Private Fiscal Information and Sovereign Default Risk

Siming Liu*[1], Ruoyun Mao†[2], and Hewei Shen‡[3]

[1]Department of Finance, Shanghai University of Finance and Economics
[2]Department of Economics, Grinnell College
[3]Department of Economics, University of Oklahoma

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Abstract

This paper introduces private fiscal information into a sovereign default model to account for the bond yield decoupling phenomenon during the recent European debt crisis. Governments are different in the credibility of fiscal policies (types), which is unknown to foreign investors. The government with credible fiscal policy is more able to discipline the default incentives by choosing a high tax rate; while the noncredible one enjoys the option value of default and is subject to more default risk. At a pooling equilibrium, the noncredible government successfully hides its type by mimicking the fiscal behavior of credible government, making the latter suffer from default risk that is not inherent to it. At a separating equilibrium, the credible government chooses a higher tax rate–relative to the optimal choice under perfect information–to help investors discern its type. Change in debt market characteristics, such as level of impatience, debt intolerance, and the ex-ante probability of a credible government, can make the economies shift from a pooling equilibrium to a separating one.

Keywords: Sovereign default; Fiscal commitment; Private information; Signaling

JEL Classification: E62, F34, F41, G15

*Email: simliu86@gmail.com
†Email: maoruoyun@grinnell.edu
‡Email: hewei.shen@ou.edu

1 Introduction

Ever since the creation of euro zone in January, 1999, bond yields across EU countries converge significantly until very recently. As shown in figure 1, there is a significant co-dive in the sovereign bond yields for the European countries over the early years of 2000's. This yield convergence arises among the countries under distinct institutions, fiscal policies and levels of productivity growth, and disappeared until the 2008 global financial crisis. After 2008, the government bond yields across countries exhibit different patterns: 1) Bond yields decoupled across countries; 2)There was a dramatic increase in the yields of the periphery countries; 3) The yields for the European core declined moderately during the crisis. Meanwhile, as shown in figure 2, no decoupling in GDP growth between the core and periphery countries is observed during the crisis and implies no difference in the economic fundamentals between the core and periphery countries. This paper provides a theoretical explanation for this yields convergence and decoupling phenomenon in Europe and try to answer the following two questions: 1) What cross-county heterogeneity can explain the divergence in bond yields after 2008 financial crisis? 2) How does this cross-country difference hide in the financially tranquil periods from 2000 to 2008?

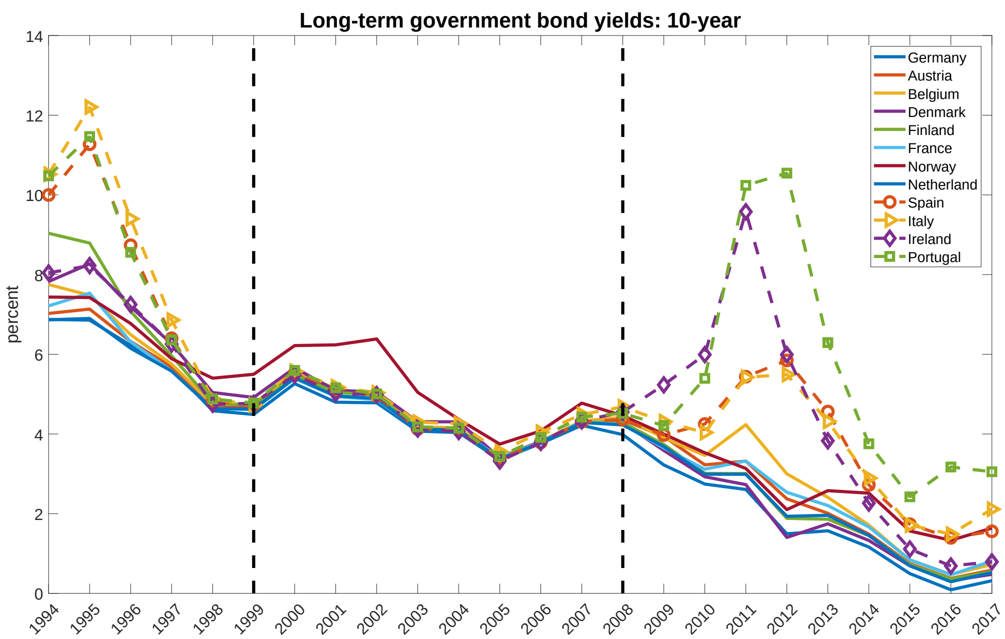


Figure 1: Government bond yields: 10-year

To address these questions, we introduce private fiscal information into a two-period sovereign default model. The economy is a small open economy. There is a random endowment realized in the second period only, so the government needs to borrow in the first period by issuing a non-contingent short-term bond. The international financial market is incomplete and the debt repayment is not enforceable. In period 1, the government also needs to choose a tax rate that is implemented

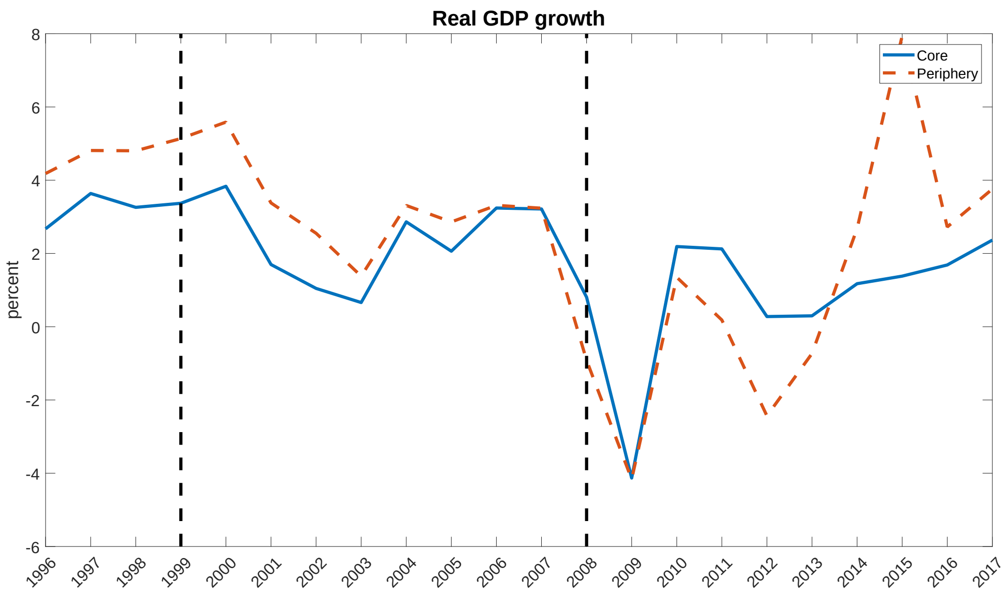


Figure 2: GDP growth rate: core and periphery

in the second period to finance its government spending and debt repayment. Depending on its credibility on the fiscal policy, the government is classified into two types. The government with less credible fiscal policy is free to adjust its planned tax rate during default time; while a more credible government is committed to implement its fiscal plan regardless of the states of the economy. The former type of government is said to have a discretionary fiscal policy (type-D) and the later type follows the policy commitment (type-C).

In the full-information environment, government's type is known to the foreign investors. The equilibrium is the similar to that in the two-period model in Liu and Shen (2018) and the credible government faces a lower financing cost and delivers higher welfare than the non-credible one. More specifically, the country with a more credible fiscal policy is able to discipline its default incentive in the future and earns a more favorable bond price. The reduced default risk in turn promotes borrowing and helps the economy better front-load consumption. At the same time, the credibility also comes with a cost: under a large negative shock in the second period, the fiscal policy cannot react correspondingly when the government defaults on its debt. So, compared to the discretionary policy, the relative welfare of the type-C government is determined by the commitment benefit on bond price in *ex ante* and lack-of-contingency cost in *ex post*. Under full-information, investors know government's type and charge an interest rate that fully reflects the default probability of each country. It shows that the type-C government is more willing to choose a high tax rate to increase its borrowing ability. So the equilibrium for the more credible government is characterized by higher debt issuance, lower default probability, and higher welfare.

The welfare difference between a credible government and a non-credible one motivates different fiscal behaviors when there is asymmetric information and the type is unknown to the foreign investors. In the first period, after the government chooses the tax rate to be implemented in the second period, foreign investors observe the tax rate signal and form expectation about the government's type. With the updated belief, the bond pricing scheduled is determined and the borrowing decision is made. The more affirmative are the investors about the government being type-C, the more favorable is the pricing schedule. Thus, the type-D government has an incentive to mimic the type-C government's tax choice. But, this pooling strategy comes with a cost for the government. At the good financial states of the second period, it must implement a tax policy that is suboptimal to the choice of its own. In front of the threat of pooling, the type-C government also tends to deviate from the full-information tax rate to separate away from the type-D, only except that sometimes it cannot do so because implementing separating strategy by raising tax rate further is too costly. We solve our model numerically and shows that the two types of equilibrium coexist: a separating equilibrium, in which two countries of different types choose different tax rates so they perfectly reveal themselves, and a pooling equilibrium, in which they choose the same tax rate and the investors fail to update the belief. Which is the dominant strategy depends on the welfare ranking of the type-C government.

We then map the yield convergence and decoupling phenomenon as in figure 1 into the model results. Consider two countries, a core country with a type-C government and a periphery country with a type-D government. In normal times, their types are hidden and the economy sustains a pooling equilibrium, characterized by similar fiscal activities and risk premiums. However, when some conditions of the debt market change, the type-C government attains greater abilities to reveal its type and a separating equilibrium is materialized. It will then result in lower interest rates for the core countries and rising ones in the periphery ones. By exploring the parameter space, we find when the economies become more *impatient* or when the *debt intolerance* level is high, the separating equilibrium is more likely to give the type-C government a higher utility. Based on that, our model uses a game theoretical approach to provide a possible explanation for the yield convergence during 2000-2008 periods, and the posterior yield decoupling. During crisis, an increase in governments' debt intolerance or impatience level across European countries separates apart the fiscal choice of each member states, leading to the "discoveries" of their fiscal types and resulting in yield decoupling.

2 Literature and Discussion of Assumptions

Our paper is built upon the literature of sovereign borrowing and default risk, such as Eaton and Gersovitz (1981), Aguiar and Gopinath (2006), and Arellano (2008). These papers predict that default risk is driven by negative shocks to GDP and they also abstract from an explicit role of fiscal policy. Figure 2 compares the mean GDP growth rate for the European core countries and for the 4 periphery countries. As the US mortgage defaults are turned into a Global Financial Crisis and spread to the European economies, we see a large contraction for all the countries but

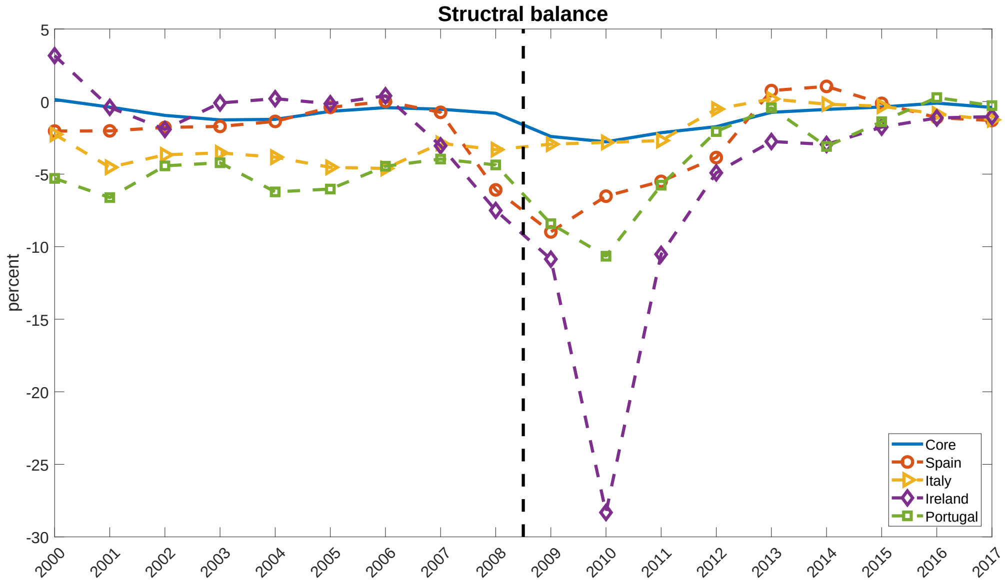


Figure 3: Structural balance as percentage of GDP: core and periphery

there is no significant difference between the core and periphery. Notice that the periphery is only trapped into a deeper recession and experiencing a slower recovery after 2014 when the full-blown debt crisis is in shape. However, things are different if we look at the structural balance to GDP ratio as in figure 3. At the same time of yield decoupling, the paths of structural balance between the core and periphery economies also decouple. In 2008, while government deficits increase for all the countries upon the shock, they spike for the periphery. The similarity between structural balance decoupling and yield decoupling phenomenon leads us to wonder their interconnection. This paper aims to explore the signaling effect of fiscal policy on sovereign default risk through the lens of private fiscal information.

Figure 4 shows the averaged debt-to-GDP ratio for the core economies and 4 periphery countries separately. We have two observations. First, at the beginning of 2008, except for Italy, the initial debt ratios in the periphery countries are at the similar level to the European core average. Second, governments' liabilities accumulate at a faster rate in the three periphery economies after 2009. This is partly due to the large deficit run by the government during the crisis (figure 3) and partly attributes to the souring interest payment (figure 1) when the sovereign debt crisis kicked in.

In addition to the vast literature on sovereign default, our paper also relates to papers studying asymmetric information and signaling activities under default risk. That includes Alfaro and Kanczuk (2005), Phan (2017) and Perez (2017). In Alfaro and Kanczuk (2005), a country signals its type (level of impatience) by making debt repayment. While an instant default extract more resources for the current consumption, it dampens the following periods by getting higher interest rates. In Phan (2017), repaying becomes a way the government used to signal good news about its domestic productivity when its true value is unknown to foreign investors. A more optimistic

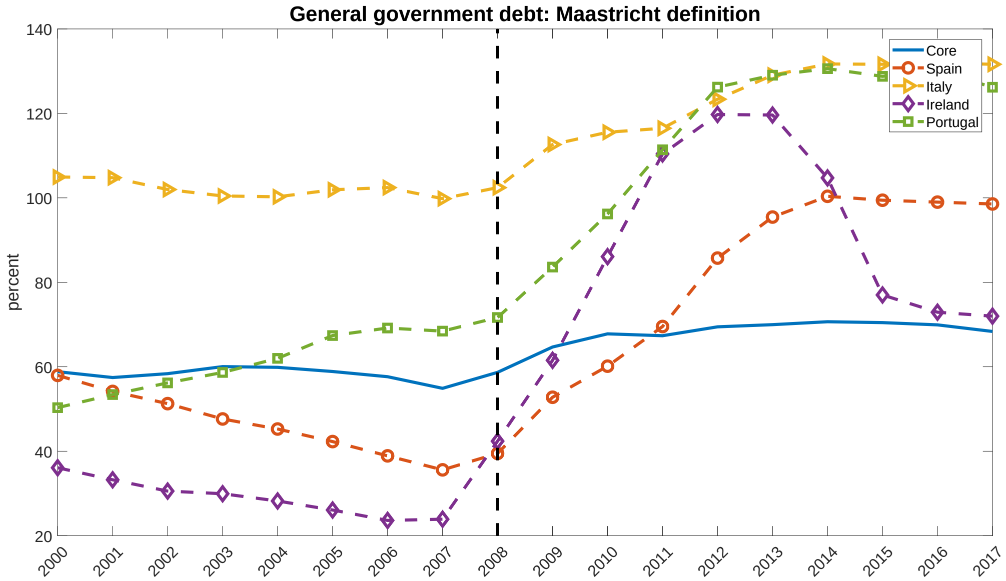
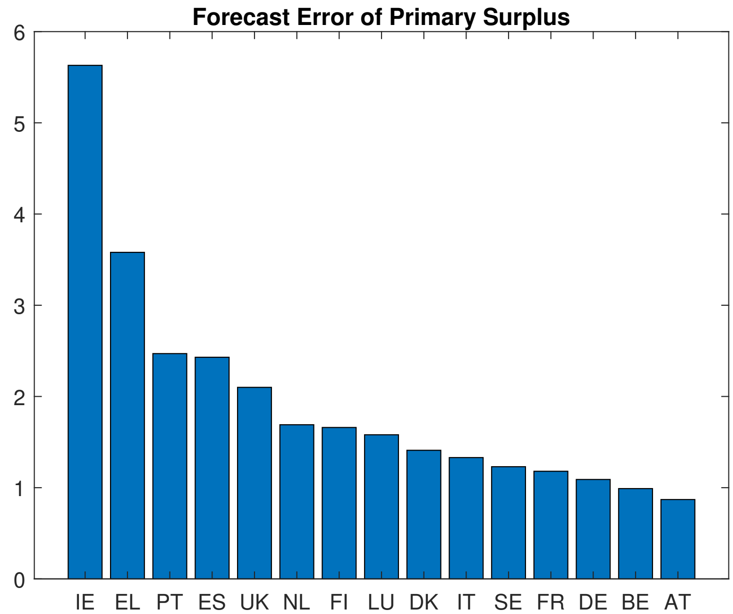


Figure 4: Debt-to-GDP ratio: core and periphery

belief on domestic productivity invites more the foreign investment and benefits the home country. Both papers emphasize the signaling effect of repayment decision under asymmetric information and explore its implications for debt sustainability. Differently, our paper focuses on the signaling motive of increasing tax rate at non-default states. As we see from the recent European crisis, the yields increase sharply for all the periphery countries but only Greece has implemented an outright default. That makes us believe that the motive to conduct signaling behaviors in non-default episodes is more relevant than default decision itself. Perez (2017) provides a theoretical framework to study the maturity choice of sovereign debt when investors are uncertain about the risk underlying the debt. Default risk is exogenous here and the paper focuses on the pooling equilibrium where risky borrowers mimic safe borrowers' behavior in making the same debt decision. However, the endogenous default probability is the key component of our model and we study how the strategic actions of governments of different types affect the default risk in equilibrium.

The paper closest to ours might be Catao et al. (2017). They also use a sovereign default model with asymmetric information to explain the yield decoupling phenomenon surrounding the recent debt crisis. In their paper, countries are different in default costs which is public information. A common negative fiscal revenue shock induces the country with lower default costs to increase debt issuance, and the country with higher default costs to adjust expenditure. Therefore, debt issuance becomes a signal for the unobservable fiscal shocks. Our paper is different from theirs in several dimensions. First, the heterogeneous factor (default cost) in their model is public knowledge. Investors perfectly know whether a country has "bad" or "good" fundamentals, and what they don't observe is the common fiscal shocks that vary across time. The later assumption is hard to be reconciled with the observation in figure 3 that the fiscal deficit during crisis is significantly larger



Note: The graph shows the one-year ahead forecast error (in absolute values) of European Commission's forecast from 2003 to 2013. The European Commission releases the economic forecast twice a year in spring and autumn and the graph shows the average one-year forecast error of the autumn forecast.

Figure 5: EC's Forecast Error of Primary Surplus

for periphery countries. Instead, we assume the countries are different in the manner they conduct fiscal policy and some of them have more credible fiscal plan than the others. Whether this "type" is revealed depends on parameter values of the model. The fiscal policy acts as a signaling device in our model rather than exogenous shock. Second, because of the different modeling strategies, their paper rationalizes the yield decoupling by analyzing each individual country's distinct equilibrium path. However, we study a cross-country signaling game and consider the yield decoupling as a shift from a pooling equilibrium to a separating one. Third, one additional benefit from using our approach is that our model also predicts the declining yields for the European core when the decoupling takes place, which is seen in figure 1.

Figure 5 presents the average one-year ahead forecast error (in absolute values) of primary surplus for EU countries. The forecast is published by European Commission's and we use it as a proxy for the credibility of the fiscal policy for those countries from the investors' perspective. Larger forecast errors proxy less credibility. Figure 5 shows that the forecast errors of all periphery countries are larger than that of the core countries. And countries with larger forecast errors are largely consistent with the countries whose yields surged during the financial crisis. The forecast error itself could also be regarded as the evidence for the information asymmetry between the governments and the investors.

3 Full-Information Benchmark

We start from the full-information case where investors know the government's type of fiscal credibility. The economy lasts for two periods: $t = 1, 2$. For simplicity, we assume the households only value public consumption (g_1) in the first period and value both private (c_2) and public consumption (g_2) in the second period. The only uncertainty is an endowment shock in the second period. There is no endowment in the first period, and so the government needs to borrow from foreign investors. The government announces a tax rate in the first period which is implemented after the shock realization in the second period. We consider two types of governments with different credibility on its fiscal policy. For a government with fiscal commitment (type-C), the same preset tax rate is implemented regardless the shock realizations and its default decisions. Specifically, in period 1, the type-C government chooses the level of borrowing and tax rate:

$$V_1^C = \max_{b_2,\tau} u(g_1) + \beta\mathbb{E}[V_2^C(b_2, \tau, y_2)], \tag{1}$$

$$s.t. \quad g_1 = b_2 q^C(b_2, \tau), \tag{2}$$

where q^C indicates the type-C government's bond price schedule and V_2^C is the continuing value in the second period. At the beginning of period 2, the government decides whether to default on its debt or to repay by comparing their corresponding values:

$$V_2^C(b_2, \tau, y_2) = \max_{d\in\{0,1\}} \{(1 - d) \times V_2^R(b_2, \tau, y_2) + d \times V_2^{DC}(\tau, y_2)\}. \tag{3}$$

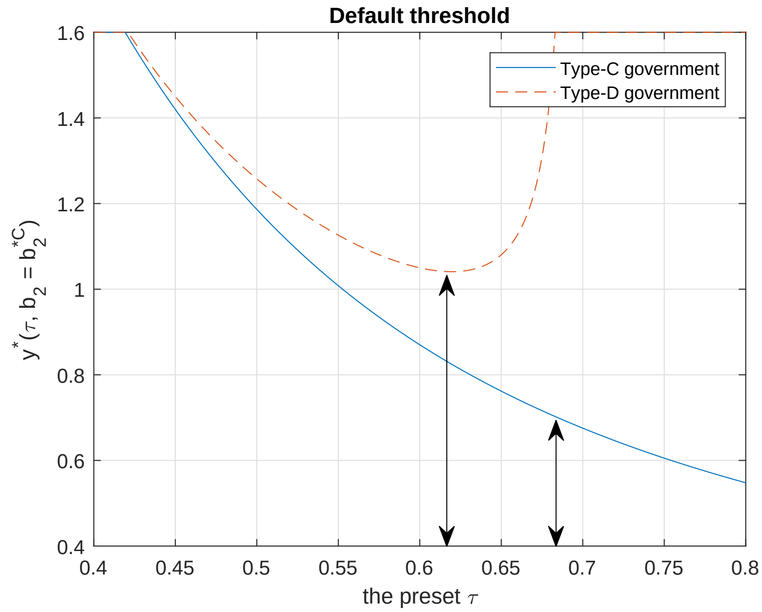
The value of repayment is:

$$V_2^R(b_2, \tau, y_2) = u((1 - \tau)y_2, \tau y_2 - b_2). \tag{4}$$

Notice that the repaying value is independent of the government's policy type, which is the key assumption in our model. If the government chooses to default, the debt is written-off and the country incurs an income loss proportional to the endowment: $(1-\phi)y_2$. Moreover, the government still follows the planned tax rate during the default. The default value for type-C government is:

$$V_2^{DC}(\tau, y_2) = u((1 - \tau)\phi y_2, \tau\phi y_2). \tag{5}$$

Next, consider a type-D government with certain discretionary power over its fiscal policy conducts. Specifically, the government still chooses a planned tax rate in period 1. But after the shock is realized in period 2, the government can renege on this preset tax rate and choose a new one if it defaults its debt. The type-D's problem in the first period is completely the same as that of type-C and we use V_1^D to denote its lifetime value. $V_2^D(b_2, \tau, y_2)$ is the period 2 value and $q^D(b_2, \tau)$ represents the bond price schedule. The only difference is that in the second period, the default



Note: This figure plots the default threshold for the type-C and type-D governments' problem. The level of debt issuance is set at the equilibrium borrowing level of type-C: $b_2^{*C} = 0.39$. The double arrows indicate the optimal tax choices for these two governments.

Figure 6: Default threshold: type-C and type-D government

problem becomes:

$$V_2^{DD}(y_2) = \max_{\tau^*} u((1-\tau^*)\phi y_2, \tau^*\phi y_2), \tag{6}$$

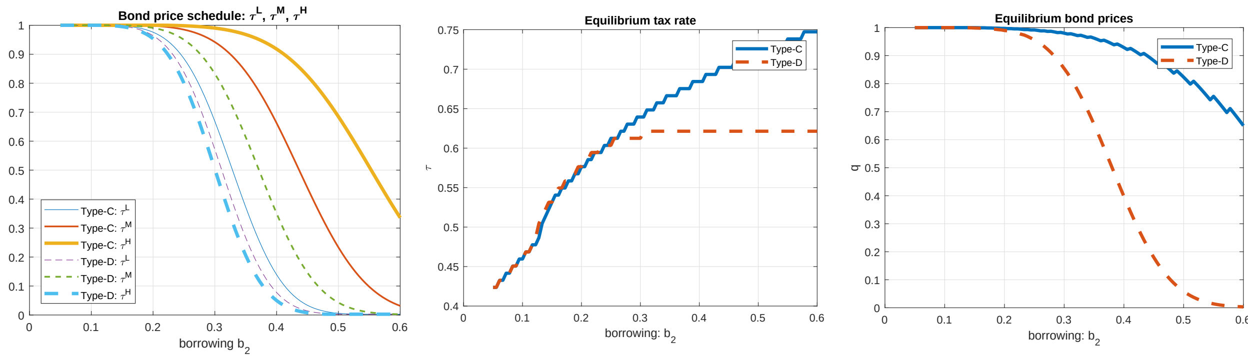
where τ^* denotes the reset tax rate after default decision has been made.

3.1 Analysis and Numerical Result

This section illustrates the mechanism of fiscal commitment in our model environment. The key difference between type-C and type-D governments is the problem of default. The type-C government is committed to follow the planned tax rate even if it defaults on its debt, but the type-D government is allowed to make fiscal adjustment at bad credit standing. The different taxation *ex post* in turn influences the default functions, leading to different bond pricing schedules at the time of borrowing in the first period.

To be clear about the effect of planned tax rate on the default incentives, we assume the utility functions are: $u(g_1) = \frac{g_1^{1-\sigma}}{1-\sigma}$ and $u(c_2, g_2) = (1-\pi)\frac{c_2^{1-\sigma}}{1-\sigma} + \pi\frac{g_2^{1-\sigma}}{1-\sigma}$. Figure 6 shows the default threshold as a function of tax rate τ when debt issuance is at equilibrium of the type-C government[1]. There are two insights from the graph. For any given tax rate, the default region is always larger if the government implements discretionary policy than policy under commitment;

[1]The analytic form of default thresholds is shown in appendix.



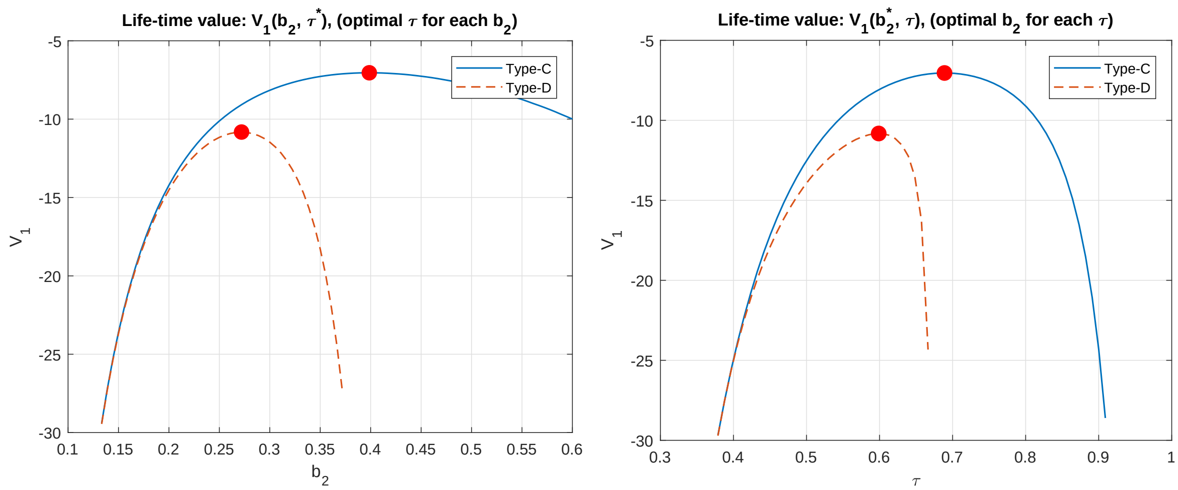
Note: The left panel plots three bond price schedules at different planned tax rates for each case; the medium panel shows the optimal tax rate for each level of intended borrowing: $\tau^{*C}(b_2) = \text{argmax}_\tau V_1^C(b_2, \tau)$ and $\tau^{*D}(b_2) = \text{argmax}_\tau V_1^D(b_2, \tau)$; the right panel plugs-in these optimal tax rates into the bond price functions and displays the equilibrium bond prices: $q^{*C}(b_2, \tau^{*C}(b_2))$, $q^{*D}(b_2, \tau^{*D}(b_2))$.

Figure 7: Bond price and optimal tax rate

for the type-D government, the default probability decreases more slowly as the tax rate increases, or even increases. Above certain value, an increase in the planned tax rate induces more defaults for the type-D government but less for the type-C. These properties give the type-D government an incentive to mimic type-C's taxation choice. But when tax rate is very high, the default probability for the type-D government is almost certain. This trade-off will be explained in the following section under private information.

The left panel of figure 7 shows the bond price schedules for three values of planned tax rate: $\tau^L < \tau^M < \tau^H$. Following the same intuition as figure 6, a more stringent tax policy always improves the term of borrowing for type-C government, but the effect on type-D's bond price is not monotone. And for each tax rate, the term of borrowing for the type-D government is worse than the type-C. The equilibrium result depends on the optimal fiscal policy chosen by each government. From the middle panel, we can see below certain threshold of borrowing, two governments choose almost the same tax rate. But a higher intended level of borrowing motivates the type-C government to continue increasing tax rate more than the type-D, since the benefit on bond price is more significant. Lastly, the right panel shows equilibrium bond prices as functions of intended borrowing. By choosing the higher tax rates, type-C government earns a more favorable bond price, even at high debt levels.

Figure 8 displays the governments' life-time utilities as function of b_2 or τ. When we plot the graph in one dimension, the other dimension is set at its optimal value. From the left panel, we find the benefit of policy commitment dominates its *ex post* cost for all level of borrowing, which greatly enlarges the borrowing ability for the type-C government. So, in equilibrium we have: $b_2^{*C} > b_2^{*D}$. Because the marginal benefit of raising tax rate is higher for the type-C and this benefit doesn't "depreciate" too much as the borrowing increases, we can see from the right panel of figure



Note: The left panel shows the lifetime utilities for each value of b_2 when τ is at the optimal value; the right panel shows the lifetime utilities for each value of τ when b_2 is at the optimal value.

Figure 8: Life-value as functions of b_2 and τ

8 that the type-C government optimally selects a higher tax rate than the type-D: $\tau_2^{*C} > \tau_2^{*D}$ [2]. The comparison between the two types here implies that government's ability in enforcing taxation *ex post* is important to its borrowing ability. This lends support to the fiscal austerity measures advocated by European policymakers during the recent debt crisis.

4 Private Information

Now, we consider the government has private information about its ability in making commitment (type) and signals its type through the planned tax rate. Denote θ as the type of the government and $\theta = 1$ ($\theta = 2$) means that the government is of type-C (type-D). Given certain *ex ante* probability, $\mathbb{P}(\theta = 1) = \alpha$, the foreign investors, observing the planned tax policy, update their beliefs about the type and create a bond pricing schedule. Then, the government chooses the debt issuance to maximize its welfare, taking bond pricing functions and investor's updated beliefs as given. The detailed timing in the first period is as follows:

1. The government chooses the tax rate to be implemented in the second period;
2. The foreign investors observe the tax rate and form expectation about the government's type;
3. Based on the belief of the investors and government optimization, he bond pricing scheduled is determined;

[2] Notice that here the value function of type-D government (dashed) drop sharply as τ gets close to certain value. That is because beyond this value, the type-D government defaults on the debt for sure in the second period and tax rate no longer has any effect on bond prices.

4. The borrowing decision is made.

The *Perfect Bayesian Equilibrium* (PBE) is characterized by the government's optimal decision rules, posterior beliefs of investors and bond pricing schedules. That is summarized as a triplet: $\{(b_2, \tau), \mu, q_2\}$.

In period 1, the type-C government solves the following problem:

$$V_1^C = \max_{b_2,\tau} u(g_1) + \beta \mathbb{E} V_2^C(b_2, \tau, y_2), \tag{7}$$

$$s.t. \quad g_1 = b_2 q(b_2, \tau, \mu(\tau)). \tag{8}$$

The continuing value V_2^C is the same as the full-information case. Notice now the bond price depends on investors' posterior beliefs about borrower's type: $q(b_2, \tau, \mu)$. In addition to the direct effect of tax rate on the bond price, the government here also incorporates how its tax policy induces foreign investors to update their beliefs. Similarly, the type-D government solves the problem of:

$$V_1^D = \max_{b_2,\tau} u(g_1) + \beta \mathbb{E} V_2^D(b_2, \tau, y_2), \tag{9}$$

$$s.t. \quad g_1 = b_2 q(b_2, \tau, \mu(\tau)). \tag{10}$$

Given the *ex ante* distribution of borrowers $[\alpha, 1-\alpha]$, investors' beliefs are updated using Bayesian rule:

$$\mu(\tau) = \mathbb{P}(\theta = 1|\tau) = \frac{\mathbb{P}(\tau|\theta = 1)\alpha}{\mathbb{P}(\tau|\theta = 1)\alpha + \mathbb{P}(\tau|\theta = 2)(1-\alpha)}. \tag{11}$$

Lastly, the price is determined by the probability of default based on investors' beliefs:

$$q(b_2, \tau, \mu) = 1 - \left[\mathbb{P}(d(b_2, \tau) = 1|\theta = 1)\mu(\tau) + \mathbb{P}(d(b_2, \tau) = 1|\theta = 2)(1 - \mu(\tau))\right]. \tag{12}$$

Since the model has a pure signal, two kinds of equilibrium emerge: a *pooling equilibrium*, where both types of governments choose the same tax rate and investors cannot distinguish their types; and a *separating equilibrium*, where different governments choose different signals and thus their true types are fully revealed. To restrict our attention to certain equilibria, we focus on the one that gives type-C government the highest utility. This is also the natural one since it is the type-C government that suffers the most from asymmetric information either from being pooled by the type-D government or from choosing a suboptimal allocation to separate from the type-D government. Our equilibrium selection criteria gives us the *Best Perfect Bayesian Equilibrium for Type-C Government* (PBE-BS), which is defined as a triplet $\{(b_2, \tau), \mu, q_2\}$ such that:

1. $\{(b_2, \tau), \mu, q_2\}$ is a Perfect Bayesian Equilibrium

2. $\{(b_2, \tau), \mu, q_2\}$ yields the highest utility to the type-C government, that is

$$V_1^C(b_2, \tau) \geq V_1^C(\tilde{b}_2, \tilde{\tau}), \tag{13}$$

for any other $\{\tilde{b}_2,\tilde{\tau}\}$ sustained by a Perfect Bayesian Equilibrium.

Denote $\{b_2^S(\theta), \tau^S(\theta)\}$ the allocations of a separating equilibrium. Consider the following artificial problem:

$$\boxed{\max_{b_2,\tau} V_1^C(b_2, \tau; \textit{separating}) \quad s.t. \quad V_1^D(b_2^*, \tau; \textit{pooling}) \leq V_1^D(FI)} \tag{14}$$

b_2^* is the type-D's optimal choice of debt when it mimics type-C's tax rate τ. $V_1^D(FI)$ is the utility attained by the type-D government under full information setting. This problem yields the allocations that maximize the type-C government's pay-off while the type-D government allows it to separate and chooses the full-information allocations. The equilibrium is sustained by the following degenerate beliefs:

$$\mu(\tau) = \begin{cases} 1, & \text{if } \tau = \tau^S(C) \\ 0, & \text{if } \tau = \tau^S(D) \end{cases} \tag{15}$$

In the numerical exercise below, we show sometimes the presence of separating equilibrium leaves type-C borrowers worse-off respect to the full-information setting since in order to separate from the type-D government, the type-C chooses an extremely high tax rate. That is the case when the constraint is binding, and we get the *least costly separating equilibrium* which is a meaningful equilibrium under the intuitive criterion made by Cho and Kreps (1987).

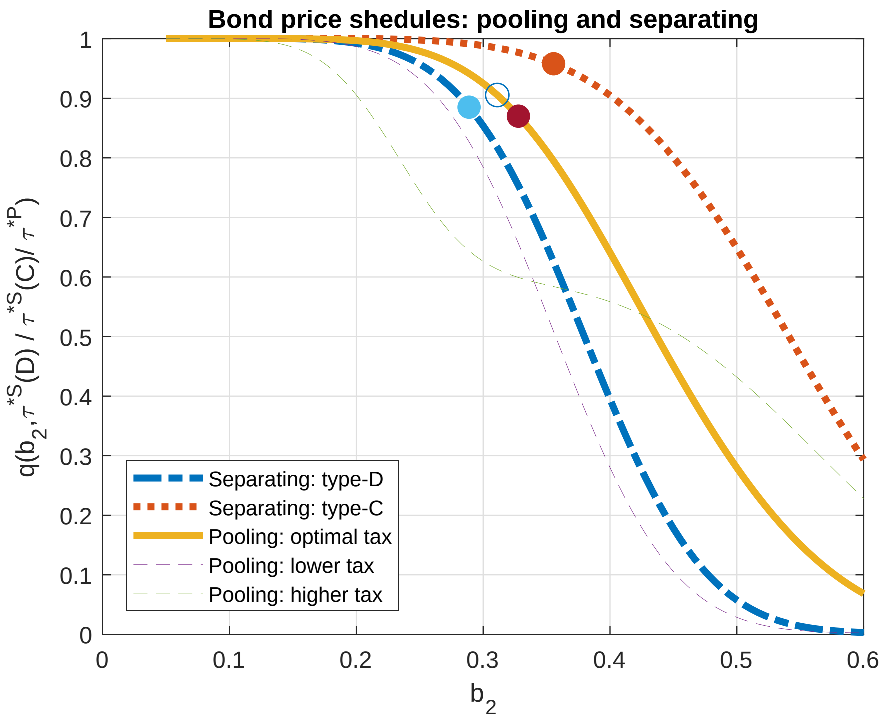
Let $\{b_2^P(\theta), \tau^P\}$ be allocations under a pooling equilibrium. In this case, the investors do not get any information from the governments' behaviors. The posterior beliefs are the same as the prior: $\mu(\tau) = \alpha$. The type-C government still optimizes its pay-off conditional on the type-D government has an incentive to pool:

$$\boxed{\max_{b_2,\tau} V_1^C(b_2, \tau; \textit{pooling}) \quad s.t. \quad V_1^D(b_2^*, \tau; \textit{pooling}) \geq V_1^D(FI)} \tag{16}$$

With certain parameter values below, we find that type-D government finds it optimal to pool with allocations that maximize the type-C borrower's unrestricted problem conditional on it is a pooling equilibrium.

4.1 Analysis and Numerical Result

This section explores the mechanisms of fiscal signaling under private information and considers how they affect the government's borrowing ability and welfare. In the next section, we pursue a comparative statics analysis and derives testable implications that are consistent with the data. We



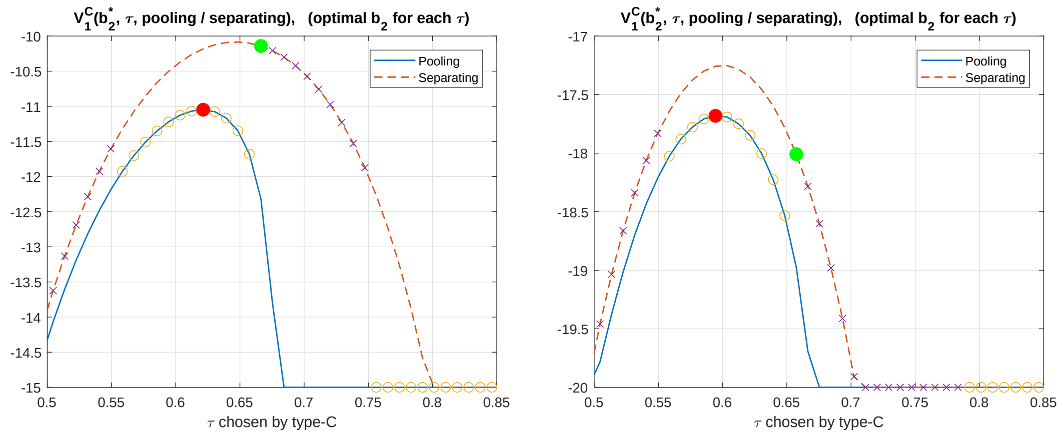
Note: The figure shows the bond price schedules at the pooling and separating equilibrium. The parameter values are: $\alpha = 0.6$, $\beta = 2$, $\phi = 0.62$. The thin dashed lines are bond prices of pooling when tax rate is higher or lower than the equilibrium tax rate: τ^{*P}. The tax rates are set at the optimum for the three thick lines. The circles represent the optimal level of borrowings. On the solid thick line, the filled (empty) circle refers to the borrowing level chosen by the type-D (type-C) government.

Figure 9: Bond price schedules at optimal tax rates

restrict our attention to PBE-BS that yields the highest utility to the type-C government. That leads to either pooling or separating equilibrium.

Figure 9 shows the bond price schedules for both the pooling and separating equilibrium. Clearly, the benefit of pooling for a type-D government comes from the more lenient bond price (from the dashed thick line to the solid thick line). However, if the tax rate is raised by too much, default in the second period becomes certain and bond price even declines at the relevant range of debt (green thin dashed line). Similarly, the benefit of separating for the type-C government also comes from the bond price (from the solid thick line to the dotted thick line). By choosing a discernible tax rate, the "good" type of government successfully reveal its type to investors and is compensated by a lower interest rate. But the cost of separating is hidden here. To separate, the type-C government has to set a tax rate–higher than the full-information setting–that is welfare-reducing in the second period.

We focus on the equilibrium strategy that yields the highest utility to the type-C borrower, that is equivalent to say, the type-C only allows the type-D to pool when it finds separating too costly.



Note: This figure shows the lifetime value of type-C government under pooling and separating strategy. $\beta = 2$ in the left panel and $\beta = 5$ in the right panel. Other parameter values are the same: $\alpha = 0.6$, $\phi = 0.62$.

Figure 10: Equilibrium selection: separating and pooling

Figure 10 shows two possible cases where separating or pooling equilibrium can emerge[3]. First, we find the type-C's value under separating is always higher than under pooling, but the feasibility depends on the restriction in the definition of problem 16. The line segment with rings indicates the tax rate values that type-D finds it optimal to mimic; the segment with crosses represents region where the type-C can separate. Which equilibrium dominates depends on the position of this pooling set of tax rates. In the left panel when β is low, the optimal tax rate for the two types of governments are very different, so the type-D's pooling incentive does not affect (or affect only a little) the type-C from choosing its own optimal tax. That leads to a separating strategy. However, when β is high in the right panel, the two optimal tax rates under full-information setting get closer, and as a result, the type-D finds it easier to mimic the type-C. To prevent type-D's pooling, the type-C government must set a higher tax rate that deviates too much from its original one. As a consequence, pooling becomes a dominating strategy.

Table 1 further illustrates this mechanism and shows the allocations and bond prices in each case. The shaded part is the selected PBE-BS from our criteria and the unshaded part is the underlying PBE dominated. When the separating equilibrium is selected (upper right panel), the difference in bond issuance and prices are both large. On the other hand, at the pooling equilibrium (lower left panel), two governments adopt the same bond price schedule when they borrow, and as a result both bond issuance and equilibrium prices are close. Notice that in this case, the type-D government borrows more heavily than the type-C because its cost of borrowing in period 2 is smaller (default has higher option value). That results in the smaller bond price.

[3]Here, the purpose is to show how the PBE-BS is selected. A comprehensive analysis about what factors can drive the equilibrium to shift between pooling and separating is postponed to the next section.

	Pooling		Separating	
Low β	type-C	type-D	type-C	type-D
tax rate	0.62	0.62	0.67	0.61
borrowing	0.31	0.33	0.36	0.29
bond price	0.90	0.87	0.96	0.86
life-time value	-11.05	-10.40	-10.14	-11.64
High β	type-C	type-D	type-C	type-D
tax rate	0.59	0.59	0.66	0.59
borrowing	0.28	0.30	0.31	0.28
bond price	0.94	0.91	0.98	0.90
life-time value	-17.68	-16.75	-18.01	-17.56

Table 1: Summary of the example

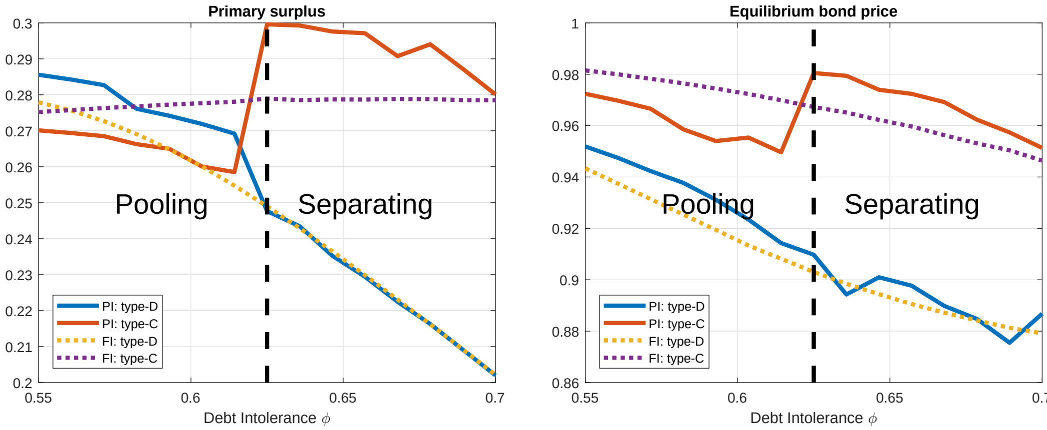
4.2 Comparative Statics

Next, we come back to our key question in the motivation of the paper: How do we explain the cross-country yield convergence and decoupling phenomenon during the recent European debt crisis? Up to now, we have a model with private information on fiscal policy and have defined the separating and pooling equilibrium. In this section, we explore the parameter space and examine what factors can account for the jump between the two types of equilibria.

We focus on two parameters related to the debt market. The first one is the government's degree of impatience: β; the second one represents the debt intolerance: ϕ. First, the higher level of impatience (smaller β) motivates governments to borrow more heavily against the second period. The strong debt-issuing motive is facilitated by the fiscal policy that can commit to a planned tax rate. Therefore, the higher impatience increases the "bad" government's incentive to pool and also increases the "good" government's ability to separate. Overall, we find the separating motive dominates. The same is true for the debt intolerance. As the default costs go down (larger ϕ), sovereign borrowers are more inclined to default in the second period and debt becomes more fragile. That applies for both types of governments. In the full-information setting, the more fragile debt market increases the value of fiscal commitment. Under private information, the discretionary government finds it more difficult to pool. As a result, the economy is more likely to end up with a separating equilibrium for greater debt intolerance. So, in our model of private fiscal information, the separating equilibrium is the PBE-BS when ϕ is above (or when β is below) certain threshold.

Figure 11 shows the model simulation for different values of ϕ. The result for different β is similar[4]. Since there is no further debt issuance in the second period, the simulated primary surplus is defined as $\mathbb{E}(\tau y_2 - g_2)$ which is equal to the expected debt repayment: $b_2[1-\mathbb{P}(d(b_2,\tau)=1)]$. Consistent with our intuition above, when ϕ is smaller than a threshold (vertical dashed

[4]The solutions of model for different β and α is in appendix.



Note: This figure shows the equilibrium bond prices and primary surpluses for each value of ϕ. In the model, the expected primary surplus is defined as $PS(b_2, \tau) = \mathbb{E}[\tau(y_2)y_2 - g_2(y_2)]$. $\beta = 5$ and $\alpha = 0.6$ throughout the simulations.

Figure 11: Debt Intolerance

line), the economy drops into the pooling equilibrium region. Notice that due to the asymmetric information, the type-D's (type-C's) bond prices are higher (lower) than the full-information bond prices. Besides, the primary surplus for the type-D is higher than the type-C. That is because given the same bond price schedule, the type-D agents are more indebted and engaged in more debt repayment. The equilibrium is separated when ϕ goes up, making the difference in bond prices larger. At the separating equilibrium, the type-D's allocations are the same as full-information benchmark. But for the type-C government, it has to increase tax rate more strongly to reveal its type, resulting in higher bond price and primary surplus relative to the full-information case.

4.3 Implication: Fiscal Signaling and Yield Decoupling

How can this model help to rationalize the yield decoupling phenomenon as shown in figure 1? The economy can be summarized as $\{\theta^i_t, \delta_t\}_{i=1}^{N}\ {}_{t=0}^{\inf}$ where θ is the individual country's type that shifts over time and δ represents a common shock to the fundamental[5]. Investors perfectly know the debt market fundamental of each country but cannot directly observe their fiscal policy type. The key mechanism in our analysis is that the variation of fundamentals δ_t changes the incentives of pooling and separating and determines where the equilibrium is located.

It is worth mentioning that we rationalize the sudden yield decoupling phenomenon as a jump between two equilibria in a cross-country game. When fundamental things change, one type of government has more limited ability to pool while the other type is more capable of separating. This game theoretical approach distinguishes our work from Catao et al. (2017)'s explanation based on individual country's equilibrium path and allows us to account for both the yield increase

[5] In our numerical example above, that includes parameter of impatience β and debt intolerance ϕ.

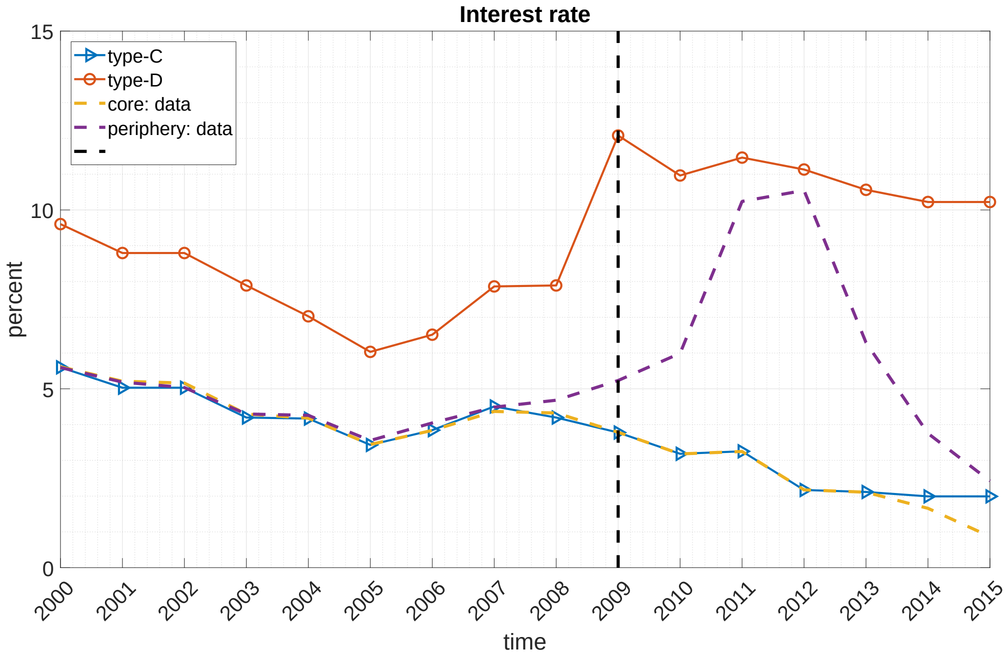


Figure 12: Bond yield decoupling: simulation

in periphery countries and yield decrease in core countries after 2009. To produce the time series pattern in the data, we consider a repeated version of our two-period model. This approach assumes the initial state at time t+2 is not influenced by the debt-issuance decision at time t, and the fiscal types are perfectly forgettable over 2 periods horizon. Although not ideal, this method is innocuous to describe the interest rates of a list of new issues when debt obligations are always honored, given we have not seen any default for the countries considered.

Figure 12 shows the simulation of interest rates for the two type of borrowers in our model, along with the average yields in the data[6]. First, we solve the model for different values of β and ϕ, and at any given point of time, we find the parameter values generating an interest rate closest to the average yield in core countries. Then, we compare the model's prediction about periphery interest rates with the data. We find, overall, the model can account for the decoupling fact after 2009 when the yields in periphery countries increased but the yields in the core countries decreased. However, the model exaggerates the yield difference between the two types of borrowers before 2009. That is because, given the same bond price at pooling states, the type-D government is willing to borrow more.

[6]The model's prediction on primary surplus and the extracted factors that are used to match data are shown in appendix.

5 Conclusion

This paper introduces asymmetric information about fiscal policy in a sovereign default model and shows it helps us understand the yield decoupling phenomenon during the recent European debt crisis. In our model, the sovereign yield dispersion can be explained by the different credibility in fiscal policy implementation for each government. The government committing to the planned tax policy is willing to choose a higher tax rate, making debt more sustainable; while the government with discretionary fiscal policy enjoys the option value of default in *ex post* but suffers more default risk in *ex ante*. Under asymmetric information, these fiscal types are unknown to foreign investors and beliefs are updated according to the observed tax rate. We show that in our model, this cross-country difference is concealed when the debt market parameters fall into certain region but amplified for the others, resulting in the shift between pooling and separating equilibrium. Compared to the full-information version of the model, asymmetric information introduces a signaling motive for the "bad" government to pool and also for the "good" government to separate.

Our model explains the yield convergence and decoupling from the change in debt market characteristics: level of impatience, debt intolerance or *ex ante* belief of investors, rather than resorting to country's fundamentals like GDP. In that sense, our paper provides a minimal interpretation about this fact which is totally based on the information asymmetry. Policy implications are apparent in our model. Low fiscal transparency makes "good" countries unable to display their own type and the pooled default risk is welfare-reducing. That is exactly the case when Greece was condemned for falsifying its fiscal data at the beginning of debt crisis. That also provides us an important reason to understand the current ECB's policy dealing with debt market crisis emphasizing the timely release of fiscal information.

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Appendix

A Default Threshold

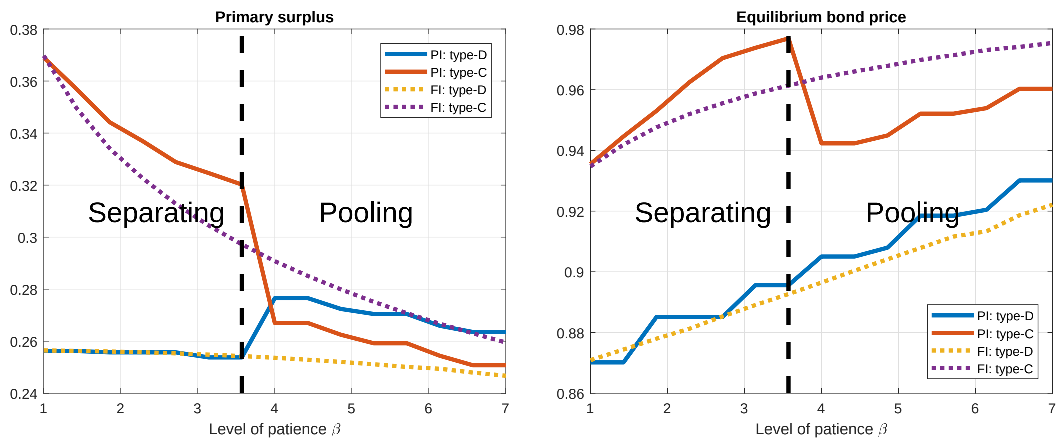
The analytic form of default threshold for the type-C government is:

$$y^{*C}(b_2,\tau) = \frac{b_2}{\tau - [(\tau\phi)^{1-\sigma} - \frac{1-\pi}{\pi}(1-\phi^{1-\sigma})(1-\tau)^{1-\sigma}]^{\frac{1}{1-\sigma}}}, \tag{A.1}$$

which depends on debt issuance b_2 and the preset tax rate τ.
The default threshold for the type-D government is:

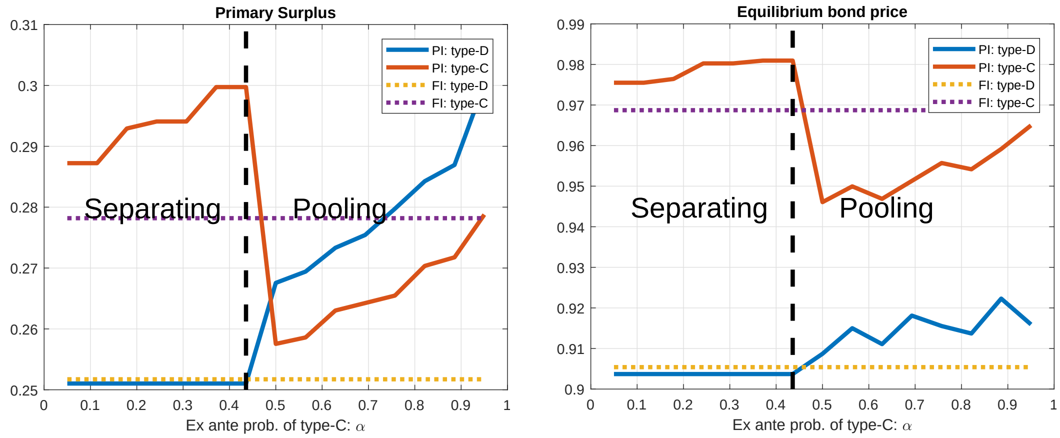
$$y^{*D}(b_2,\tau) = \frac{b_2}{\tau - [(1+(\frac{1-\pi}{\pi})^{\frac{1}{\sigma}})^{\sigma}\phi^{1-\sigma} - \frac{1-\pi}{\pi}(1-\tau)^{1-\sigma}]^{\frac{1}{1-\sigma}}}. \tag{A.2}$$

B Additional Figures



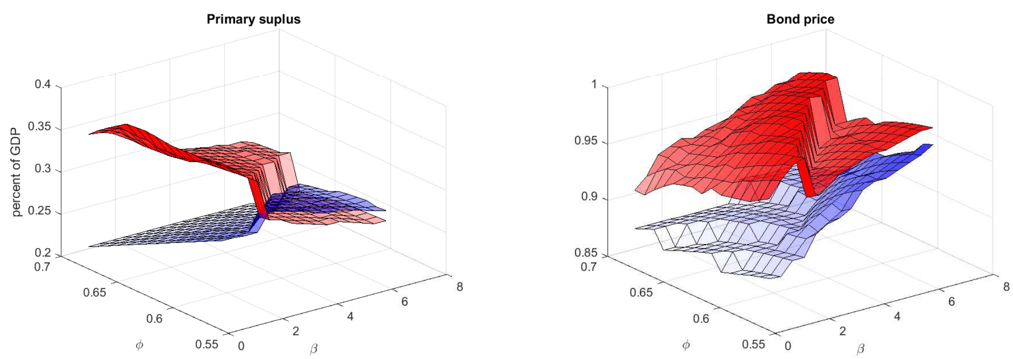
Note: This figure shows the equilibrium bond prices and primary surpluses for each value of β. $\phi = 0.62$ and $\alpha = 0.6$ through all the simulations.

Figure B.1: Level of impatience



Note: This figure shows the equilibrium bond prices and primary surpluses for each value of α. $\beta = 5$ and $\phi = 0.62$ through all the simulations.

Figure B.2: *Ex ante* probability of a "good" government



Note: This figure shows the equilibrium bond prices and primary surpluses for each combination of β and ϕ. $\alpha = 0.5$ through all the simulations.

Figure B.3: Impatience level and debt intolerance

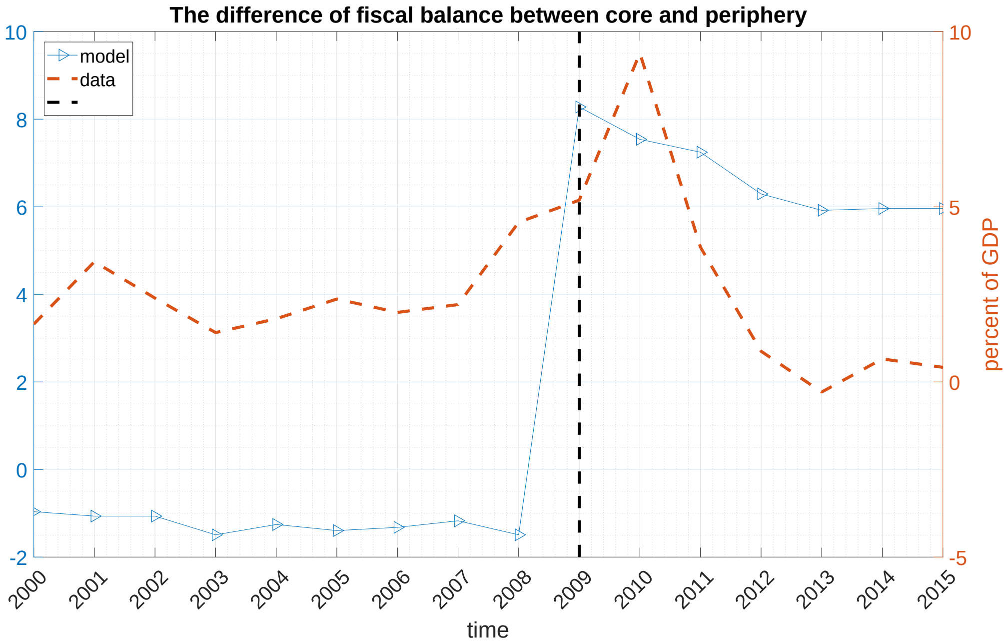


Figure B.4: Fiscal balance decoupling

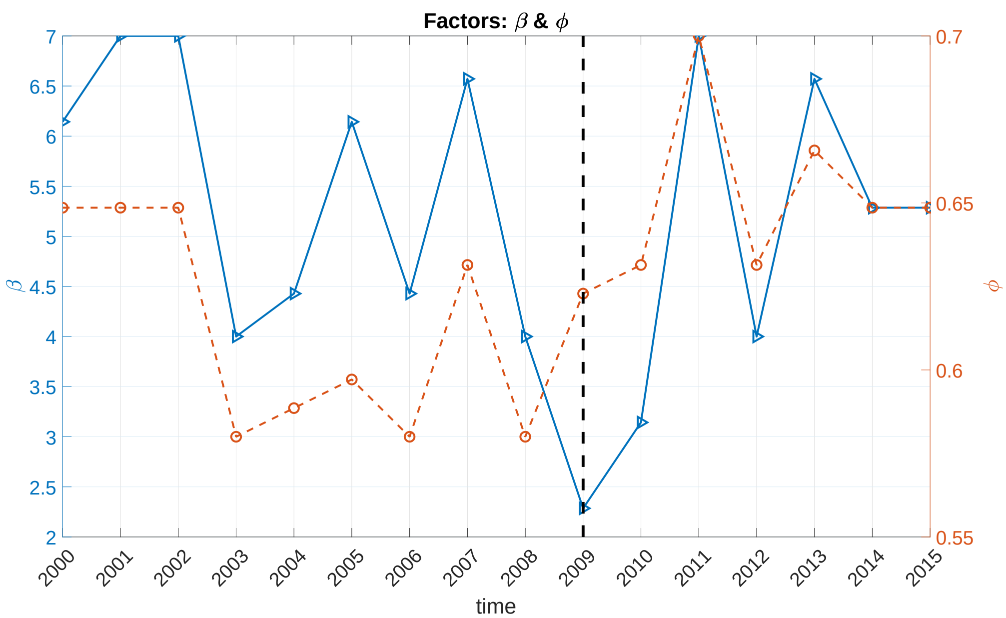


Figure B.5: Extracted factors: β and ϕ