

Prein, Timm

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Persistent Unemployment, Sovereign Debt Crises, and the Impact of Haircuts*

Timm M. Prein
University of Konstanz

Job Market Paper
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Most recent version *here*

Abstract

After 2008, the Southern European economies suffered a strong and persistent increase in unemployment. Rising government bond spreads necessitated the implementation of austerity policies. Austerity however, may increase unemployment. If workers lose human capital during unemployment spells, the economy's future production potential and thus the fiscal capacities to serve public debt will decline, aggravating a sovereign debt crisis. Debt renegotiations can help to avoid the costs of austerity. I develop a dynamic stochastic model of sovereign debt with long-term debt, endogenous haircuts and skill loss during unemployment to study optimal fiscal policy in sovereign debt crises. In a quantitative exercise, I find that with higher intensity of the skill loss, ex ante, the government issues less debt and the pro-cyclicality of fiscal policy declines. For Portugal, the model predicts debt renegotiations as optimal fiscal response in 2011 with a medium-run unemployment reduction of up to 3.63 percentage points.

Keywords: sovereign debt, debt renegotiations, haircuts, unemployment, austerity

JEL-Codes: E44, E62, F34, F41

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1 Introduction

During the Great Recession, the Southern European countries experienced a strong and persistent increase in unemployment. At the same time, rising spreads on sovereign bonds necessitated the implementation of austerity measures. However, procyclical fiscal policy may have adverse effects on employment, production, and tax revenues and thus elevate debt problems.

Beside the short-run costs from unemployment in form of lower production and higher expenditures on unemployment transfers, long-run effects on the countries' production potential may occur. Empirical evidence suggests that workers' human capital may depreciate during spells of unemployment (e.g. Schmieder et al., 2016), such that an economy with increasing long-term unemployment becomes less productive. Debt renegotiations are an option to avoid the costs of fiscal consolidation.

The experiences of the Southern European countries during the Great Recession give rise to three important questions. How does skill loss during unemployment spells affect optimal fiscal policy in the presence of default risk and what is the impact of such fiscal policy on macroeconomic outcomes? What are the consequences of debt renegotiations on unemployment in the short and long run? Do creditors suffer smaller losses if they agree on haircuts at the beginning of a crisis, enabling the sovereign to avoid the loss of production potential through austerity? To study these questions, this paper develops a dynamic stochastic model of sovereign debt with endogenous haircuts, long-term debt, matching frictions, and skill loss during unemployment.

The model features a small open economy populated by infinitely-lived households and a continuum of identical profit-maximizing firms. Households consist of workers. Employed workers face an exogenous job separation risk. Following Sterk (2016), workers are either high-skilled or low-skilled. If a high-skilled worker does not find a new job in the period of job separation, her human capital depreciates. Low-skilled unemployed workers regain their skills after one period of employment. In each period, firms decide on posting vacancies taking into account the realization of a productivity shock, the job separation rate, the average skills of job seekers, and a tax rate on sales. Matching follows a Cobb-Douglas function and depends on the number of job searchers and the number of vacancies posted.

The government finances public consumption and unemployment transfers by raising sales taxes and issuing external debt. Following Chatterjee and Eyigungor (2012), external debt is long-term and matures probabilistically. Risk-neutral private foreign investors borrow at the risk-free interest rate and provide credit. They have complete information about the current state of the economy and demand a premium which reflects the endogenous risk of renegotiations. The government cannot commit to repay its debt and has the option to enter debt renegotiations, in which case it suffers a one-time utility cost as in Bianchi et al. (2018). In the period of renegotiations, the government is excluded from international financial markets and bargains with the foreign creditors on the total surplus of an agreement. In the following period, the government regains

access to foreign credits with reduced debt obligations.

In a quantitative exercise, I apply the model to Portugal. The policy functions imply that the government enters debt renegotiations when employment and exogenous productivity are low and the debt level is high. With lower employment, the share of low-skilled workers increases and the expected lower productivity of job seekers reduces the willingness of firms to hire. It follows that, if debt is low and unemployment increases, the government issues debt and reduces taxes to increase the firms' benefit from hiring. Thus, there is a positive feedback between employment and expansionary fiscal policy. At high debt levels, the government is borrowing constrained and prefers to enter debt renegotiations to avoid the negative impact of austerity on employment.

From an *ex ante* perspective, a higher intensity of the skill loss during unemployment reduces public debt issuance and the pro-cyclicality of fiscal policy. Firms increase job creation and the employment level is generally higher. There are two opposing forces at work. On the one hand, with a higher intensity of the skill loss, the productivity of job seekers is lower and newly hired workers are less productive such that the benefits from hiring decline. On the other hand, firms benefit from preventing skill depreciation of newly displaced workers by posting costly vacancies. The second effect dominates. Instead of entering renegotiations more frequently to reduce taxes, the government finds it optimal to issue less debt such that debt-to-GDP declines. This result is due to a general equilibrium effect. For a given debt and employment level, the probability of renegotiations increases in the intensity of the skill loss. Higher interest spreads would require larger tax hikes to service debt amplifying the procyclicality of fiscal policy. In general equilibrium, however, since interest rates are higher, the government is more borrowing constrained and issues less debt. Lower debt service obligations reduce taxes and dampen tax hikes during economic downturns. Thus, taxes become less procyclical. Related to the model implication of less procyclical taxation in the presence of a higher intensity of the skill loss, cross-country evidence for OECD countries suggests that fiscal policy in economies with higher GDP per capita is less procyclical (c.p. Vegh and Vuletin, 2015).

To study the model dynamics, I run a series of simulations. I find that renegotiations are preceded by periods of increasing unemployment rates and rising debt-to-GDP ratios. Unemployment decreases after a haircut despite high shares of low-skilled job seekers, bad exogenous productivity realizations and high separation rates because the government has more fiscal space to reduce taxes and to improve the firms' benefit from hiring. Due to low tax rates, the government starts accumulating debt again, such that the strong expansionary fiscal policy is short-lived and unemployment temporarily increases again.

I use my model to evaluate what would have been the optimal debt rescheduling decision for Portugal. First, I employ a counterfactual analysis in which I choose a series of productivity shocks such that the unemployment rate from 1996 to 2017 is matched. For this series, I suppose that the government does not reschedule its debt obligations, which I technically implement by assuming high utility costs. Then, I control whether renegotiations would have been optimal under

my benchmark specification with lower utility costs. The model predicts that debt renegotiations would have been optimal in 2011 with an immediate unemployment reduction of 0.85 percentage points and a medium-run reduction of up to 3.63 percentage points. If, instead, debt is rescheduled one year later in 2012, unemployment is lowered by 1.34 percentage points immediately, but shows a weaker medium-run decline of up to 3.32 percentage points. However, foreign creditors benefit from later haircuts because the reduction of the remaining debt obligations at the time of renegotiations. The recovery rate increases from 23% in 2011 to 23.5% if debt is rescheduled in 2012. Debt renegotiations in 2013 imply an even larger recovery rate of 28.1%.

In a robustness analysis, I consider variations of the sovereign's bargaining power to assess the impact of the outcome of debt renegotiations. A higher bargaining power and thus larger haircuts make the government less reluctant to enter debt renegotiations at low debt levels. Due to the higher probability of debt renegotiations, the government faces higher bonds spreads and therefore accumulates less debt. The long-term average of the unemployment rates is U-shaped in the borrower's bargaining power. On the one hand, lower debt accumulation implies a declining debt service and lower tax rates. On the other hand, more fiscal space allows for stronger tax reductions with a persistent, positive impact on employment. The second effect dominates for very low bargaining power of the government. Because of the strong effect on the borrowing ability, welfare is higher when the borrower's bargaining power and thus the size of the haircut is low.

Related Literature. The paper builds on three strands of the literature. First, this paper is related to the literature on fiscal policy and sovereign debt crises. Cuadra et al. (2010) rationalize pro-cyclical fiscal policy in a model with endogenous default risk and endogenous fiscal policy. Arellano et al. (2019), de Ferra (2018), and Kaas et al. (2019) study the impact of fiscal policy on firms' access to credits during sovereign debt crises. Bianchi et al. (2019) study the trade-off between unemployment reduction through expansionary fiscal policy and increasing borrowing costs in a two-sector economy with downward-rigid nominal wages and fixed exchange rates. Na et al. (2018) consider the impact of devaluations on unemployment around sovereign defaults. Anzoategui (2017) quantifies the difference in the macroeconomic outcome of Spain during the European sovereign debt crisis when fiscal policy follows estimated pre-crisis rules instead of fiscal consolidation. Balke and Ravn (2016) integrate matching frictions a sovereign debt model and conclude that procyclical fiscal policy is optimal in normal times, but austerity is optimal during crisis times.¹ All these papers abstract from persistence of unemployment and the transmission of the impact of distortionary fiscal policy to future periods, which is my focus here.² Balke (2017) studies the impact of sovereign risk on unemployment via financial intermediaries. She finds that a default is accompanied by peaking unemployment rates since banks cannot provide the financial

¹Shi (2018) proposes a similar model, but abstracts from distortions from fiscal policy.

²The persistent impact of distortionary fiscal policy during sovereign debt crises has only been studied in the context of the government's ability to raise taxes (Pappadà and Zylberberg, 2019) and regional migration (Gordon and Guerron-Quintana, 2019).

assistance required by firms to pay wages and vacancies. While her emphasis is on persistent unemployment as a cost of default in the absence of distortionary fiscal policy, unemployment in my model is amplified by fiscal consolidation. Additionally, I provide an endogenous mechanism to explain variations in fiscal policy cyclicity by incorporating skill loss during unemployment.³ Second, the paper is related to the literature on skill loss during unemployment. Pissarides (1992) employs an overlapping generations model to show that unemployment can become persistent if unemployed workers lose a part of their human capital. The reason is a reduction in vacancy posting as firms' incentives to hire decrease with the skill level. The lower number of jobs implies an extended unemployment duration.⁴ Sterk (2016) uses a quantitative version of the model of Pissarides (1992) to study the occurrence of multiple steady states in labor market dynamics. In a similar set-up, Laureys (2014b) focuses on quantitative effects of hiring externalities. The literature has further considered the influence of skill loss on labor market fluctuations (Lalé, 2018) and the contribution of differences in unemployment history to wage dispersion (Ortego-Marti, 2016). Laureys (2014a), Esteban-Pretel and Faraglia (2010), and Acharya et al. (2018) study the impact of monetary policy in the presence of human capital depreciation. I use a search and matching model with skill loss during unemployment that closely follows Laureys (2014b) and Sterk (2016) to study the optimal fiscal policy during sovereign debt crises. Like Laureys (2014b), I restrict to parameterizations for which no multiplicity of steady states occurs.

Third, this paper builds on the literature on sovereign debt renegotiations. Yue (2010) endogenizes debt recovery rates by incorporating Nash bargaining in a sovereign debt model. Further contributions include dynamic bargaining with incomplete informations (Bai and Zhang, 2012), the dependence of recovery rates on the debtor's (Sunder-Plassmann, 2018) and the external creditors's business cycle Asonuma and Joo (forthcoming), and stochastic bargaining to generate delays in debt renegotiations (Benjamin and Wright, 2013; Bi, 2008). While these papers assume that restructurings follow a default, Asonuma and Trebesch (2016) allow for preemptive restructurings. Hatchondo et al. (2014) study the possibility of voluntary debt exchanges with benefits to debtor and creditor. All these papers use endowment economies. Asonuma and Joo (2019) consider renegotiations in a production economy with productive public capital. I contribute to the literature by studying endogenous haircuts in a production economy with skill loss during unemployment.

The remainder of the paper is structured as follows. In Section 2, I discuss the empirical evidence on unemployment and sovereign default risk in the Southern European countries during the Great Recession. I further review the empirical evidence on labor market dynamics during sovereign debt crises. In Section 3, I describe the theoretical model. Section 4 presents the quantitative

³In an alternative approach, Joo (2014) uses news shocks to explain differences in the cyclicity of fiscal policy across countries.

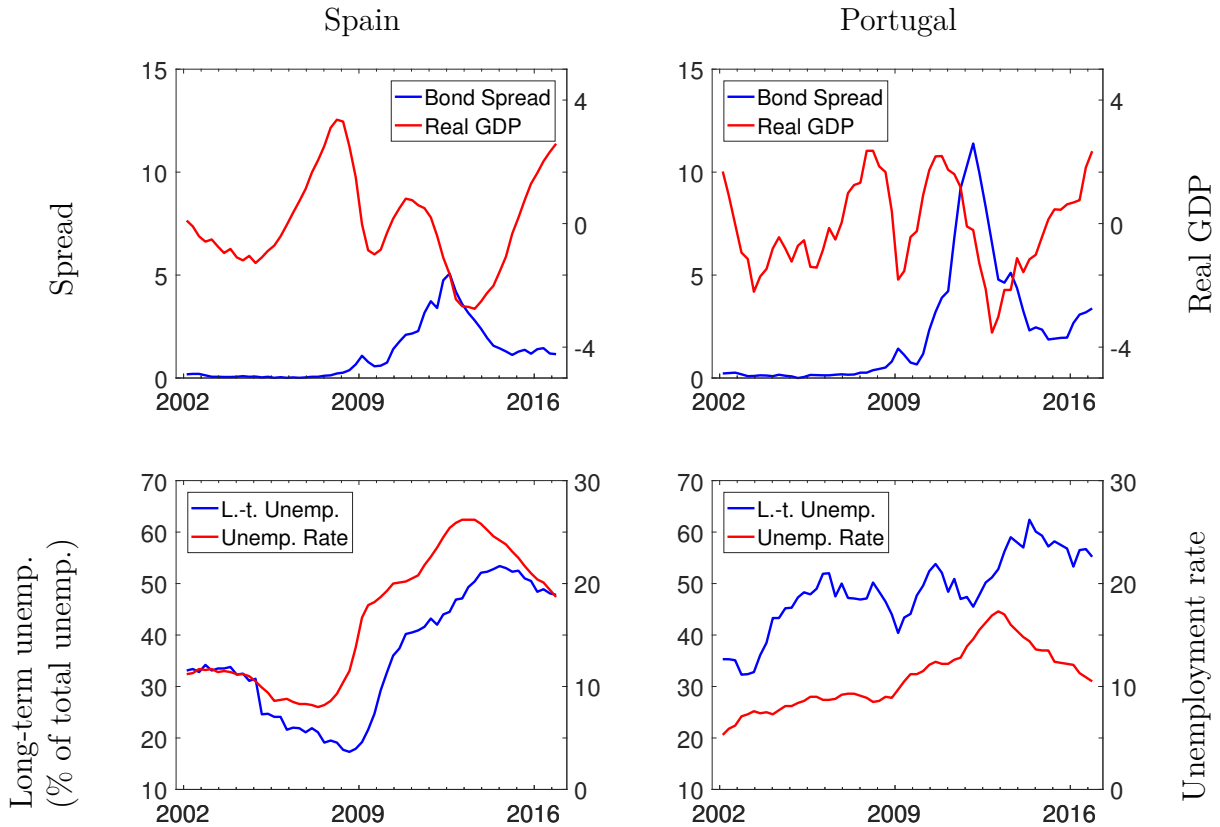
⁴Another strand of the literature builds on Ljungqvist and Sargent (1998, 2008), where longer unemployment durations and bigger skill losses arise from higher unemployment benefits which alter the workers' labor supply decisions.

results. Section 5 concludes.

2 Empirical Evidence on Austerity, Unemployment, and Sovereign Default Risk

During the European Sovereign Debt crisis, several economies faced a large increase in unemployment. Interest rates on bonds increased because of increasing doubts on the countries' ability to serve their debt. Figure 1 takes Spain and Portugal as examples and presents in the upper panels the spread between 10-year Spanish (Portuguese) and German government bonds (blue, left axis) and the cycles of HP-filtered real GDP (red, right axis) for the years from 2002 to 2016. The lower panels show the percentage share of long-term unemployed in the total number of unemployed (blue, left axis) and the unemployment rate (red, right axis).

Figure 1: Spain and Portugal during the Great Recession

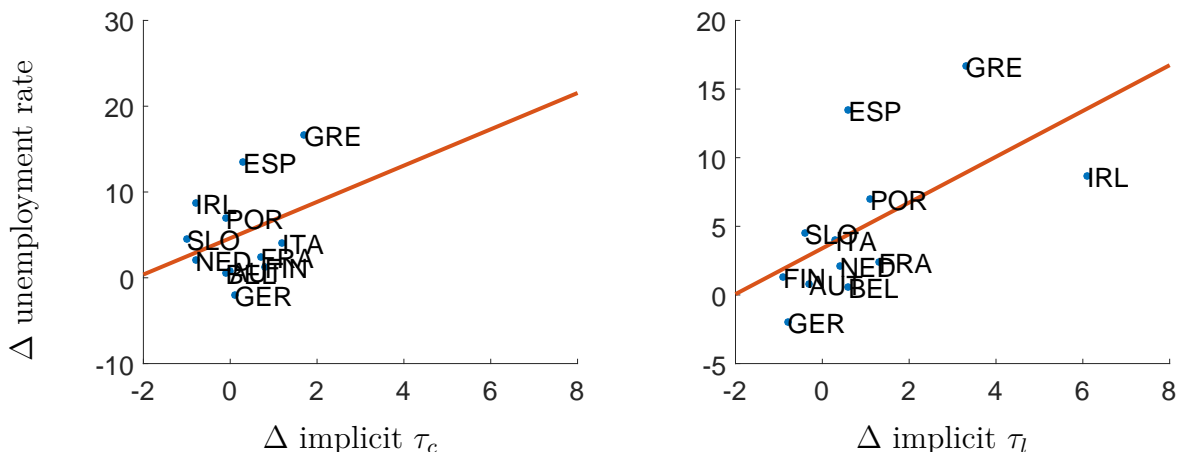


Notes: The upper panels show the spread between the interest rates on 10-year Spanish (Portuguese) and German bonds (blue line, left axis) and the cycles of HP-filtered real GDP (red line, right axis) of Spain (Portugal) from 2002 to 2016 in the left (right) column. The lower panels show the share of long-term unemployed in percent of total unemployment (blue line, left axis) and the unemployment rate (red line, right axis). All data is from Eurostat.

While long-term interest rates before the crisis did not differ across the Euro zone, spreads strongly increased from 2008 to 2012 until the announcement of the Outright Monetary Transactions

(OMT) program. Real GDP dropped, accompanied by rising unemployment rates and a lagged increase in long-term unemployment. Unemployment in general and long-term unemployment in particular remained at persistently high levels and did not return to pre-crisis levels until 2016.

Figure 2: Cyclicalities of Fiscal Policy and Change in Unemployment



Notes: The left (right) graph plots the change in the unemployment rate between 2008 and 2012 against the change in the implicit tax rate on consumption τ_c (on labor τ_l) during the same period. The data points refer to 12 Euro area members. All data is from Eurostat. The red lines denote OLS regressions.

In response to rising bond spreads and lower revenues because of the recession, the Southern European economies implemented strong fiscal consolidation measures. Alesina et al. (2015) construct a narrative data set on fiscal consolidation plans. For Portugal between 2010 and 2013, they find government spending cuts of 0.1% to 0.8% of GDP and revenue increases via tax hikes of 0.4% to 0.6% of GDP per year. The austerity policies, however, had adverse economic effects: Blanchard and Leigh (2013) find that spending cuts and tax hikes caused a further increase of the unemployment rate. In a related study, Vegh and Vuletin (2014) provide empirical evidence suggesting that the increase in unemployment was stronger for countries with a more procyclical fiscal policy. They find that the change in unemployment varied positively with the correlation between GDP and government spending and conclude that countries with more fiscal space before 2008 could respond more actively and reduce the duration and the intensity of the crisis.⁵ Figure 2 shows the correlation between unemployment and tax changes for 12 Euro area members, using data from Eurostat. In particular, I plot the change in the unemployment rate between 2008 and 2012 against the change in the implicit tax rates on consumption and labor during the same period. The red OLS regression lines suggest a positive relationship between taxation and unemployment, which also holds at shorter time horizons. The observations for the European economies are in line with empirical evidence by Agnello et al. (2014) and Ball et al. (2013) for spending- and

⁵Vegh and Vuletin (2014) argue that these results confirm the finding of reduced duration and intensity of crises in Latin American countries with countercyclical fiscal policy, specifically Brazil and Chile after 1998.

tax-based consolidations in OECD countries between 1978 and 2009.

Apart from short-run costs related to lower production and higher unemployment, unemployment may also cause a depreciation of human capital. Numerous studies, e.g. Couch and Placzek (2010), find empirical evidence for a negative effect of unemployment on workers' income.⁶ Ortego-Marti (2017) finds that wages depend on a person's entire unemployment history. He uses a search and matching model with skill loss during unemployment to explain the observed differences in total factor productivity across OECD countries.

During the European sovereign debt crisis, only Greece renegotiated its debt. In 2012, Greece received a haircut of 100 billion euro on its privately held debt and was granted official financial assistance in return to the implementation of austerity policies. Despite the debt reduction, the debt ratio remained above 160% of GDP in 2013. Greek GDP further dropped and unemployment persistently increased.⁷ The observations for Greece are in contrast to the experience with emerging economies. Levy Yeyati and Panizza (2011) examine 20 default episodes between 1980 and 2006 and find that in the quarters before defaults unemployment rates remain constant or increase and in the quarters following a default unemployment rates tend to decrease.

3 The Model

3.1 The Environment

I consider a small open economy inhabited by identical infinitely lived households and a continuum of identical profit-maximizing firms. Households consist of employed and unemployed workers, own the firms, and derive utility from private consumption. Following Sterk (2016) and Laureys (2014b), workers differ in their skills. Skill loss occurs during unemployment. Firms use labor as input and are subject to productivity shocks and matching frictions. In each period, they choose their optimal amount of hiring. The government imposes sales taxes and issues external debt on international financial markets. Debt contracts mature probabilistically as in Chatterjee and Eyigungor (2012), are not enforceable and subject to default risk. In each period, the government can decide to enter debt renegotiations. In renegotiation periods, the government loses access to international financial markets and suffers an exogenous one-time utility cost which depends on the realization of the productivity shock. The utility cost can be interpreted as a loss of reputation to the incumbent.⁸ Following Yue (2010), debt renegotiations take the form of one-round Nash bargaining between the policymaker and the international creditors. Renegotiations last one

⁶E.g. Schmieder et al. (2016) consider German data and find a daily wage reduction of almost 1% per additional month of unemployment duration. For overviews of the findings in the early empirical literature on job displacements, see Fallick (1996) and Kletzer (1998).

⁷C.p. Zettelmeyer et al. (2013) and Eurostat data.

⁸The formulation of the utility cost is similar to Bianchi et al. (2018) where the cost depends on the realization of an endowment shock. Alternative formulations of exogenous utility costs have been considered by Chang (2007), Müller et al. (forthcoming), and Roch and Uhlig (2018).

period and end with an agreement on the government's debt obligations in the following period.

Workers. At the beginning of each period, a share $n_t \in [0, 1]$ of workers is employed. Employed workers lose their job with exogenous probability ρ_x . I follow Pries (2008) and assume the job separation rate $\rho_{x,t} = \rho_x(z_t) \in [0, 1]$ to be a function of productivity shocks z_t .⁹ Following the realization of the productivity shock, firms post vacancies and hire such that unemployed workers find a job with probability $\rho_{f,t} \in [0, 1]$. Workers are heterogenous with respect to their skills and are either high-skilled (H) or low-skilled (L). As in Sterk (2016), high-skilled workers become low-skilled after one period of unemployment. In particular, high-skilled workers lose a fraction ξ of their productivity. Low-skilled workers who find a job become high-skilled in the following period. The share p_t of low-skilled job seekers is

$$p_t = \frac{u_t}{u_t + \rho_{x,t}(1 - u_t)}, \quad (1)$$

where $u_t = 1 - n_t$ is the fraction of unemployed workers at the beginning of a period before the productivity shock is realized. The denominator denotes the total share of job seekers consisting of previously and newly unemployed workers. I assume employed workers receive skill-dependent wages $w_t^{\{H,L\}}$. Job seekers who cannot find a job obtain transfers $T_t^{\{H,L\}}$ which equal a fixed share Ω of the respective wage $w_t^{\{H,L\}}$, such that newly unemployed workers receive higher payments.

Firms. Production uses labor as input, follows a constant return to scale production technology $f(n_t)$, $f : \mathbb{R}_+ \rightarrow \mathbb{R}_+$, and is subject to productivity shocks z_t . I assume that productivity $z_t \in \mathcal{Z}$ has a compact support, $\mathcal{Z} = [\underline{z}, \bar{z}] \subset \mathbb{R}_+$, and follows a Markov process with transition function $\mu(z_{t+1}, z_t)$. Firms pay sales taxes τ_t . After job separation, firms decide on hiring $h_t = n_{t+1} - (1 - \rho_{x,t})n_t$, where n_{t+1} is the new optimal employment level. I follow Sterk (2016) and assume that firms cannot observe the skill status of new hires before hiring such that search for new hires is entirely random. However, I assume that firms know the skill level directly after hiring and pay wages w_t^H and w_t^L accordingly. A share p_t of hires is low-skilled with productivity reduced by a fraction ξ . In each period, firms post a number of vacancies v_t at a fixed cost $\kappa > 0$ per unit. When production is linear in labor, firms' per-period profits Π_t are given by

$$\Pi_t = (1 - \tau_t)z_t(n_{t+1} - \xi p_t h_t) - (n_{t+1} - p_t h_t)w_t^H - (p_t h_t)w_t^L - \kappa v_t, \quad (2)$$

where

$$n_{t+1} = (1 - \rho_{x,t})n_t + h_t \quad (3)$$

$$h_t = a_t v_t \quad (4)$$

$$h_t \geq 0. \quad (5)$$

⁹With constant separation rates, productivity shocks generate too small employment fluctuations in standard matching models with flexible wages.

Condition (3) is the transition equation of employment. Condition (4) defines hiring as the product of the vacancy yield a and vacancy posting. Condition (5) is the non-negativity constraint on hiring.

Matching follows a Cobb-Douglas function such that the number of hires is given by

$$h_t = s_t^\alpha v_t^{1-\alpha},$$

where $s_t = u_t + \rho_{x,t}(1 - u_t)$ denotes the number of job seekers. As in Pissarides (2000), wage setting follows from repeated Nash bargaining on the total surplus of a job and is described in detail in Appendix B.¹⁰ Households receive the firm profits.

Households. The representative household derives utility from private consumption c_t . Let preferences be described by a per-period utility function $u : \mathbb{R}_+ \rightarrow \mathbb{R}$, which is continuous, twice differentiable and strictly increasing in c_t , concave in c_t , and satisfies the Inada conditions. The household finances private consumption with profits from firms Π_t , wage income from employed workers and transfers from unemployed workers. A share n_{t+1} of workers is employed and receives a wage $w_t^{\{H,L\}}$, which depends on the skill level of the worker. A share p_t of newly employed workers is low-skilled (L), while all other employed workers are high-skilled (H). Unemployed workers receive transfers $T_t^{\{H,L\}}$. Only newly unemployed workers are high-skilled and receive the higher transfer payment T^H . The household budget constraint is given by

$$c_t = \Pi_t + (n_{t+1} - p_t h_t) w_t^H + (1 - p_t)(1 - n_{t+1}) T_t^H + p_t h_t w_t^L + p_t(1 - n_{t+1}) T_t^L. \quad (6)$$

Government. The government has access to incomplete international financial markets. It uses revenues from sales taxes and issuance of non-contingent bonds to finance public consumption g_t and unemployment transfers $T_t^{\{H,L\}}$. I follow Chatterjee and Eyigungor (2012) and assume a bond to mature in the next period with probability δ and otherwise to imply a coupon payment ψ . I assume for simplicity that public consumption does not provide utility and set the size of public consumption to a constant share γ of private consumption such that $\frac{g_t}{c_t} = \gamma$. Let total transfer payments T_t be the sum of transfers to high-skilled and low-skilled unemployed:

$$T_t = (1 - p_t)(1 - n_{t+1}) T_t^H + p_t(1 - n_{t+1}) T_t^L.$$

If the government repays its debt, the government budget constraint reads as

$$g_t + T_t = \tau_t z_t (n_{t+1} - \xi p_t h_t) - q_t (b_{t+1} - (1 - \delta) b_t) + (\delta + (1 - \delta) \psi) b_t, \quad (7)$$

where q_t denotes the unit price of a bond of size b_{t+1} when the government faces the productivity shock z_t and the firms choose the current period employment level n_{t+1} . In the following, similar to Aguiar et al. (2017), I will assume without loss of generality that the coupon payment ψ is

¹⁰In the set-up with productivity shocks and sales taxes, endogenous wages ensure that the net present value of a firm is non-negative.

equal to the real interest rate r . To prevent the government from choosing maximal debt dilution before renegotiations, I follow Chatterjee and Eyigungor (2015) and restrict new debt issuance to debt levels where the probability of renegotiations in the following period does not exceed an exogenous value $\phi \in (0, 1)$.¹¹

If the government decides to enter renegotiations, it suffers an exogenous one-time utility cost $\chi(z_t)$ and is excluded from international financial markets for the rest of the period. The size of the utility cost $\chi(z_t)$ is exogenously determined by the realization of the productivity shock z_t , similar to the cost in Bianchi et al. (2019) and Bianchi et al. (2018) who consider an income utility cost depending on the realization of an endowment shock. The budget constraint reads as

$$g_t + T_t = \tau_t z_t (n_{t+1} - \xi p_t h_t). \quad (8)$$

The government regains access to international financial markets in the period after debt renegotiations.

International Creditors. There is a continuum of identical infinitely-lived international creditors. International creditors are risk-neutral and borrow from international markets at the constant risk-free interest rate r . They have perfect information about the state of the economy. International creditors demand a risk premium and internalize the risk of debt renegotiations and the expected return from an agreement.

Timing. The timing is as follows. At the beginning of a period, job separation occurs. The policymaker observes the realization of productivity z_t and chooses its optimal policies. The firms take the public sector policies as given and post vacancies. After hiring, production takes place with initially employed workers and new hires. At the end of the period, separated workers that have not found a job become low-skilled. If the government chooses to enter debt renegotiations at the beginning of the period, there will be an agreement on the new debt level before the firms decide on hiring.

3.2 Recursive Equilibrium

In equilibrium, firms take the government's policy decision as given and maximize the expected discounted life-time profits subject to a non-negativity constraint on hiring. The government maximizes the expected life-time utility of households taking into account the optimal response in firms' decisions.¹² In each period, the government can choose to repay its debt or to enter debt renegotiations, where the government suffers a utility cost. Sovereign debt renegotiations

¹¹Chatterjee and Eyigungor (2015) refer to the observation of limits on the expected immediate default risk of newly issued bonds in sovereign debt markets. In a similar approach, Hatchondo et al. (2016) impose a lower bound on the bond price.

¹²Ortigueira (2006) shows that the quantitative results of a Markov equilibrium may change if the public and the private sector choose their policies simultaneously.

take the form of one-time Nash bargaining between the foreign creditors and the policymaker. Foreign creditors are risk-neutral, borrow or lend from international financial markets at the risk-free interest rate r , have perfect information about the state of the economy, and charge a risk premium. The following subsections describe the optimization problems of the firms and the government, the details of the debt renegotiations, and the zero-profit condition of foreign creditors. The formal definition of the recursive equilibrium is provided in Appendix A.

3.2.1 The Private Sector

The firms take the public sector policies as given and maximize their expected discounted lifetime profits. I assume that firms discount future profits with the stochastic discount factor of the households. As sales taxes are uniform, the decisions on vacancy posting and hiring are identical for all firms. The optimality condition of the firms is given by:

$$(1 - \tau)z(1 - \xi p) - (1 - p)w^H - pw^L + \lambda + \beta \int_{z'} \frac{u'(c')}{u'(c)} (1 - \rho_x(z')) \left((1 - \tau')z'\xi p' - p'(w^{H'} - w^{L'}) + \frac{\kappa'}{a'} - \lambda' \right) dz' = \frac{\kappa}{a}, \quad (9)$$

where λ is the Lagrange multiplier from the non-negativity constraint on hiring. The term on the right-hand side denotes the hiring costs per new hire. On the left-hand side, the term in the first line gives the expected profit from a newly hired worker to the firm in the current period. The term in the second line describes the present discounted expected benefit from having a high-skilled worker in the next period instead of hiring a new potentially low-skilled worker.

3.2.2 The Public Sector

In each period, the policymaker chooses between two options:

$$V(z, b, n) = \max \left\{ V^R(z, b, n), V^D(z, n) \right\}. \quad (10)$$

$V^R(z, b, n)$ denotes the value function of the government in case of debt repayment. $V^D(z, n)$ is the value function in case of sovereign debt renegotiations. The discount factor $\beta \in [0, 1]$ is common for all individuals in the economy.

When the government chooses to repay its debt, the value function solves:

$$V^R(z, b, n) = \max_{b', \tau, g} \left\{ u(c) + \beta \int_{z'} V(z', b', n') \mu(z', z) dz' \right\} \quad (11)$$

subject to

$$\begin{aligned} g + T &= \tau z(n' - \xi p h) - q(z, b', n')(b' - (1 - \delta)b) + (\delta + (1 - \delta)\psi)b \\ c &= \Pi + (n' - p h)w^H + p h w^L + T \\ \frac{g}{c} &= \gamma \\ \eta(z, b', n') &\leq \phi \\ p &= \frac{1 - n}{1 - n + \rho_x n} \\ n' &= \mathcal{N}(z, \tau, n), h = \mathcal{H}(z, \tau, n), \end{aligned}$$

where $\eta(z, b', n')$ is the probability of debt renegotiations in the next period. The private sector policies n' and h follow from the optimality condition (9).

If the policymaker chooses to enter debt renegotiations, the economy is excluded from international financial markets for the rest of the period and the policymaker suffers a one-time utility cost $\chi(z)$. The government and external creditors bargain to find an agreement on the new debt level \tilde{b} , which is independent from the size of renegotiated debt. The renegotiation mechanism is described in detail in Section 3.2.3. In the following period, the government can reenter financial markets and decides on serving the reduced debt stock. The value function associated with debt renegotiations is given by:

$$V^D(z, n) = u(c) - \chi(z) + \beta \int_{z'} V(z', \tilde{b}, n') \mu(z', z) dz' \quad (12)$$

subject to

$$\begin{aligned} g + T &= \tau z(n' - \xi p h) \\ c &= \Pi + (n' - p h) w^H + p h w^L + T \\ \frac{g}{c} &= \gamma \\ p &= \frac{1 - n}{1 - n + \rho_x n} \\ n' &= \mathcal{N}(z, \tau, n), h = \mathcal{H}(z, \tau, n). \end{aligned}$$

The following indicator function describes the government's choice on entering debt renegotiations:

$$d(z, b, n) = \begin{cases} 1 & \text{if } V^R(z, b, n) < V^D(z, n) \\ 0 & \text{else.} \end{cases}$$

The set of productivity shocks $z \in \mathcal{R}_z$ for which the government enters debt renegotiations is given by:

$$\mathcal{D}(b, n) = \{z \in \mathcal{R}_z : d(z, b, n) = 1\}. \quad (13)$$

The probability of debt renegotiations reads as

$$\eta(z, b', n') = \int_{\mathcal{D}'(b', n')} \mu(z', z) dz'. \quad (14)$$

3.2.3 Debt Renegotiations

As in Yue (2010), debt renegotiations follow a generalized Nash bargaining game, in which an agreement implies a new debt level \tilde{b} . The value of the agreement to the government is given by $V^D(z, n)$. The creditors receive the present value of the reduced debt in terms of expectations

$q(z, \tilde{b}, n')\tilde{b}$. The government's outside option to an agreement is permanent autarky, while external creditors would lose their investment. The expected continuation value of autarky reads as

$$V^A(z, n) = u(c) + \beta \int_{z'} V^A(z', n') \mu(z', z) dz',$$

where

$$\begin{aligned} g + T &= \tau z(n' - \xi ph) \\ c &= \Pi + (n' - ph)w^H + phw^L + T \\ \frac{g}{c} &= \gamma \\ p &= \frac{1 - n}{1 - n + \rho_x n} \\ n' &= \mathcal{N}(z, \tau, n), h = \mathcal{H}(z, \tau, n). \end{aligned}$$

The borrower's bargaining surplus is given by

$$\Delta_B(z, \tilde{b}, n) = V^D(z, n) - V^A(z, n),$$

where $V^D(z, n)$ changes with the debt level \tilde{b} , see Equation (12).

The bargaining surplus of the international creditors reads as

$$\Delta_L(z, \tilde{b}, n) = q(z, \tilde{b}, n')\tilde{b}.$$

Let θ denote the borrower's bargaining power. The bargaining problem¹³ solves

$$\tilde{b} = \operatorname{argmax}_b \left[\left(\Delta^B(z, b, n) \right)^\theta \left(\Delta^L(z, b, n) \right)^{1-\theta} \right] \quad (15)$$

subject to

$$\begin{aligned} \Delta^B(z, b, n) &\geq 0, \\ \Delta^L(z, b, n) &\geq 0. \end{aligned}$$

The recovery rate is given by the ratio of the debt stocks before and after the renegotiations $\frac{\tilde{b}}{b}$.

3.2.4 International Creditors

International creditors are risk-neutral and internalize the risk of debt renegotiations and the expected return from an agreement. The bond price follows from the zero-profit condition:

$$\begin{aligned} q(z, b', n') &= \frac{1}{1+r} \int_{z'} (1 - d(z', b', n')) (\delta + (1 - \delta)(\psi + q(z', b'', n''))) \mu(z', z) dz' \\ &+ \frac{1}{1+r} \int_{z'} d(z', b', n') \frac{\tilde{b}'}{b'} q(z', \tilde{b}', n'') \mu(z', z) dz'. \end{aligned} \quad (16)$$

The spread is the difference between the internal rate of return $i(z, b', n')$ and the risk-free rate r , where i follows from $q(z, b', n') = (\delta + (1 - \delta)\psi)/(\delta + i(z, b', n'))$. The bond price lies in the interval $[0, (\delta + (1 - \delta)\psi)/(\delta + r)]$.

¹³For computational reasons, I deviate from Yue (2010) and omit the restriction on the new debt level such that recovery rates can exceed one, similar to Chatterjee and Eyigungor (2015) and Sunder-Plassmann (2018). The change only affects states in which the government would not enter renegotiations.

4 Quantitative Analysis

4.1 Calibration

For the quantitative analysis, I calibrate the model to Portugal for the time period from 1995 to 2017. A period in the model corresponds to a year. The annual calibration implies that a low-skilled worker has been unemployed for at least one year and can be considered as long-term unemployed. Kroft et al. (2013) provide empirical evidence for the U.S. which suggests that the probability of receiving an interview call-back is decreasing in unemployment duration, where most of the decline occurs within the first eight months of unemployment. Thus, it seems reasonable to assume that most of the human capital depreciation occurs during the first year after job loss. Table 1 summarizes the parameter values. I employ seasonally adjusted annual series for real GDP, real private consumption, real government consumption, the unemployment rate and the long-term interest rates of Portugal and Germany which are taken from Eurostat. For external debt statistics, I rely on OECD data.

I assume that the per-period utility of households is specified by the following constant relative risk-aversion (CRRA) utility function

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma},$$

where σ is the relative risk aversion. I set σ to 2, which is a standard value in the literature. The annual risk-free interest rate r of 4.2 percent corresponds to the average German 10Y-bond yield. Following Cuadra et al. (2010), I assume that production is linear in labor, $f(n) = n$. Productivity shocks follow an AR(1) process:

$$\ln(z') = \rho_z \ln(z) + \epsilon$$

where ϵ is i.i.d. $N(0, \sigma_\epsilon^2)$. The values for the parameter ρ_z and σ_ϵ are set to match the autocorrelation and standard deviation of the log-quadratically detrended annual Portuguese real GDP series between 1995 and 2017.

For simplicity, similar to Pries (2008), I assume the job separation rate ρ_x to be negatively correlated with the productivity shock z . In particular, I choose the following relationship which ensures that the job separation rate is always non-negative:

$$\rho_x = \bar{\rho}_x \exp(-\sigma_x \ln(z)),$$

where $\bar{\rho}_x$ is a constant around which the separation rate fluctuates. σ_x is a parameter for the sensitivity of the job separation rate to productivity z . I set $\bar{\rho}_x$ and σ_x to match the mean of the short-term unemployment rate and the standard deviation of the percentage share of long-term unemployed on total unemployment in Portugal.

In my model, the ratio of government consumption over private consumption is fixed. I set the parameter γ to 0.32, which corresponds to the empirical mean ratio of government to private

Table 1: Calibration

	Parameter	Value	Empirical Target
r	Risk-free rate	0.042	Mean German 10-Y bond rate
σ	Relative risk aversion	2.0	Standard value
β	Discount factor	0.87	Mean external debt to GDP
γ	Public good weight	0.32	Mean of g/c
Λ_0	Utility cost (intercept)	0.9	Mean spread
Λ_1	Utility cost (slope)	6.9	$ \Delta s $ 90% quantile ¹
θ	Borrower's bargaining power	0.31	Market value of renegotiated debt 23%
δ	Maturing probability	0.16	Mean residual maturity
α	Matching function elasticity	0.50	Petrongolo and Pissarides (2001)
ω	Workers' bargaining power	0.50	Laureys (2014a)
Ω	Size of transfers	0.50	Replacement rate 50%
ξ	Skill cost	0.50	$ \Delta u $ 90% quantile ²
κ	Vacancy cost	2.8	Mean unemployment rate
$\bar{\rho}_x$	Mean job separation rate	0.095	Mean short-term unemployment rate
σ_x	Separation rate sensitivity	8.8	Std. $u_{\text{long-term}}/u$
ρ	Productivity	0.85	Autocorrelation of real GDP
σ_ϵ	Standard deviation of ϵ	0.0115	Standard deviation of real GDP

¹ $|\Delta s| = |s - s_{-1}|$ denotes the absolute change in the bond spread.

² $|\Delta u| = |u' - u|$ denotes the absolute change in the unemployment rate.

consumption.¹⁴ I follow Bianchi et al. (2018) and assume the utility cost¹⁵ to be specified by

$$\chi(z) = \max\{0, \Lambda_0 + \Lambda_1 \log(z)\}.$$

The slope Λ_0 is set to match the mean spread. In the data, the spreads are close to zero for a large share of periods and exhibit spikes after sequences of increasing default risk. In the model, spreads are permanently substantially larger than zero because the government has a low discount factor and chooses large debt levels. Thus, the spikes cannot be reproduced without triggering debt renegotiations and the spreads are less volatile. Given that the model is not able to replicate the volatility of the spread observed for Portugal, the intercept Λ_1 targets the 90%-quantile of the absolute change of the spread $|\Delta s| = |s - s_{-1}|$. With respect to the short length of the time series, I choose the 90%-quantile to ensure that the calibration does not target potential outliers. Portugal has not renegotiated its debt obligations over the past 100 years. I set the bargaining power of the borrower in debt renegotiations θ to match the market value of outstanding debt during debt renegotiations of 23%. This value corresponds to Greece in 2012 (Zettelmeyer et al., 2013), which has been the only case of a default on external debt during the European sovereign debt crisis. The analysis of Section 4.2.6 includes the results for alternative values of the bargaining power. The

¹⁴For the time period from 1995 to 2017, this ratio has a standard deviation of 0.90% and fluctuates between 30.59% and 33.65%.

¹⁵In Bianchi et al. (2018) the cost depends on the realization of an endowment. I slightly deviate from this specification in considering a production economy such that the utility cost depends on productivity.

discount factor β is set to match the average external debt-to-GDP ratio of 50.18%. The value of the maturing probability δ corresponds to an average residual maturity of 6.3 years.¹⁶ The upper limit on the renegotiation probability of new debt issuance ϕ is set to 75%. The numerical results are robust for values between 60% and 99%.

The matching function elasticity is set to α to 0.5, which is in the range of estimates reported by Petrongolo and Pissarides (2001).¹⁷ I follow standard practices and set the bargaining power of workers ω to the same value, which ensures that the congestion externality, which follows from the search frictions, is internalized when all job seekers find a match with the same probability (Laureys, 2014b). The Portuguese unemployment insurance system features a gross replacement rate of 65% and a net replacement rate of more than 90% (Esser et al., 2013). However, for 2011, Matsaganis et al. (2014) report shares of benefit recipients of only 37.4% on workers that are unemployed for 3 to 5 months as well as 42.9% and 23.2% for those with an unemployment duration of 6 to 11 months and more than 11 months, respectively. To take account of these factors, I set the size of transfers in terms of wages Ω to 0.5 and provide a robustness analysis on this parameter in section 4.2.7. The vacancy cost κ is set to match the empirical mean unemployment rate. The empirical target for the skill cost parameter ζ is the 90%-quantile of the absolute change in the unemployment rate $|\Delta u| = |u' - u|$.

4.2 Quantitative Results

4.2.1 Policy Functions

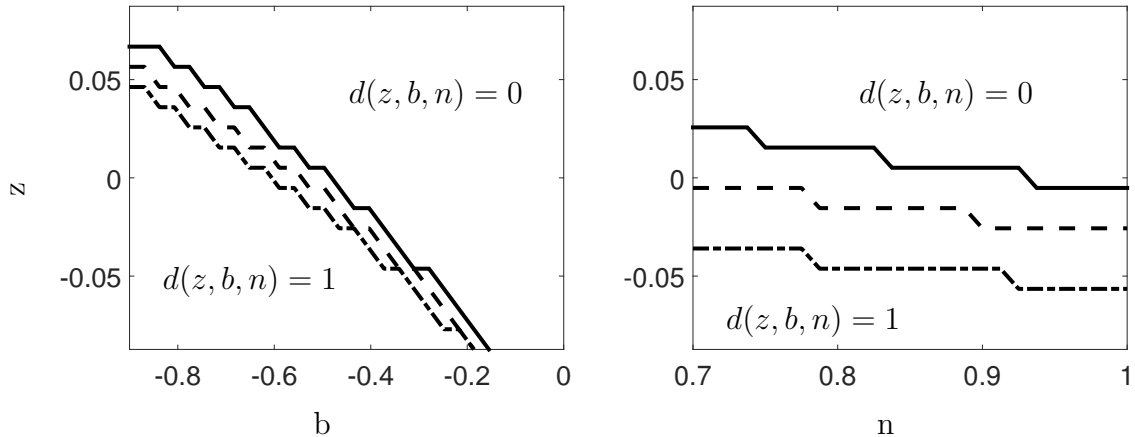
I first consider the optimal decision on entering debt renegotiations. The left panel of Figure 3 presents the combinations of productivity shocks z and debt levels b for which the government enters debt renegotiations. The solid line refers to an employment level n of 80%. The dashed (dashed-dotted) line shows the combinations for an employment level of 90% (100%). The right panel presents the optimal decision for combinations of productivity shocks z and employment n . The solid, dashed and dashed-dotted lines represent the choice for a high (-0.53), medium (-0.40), and low debt level (-0.28). In the areas to the left of the lines, the government enters debt renegotiations. Repayment is optimal for states to the right of the lines. The panels reveal that renegotiations are optimal when the realization of the productivity shock is low, debt is high, and employment is low.

Figure 4 presents the borrowing decisions, the bond price functions, the recovery rates, the tax policies, the employment decisions, and endogenous productivity for employment levels of 90% (solid lines) and 80% (dashed lines) as functions of the debt level. Endogenous productivity refers to the share of employed workers who are high-skilled. The first and third (second and fourth)

¹⁶This value is based on monthly data from the Portuguese national statistics office for the time span from December 2000 to December 2017.

¹⁷This value ensures that there are no multiple steady states, see e.g. Pissarides (1992). Sterk (2016) studies multiple steady states using a calibration with $\alpha > 0.5$.

Figure 3: Renegotiation Decision



Notes: The left (right) panel shows the combinations for the productivity shock z and debt b (employment n) for which the government just prefers to enter debt renegotiations. Right of the lines, the government prefers to serve its debt obligations. The lines in the left panel refer to an initial employment level of 80% (solid), 90% (dashed), and 100% (dashed-dotted). The lines in the right panel refer to initial debt of -0.56 (solid), -0.43 (dashed), and -0.31 (dashed-dotted).

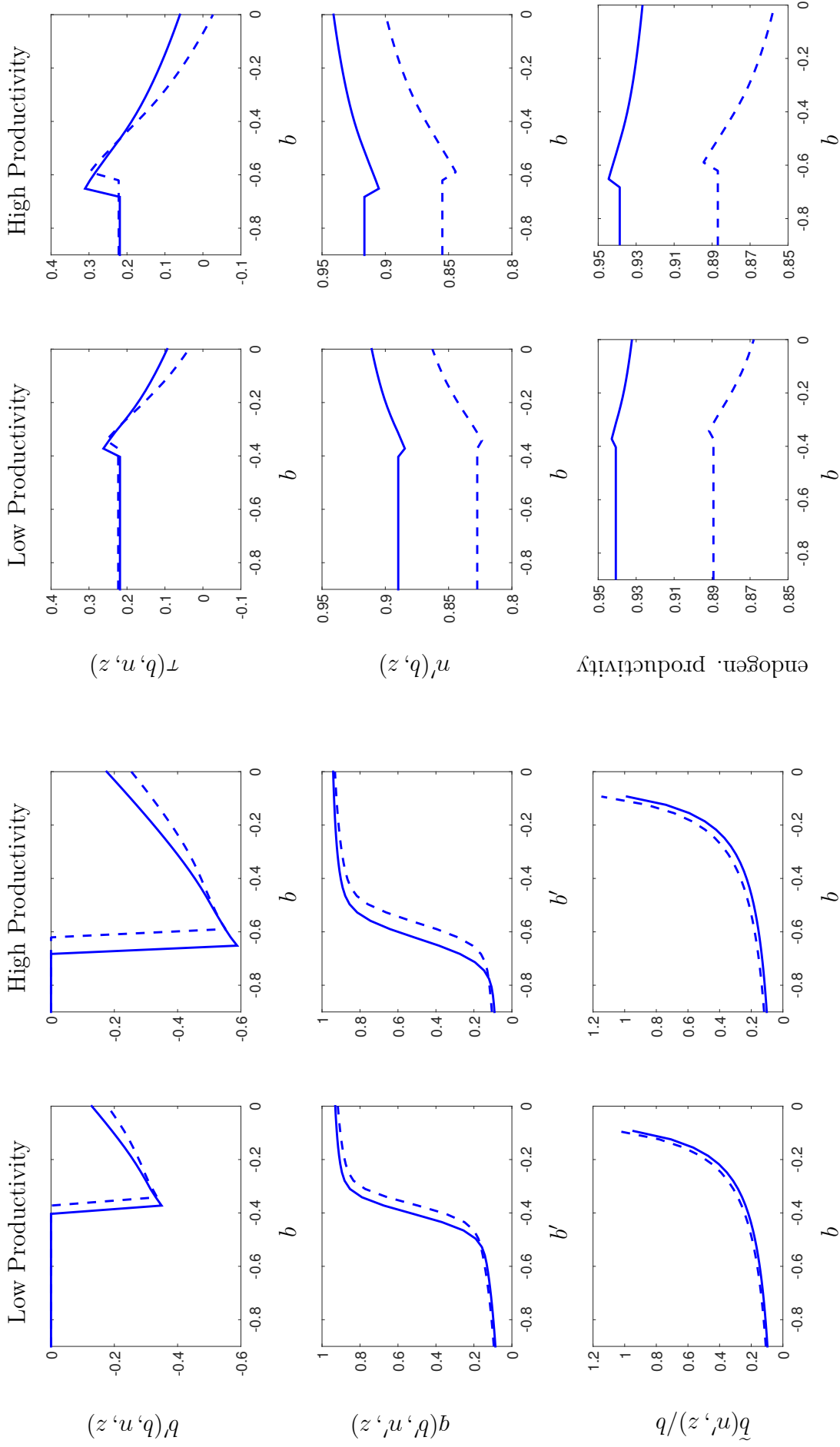
column refer to productivity realizations 2.6% below (above) the trend. The panels reveal that the bond price is decreasing in the debt level and increasing in exogenous productivity z . For small debt levels, the government never finds it optimal to enter renegotiations such that the bond price converges towards the risk-free bond price. With increasing debt, the government has more incentives to dilute debt in the future and the probability of debt renegotiations increases. For high debt levels, the government always enters renegotiations and the bond price equals the expected bond price on the bargained debt level weighted with the debt recovery rate. Since the outcome of bargaining \tilde{b} is independent from the initial debt level b by assumption, the recovery rate $\frac{\tilde{b}}{b}$ decreases in the debt level.¹⁸

For a lower level of employment, the government faces lower bond prices. Lower employment implies a smaller tax base, higher expenditures for unemployment transfers, and a lower expected skill level of new hires such that the government is less reluctant to enter debt renegotiations. The recovery rates are marginally increasing with higher unemployment. The underlying reason is the increased benefit from access to financial markets in form of the ability to set lower tax rates and thus to improve hiring incentives.

The third and fourth column of Figure 4 present the tax policies, the employment decisions, and endogenous productivity. With increasing debt, the government has to impose higher sales taxes to pay the interest rates on its debt obligations. The higher tax rates reduce the firms' benefit from hiring and the employment level decreases. Lower hiring implies a lower inflow of

¹⁸While the assumption of independence of initial debt is common to models with one-round bargaining, Cruces and Trebesch (2013) find that a higher debt-to-GDP ratio may imply longer durations of renegotiations. Benjamin and Wright (2013) provide evidence on the relation between renegotiation outcome and duration.

Figure 4: Policy Functions - Fixed Initial Employment Level

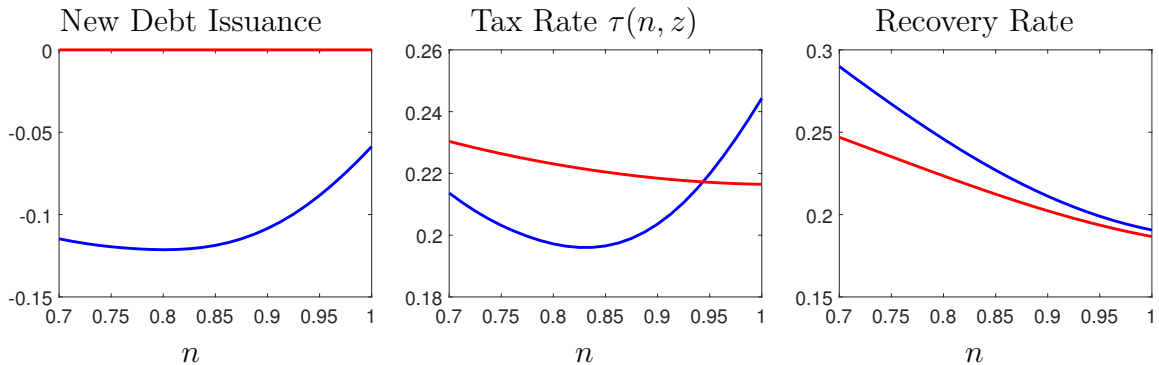


Notes: The solid (dashed) lines represent the debt policies $q'(b, n, z)$, the bond prices $q(b', n', z)$, the recovery rates $\tilde{b}(n', z)/b$, the tax policies $\tau(b, n, z)$, and the employment policies $n'(b, n, z)$ at different debt levels b for an employment level n of 90% (80%). Endogenous productivity denotes the share of employed workers who are high-skilled. In the first and third column, productivity is 2.6% below the trend. High productivity refers to a level 2.6% above the trend.

low-skilled workers such that the share of employed workers who are high-skilled increases. The employment level is increasing in initial employment and exogenous productivity z . The net change in employment decreases in the initial employment level because of increasing hiring costs per worker. Endogenous productivity is higher for low productivity shocks because lower hiring reduces the inflow of low-skilled workers and higher job separation rates increase the share of high-skilled job seekers and thus the share of high-skilled new hires.

When debt is low, the tax rate is increasing in the employment level. There are two underlying channels. First, higher taxes have a negative effect on the firms' hiring incentives. As a reduction in unemployment implies higher production and a higher skill level of newly hired workers in the future, the government has an incentive to set lower tax rates when unemployment is high. The government can reduce the taxes and improve hiring incentives by higher debt issuance. Second, when employment is low, firms have higher expenditures for vacancy posting. It follows that firm profits drop and private consumption declines overproportionally compared to the change in firms' output. Thus, the government needs a smaller share of total production to finance the public good which is proportional in size to private consumption.¹⁹ The reduction in public consumption dominates increasing transfer payments. When debt is high, the government is more borrowing constrained such that the tax rate increases with higher unemployment rates. Additionally, higher debt service in the presence of lower employment necessitates a larger increase in sales taxes. It follows that high debt has a quantitatively smaller negative effect on the employment level when initial employment is high.

Figure 5: Policy Functions - Fixed Initial Debt Level



Notes: The graphs show the amount of new debt issuance, the tax policies, and the recovery rates at different employment levels n for a debt level of -0.43 , which is close to the mean in simulations. Blue (red) lines refer to exogenous productivity 2.6% above (below) the trend. New debt issuance is defined as $b' - (1 - \delta)b$ in repayment and 0 if the government enters debt renegotiations.

Figure 5 shows the amount of new debt issuance, the tax policies, and the recovery rate at different employment levels n for a debt level of -0.43 , which is close to the mean in the simulations of Section 4.2.2. New debt issuance is given by $b' - (1 - \delta)b$ if the government repays its debt

¹⁹Assuming a constant government spending would extinguish this channel. However, tax rates would have to strongly increase in unemployment.

and equals zero if the government enters debt renegotiations. Blue and red lines refer to exogenous productivity 2.6% above and below the trend, respectively. The government enters debt renegotiations when exogenous productivity is low and repays its debt obligation when exogenous productivity is high (c.p. the dashed line in the right panel of Figure 3). During renegotiations, the government is excluded from international financial markets and has to impose higher tax rates at lower employment levels to finance rising unemployment benefits. When productivity is high, borrowing and tax rates are u-shaped in initial employment. At high employment levels, the government can react to an increase in unemployment with extended borrowing and tax cuts to increase the firms' benefits from additional hiring. When employment is low, the government has to make higher total unemployment transfer payments and is more budget constrained such that it issues less new debt and has to set higher tax rates. Tax rates for high exogenous productivity exceed tax rates for low exogenous productivity at high employment levels because new debt issuance is lower than the amount of matured debt, which is about -0.07 . High productivity also implies less job separation such that the hiring costs per worker are higher and firms post less vacancies. Firm profits are higher because of lower vacancy costs and private consumption increases. It follows that the share of total resources allocated to the proportional amount of public spending increases.

The increase of the recovery rate in unemployment is smaller when exogenous productivity is low. Since exogenous shocks are persistent and job separation is high, a large share of hiring is lost when productivity is low in the periods following a haircut. Thus, the employment increase after a haircut is short-lived which reduces the impact of initial employment on the recovery rate.

4.2.2 Cyclical Properties

In this section, I compare the cyclical properties of the Portuguese economy with the statistics from simulations of the model. The first column of Table 2 summarizes the statistics from the Portuguese data. I consider log-quadratically detrended series for the time period from 1995 to 2017. In column (2), I report the cyclical properties of the model simulations for the benchmark calibration. Out of a simulation of 500 000 years where the first 100 observations are discarded, I consider episodes of at least 23 periods without renegotiations, preceded by at least four periods of good credit standing.

Overall, the model describes the properties of the Portuguese economy well. In line with the sovereign debt literature, e.g. Arellano (2008) and Cuadra et al. (2010), private consumption is more volatile than output, sovereign bond yields are countercyclical and fiscal policy is procyclical, in particular tax rates and output are negatively correlated. The behavior of fiscal policy corresponds to Vegh and Vuletin (2015) who find that Portugal belongs to the industrial countries with the most procyclical fiscal policy and is similar to emerging economies in terms of tax policy cyclicity. The mean and the 90%-quantile of absolute changes of the spread are close to the data. The model, however, does not match the distribution of spreads, especially the large number of

spreads close to zero, such that the volatility is too low.²⁰

Targeted statistics on the labor market are well matched, but the volatility of unemployment is too low. In line with the data, the model produces a larger autocorrelation for unemployment than for output.

4.2.3 The Dynamics of Unemployment and Sovereign Debt Renegotiations

In this section, I employ an event analysis to study the dynamics of unemployment and sovereign debt renegotiations. Out of the model simulations of 500 000 years, I consider episodes in which the government enters debt renegotiations at $t = 0$. Similar to the procedure for the simulation statistics, I restrict to renegotiations which have been preceded by at least 27 periods of good credit standing. Figure 6 shows the dynamics around renegotiations at $t = 0$, denoted by the grey bars. Productivity, output, and private consumptions are presented as percentage deviations from a log-linear trend, which I apply to the complete series.²¹ The tax rate, initial debt-to-GDP, unemployment, the sovereign spread and the probability of renegotiations are denoted in percent. Endogenous productivity is the percentage share of high-skilled employed workers. The panels show the variables 4 years before and 12 years after the event at $t = 0$. The solid lines refer to the benchmark model.

Renegotiations are preceded by a drop in exogenous productivity and output as well as periods of increasing unemployment and high debt-to-GDP ratios. Simultaneously, the tax rates and the spread increase, reflecting an increased probability of debt renegotiations. While higher tax rates dampen hiring, firms still post more vacancies because of increased returns following from the increase in the number of job seekers in response to higher separation rates. The inflow of low-skilled workers prevents an increase in the share of high-skilled unemployed workers. In the period of renegotiations, the government can reduce the tax rates since it does not serve the coupon payments and the maturing debt. There is a haircut such that the debt-to-GDP ratio drops. In the year after the haircut, the government reenters international financial markets and uses new borrowing for tax cuts. The lower tax burden and increasing productivity improve the firms' hiring incentives such that the unemployment rate declines. Since unemployment is high in the previous period, the productivity of job seekers is low such that increased hiring is followed by a decline in endogenous productivity. The drop in unemployment is in line with the findings of Levy Yeyati and Panizza (2011) for sovereign defaults in emerging economies. In response to increasing output, private consumption peaks.

The decrease in the tax rate, however, is short-lived. Since the debt level rises again, the government has to increase taxes. As productivity has not yet fully recovered, the separation rate is

²⁰Bocola et al. (2019) are able to generate higher shares of spreads close to zero by the introduction of domestic government debt.

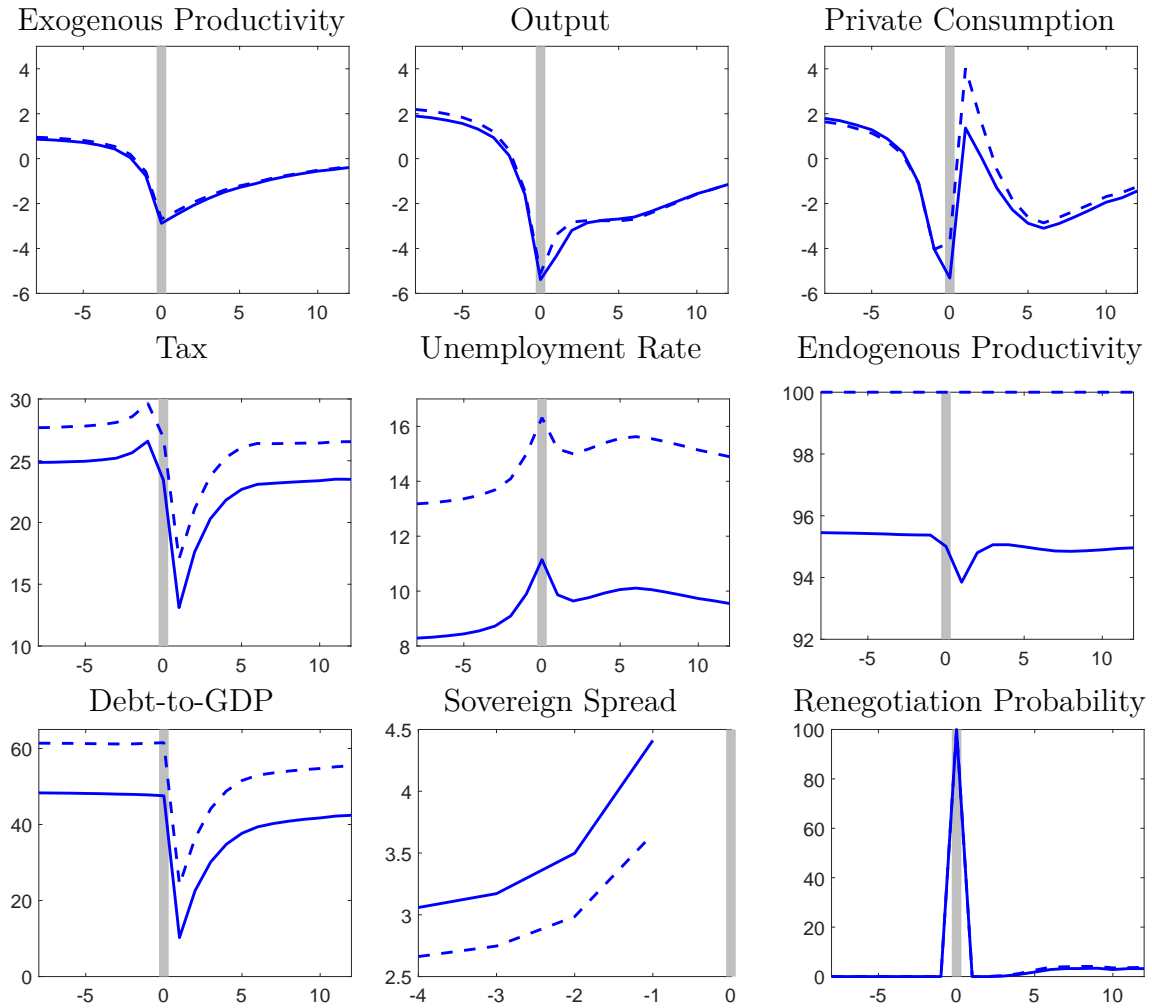
²¹I deviate from the procedure for the business cycle statistics because, for the complete series, the system is underdetermined in case of log-quadratic detrending. I use the complete series instead of short episodes to abstract from distortions on detrending around renegotiation episodes.

Table 2: Business Cycle Statistics

	Data	Model Simulations						
	(1)	(2) Benchmark	(3) $\xi = 0$	(4) $\xi = 0.25$	(5) $\xi = 0.75$	(6) $\theta = 0$	(7) $\theta = 0.5$	(8) $\theta = 1$
$\sigma(y)$	2.81	2.97	3.11	2.95	2.89	2.77	2.98	3.03
$\sigma(c)/\sigma(y)$	1.11	1.57	1.49	1.58	1.66	1.70	1.57	1.56
$\sigma(s)$	2.62	1.16	0.90	1.03	1.25	0.94	1.28	1.46
$\sigma(u)$	3.71	1.83	2.24	1.94	1.60	1.63	1.83	1.85
$\rho(c, y)$	0.95	0.97	0.96	0.97	0.97	0.97	0.97	0.97
$\rho(\tau, y)$	—	-0.39	-0.54	-0.46	-0.32	-0.40	-0.39	-0.38
$\rho(s, y)$	-0.52	-0.66	-0.69	-0.69	-0.65	-0.68	-0.65	-0.64
$\rho(y, y')$	0.71	0.73	0.68	0.71	0.75	0.71	0.73	0.74
$\rho(u, u')$	0.93	0.85	0.87	0.86	0.85	0.84	0.86	0.86
$E(s)$	2.55	2.93	2.57	2.76	3.00	2.45	3.13	3.48
$E(b'/y)$	50.18	47.14	60.38	54.24	43.73	59.10	43.96	38.46
$ \Delta s $ 90% quantile	2.69	2.06	1.60	1.84	2.20	1.64	2.28	2.62
$E(u)$	8.67	8.63	13.61	10.11	6.68	7.81	8.62	8.60
$E(u_{\text{short-term}})$	4.34	4.26	5.05	4.56	3.74	3.75	4.25	4.25
$E(u_{\text{long-term}})$	4.33	4.37	8.56	5.54	2.94	4.06	4.36	4.35
$\sigma(u_{\text{long-term}}/u)$	6.86	6.76	5.48	6.28	7.17	6.59	6.78	6.85
$ \Delta u $ 90% quantile	1.54	1.48	1.70	1.55	1.32	1.37	1.48	1.48
Market value of reneg. debt	23.1	21.25	38.63	28.80	16.95	36.35	14.45	0
Reneg. Prob.	—	3.05	3.54	3.21	2.94	3.26	2.96	2.76
Welfare equivalent (in %)	—	0.65	—	—	—	4.48	0.40	—

Notes: Column (1) is based on annual Eurostat data for Portugal and considers the time period from 1995 to 2017. y and c denote real output and real private consumption, respectively. y and c are log-quadratically detrended. s denotes the sovereign spread, calculated as the difference between the interest rates on Portuguese and German 10-year bonds. u refers to the unemployment rate. Shares and probabilities are given in %. Column (2) and (3) are based on simulations of 500 000 years, where I omit the first 100 observations. I refer to episodes of at least 23 years without renegotiations, which are preceded by at least 4 years without renegotiations. Column (2) reports the statistics for the benchmark model, columns (3) to (5) and (6) to (8) consider variations of the skill loss parameter ξ and the bargaining power θ , respectively. Renegotiation probabilities and welfare equivalents refer to the complete series of 499 900 years.

Figure 6: Event Analysis



Notes: The solid (dashed) lines present the statistics for episodes out of a model simulation of 500 000 years of the benchmark model (the model without skill loss), where the first 100 are omitted. I consider sovereign debt renegotiations which have been preceded by at least 27 years of repayment. The grey bars represent the event period. Productivity, output and private consumption are shown as percentage deviations from a log-linear trend. The tax rate, debt to GDP, unemployment, the sovereign spread and the probability of renegotiations are denoted in percent. Endogenous productivity denotes the percentage share of high-skilled employed workers. The panels show the variables 4 years before and 12 years after the event at $t = 0$.

still high. High separation rates and increasing taxes have a negative effect on hiring incentives such that the unemployment rate increases again in the medium run. Private consumption drops. In the long run, on average, productivity returns to the trend. Since the separation rate becomes lower, the unemployment rate falls and converges to its pre-crisis level. In a minor share of episodes, starting in the third period after the renegotiations, the government chooses to bargain on the remaining debt again.

4.2.4 The Impact of the Human Capital Depreciation

The intensity of human capital depreciation determines the level of employment and the response of fiscal policy on cyclical fluctuations. The degree of skill loss is implied by the difference in skills between high-skilled and low-skilled workers. Figure 7 shows the policy functions for two different values of the skill loss parameter ζ , given an employment level of 90%. The solid lines refer to the benchmark model with $\xi = 0.5$. The dashed lines present policy functions for the benchmark model without skill depreciation $\xi = 0$. When human capital depreciates during unemployment spells, the share of low-skilled workers is higher and, for identical initial states, the economy has less resources to serve its debt obligations. The benefits from entering debt renegotiations and avoiding higher tax rates to prevent higher employment losses are larger because the loss of productivity in the following periods can be avoided. Thus, the government is less reluctant to enter debt renegotiations and faces lower bond prices. Since lower bond prices imply a lower debt market value at any given debt level, the debt level after renegotiations is reduced and the debt recovery rate is lower.

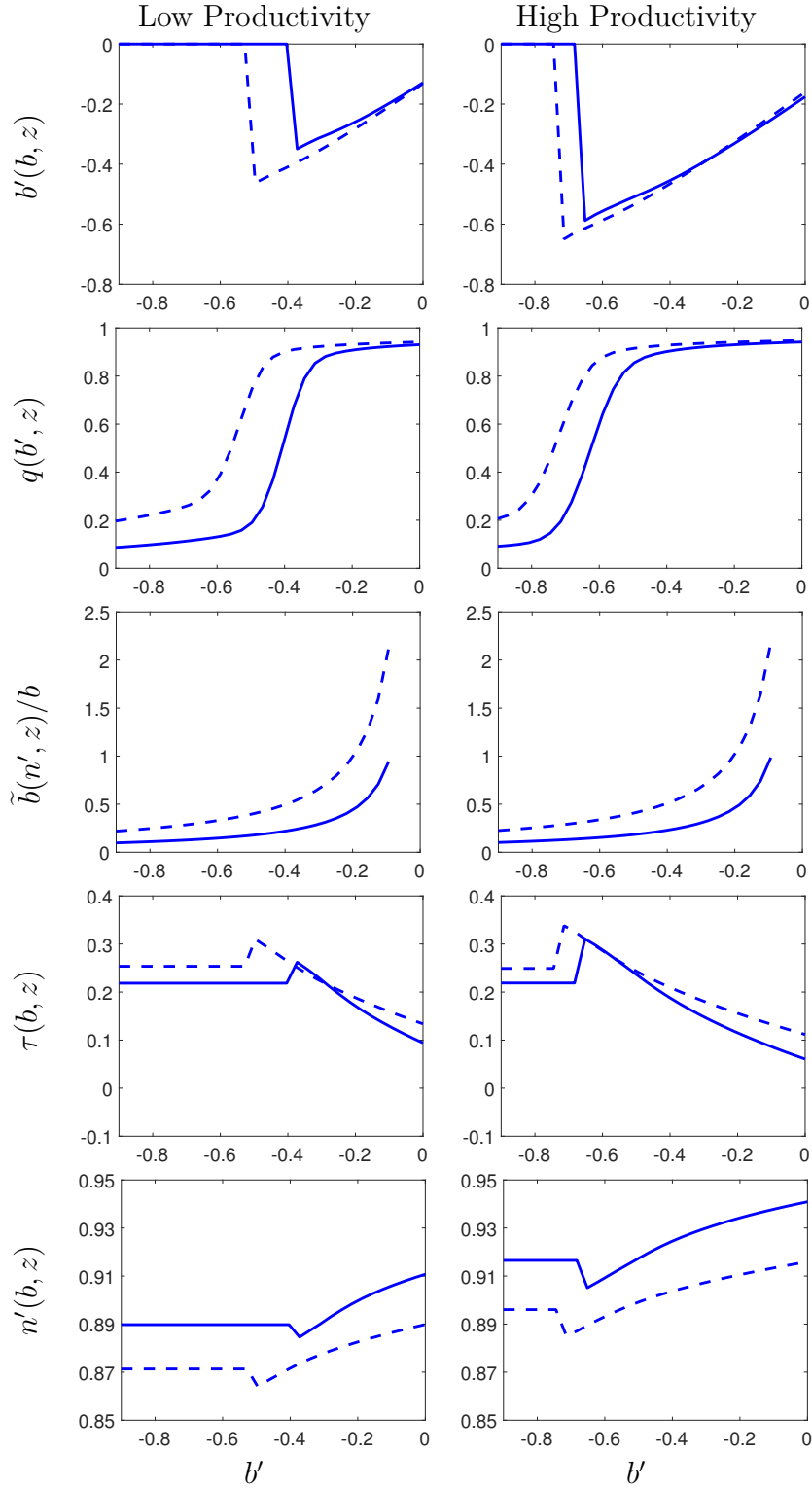
The firms' decision on employment is affected by two opposing forces. First, as skill loss occurs, the productivity of newly hired workers is lower which reduces the benefits from hiring. On the other hand, there are incentives for hiring to prevent skill depreciation of newly displaced workers. The second effect dominates such that firms increase their vacancy posting expenditures and the employment level is higher for any considered initial state of the economy. Note that this finding is in line with Laureys (2014b).

In the economy with skill loss, the tax rate is lower when bond prices are high and the government is not budget-constrained. Lower tax rates increase the firms' benefits from hiring and thus support higher employment levels. However, taxes are also lower during debt renegotiations when taxes cannot be reduced by debt issuance because higher employment levels imply lower expenditures on unemployment transfers. Additionally, since firms have higher expenditures on vacancy posting, firm profits are lower and the households have less resources to spend on private consumption. Due to the assumption of a constant ratio of public to private consumption, it follows that public consumption is also reduced and the government needs less income from sales taxes.²²

The statistics in columns (3) to (5) of Table 2 confirm the reduction of unemployment and long-term unemployment in equilibrium. The volatility of unemployment decreases as both firms and the government provide more resources to keep employment at a high level. Instead of entering debt renegotiations more often, the government, from an ex ante perspective, issues less debt and enters debt renegotiations less frequently when human capital depreciation is larger. By choosing lower debt levels, the government avoids higher interest spreads and reduces the likelihood of larger tax increases in case of bad realizations of the exogenous productivity shock. It follows that the

²²The tax rate would increase when public consumption is instead assumed to be constant because the tax base is reduced when human capital depreciation is larger.

Figure 7: Policy Functions - Skill Loss Variation



Notes: The solid (dashed) lines represent the debt policies, the bond prices, the recovery rates, the tax policies and the employment policies at different debt levels b for the benchmark model with $\xi = 0.5$ (the model without skill loss $\xi = 0$), given an employment level of 90%. In the left column, productivity is 2.6% below the trend. High productivity refers to levels 2.6% above the trend.

tax rates become less procyclical in the intensity of the skill loss, i.e. the negative correlation between output and tax rates declines. Cyclical fluctuations in the size of total transfer payments to unemployed workers, which also depends on the degree of skill loss, may be an important driver of fiscal policy cyclicity. In Section 4.2.7, I provide a robustness analysis on the size of transfers Ω . Despite lower debt-to-GDP ratios, the market value of renegotiated debt is lower with increasing skill loss because of decreased recovery rates and lower bond prices.

The dashed lines in Figure 6 show the dynamics around renegotiations for the model without human capital depreciation. Qualitatively the patterns do not deviate from the benchmark model except for private consumption in the year of renegotiations. While private consumption declines at $t = 0$ in the benchmark, there is a small increase in the case without skill loss. In the absence of human capital depreciation, firms are more reluctant to post vacancies if separation rates are high because of the high risk of separation of new hires in the next period, the low exogenous productivity realization, and the lack of impact on future endogenous productivity. Unemployment exhibits a stronger increase despite higher vacancy yields. Due to lower vacancy expenditures, firm profits increase and there are more resources for private consumption. Since the employment enhancing effects are reduced, the government uses less of its fiscal capacities immediately after renegotiations such that the return of the debt-to-GDP ratio to a higher level and the reduction in the unemployment rate occur at a slower speed. Since the government faces a lower debt-to-GDP ratio and thus a smaller debt service ratio in the model with skill loss, it can serve a stronger spread increase before renegotiations.

4.2.5 Case Study: Portugal 1996 - 2017

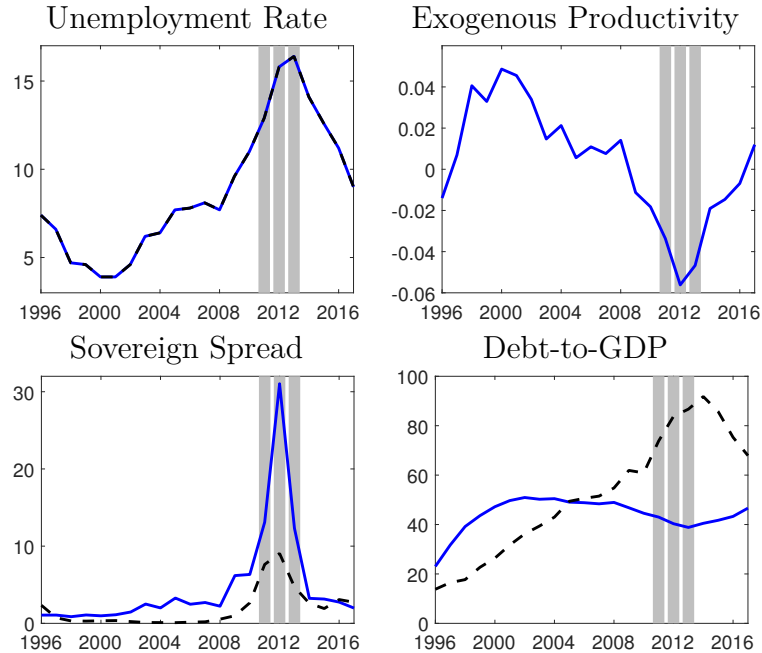
To evaluate the model predictions for Portugal, I employ the following experiment. I take the Portuguese unemployment rate in 1995 and assume that all workers are high-skilled in 1995. I calculate a value for debt based on the debt-to-GDP ratio in 1995 and define productivity to be on the trend in the initial period. Then, I run a simulation series of 22 years, for which I choose realizations of productivity z such that the unemployment rate of Portugal from 1996 to 2017 is matched. To ensure that the simulation series corresponds to the observed time period and does not contain debt renegotiation episodes, I extend the utility cost function of debt renegotiations by an exogenous stochastic component ϵ_χ as in Roch and Uhlig (2018). The shock to the utility cost can be interpreted as a change in political factors affecting the willingness to repay, e.g. third party interventions. The new specification of the utility cost function is given by

$$\chi(z) = \max\{0, \Lambda_0 + \Lambda_1 \log(z)\} + \epsilon_\chi.$$

Following Roch and Uhlig (2018), the stochastic component can take two values $\epsilon_\chi \in \{\epsilon_\chi^L, \epsilon_\chi^H\}$. I set the low realization ϵ_χ^L to 0 and the high realization ϵ_χ^H to a value which is large enough such that repayment is always optimal when the stochastic cost is high. I further assume that ϵ_χ takes the low value with a probability very close to 1 and the high value with a probability very close

to 0. The choice of the probabilities ensures that the model with the cost shock is approximately equivalent to the benchmark model. For the experiment on Portugal, I assume that the stochastic cost is high in all episodes.

Figure 8: Model Prediction for Portugal without Renegotiations

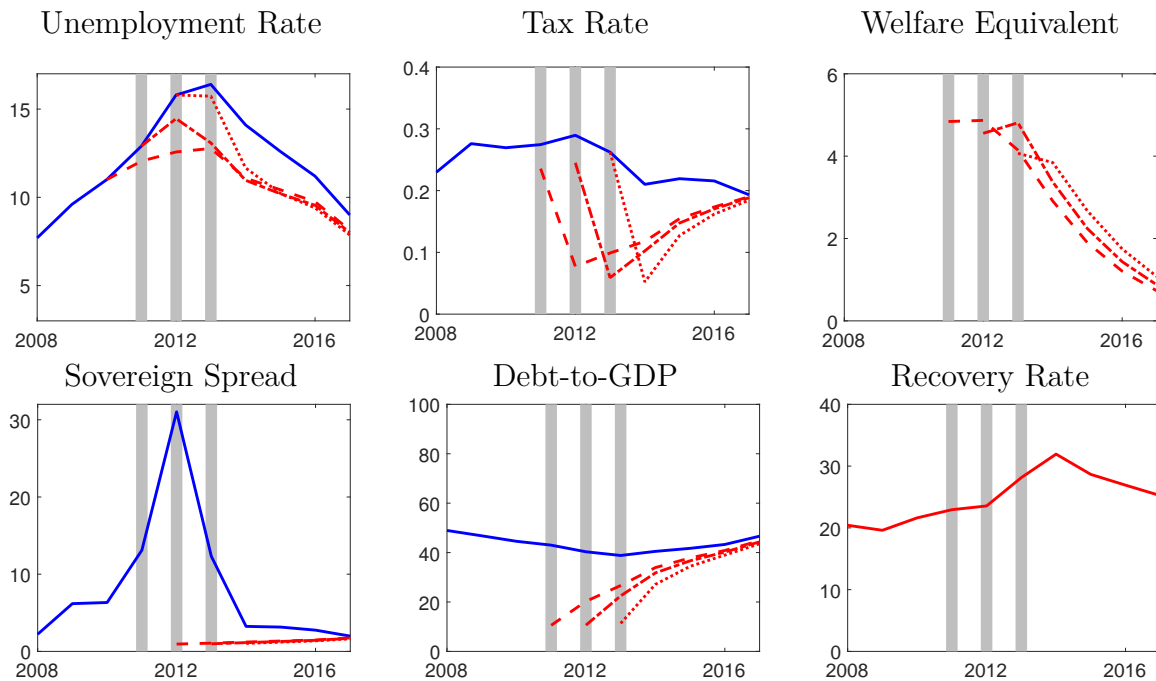


Notes: As initial situation, the figure considers the unemployment rate of Portugal in 1995, a productivity realization on the trend, and the debt to GDP ratio of Portugal in 1995 under the assumption that all workers are high-skilled. In all periods, the shock component of the utility costs is equal to the high value ϵ_x^H such that the government always repays its debt. For the time period from 1996 to 2017, a series of productivity realizations is generated such that the model produces the respective unemployment rates of Portugal. Unemployment rate, sovereign spread and debt-to-GDP are in percentage values, exogenous productivity denotes the log realization of the productivity shock z . Blue solid lines refer to the model outcome, black dashed lines to the Portuguese data.

Figure 8 shows the unemployment rate, the productivity realization, the spread and the debt-to-GDP ratio, where the blue solid and black dashed lines refer to the model outcome and the data series, respectively. The model matches the movements of the Portuguese spread, but overestimates the increase in the interest rates on Portuguese bonds especially in 2012. The model cannot reproduce the increase in debt-to-GDP after 2008. For a low realization of the utility cost shock ϵ_x , the model predicts renegotiations in 2011, 2012, and 2013, denoted by the grey bars. I assume for the renegotiations in the years 2012 and 2013 that the utility cost shock has been high in the previous years. The first predicted renegotiations in 2011 coincide with the year of the agreement on a 3-year economic adjustment program, which provided the Portuguese government with generous credits from the European Financial Stabilisation Mechanism, the European Financial Stability Facility, and the International Monetary Fund. While the model abstracts from the effect of bailouts, e.g. Fink and Scholl (2016) find that official financial assistance can help to prevent sovereign defaults in the short run. Bailouts provide the government with new liquidity

and reduce the risk premia such that the government can increase its indebtedness at lower interest rates. Thus, the absence of financial assistance can explain differences in the spread and the debt-to-GDP ratio between the data and the model during the crisis.

Figure 9: Model Prediction for Portugal - Renegotiation Counterfactuals



Notes: The blue lines represent the model outcome for the years 2008 to 2017 for a model simulation where the exogenous productivity realizations are set to match the Portuguese unemployment rate. The full series starts in 1996 and takes the unemployment rate of Portugal in 1995, productivity on the trend, and the debt to GDP ratio of Portugal in 1995 under the assumption that all workers are high-skilled as initial situation. The dashed, dashed-dotted, and dotted red lines represent the model outcome when the government chooses to enter debt renegotiations in the years 2011, 2012, and 2013, respectively. Welfare equivalent denotes the welfare improvement from moving from the economy without renegotiations to the counterfactual economy with debt relief in terms of the equivalent variation in consumption. Recovery rate refers to the percentage of debt remaining in case the government enters debt renegotiations.

Figure 9 shows the model outcome for the case that Portugal would have entered debt renegotiations in 2011 (red dashed), 2012 (red dashed-dotted), or 2013 (red dotted). Entry in debt renegotiations in 2011, 2012, and 2013 is accompanied by an immediate reduction of unemployment of 0.85, 1.34, and 0.67 percentage points, respectively. In the year after renegotiations, the government uses the low debt-to-GDP ratio at market reentry to issue new debt and set lower tax rates. The lower tax rates improve the firms' hiring incentives and unemployment is lowered by up to 3.63, 3.32, and 2.43 percentage points in the aftermath. In the following years, however, the government becomes more budget constrained because of increasing debt, faces higher spreads, and has to increase taxes. Spread, debt, and tax level converge to the level observed without renegotiations in 2017. However, in 2017, unemployment is still 0.86 (2011), 0.99 (2012), and 1.13 (2013) percentage points lower than in the case without renegotiations. The unemployment rate is lowest in 2017 if the government renegotiates in 2013 because of the timing of expansionary

fiscal policy and the realization of bad productivity shocks and high separation rates. Since the government tends to use the new fiscal space after renegotiations directly to decrease tax rates, high separation rates in the following periods reduce the positive effect from renegotiations on employment.

The right panel in the second column shows for each year the recovery rate if the economy enters debt renegotiations. For the years 2011 to 2013, the haircuts are decreasing over time with recovery rates of 23%, 23.5%, and 28.1%, respectively. The decline follows from the reduced renegotiated debt stock. Despite the reduction of GDP in 2012 and 2013 following from increased unemployment and low productivity realizations, the debt-to-GDP ratio decreases after 2011 because matured debt is not completely replaced by new debt issuance. At the same time, the debt level after renegotiations, which is independent from the renegotiated debt stock, is lowest (-0.083) in 2012 which is the year of the weakest productivity realization. The debt level for renegotiations in 2013 (-0.088) is marginally higher than the one for 2011 (-0.087) despite the worse productivity shock. The policy functions in Section 4.2.1 show that the unemployment rate, which peaks in 2013, has a negative impact on the recovery such that higher unemployment implies a higher debt level after renegotiations.

To evaluate the welfare effects of debt renegotiations, I compute the equivalent variation in consumption Λ . The use of GHH-preferences allows me to follow Durdu et al. (2013) and to calculate the welfare gain of moving from an economy with a high realization of the utility cost shock ϵ_χ to the counterfactual economies in which the government enters debt renegotiations:

$$E_0 \sum_{t=0}^{\infty} \beta^t u((1 + \Lambda) c_t(\circ)) = E_0 \sum_{t=0}^{\infty} \beta^t u(c_t(*)).$$

‘ \circ ’ refers to the model with high realizations of the utility cost shock ϵ_χ , and ‘ $*$ ’ denotes the counterfactual model in which the government enters debt renegotiations. The equivalent variation follows from this equation as

$$\Lambda = \left(\frac{V^0(*)}{V^0(\circ)} \right)^{\frac{1}{1-\sigma}} - 1,$$

where V^0 is the expected lifetime utility. For welfare calculations, I use the expected lifetime utility realized by the households, i.e. I abstract from the one-time utility cost which the policy maker suffers. Renegotiations in 2011 imply the largest immediate welfare gains of up to 4.84%. The welfare gain for renegotiations in 2012 and 2013 is 4.55% and 4.07%, respectively. The reduction in the immediate benefit of a debt relief results from both the larger percentage debt relief and the lower unemployment peak following early renegotiations. Since the debt-to-GDP ratio and the unemployment rate converge back to the levels in the model outcome without renegotiations, welfare gains of being in the counterfactual economy decline over time. However, in 2017, the welfare gain is still in the range from 0.73% to 1.07%.

4.2.6 The Size and Welfare Effects of Haircuts

The size of haircuts is controlled by the borrower's bargaining power θ . Columns (6) to (8) of Table 2 provide the statistics for variations of θ . For lower bargaining power, the average recovery rate increases such that the borrower receives a smaller debt relief, reflected in the increasing market value of renegotiated debt. As smaller haircuts reduce the incentives to enter debt renegotiations, the government serves its debt obligations at higher debt levels, becomes less budget constrained and accumulates more debt. For the chosen debt levels, the government faces higher bond prices where the increased market value of renegotiated debt dominates the negative effect of an increased probability of debt renegotiations. The maximum recovery rate in terms of the market value of renegotiated debt is 36.35%, which is below the average of 40.01% found by Cruces and Trebesch (2013). Their analysis, however, includes a large number of renegotiations of emerging economies which may feature substantially lower debt-to-GDP ratios.

The effect of the bargaining power on the long-term averages of employment-related variables is U-shaped. There are two opposing forces at work. On the one hand, since the debt level is higher in the long run, debt service and thus tax rates are higher with decreasing bargaining power. Increased tax rates reduce the firms' benefit from hiring such that employment marginally decreases. On the other hand, since recovery rates increase with declining bargaining power, bond prices increase and the government becomes less borrowing constrained. More fiscal space allows the government to reduce taxes and improve hiring incentives. While the first effect dominates for medium and large bargaining powers, the second effect becomes particular strong for very small values of the borrower's bargaining power.

The last row of Table 2 shows the percentage equivalent variation in consumption across the full simulation series from the perspective of the policymaker. Welfare is decreasing in the government's bargaining power. While a decreasing bargaining power implies smaller debt reductions after renegotiations, the government benefits from higher bond prices and access to larger amounts of debt. The benefit increases exponentially up to a maximum of 4.48%.

4.2.7 Robustness

In this section I study the impact of the size of transfers to unemployed workers paid the government Ω on the model dynamics. The first three columns of Table 3 present the statistics for variations of Ω given the benchmark choice of the skill loss parameter $\zeta = 0.5$.

The size of total transfer payments T is highly sensitive to changes in the unemployment rate and cyclical fluctuations. It follows that with increasing transfer size, government expenditures become more volatile and more negatively correlated with the realizations of the exogenous productivity shock. A stronger increase in total transfer payments during an economic downturn demands increasing sales tax rates such that the tax policy becomes more procyclical. External creditors incorporate an increased renegotiation probability at high debt levels such that the government

Table 3: Robustness Analysis: The Impact of Transfers

	$\zeta = 0.5$			$\zeta = 0$
	$\Omega = 0$	$\Omega = 0.25$	$\Omega = 0.75$	$\Omega = 0$
$\rho(\tau, y)$	-0.28	-0.34	-0.40	-0.38
$E(s)$	2.85	2.85	3.18	2.64
$E(b'/y)$	52.16	51.56	41.58	58.94
$E(u)$	9.42	8.88	4.67	12.91
Reneg. Prob.	3.26	3.18	2.58	3.44

Notes: All statistics are based on simulations of 500 000 years, where I omit the first 100 observations. I refer to episodes of at least 23 years without renegotiations, which are preceded by at least 4 years without renegotiations. The first three columns present variations of the size of transfers to unemployed workers Ω given a value for the skill loss parameter ζ of 0.5. The last column shows the statistics for the model without skill loss and without transfer payments. Renegotiation probabilities and welfare equivalents refer to the complete series of 499 900 years.

faces higher bond spreads and issues less debt.

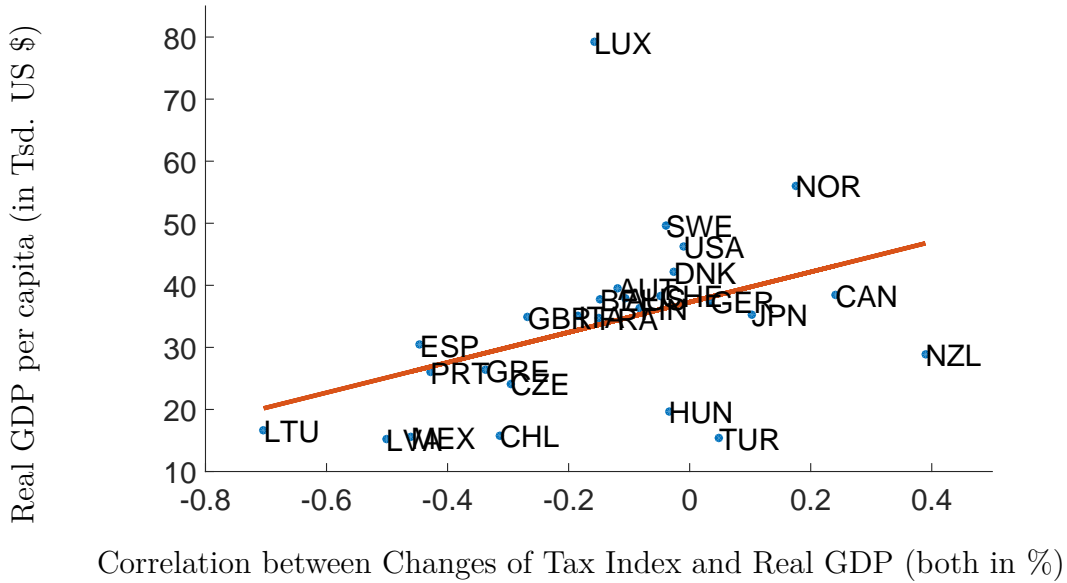
Column (4) of Table 3 displays the statistics for the model without skill loss and without transfers. The comparison with column (1) shows that two thirds of the reduction in tax cyclicity and half of the debt reduction observed for the benchmark model in Table 2 cannot be explained by cyclical fluctuations of transfer payments.

4.2.8 Discussion

In this section, I compare the main implications of the model to empirical observations. To control for more procyclical fiscal policy in the presence of lower skill loss during unemployment, I consider the relation between GDP per capita as a measure of human capital intensity and a measure of tax cyclicity. Figure 10 plots the correlation between percentage changes in real GDP and a tax index against the average GDP per capita between 1996 and 2013 for 27 OECD economies. Real GDP per capita data is from the OECD. The tax index information is taken from Vegh and Vuletin (2015) and includes changes in corporate, personal, and value-added tax rates.

In line with the model outcome, countries with higher GDP per capita follow a less procyclical fiscal policy. While developed economies tend to have an acyclical or procyclical tax policy, fiscal policy in Spain, Portugal and Greece is particularly procyclical while both countries also feature lower GDP per capita. The two latter economies, however, feature exceptionally high debt to GDP ratios, where the model would ex ante predict lower debt levels. An explanation may be that the model abstracts from several features which determine the sovereign's ability to issue debt. The literature has studied numerous aspects including political stability (Cuadra et al., 2010), the availability of bailout credits (Fink and Scholl, 2016), and domestic public debt (Bocola et al., 2019).

Figure 10: Tax Cyclicity and GDP per capita in OECD economies



Notes: The figure plots the correlation between the percentage changes of real GDP and the tax index of Vegh and Vuletin (2015) against the average real GDP per capita between 1996 and 2013 for 27 OECD economies.

5 Conclusions

In this paper, I have developed a dynamic stochastic model of sovereign debt with endogenous haircuts, matching frictions, and skill loss during unemployment to study optimal fiscal policy when human capital is lost during terms of unemployment. While contractionary fiscal policy may serve to avoid a default, it has a negative effect on employment. Since skills are lost during unemployment, the economy's production potential may be reduced and there will be less resources to serve external debt obligations in the future. Thus, debt renegotiations may be considered as an alternative.

In a quantitative exercise, I have applied the model to Portugal. The policy functions reveal that the government enters debt renegotiations when employment and productivity are low and debt is high. If debt is sufficiently low, the government responds to rising unemployment with tax reductions to increase the firms' hiring incentives. If debt is high, fiscal policy is contractionary and higher tax rates reduce the firms' benefit from hiring such that the government may prefer to enter debt renegotiations.

From an ex ante perspective, a higher intensity of skill loss during unemployment reduces the procyclicality of fiscal policy. For larger human capital depreciation, the government issues less debt, faces lower debt-to-GDP ratios and enters debt renegotiations less frequently. With lower debt levels, the government can avoid large tax hikes during economic downturns such that fiscal policy becomes less procyclical. Similarly, firms increase hiring in response to larger human capital

depreciation and average employment rises. When the bargaining power of the government is lower, haircuts become smaller such that the fiscal space after renegotiations to reduce taxes and to improve the firms' benefit from hiring declines. However, since higher recovery rates imply lower spreads, the government becomes less borrowin-constrained and enters renegotiations more frequently. The long-term average of employment is U-shaped in the bargaining power. In equilibrium, there is a welfare gain to the sovereign from lower bargaining power and smaller haircuts.

For Portugal, the model predicts that renegotiations would have been optimal in 2011, 2012, and 2013 with a medium-run unemployment reduction of up to 3.63%. Early renegotiations imply a lower peak of the unemployment rate in the short run, but slightly higher unemployment rates in the medium run because persistently low productivity realizations reduce the long-term effects of expansionary fiscal policy. The model cannot match the debt increase after 2009 since it abstracts from bailouts. The question how financial assistance and conditionality should be tailored such that the persistent negative effects of austere fiscal policy are minimized is left for future research.

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A Recursive Equilibrium

Definition. *The recursive equilibrium for the small open economy is defined as*

1. a set of policy functions for private consumption $c^R(b, n, z)$, $c^D(n, z)$,
2. a set of policy functions for hiring, vacancy posting and employment $h^R(\tau, n, z)$, $h^D(\tau, n, z)$, $v^R(\tau, n, z)$, $v^D(\tau, n, z)$, $n'^R(\tau, n, z)$, $n'^D(\tau, n, z)$,
3. a set of wages $w^{H,R}(\tau, n, z)$, $w^{H,D}(\tau, n, z)$, $w^{L,R}(\tau, n, z)$, $w^{L,D}(\tau, n, z)$ and transfers to unemployed workers $T^{H,R}(\tau, n, z)$, $T^{H,D}(\tau, n, z)$, $T^{L,R}(\tau, n, z)$, $T^{L,D}(\tau, n, z)$,
4. a set of value functions for the firms' value of a high-skilled and low-skilled job $J^H(\tau, n, z)$, $J^{H,R}(\tau, n, z)$, $J^{H,D}(\tau, n, z)$, $J^L(\tau, n, z)$, $J^{L,R}(\tau, n, z)$, $J^{L,D}(\tau, n, z)$, for the value of a job to a high-skilled and low-skilled worker $W^H(\tau, n, z)$, $W^{H,R}(\tau, n, z)$, $W^{H,D}(\tau, n, z)$, $W^L(\tau, n, z)$, $W^{L,R}(\tau, n, z)$, $W^{L,D}(\tau, n, z)$, and the value of being unemployed $U^H(\tau, n, z)$, $U^{H,R}(\tau, n, z)$, $U^{H,D}(\tau, n, z)$, $U^L(\tau, n, z)$, $U^{L,R}(\tau, n, z)$, $U^{L,D}(\tau, n, z)$,
5. a set of policy functions for the government's borrowing choice $b'(b, n, z)$, government consumption $g^R(b, n, z)$, $g^D(n, z)$, and the tax policy $\tau^R(b, n, z)$, $\tau^D(n, z)$,
6. a default set $\mathcal{D}(b, n)$,
7. the bond price function charged by international creditors, $q(b, n, z)$,
8. the bond level determined in debt renegotiations, $\tilde{b}(n, z)$,
9. a set of value functions for the government $V(b, n, z)$, $V^R(b, n, z)$, $V^D(n, z)$,

such that

1. taking as given the public sector policies and the firms' policy choices $c^R(b, n, z)$ and $c^D(n, z)$ satisfy the household's budget constraint (6),
2. taking as given the public sector policies, hiring $h^R(\tau, n, z)$, $h^D(\tau, n, z)$ and vacancy posting $v^R(\tau, n, z)$, $v^D(\tau, n, z)$, and employment $n'^R(\tau, n, z)$, $n'^D(\tau, n, z)$ satisfy the optimality condition (9) as well as the transition equation, the equation of the vacancy yield a , and the non-negativity constraint on hiring from the firms' profit maximization problem (2),
3. given the public sector policies and the firms' choices on vacancy posting and hiring, wages $w^{\{H,L\},R}(\tau, n, z)$ and $w^{\{H,L\},D}(\tau, n, z)$ solve the bargaining problems (23) and (24) and transfers to unemployed workers $T^{\{H,L\},R}(\tau, n, z)$ and $T^{\{H,L\},D}(\tau, n, z)$ equal a share Ω of wages,

4. the value functions for firms $J^{\{H,L\}}(b, n, z)$, $J^{\{H,L\},R}(b, n, z)$, $J^{\{H,L\},D}(b, n, z)$, and the value functions of employed and unemployed workers $W^{\{H,L\}}(b, n, z)$, $W^{\{H,L\},R}(b, n, z)$, $W^{\{H,L\},D}(b, n, z)$, $U^{\{H,L\}}(b, n, z)$, $U^{\{H,L\},R}(b, n, z)$, and $U^{\{H,L\},D}(b, n, z)$ fulfill equations (17), (18), (19), (20), (21) and (22),
5. given the bond price functions $q(b', n', z)$, the debt level after renegotiations $\tilde{b}(n, z)$, and the private sector equilibrium, the government's value functions $V(b, n, z)$, $V^R(b, n, z)$, $V^D(n, z)$, the default set $\mathcal{D}(b, n)$, and the policy functions $b'(b, n, z)$, $g^R(b, n, z)$, $g^D(n, z)$, $\tau^R(b, n, z)$, $\tau^D(n, z)$ solve (10), (11), (12) and (13),
6. given the bond price function $q(b', n', z)$ and the value function $V^D(b, n, z)$, the renegotiated debt level $\tilde{b}(n, z)$ solves the bargaining problem (15),
7. given the expected debt level after renegotiations $\tilde{b}(n', z)$, bond prices $q(b', n', z)$ fulfill equation (16), such that risk-neutral international creditors earn zero expected profits.

B Wage Determination

Following Den Haan et al. (2000) and Rendahl (2016), I abstract from complete insurance markets across households and consider each worker as a single risk-neutral entity. Thus, the surplus of a job to a worker is the difference between the expected discounted values of receiving a wage and being high-skilled at the beginning of the next period and receiving unemployment benefits and being or becoming low-skilled. As in Pissarides (2000), wages are determined by Nash bargaining on the total surplus of the job. The firm's value J of a high-skilled and low-skilled job are

$$J^H = (1 - \tau)z - w^H + \beta \frac{u'(c')}{u'(c)} E((1 - \rho'_x)J^H) \quad (17)$$

$$J^L = (1 - \tau)z(1 - \xi) - w^L + \beta \frac{u'(c')}{u'(c)} E((1 - \rho'_x)J^H). \quad (18)$$

The equilibrium condition of the private sector on hiring implies that the value of a vacancy V equals zero:

$$V = -\frac{\kappa}{a} + pJ^L + (1 - p)J^H = 0.$$

The value of a job to a high-skilled and low-skilled worker are

$$W^H = w^H + \beta \frac{u'(c')}{u'(c)} E\left((1 - \rho'_x + \rho'_x \rho'_f)W^H + \rho'_x(1 - \rho'_f)U^H\right) \quad (19)$$

$$W^L = w^L + \beta \frac{u'(c')}{u'(c)} E\left((1 - \rho'_x + \rho'_x \rho'_f)W^H + \rho'_x(1 - \rho'_f)U^H\right). \quad (20)$$

The value of being unemployed is

$$U^H = T^H + \beta \frac{u'(c')}{u'(c)} E(\rho_f W^L + (1 - \rho_f)U^L) \quad (21)$$

$$U^L = T^L + \beta \frac{u'(c')}{u'(c)} E(\rho_f W^L + (1 - \rho_f)U^L), \quad (22)$$

where $T^H = \Omega w^H$ ($T^L = \Omega w^L$).

Let the Nash bargaining power of workers be denoted by ω . The equilibrium wages are given by

$$w^H = \operatorname{argmax}\{(J^H)^{1-\omega}(W^H - U^H)^\omega\} \quad (23)$$

$$w^L = \operatorname{argmax}\{(J^L)^{1-\omega}(W^L - U^L)^\omega\} \quad (24)$$

The surplus is divided between the firms and the workers such that the wages for high-skilled and low-skilled workers are respectively

$$w^H = \omega(1 - \tau)z + \frac{(1 - \omega)}{1 - \Omega} \beta \frac{u'(c')}{u'(c)} E \left[\rho'_f W'^L + (1 - \rho'_f) U'^L - \rho'_x \rho'_f W'^H - (1 - \rho'_x \rho'_f) U'^H \right]$$

$$w^L = \omega(1 - \tau)z(1 - \zeta) + \frac{(1 - \omega)}{1 - \Omega} \beta \frac{u'(c')}{u'(c)} E \left[\rho'_f W'^L + (1 - \rho'_f) U'^L - \rho'_x \rho'_f W'^H - (1 - \rho'_x \rho'_f) U'^H \right].$$

C Numerical Algorithm

I use value function iteration to solve the model. The algorithm closely follows Hatchondo et al. (2010) and employs cubic spline interpolations. I approximate the equilibrium as the equilibrium of the finite-horizon economy and execute simultaneously iterations on the value functions and the bond price function.

Given the budget constraints (6), (7), (8), and the relationship between private and public consumption, the tax rate τ can be written as a function of the employment policy n' and the debt policy b' . For a given choice of the debt level b' , the optimal employment level n' follows from the optimality conditional of the private sector (9).

To solve the model, I employ the following algorithm. I define evenly distributed grid points for international debt $b \in [\underline{b}, \bar{b}]$, employment $n \in [\underline{n}, \bar{n}]$, and productivity $z \in [\underline{z}, \bar{z}]$. I set initial guesses for the value functions $V_{(0)}(b, n, z)$, $V_{(0)}^R(b, n, z)$ and $V_{(0)}^D(n, z)$, the values for firms $J_{(0)}(\cdot)$, employed workers $W_{(0)}(\cdot)$, unemployed workers $U_{(0)}(\cdot)$, the private and public sector policy functions and the bond price function $q_{(0)}(b, n, z)$. Given the guesses for the value functions, I employ a global search procedure to find candidate values for $b'_{(0)}(b, n, z)$ for every grid point $(b, n, z) \in [\underline{b}, \bar{b}] \times [\underline{n}, \bar{n}] \times [\underline{z}, \bar{z}]$. Using these candidate values as initial guesses, I find optimal values with the FORTRAN optimization routine BC POL from the IMSL library. The probability of debt renegotiations $\eta_{(0)}(z, b'_{(0)}, n'_{(0)})$ and the bond price $q_{(0)}(z, b'_{(0)}, n'_{(0)})$ follow from equations (14) and (16), respectively. The debt level after debt renegotiations $\tilde{b}_{(0)}(n'_{(0)}, z)$ is determined by the bargaining problem (15). Expected continuation values and expected policies are evaluated with Gauss-Hermite quadrature points and weights. I employ cubic spline interpolation to compute values for policies and productivity realizations off the grid using the FORTRAN routine by Habermann and Kindermann (2007).

Given the solutions found at each grid point, I update the value functions $V_{(0)}(b, n, z)$, $V_{(0)}^R(b, n, z)$

and $V_{(0)}^D(n, z)$ as well as the values for firms, workers, private and public sector policy functions and the bond price function. I iterate until the value functions converge.