\
& w \geq \phi w_{-1} \quad and \quad w = Zf_H(H) \\
& \frac{u_H(C, H)}{u_C(C, H)} \leq (1 - \bar{\tau}) z f_h(h) \ if \ w = \phi w_{-1} \\
& \frac{u_H(C, H)}{u_C(C, H)} = (1 - \bar{\tau}) Z f_H(H) \ if \ w > \phi w_{-1},
\end{aligned}
$$

with an analogous specification for the value under default v^{def}.

Table 7 shows the computational results of the different alternatives against the baseline model. These highlight the relevance of the two channels introduced in this paper to explain the large fluctuations of employment during default events. In particular, when the sovereign has access to *lump sum* taxes (column "*Lump sum* tax"), the fall of employment during a default is reduced by 4pp to 11%, a magnitude that is lower than what is observed in the data. This happens because, under such environment, the government is not pushed into raising distortionary income taxes when the economy is in recession. For that reason, part of the tax distortions that increase the instability in labor markets disappear and, as a consequence, the output volatility becomes smaller. When, on top of *lump sum* policies, working capital requirements are withdrawn (column "No working capital"), the employment drop is reduced by some additional 2pp to 9%. These effects highlight the importance of the two added frictions to generate labor market distortions.

Table 7: Model experiments and robustness checks

Targeted moments	Data	Baseline	LS tax	No WC	External	Endog G	Rigid w
$stdev(Y)$	1.9%	1.9%	1.4%	1.3%	1.9%	1.7%	1.6%
$corr(Y_t, Y_{t-1})$	0.80	0.79	0.82	0.83	0.79	0.79	0.87
$stdev(i^{spread})$	1.6%	1.6%	1.7%	1.9%	1.6%	1.7%	2.1%
$stdev(TB/Y)/stdev(Y)$	0.4	0.4	0.7	0.7	0.4	0.6	0.8
Non-targeted moments							
$stdev(C+G)/stdev(Y)$	1.2	1.3	1.5	1.5	1.3	1.5	1.5
$corr(TB/Y, Y)$	-0.45	-0.73	-0.53	-0.48	-0.72	-0.57	-0.43
$mean(i^{spread})$	3.2%	2.2%	2.5%	2.7%	2.2%	2.6%	2.3%
$corr(Y, i^{spread})$	-0.58	-0.78	-0.82	-0.80	-0.78	-0.80	-0.84
$corr(TB/Y, i^{spread})$	0.44	0.63	0.64	0.56	0.62	0.68	0.47
$corr(H, i^{spread})$	-0.74	-0.76	-0.87	-0.80	-0.75	-0.75	-0.88
$corr(H, \tau)$	-0.58	-0.89	-	-	-0.89	-0.67	-
$corr(Y, \tau)$	-0.47	-0.79	-	-	-0.78	-0.45	-
$mean\ (\tau)$	37%	21%	-	-	21%	21%	-
$stdev(\tau)/stdev(Y)$	0.47	0.46	-	-	0.45	0.35	-
$mean(H_t/H_{t-12}) - 1$	-17%	-15%	-11%	-9%	-15%	-11%	-13%
$mean(D/Y)$	110%	43%	47%	45%	41%	42%	56%
$default\, rate$	1-4%	2.5%	2.9%	3.4%	2.6%	2.9%	4.1%

The column "External" shows that, when the working capital channel is not internalized by the government, most of the dynamics of the model stay constant. The main difference is that default becomes slightly more frequent[39]. Given the small magnitude of this effect, it does not seem unreasonable to think that a government may not take into consideration that its own borrowing decisions affect firms credit conditions, similarly to what is

[39] A similar result is found in Kim and Zhang (2012)

implicitly assumed in previous papers that use working capital requirements to generate a channel between interest rates and labor demand (Neumeyer and Perri, 2005; Uribe and Yue, 2006)[40].

In the column "Endogenous G" of table 7, government consumption is endogenized to allow for the fact that government consumption usually falls during default episodes (Cuadra et al., 2010). Qualitatively, this alternative specification behaves similarly to the baseline model. However, a few important quantitative differences should be noted. First, the correlation of the tax rate with output falls to levels more close to what is observed with the data. This happens because, as productivity falls, both private and public consumption follow, implying that income taxes do not need to be raised as much. However, this also implies that the cost of a default becomes less severe than in the baseline model and this increases the default frequency. Given that the model preforms better in some dimensions while worse in others, a more flexible but also more complex approach may be necessary to properly match the data[41].

Finally, the last column shows how the model performs under real wage rigidity. A key parameter that influences the results for this experiment is the degree of real wage rigidity ϕ. Following the calibration strategy of Schmitt-Grohé and Uribe (2016), one can identify 2013 as the year where nominal wages fell faster during the Greek crisis, with a decline of labor compensations of about 12.1%[42]. This, together with a rate of inflation of -0.85%, implies a total fall of real wages of about 11.3%, which suggests using a value for wage rigidity of $\phi = 0.9717$. Solving and simulating the model (column "Rigid w") generates a fall of employment during a crisis of about 13% relative to pre-crisis levels, which is slightly less than the 15% fall generated in the baseline model[43]. One can conclude that real wage downward rigidity can also deliver large falls in employment during sovereign debt defaults. Note however that the underlying mechanism associated with wage rigidity is not operational whenever monetary authorities ease the interest rate policy as a reaction to falls of employment or if countries are within a fully flexible exchange rate regime (Na et al., 2017). This implies that the frictions used in the baseline model can provide an

[40] Alternative parameterizations that imply larger default frequencies generate also larger differences between the "Baseline" and the "External" models where the later generates larger default probabilities and larger standard deviations of the spread.

[41] A potential source of additional costs of default may be related with political uncertainty that such events produce as in, for example, Hatchondo, Martinez, and Sapriza (2009).

[42] The data source for these numbers is the Eurostat using series for (total) nominal wages and salaries, and the harmonized index of consumer prices for Greece.

[43] The fall of employment during a crisis would have been 15% if instead $\phi = 0.99$ is used in the simulations.

alternative explanation for the decline of employment around sovereign default crises even in an environment where wages are fully flexible.

4.6 Counterfactual dynamics of the Greek default

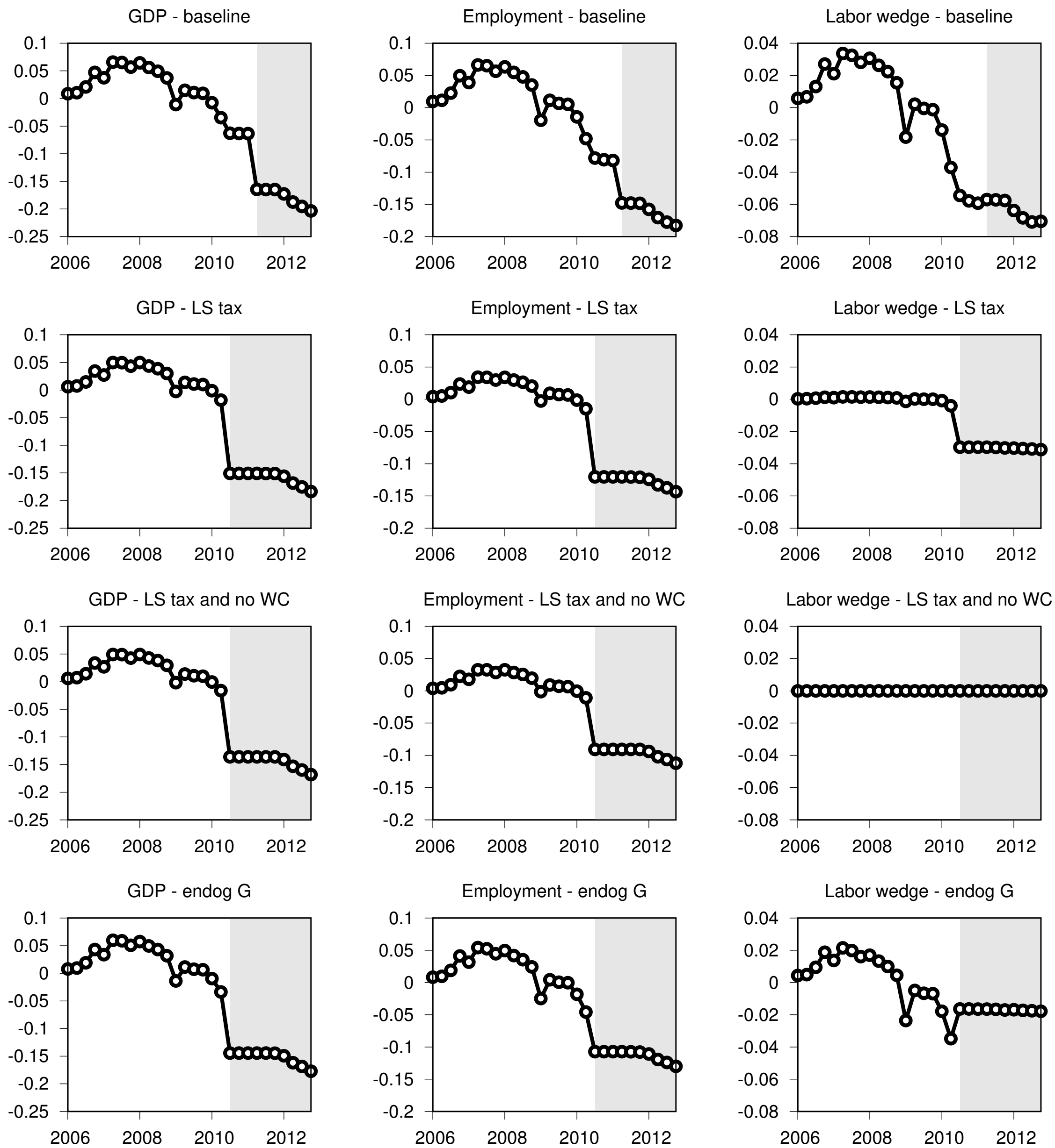
The models introduced above can also be used to assess how the Greek economy would have fared between 2006 and 2012 under alternative setups. This exercise is done using the same sequence of productivity shocks as derived in section 4.4 (that matched the observed Greek output under the baseline calibration) to feed in alternative models. To focus on the main mechanisms introduced in this paper, the "Lump sum taxation" and the "Lump sum taxation with no working capital" models are evaluated; additionally the "Endogenous government expenditure" model is also used to determine whether the economy dynamics would have been different if government spending had been squeezed, thus allowing for milder tax increases.

The results of such counterfactual experiments can be found in figure 9 where the first line shows outcomes for the baseline model, while the remaining lines show for the alternative models. One should first note that neither of the counterfactual scenarios would have prevented the sovereign default given the path of productivity shocks. In fact, for all specifications evaluated, default would have occurred 3 quarters before the baseline. This happens since the labor market distortions introduced in this paper partially endogenize the costs of default, adding up to the exogenous productivity loss. Thus, if one shuts down distortions that emerge from distortionary taxation (line two in the figure) or from the working capital constraint (line three of the table), then the cost of default becomes smaller and the sovereign tends to default more often (see also default frequencies in table 7).

Although default is not prevented, the counterfactuals still generate lower swings in distortions as measured by the labor wedge. This implies that the labor market frictions presented in the baseline framework contribute to additional volatility of employment. In particular, the baseline model generates a level of employment at default that is 15% below the 2006 level. Once distortionary taxation is shut down, this variation reduces to 12%, falling further to 9% when the working capital channel is also shut down[44]. These results emerge because, once distortionary taxation is gone, firms still face higher labor costs when the sovereign defaults (and interest rates increase) due to the working capital constraint.

[44]For the working capital channel, setting $\theta = 0$ or making the function $m(.)$, from equation (25), flat at the risk-free interest rate generates almost the same results.

Figure 9: Counterfactual dynamics of output, employment, and labor wedges for the Greek crisis (2006-2012)



Notes: This figure shows model implied dynamics imputing the same sequence of productivity shocks derived in section 4.4 used to match the observed path of GDP for Greece under the baseline model specification and calibration (described in sections 4.1 and 4.2). The 1st line of the figure shows macroeconomic dynamics for that baseline framework (same as in figures 7 and 8). The remaining lines show dynamics keeping the same sequence of productivity shocks, but changing the model as described in section 4.5, in particular: the 2nd line allows for lump sum taxation; the 3rd line allows lump sum taxation and eliminates working capital constraints; the 4th allows for endogenous government consumption. Shaded areas correspond to default periods as generated in the model.

Finally, note that allowing for endogenous government expenditure while keeping the baseline labor frictions, also prevents employment from falling more than 11% relative to 2006 levels. Under this environment, government consumption is reduced during the crisis, sustaining lower tax rates as well as lower labor market distortions.

5 Conclusion

This paper presents new evidence from the recent Euro Area debt crisis supporting the idea that financial crises, arriving in the form of sovereign default, generate distortions in labor markets. Countries that were affected by the sovereign debt crises, such as Greece, Portugal, or Ireland, were also the ones where employment suffered the most dramatic reduction relative to pre-crisis levels. Because standard economic theory is unable to account reasonably for these drops in employment, an alternative explanation relies on un-modeled labor market distortions. Using a standard labor wedge decomposition to quantify such distortions, it is shown in this paper that the labor wedge deteriorates when government interest rate spreads increase. Since increasing spreads are indicative that external credit is less available, governments need to rely more on taxation, often distortionary, to finance public expenditures thus affecting labor markets. At the same time, a close link between government and corporate interest rates provides an additional source through which distortions may affect labor markets when firms are required to maintain working capital.

In order to evaluate the quantitative importance of these two channels, an economic model is used to account for labor market dynamics in countries that are subjected to sovereign debt risk. To that end, this paper augments a standard sovereign default model to include distortionary income taxation and firm working capital requirements. Calibrated to match several data moments of Greece, the model replicates important data observations. In particular, the baseline specification is able to generate an endogenous increase in both tax and interest rates when productivity falls, a feature already pointed in the literature. More novel is the observation that these dynamics also imply a deterioration of the labor wedge, an implication that is especially true when combined with firm working capital constraints. These two elements can jointly account for an average 15% reduction in employment with respect to pre-crisis levels at the time of a default event, which is close to the 17% employment fall observed during the Greek debt crisis. From these 15%, 4pp can be accounted with an increase in tax rates, and an additional 2pp due to a spill-over from high government interest rates to corporations. It can be concluded that these channels provide an important quantitative explanation for the labor market dynamics that precede sovereign defaults. Directing policies that support corporate credit flow and avoid the implementation of austerity taxation may be crucial for governments desiring to sustain domestic employment or for official lenders that aim to generate support for bailout programs. Counterfactual exercises that were specifically done for the Greek financial crisis suggest that better credit access could have increased employment by almost 3pp, while a less distortionary tax collection could have generated a 3pp positive impact as well. These results suggest that alternative policies that avoid the frictions analyzed in this paper could have reduced the observed slump of employment by up to 40%.

Because the model was purposely designed to be simple, several dimensions were overlooked that can also be important, in particular, the role of international trade. As underlined in Gorodnichenko, Mendoza, and Tesar (2012), a sudden change in importing conditions, for example through terms of trade shocks, can impose an important adjustment cost to firms that may prolong recessions. Relating sovereign debt crises with firms international trade conditions can be a source of improvement to the explanations provided in this paper, especially if there are strong complementarities between imported goods and employment. These are ideas that should be integrated in future research.

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A Appendix

A.1 Corporate and Sovereign Interest Rates in Greece

Using data from the ECB, two measures of interest rate spreads are used:

1. Government interest rate spreads, defined as the difference between 10 year government bond yield of each country against Germany;

2. Corporate interest rate spreads, defined as the difference between average corporate yields charged on new loans in each country against Germany[45];

Comparisons between these 2 indicators should be cautious for a variety of reasons: government bonds don't have any collateral associated with it, while corporate bonds be collateralized; heterogeneous institutional frameworks across countries should impact interest rates charged by banks as, for example, stricter enforceability laws against default should imply different interest rates; a selection effect where only healthy firms have access to credit markets may contaminate cross-country comparisons of corporate bond yields. Given these caveats, table 8 presents simple correlations between the two interest rate indicators for Euro Area countries.

Table 8: Correlation between government and corporate yield spreads (2002-16)

	correlation	95% CI		observations
Austria	-0.33	-0.46	-0.18	156
Belgium	-0.16	-0.31	0.00	156
Germany	-	-	-	-
Spain	0.82	0.75	0.86	155
Finland	0.74	0.66	0.80	156
France	-0.14	-0.29	0.02	156
Greece	0.55	0.43	0.65	156
Ireland	0.11	-0.04	0.27	156
Italy	0.67	0.57	0.75	156
Netherlands	0.04	-0.12	0.20	156
Portugal	0.86	0.81	0.89	156

Data source: Eurostat and ECB

Data source: Eurostat and ECB

Notes: The corporate interest rates refer to ECB data on the average interest rate new loans made to non-financial corporations with maturity less than one year. Spreads are computed as the difference of the country average corporate interest rate with respect to the German average corporate interest rate. Similarly government interest rate spreads are computed as the difference between the country's yields on 10 year government maturity bonds with respect to German yields. The data frequency used is monthly.

[45] The ECB defines these yields as a composite cost-of-borrowing indicator for new loans to non-financial corporations (percentages per year, rates on new business).

A.2 Baseline simulation results for different choices of the Frisch elasticity

The calibration for this robustness check can be found in tables 4 and 5 changing only the Frisch elasticity $1/\gamma$ into high ($1/\gamma = 3$) and low ($1/\gamma = 1$).

Table 9: Targeted and non-targeted moments: simulation and data

Targeted moments		Data	Baseline $1/\gamma = 2$	High $1/\gamma = 3$	Low $1/\gamma = 1$
standard deviation of output	$stdev(Y)$	1.9	1.9	2.1	1.6
autocorrelation of output	$corr(Y_t, Y_{t-1})$	0.80	0.79	0.77	0.79
standard deviation of the spread	$stdev(i^{spread})$	1.6	1.6	1.4	1.7
relative volatility of trade balance to output	$stdev(TB/Y)/stdev(Y)$	0.4	0.4	0.3	0.5
Non-targeted moments					
relative volatility of consumption to output	$stdev(C+G)/stdev(Y)$	1.2	1.3	1.3	1.4
correlation of output with trade balance	$corr(TB/Y, Y)$	-0.45	-0.73	-0.76	-0.70
mean spread	$mean(i^{spread})$	3.2%	2.2%	1.9%	2.5%
correlation of output with spread	$corr(Y, i^{spread})$	-0.58	-0.78	-0.75	-0.80
correlation of trade balance with spread	$corr(TB/Y, i^{spread})$	0.44	0.63	0.63	0.64
correlation of employment with spread	$corr(H, i^{spread})$	-0.74	-0.76	-0.74	-0.76
correlation of employment with tax rate (annual)	$corr(H, \tau)$	-0.58	-0.89	-0.91	-0.86
correlation of output with tax rate (annual)	$corr(H, \tau)$	-0.47	-0.79	-0.83	-0.70
mean tax rate (annual)	$mean\,(\tau)$	37%	21%	21%	21%
relative volatility of tax rate to output (annual)	$stdev(\tau)/stdev(Y)$	0.47	0.46	0.43	0.53
employment drop from 3 years before default	$mean(H_t/H_{t-12}) - 1$	-17%	-15%	-18%	-9%
Mean debt to output (annual)	$mean(D/Y)$	110%	43%	43%	42%
Default rate (annual)	$default\,rate$	1-4%	2.5%	2.0%	2.8%

Notes: data from OECD, ECB, and Eurostat and refers to Greece. The quarterly data spans from 1994 to 2012 in order to exclude the default period. All data series are log-detrended using the Hodrick-Prescott filter with a smoothing parameter of 1600 for quarterly data and of 100 for yearly data (the trade balance is detrended in levels). The interest spread is computed using the yield long-term government bonds in Greece and Germany. The computation of taxes take into consideration variations in consumption and income taxes. The model statistics are calculated using 50 simulation samples, each with 3000 periods (quarters).

A.3 Computation and Algorithm of Baseline Model

The solution of the dynamic problem follows similar papers, e.g. Hatchondo et al. (2016), and approximates continuously the problem using *b-splines* of degree 3 for the state space of D and 2nd degree *b-splines* for z. The code is implemented in Fortran imposing 31 grid points for the state variable z and 59 for D. The state space of D ranges between $[0; 3.5]$, and z is given by $\log Z \in \left[-6.5 \cdot \sigma_z/\sqrt{1-\rho_z^2}; 6.5 \cdot \sigma_z/\sqrt{1-\rho_z^2}\right]$. The algorithm uses value function iteration with the following structure:

1. Guess the value function $v^0(D, Z)$; debt price functions $q^0(D', Z)$ and $q^{def,0}(D', Z)$;

and debt policy function $D'^{0}(D, Z)$

2. Use $v^{rep,0}(D, Z)$ and $v^{def,0}(D, Z)$ to solve (17) and (20) using a global optimizer (NEWUOA from Powell) over the space of D:

   (a) labor equilibrium is obtained using a non-linear equation solver (Brent method)

   (b) the resulting functions of this maximization step are $v^{rep,1}(D, z)$, $v^{def,1}(D, z)$, and $D'^{1}(D, z)$

3. With $v^{rep,1}(D, Z)$ and $v^{def,1}(D, Z)$ compute $v^1(D, Z) = \max\left\{v^{rep,1}(D, Z), v^{def,1}(D, Z)\right\}$ and find the optimal debt prices that are consistent with (12): $q^1(D', Z)$ and $q^{def,1}(D', Z)$

4. Evaluate $\max\{||v^1(D, Z) - v^0(D, Z)|\}$; if it is larger than ϵ_v iterate on (1) using $v^0(D, z) := v^1(D, Z)$, $D'^{0}(D, Z) = D'^{1}(D, Z)$, $q^0(D', Z) = q^1(D', Z)$ and $q^{def,0}(D', Z) = q^{def,1}(D', Z)$ until convergence is achieved

The maximum error allowed is $\epsilon_\nu = 10^{-5}$.

A.4 Definition and Algorithm of Model with External Impact of Working Capital

To implement an externality from a spill-over of the government interest rate spread to corporate interest rates, the definition of the equilibrium changes from a Markov Perfect Equilibrium to a Recursive Competitive Equilibrium as in Kim and Zhang (2012):

Definition. A recursive competitive equilibrium is a set of:

i) Value function: $v(D, Z, \tilde{r})$

ii) Debt price function: $q(D', Z, \tilde{r})$

iii) Law of motion: $\tilde{r}' = \Psi(D', Z')$

iv) Policy function: $D' = \chi(D, Z, \tilde{r})$

Such that

a) Given the debt price function $q(D', Z, \tilde{r})$ and law of motion $\tilde{r}' = \Psi(D', Z')$, the value function $v(D, Z, \tilde{r})$ solves the government problem and yields $D' = \chi(D, Z, \tilde{r})$

b) Given the value function $v(D, Z, \tilde{r})$, the debt price function $q(D', Z, \tilde{r})$ is consistent with the lenders zero profit condition

c) The law of motion is consistent with firms interest rate: $\Psi(D, Z) = m(1/q(\chi(D, z, \tilde{r}), z, \tilde{r}))$ for $\tilde{r} = \Psi(D, Z)$.

Noting that the consistency of the law of motion implicitly defines $\tilde{r}$ as a function of Z and D, the value function $v(D, Z, \tilde{r})$ can also be implicitly defined by only D and Z. Defining this function as $\tilde{v}(D, Z)$, an algorithm to solve the model can be schematized as:

1. Guess the value functions $\tilde{v}^0(D, Z)$, debt price functions $q^0(D', Z)$ and $q^{def,0}(D', Z)$; debt policy function $D'^0(D, Z)$; and a function $\Omega^0(D, Z)$

2. Use $\tilde{v}^0(D, Z)$, and $\tilde{r} = \Omega^0(D, z)$ to solve (28) and the update the values of repayment $\tilde{v}^{rep,1}(D, Z)$ and default $\tilde{v}^{def,1}(D, Z)$ using a optimizer over the space of D:

   (a) labor equilibrium is obtained using a non-linear equation solver

   (b) the resulting functions of this maximization step are $\tilde{v}^1(D, Z) = \max\left\{\tilde{v}^{rep,1}, \tilde{v}^{def,1}\right\}$ and $D' = \chi(D, z)$

   (c) compute $\Omega^1(D, Z) = m(1/q(\chi(D,)Z, Z))$

3. Evaluate $\max\{|\tilde{v}^1(D, Z) - \tilde{v}^0(D, Z)|\}$; if it is larger than ϵ_v iterate on (1) using $\tilde{v}^0(D, Z) := \tilde{v}^1(D, Z)$, $D'^0(D, Z) = D'^1(D, Z)$, $q^0(D', Z) = q^1(D', Z)$, $q^{def,0}(D', Z) = q^{def,1}(D', Z)$, and $\Omega^0 = \Omega^1$ until converge is achieved

B Online Appendix

B.1 Okun's law in European Countries

A simple way to analyze whether employment is falling disproportionally relative to output during certain periods of crises is to identify deviations of the historical relationship between employment and output change. Figure 1 illustrates, for a selected number of countries, how output is negatively correlated with unemployment, a well documented relationship known as Okun's law (Okun, 1962). Recent studies[46] indicate that such relationship has been kept strong and stable for most countries, even after including the 2008 Great Recession. Typical analyses point that different linear slopes characterizing the relationship employment/output in different countries are due to different labor market frictions such as employment protection legislation or wage nominal rigidities. However, if such environments are invariable during the business cycle, then the slope of the relationship absorbs most of such institutional features. In this sense, systematic deviations of that long-term relationship can be indicative of a structural break thus suggesting a closer look at labor markets for deeper explanations.

Figure 10 plots a scatter diagram of employment percentage changes against output percentage changes for some Euro Area member countries to illustrate that the Okun's law may have indeed broke down in countries affected by the debt crisis. The figure suggests that employment has fallen faster relatively to output during the period of 2009-2014 for the countries represented at the top panels as the solid circles are substantially below the historical trend line. This indicates that over the period, for each one percent of output drop, employment fell more than the historical average.

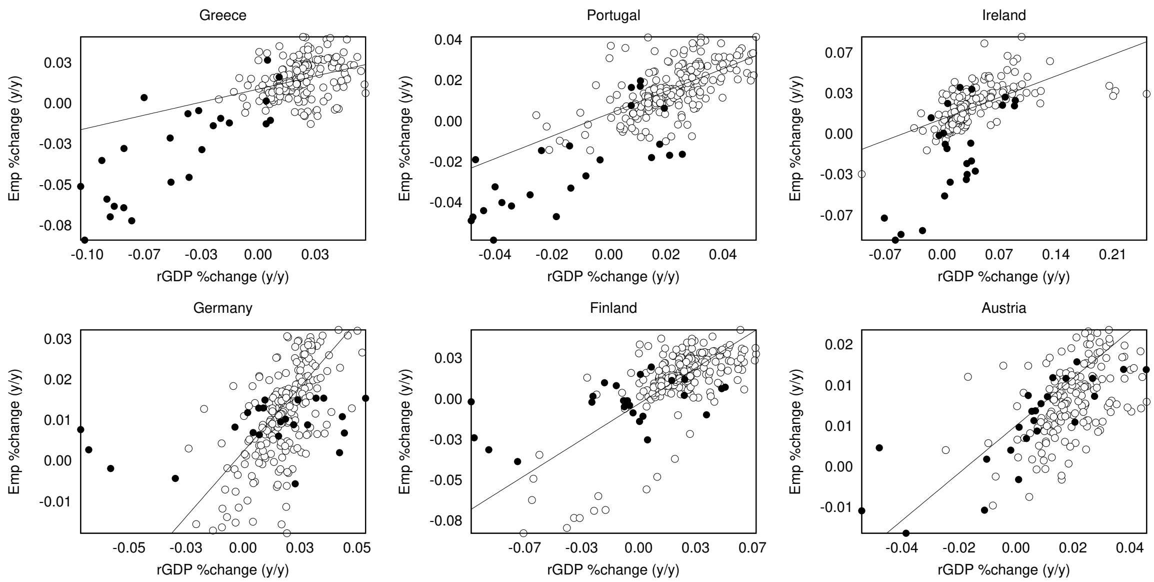
In order to explore formally whether the financial crisis was associated with a different regime relative to output and employment, a structural break of the relationship is evaluated using a Chow statistical test. The test consists in (first) estimating for each member country i of the Euro Area the following regression using OLS:

$$\Delta \log E_{it} = \beta_{i0} + \beta_{i1} \Delta \log Y_{it} + \alpha_{i0} Crisis_{it} + \alpha_{i1} \Delta \log Y_{it} \cdot Crisis_{it} + u_{it}, \tag{30}$$

where $\Delta \log E_{it}$, $\Delta \log Y_{it}$, and $Crisis_{it}$ are, respectively, quarterly percentage changes in employment, output, and a dummy variable indicative of a crisis period; and (second) testing the null hypothesis that $\alpha_{i0} = 0$ and $\alpha_{i1} = 0$ using a Wald statistic. The structural

[46] Examples include Ball et al. (2013) or Elsby, Hobijn, Şahin, Valletta, Stevenson, and Langan (2011).

Figure 10: Employment and output growth correlation for selected Euro Area countries (solid circles for observations between financial crisis of 2009-2014)



Data source: Eurostat
Notes: The selected time period includes data from 1995 until 2018 measured at a quarterly frequency (Germany starts from 1991 and Finland from 1990). Solid circles represent observations between 2009 and 2014 to capture the European financial crisis, and the fit line depicted exclude those years. Both variables depicted measure year to year percentage changes (%y/y) by taking the log difference of the corresponding variable and the analogous observation of the previous year. The replication of this figure for the complete set of Euro Area countries can be found in figure 12 of the Online Appendix.

break of the relationship between output and employment is tested for the European debt financial crisis, starting at the 2nd quarter of 2009 and ending in the first quarter of 2014[47].

The results of applying this structural break test for all member countries of the Euro Area can be found in table 10 where the constant and slope coefficients of an OLS are estimated for two different period selections. If one considers, for example, the case of Greece, a 1% fall in output is associated with a 0.09% average fall in employment if the crisis period is excluded, but that coefficient increases to an average fall of 0.43% if only the crisis period is considered. These results suggest that labor markets in Greece behaved in a structurally different fashion during the crisis period. Such interpretation is reinforced by the fact that the Chow test excludes the hypothesis of structural stability between the two periods. In fact, the table shows that for 6 out of 12 countries in the Euro Area there is significant statistical evidence of a structural break of the relationship employment/output.

[47]The interval is chosen to track the Greek crisis where, in October 2009, the Greek government announced that the budget deficit would be substantial larger than what was previously reported; and, in April 2014, the period of debt financial exclusion effectively ended when the Greek government was able to issue bonds at a rate below 6%.

Table 10: Okun's Law structural break: OLS regressions of employment (E) growth against output (Y) growth for different sub-periods

dependent var: % empl change ($\Delta \log E_t$); regressor: % output change ($\Delta \log Y_t$)

	excluding 2009q2-2014q1				for 2009q2-2014q1				Chow Test
country	β_0	β_1	R^2	N	β_0	β_1	R^2	N	(p-value)
Austria	0.002	0.8	0.21	70	0.002	0.13	0.15	20	0.89
Belgium	0.002	0.09	0.06	73	0.001	0.15	0.09	20	0.08
Germany	0.001	0.11	0.09	90	0.002	0.04	0.03	20	0.48
Greece	0.002	0.09	0.02	73	-0.004	0.43	0.34	20	0.00***
Spain	-0.003	1.23	0.80	74	-0.003	1.04	0.70	20	0.57
Finland	-0.001	0.36	0.28	93	0.000	-0.02	0.01	20	0.12
France	0.000	0.26	0.34	153	0.001	0.09	0.10	20	0.44
Ireland	0.006	0.06	0.05	73	-0.002	0.13	0.07	20	0.00***
Italy	0.002	0.15	0.08	73	-0.001	0.17	0.09	20	0.01
Netherlands	0.002	0.25	0.23	70	-0.001	0.22	0.15	20	0.00***
Portugal	0.001	0.37	0.23	73	-0.003	0.68	0.33	20	0.01***
Slovenia	0.001	0.16	0.13	73	-0.003	0.14	0.10	20	0.01***

Data source: Eurostat

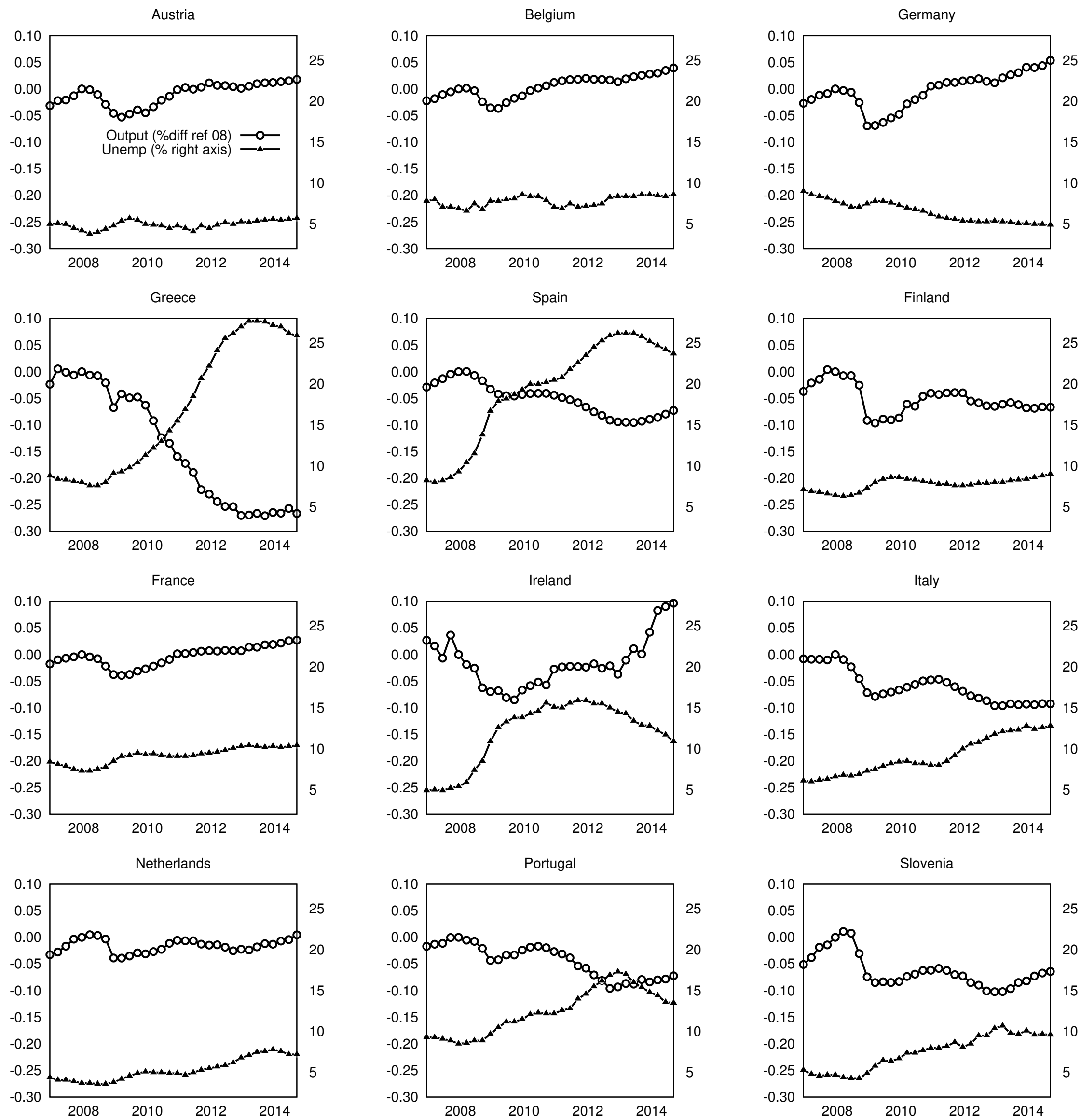
Notes: The coefficients β_1 and β_0 are the intercept and slope estimates of OLS regressions of the quarterly log change in employment against the log change of real output done for each member of the Euro Area. A standard dummy variables method is used to preform the Chow's test, as shown in equation 30 assuming that the break occurs between the second quarter of 2009 and the first quarter of 2014.

*** corresponds to a significance level of 1%.

Note that for the case of Greece, Ireland and Portugal, all countries that received assistance from international institutions during the crisis, the structural break implies an aggravation of labor market conditions with an increase of the employment elasticity with respect to output. For the remaining countries where one can also find a structural break, Italy, which didn't receive any assistance, also falls in that category, while for the Netherlands and Slovenia there is an decrease in the elasticity coefficient, implying a stronger resilience of labor markets during the crisis. In conclusion, the evidence seems to point that for countries that were more severely affected by the financial crisis, labor market conditions deteriorated relative to standard recessions.

B.2 Additional empirical evidence

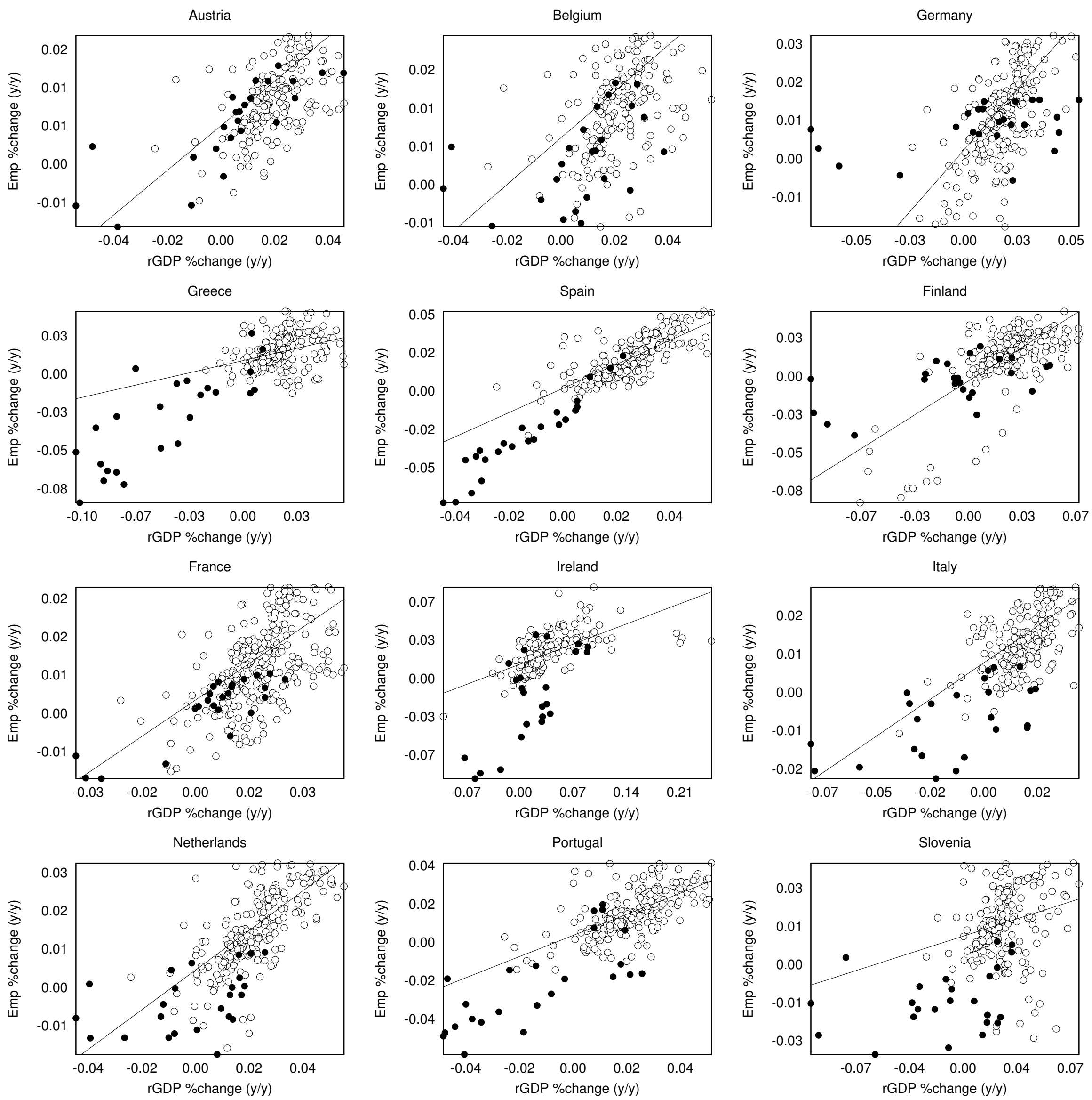
Figure 11: Output (% change relative to 2008 at left axis) and unemployment (% of active population at right axis) dynamics around the Euro Area debt crisis for all member countries



Data source: Eurostat

Notes: Output refers to the percentage change relative to the beginning of 2008 (left axis), measured at constant 2010 prices. Unemployment corresponds to the percentage of unemployed persons with respect to the active population (right axis). Both variables are seasonally adjusted at the quarterly frequency. Both axis used are fixed for all countries to increase comparability. See footnote 2 for explanation of the selection of Euro Area countries.

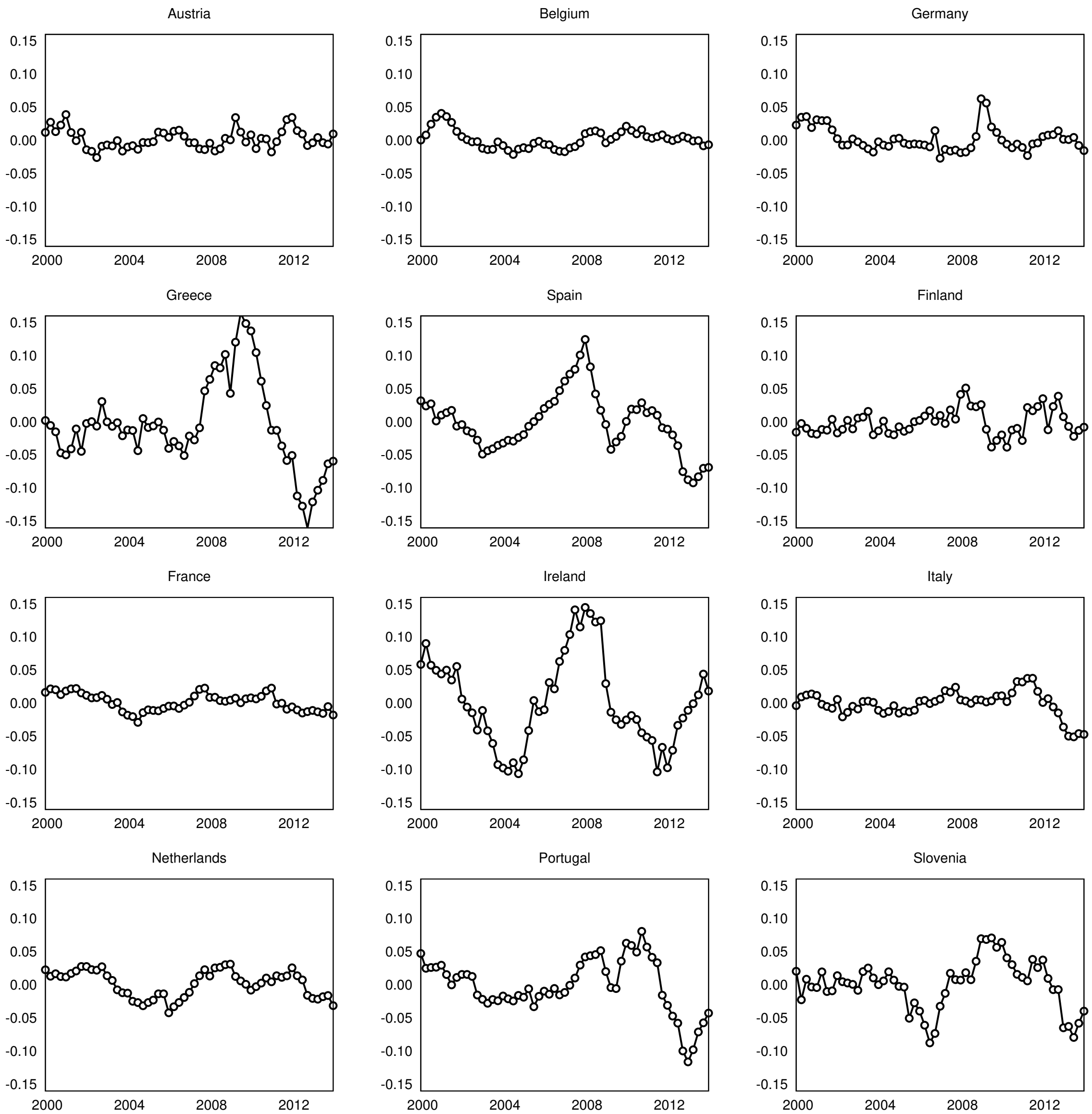
Figure 12: Employment and output correlation for all Euro Area countries (solid circles for observations between the financial crisis of 2009-2014)



Data source: Eurostat

Notes: The variables presented are measured at a quarterly frequency. Solid circles represent observations between 2009 and 2014 to capture the European financial crisis, and the fit line depicted exclude those years. Both variables depicted measure year to year percentage changes (%y/y) by taking the log difference of the corresponding variable and the analogous observation of the previous year. See footnote 2 for explanation of the selection of Euro Area countries.

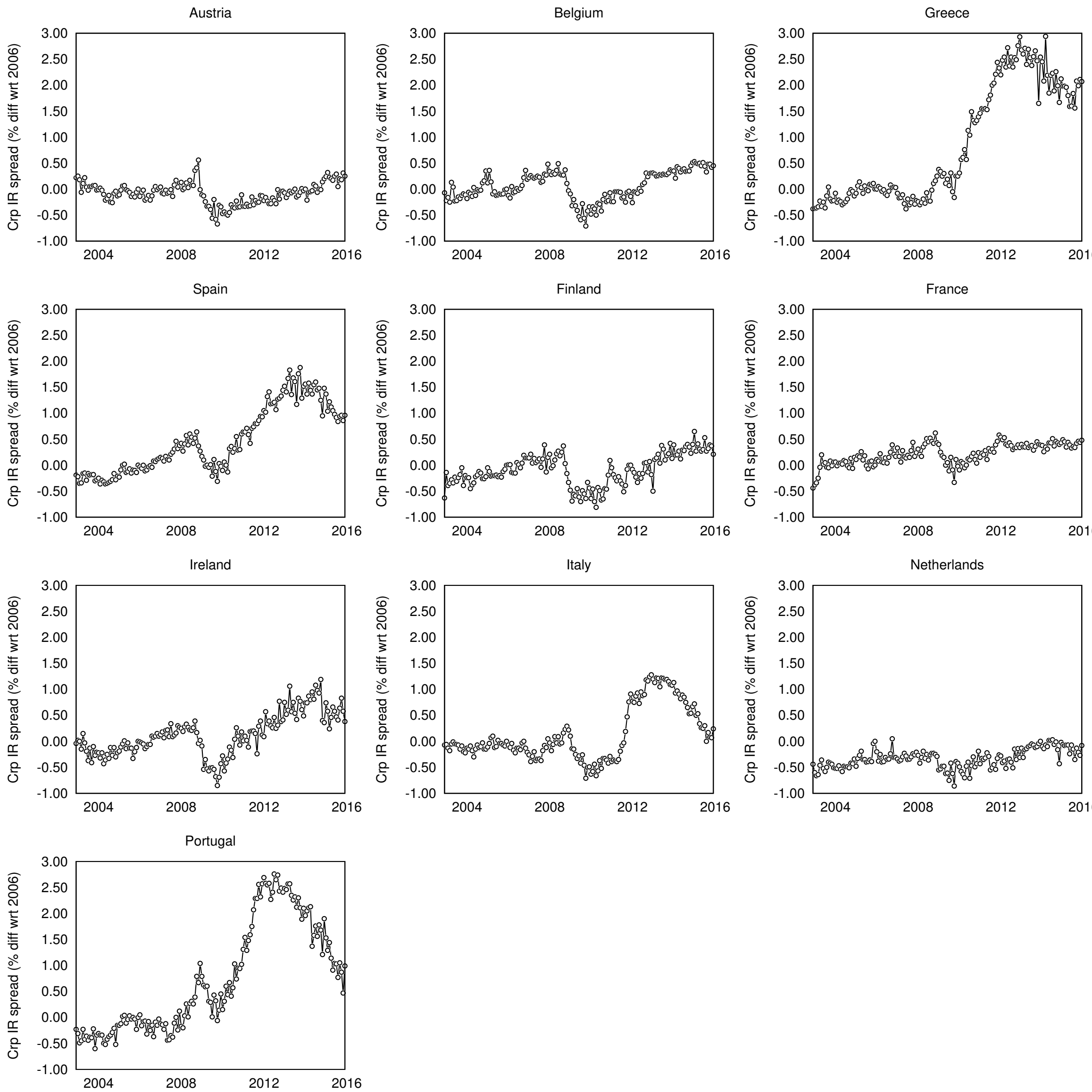
Figure 13: Aggregate labor wedges for all Euro Area countries



Data source: Eurostat

Notes: The variables used to compute the wedges include quarterly seasonal adjusted real output, real consumption, and employment, while the parameters used are the ones referred in footnote 5. Both axis used are fixed for all countries to increase comparability. The line plots correspond to the computation of the wedge using a CRRA utility function accordingly to equations (2). See footnote 2 for explanation of the selection of Euro Area countries.

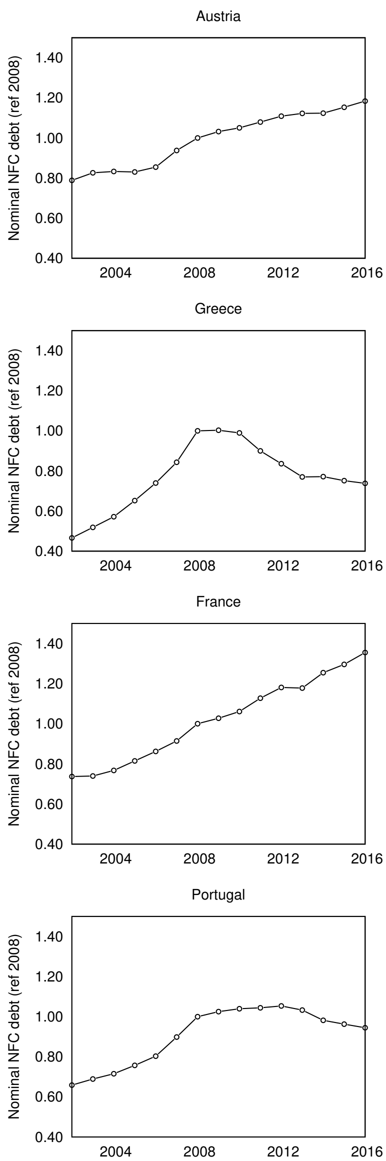
Figure 14: Corporate interest spreads for Euro Area countries (in %, difference with respect to 2006)



Data source: ECB

Notes: The corporate interest rate spread is computed as the difference between the country corporate interest rate and Germany's corporate interest rate. Slovenia is excluded from the sample since it joined the Euro Area only in 2007 and Germany is also not included since the basis for the spread calculation is the corporate interest rate in Germany itself.

Figure 15: Aggregate nominal non-financial corporations total debt (normalized to 2008)



Data source: Eurostat

Notes: This figure shows the path of nominal aggregate debt (bank loans and debt securities) of non-financial corporations for Euro Area countries. Slovenia is excluded from the sample since it joined the Euro Area only in 2007. Ireland is excluded from this figure as multinational corporation activities may overestimate recent trends (see 'Why are Irish Non-Financial Corporations so Indebted?', from Mary Cussen and Bridin O'Leary, published in the Quarterly Bulletin 01 / January 13, Central Bank of Ireland).

B.3 Business cycle statistics for earning taxes and consumption taxes

Given that the model doesn't include capital, both earning and consumption taxes are equivalent. Since Greece indeed increased income taxes in some periods of the sample, one may want to compute an household tax wedge that takes into consideration both income and consumption taxes. Letting τ_l and τ_c be the tax rates for labor and consumption, respectively, tax wedges can be associated to:

$$T^{unadjust} = 1 - \tau_l$$
$$T^{adjust} = \frac{1 - \tau_l}{1 + \tau_c}.$$

Deriving the implied tax rates from these two measures to compute business cycle statistics as the ones presented in table 6, generates the following results (table 11). Note that with the exception of the tax level business cycle statistics change very little. This is due to the fact that VAT rates were rarely changed during the period of analysis.

Table 11: Business cycle statistics between employment, output, and taxes

Moments		Unadj ($T^{unadjust}$)	Adj (T^{adjust})
correlation of employment with tax rate (annual)	$corr(H, \tau)$	-0.51	-0.58
correlation of output with tax rate (annual)	$corr(Y, \tau)$	-0.26	-0.47
mean tax rate (annual)	$mean\,(\tau)$	25%	37%
relative volatility of tax rate to output (annual)	$\frac{stdev(\tau)}{stdev(Y)}$	0.42	0.47

Notes: data from OECD, ECB, Eurostat, European Commission and refers to Greece. The data spans from 2000 to 2012 in order to exclude the default period. All data series are log-detrended using the Hodrick-Prescott filter with a smoothing parameter of 100 for yearly data. Earning taxes uses Eurostat data on income taxes computed for a typical household with average income and two children. Consumption taxes uses European Commission data for standard VAT rates.