# The effects of Eurobonds

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April 6, 2016

**Abstract**

This paper analyzes the impact of introducing bonds with joint liability in the Eurozone. The introduction of such an instrument gives rise to two contradictory forces. First, there exist a problem of "moral hazard", in the sense that this instrument may give incentives to some countries to increase their sovereign debt accumulation. Second, it might provide a higher level of "risk sharing" among the countries of the Eurozone. The model predicts that after the introduction of Eurobonds there are significant reductions on bond yields, and moderate welfare improvements. Overall, the moral hazard problem does not seem to be very severe.

**Keywords:** Sovereign Default, Interest Rates, Eurobonds

**JEL Classification:** E44, F34, H63, H68

## 1 Introduction

We introduce bonds with joint liability in an otherwise standard model of sovereign default. The exercise is intended to understand the potential implications of the introduction of Eurobonds. In the model there are two equal countries (up to the realization of uncertainty) that optimally decide how much to issue of a joint liability bond. As a consequence, the two countries interact strategically on their borrowing and repayment decisions. On the one hand, with the introduction of this instrument there exist a problem of "moral hazard", in the sense that this instrument may give incentives to some countries to increase their sovereign debt accumulation. On the other hand, it might provide a higher level of "risk sharing" among the two countries. Our quantitative exercise determines which of these two opposing forces prevails.

The recent Eurozone crisis highlighted the necessity for the development of financial instruments that mitigate the effects of the financial crisis and stabilize the yields of sovereign bonds. One of the mechanisms that is proposed as a potential solution is the implementation of bonds with joint liability (Eurobonds). On the one hand, with this mechanism some member states may increase their debt accumulation, since they will have easier access to the financial markets. This would be problematic since a failure of a country to repay may trigger a domino effect if the other countries do not have enough resources to absorb the troubled debt[1]. On the other hand, the introduction of Eurobonds could provide better access to financial markets to those countries under stress. Moreover, it could decrease the incentives for some Eurozone countries to abandon the Euro or to default, by promoting stability and setting the basis for a prospective fiscal integration, European Commission (2014).

We consider two economies with exogenous incomplete markets. The first studies the benchmark case, where countries can issue only individual sovereign bonds, and it is identical to Arellano (2008). Secondly, we study the interactions between two identical countries that can issue bonds with full joint liability. Their endowments follow a stochastic process that is derived according to the performance of these two groups of countries. In our analysis the prices of the bonds are endogenously determined, and depend on the other country choices, generating a strategic interaction between the two countries. We do not allow for partial default, and the penalty of default is a permanent output loss and exclusion from financial markets.

This paper is related to several studies that have focused on Eurobonds. Delpla & von Weizsacker (2010) discuss the 'blue and red bond' proposal, in which they propose pooling debt up to 60% of GDP (blue bonds) and beyond that threshold there will be individual bonds issued by each country separately (red bonds). Hellwig & Philippon (2011) foresees a mutualization of 10% of GDP for the short term debt. Claessens *et al.* (2012) discuss in depth various proposal about the Eurobonds and analyze potential effects in the Eurozone. None of these papers provide a theoretical analysis of the implications of Eurobonds. In contrast, Beetsma & Mavromatis (2014) and Tirole (2015) analyze stylized finite-period models of the strategic interactions between two countries that can issue joint liability bonds. However, these two papers abstract from the long run implications of Eurobonds and do not provide quantitative predictions of the implications of joint liability.

[1] The European Commission (2011) has tried to asses the feasibility of common issuance of sovereign bonds among Member States of the Eurozone and they have mentioned "moral hazard" as a potential problem.

Moreover, this paper is very related to the literature about the quantitative implications of debt dynamics and default in models with incomplete asset markets. In fact, our benchmark for comparison is Arellano (2008), that accounts for the empirical regularities in emerging markets as an equilibrium outcome of the interaction between risk-neutral creditors and a risk averse borrower that has the option to default. In a similar framework, Hatchondo *et al.* (2014) studies the effects of introducing a limited non-defaultable financing option in a small-open economy. Their results suggest that access to such an asset could produce substantial welfare gains and lead to significant reductions in sovereign debt and spreads, for a specific country. Alternative models of default focus on rollover risk, such as Conesa & Kehoe (2014) and Cole & Kehoe (2000), but I do not consider this issue in my analysis. Arellano & Bai (2014) and Lizarazo (2009) examine the contagion across sovereign defaults through the existence of common lenders, but they do not consider the case that countries have Eurobonds or any from of joint liability. To the best of my knowledge, none of the papers in the quantitative default literature addresses the impact of the strategic interactions that joint liability bonds might generate.

The benchmark model is calibrated for the case of a single country issuing individual bonds. Then, we compare this benchmark with a world where two identical countries subject to the same process of idiosyncratic income risk can issue joint liability bonds. First, when the countries face the same idiosyncratic income realization the default thresholds are analogous to the benchmark scenario. However, when the countries face different income realizations the behavior changes drastically relative to the benchmark economy. More specifically, in these cases we can notice that the countries with lower income level tend to default less frequently compared to the benchmark case, while countries with relatively higher income are more likely to default.

Overall, the economy with joint liability bonds faces risk spreads below those in the benchmark economy, although there is a modest increase in the Debt to GDP ratio. Moreover, countries experience higher welfare, they have cheaper access to the financial markets, and the moral hazard problem is quantitatively small.

The paper is structured as follows: Section 2 presents the theoretical models for the benchmark economy and the Eurobonds, Section 3 calibrates the model and assesses the quantitative implications of the model, and Section 4 concludes.

## 2 The Model

We consider two cases of sovereign bonds markets in our theoretical world: *first* the benchmark economy, in which countries issue only individual bonds to the international markets, i.e. no joint liability. *Secondly,* both countries are allowed to issue only bonds with joint liability.

We assume that the countries are risk-averse and they cannot affect the world risk free interest rate. The period utility function $u(.) : \mathcal{R}_+ \rightarrow \mathcal{R}$ and is assumed to be strictly increasing, strictly concave and satisfies INADA conditions. The lifetime payoff of each borrowing country $i$ is $E_0 \sum_{t=0}^{\infty} \beta^t u(c_{i,t})$, where $\beta \in (0,1)$ is the discount factor, $i \in \{1,2\}$ is the index for each set of countries, $c_{i,t}$ denotes each country's level of consumption at period $t$. Moreover, in each period the countries receive a stochastic endowment of a single perishable consumption good $y_{i,t}$, which is drawn from a compact set $Y = [\underline{y}, \overline{y}]$. These shocks follow a Markov process with transition matrix $\pi_i(y_i', y_i)$.

In both models, the risk averse countries trade one-period assets with the risk-neutral competitive financial intermediaries. The foreign intermediate creditors have access to an international credit market where they can trade as much as they need at a constant risk free interest rate $r$. We assume that the intermediate creditors always commit to repay their debt. However, the governments each period can decide whether to repay their debt or to default.

The intermediaries have perfect information about the history of endowments and they can observe the demand for next period's assets. Given these two variables they estimate the probability that the countries will be insolvent and they offer an interest rate that is analogous to breaking even the expected profits. More specifically, taking the bond price as given the expected profit ($\Pi$) function of the financial intermediaries is given by:

$$\Pi = \frac{[1-\phi]}{1+r}(B') - q(B') \tag{1}$$

where, $q$ is the price, $\phi$ is the endogenously derived default probability. In the Benchmark case the $B'$ is the same as the individual country's savings/borrowing, while in the Eurobonds case $B'$ is the aggregate level of savings/borrowing. Considering the risk-neutrality and the zero expected profits, we get the equilibrium prices,

$$q = \frac{1-\phi}{1+r} \tag{2}$$

The bond prices $q$ lies in $[0, \frac{1}{1+r}]$, since, $0 \leq \phi \leq 1$. The probability of default is zero for any $B' \geq 0$ and the sovereign bond price indicates the price of a risk free bond $\frac{1}{1+r}$. When, $B' < 0$, there might be some positive probability $\phi$ for the government to default which has a negative effect on the price of the sovereign bond to compensate the international creditors.[2] The sovereign's interest rate is defined as the inverse of the bond price, $r^s = \frac{1}{q} - 1$ and the country's spread is the difference between the interest rate and the risk free interest rate, $s = r^s - r$.

Influenced by the default episodes in various emerging economies, the cost originated by default episodes can be two fold: (i) de facto prohibited access to the financial markets because of high interest rates and (ii) a direct output loss due to liquidity problems, outflow of capital, banking problems. If a country chooses to default, we assume that it will remain in permanent financial autarky since the incidence of the insolvency has created bad reputation for the country from the international creditors. The output cost is a function $g(y_i) \leq y_i$ that county has when defaults and is an increasing function respect to $y_i$, as in Arellano (2008).

## 2.1 Benchmark

Define the $V_i(b_i, y_i)$ be the life-time value function for each country $i$ that has the option to default or not. Each country starts the current period with assets $b_i$ and endowment $y_i$.

This section is our benchmark economy and follows a standard sovereign debt model á la Arellano (2008) and Eaton & Gersovitz (1981). In this case the country chooses to maximize the present value of its welfare by choosing to repay its debt or to default. Therefore, $V_i(b_i, y_i)$ satisfies

$$V_i(b_i, y_i) = \max \ \{W_i^{def}(y_i), W_i^r(b_i, y_i)\} \tag{3}$$

where $W_i^{def}(y_i)$ is the value that is associated with the default, while $W_i^r(b_i, y_i)$ is the pay-off function associated with not defaulting and staying in contract:

$$W_i^r(b_i, y_i) = \max_{c_i, b_i'} u(c_i) + \beta E_{y_i'/y_i} V_i(_i', y_i) \tag{4}$$

$$\text{s.t.} \qquad c_i + q_i(b_i', y_i) \cdot b_i' = y_i + b_i \tag{5}$$

[2] Arellano (2008) model the price function in similar method.

If the country defaults then it faces a permanent financial autarky and its consumption equals to the endowment, which entails some direct costs. The value of default, $W_i^{def}(y_i)$ is given by the following:

$$W_i^{def}(y_i) = \max_{c_i = g(y_i)} u(c_i) + \beta E_{y_i'|y_i} W_i^{def}(y_i') \tag{6}$$

Let $A_i(b_i)$ be the set of $y_i$'s for which it is optimal for the country $i$ to default. The default set of the country $i$ given that it has good credit history it is derived by:

$$A_i(b_i) = \{y_i \in Y : W_i^r(b_i, y_i) \leq W_i^{def}(y_i)\} \tag{7}$$

The country may have incentives to default because it had a bad shock in the output combined with a massive debt that creates an unsustainable debt. However, the country loses its ability to have an intertemporal consumption smoothing since it has no access to the financial markets. If the country has a bad credit history then the default set is $A_i(b_i) = Y$.

The default probability for the country $i$ is defined as:

$$\phi_i(b_i', y_i) = \int_{A_i(b_i')} d\mu(y_i'|y_i) \tag{8}$$

When the default set is empty, $A_i(b_i) = \emptyset$, then the equilibrium default probability is zero, since it is not optimal for the country to default. When, $A_i(b_i) = Y$, then the probability to default is equal to one. In general, the probability changes in a positive manner as the assets shift (i.e. if the government debt is high then the probability is higher).

To derive the equilibrium prices we use Eq. 2, and we get:

$$q_i(b_i', y_i) = \frac{1 - \phi_i(b_i', y_i)}{1 + r} \tag{9}$$

The level of the asset's price depends on the probability that the country has to default. In the extreme case that the probability is equal to one then the price is equal to zero and the country can not borrow. As the probability decreases, the price gets closer to the price of a risk free bond.

**Definition 1:** A Recursive Equilibrium for a single country $i$ consist of: *(i)* policy functions for borrowing and consumption $\{b_i'(b_i, y_i), c_i(b_i, y_i)\}$ and value function $\{V_i(b_i, y_i)\}$ ,*(ii)* the price function for individual bonds $q_i(b_i, y_i)$ st:

1. Given the prices, the policy functions and the value functions of the country $i$ solve its maximization problem 3 - 6.

2. Taking as given country's policy functions and value function, the bond price function satisfies the maximization problem of the intermediaries 9.

## 2.2 Only Eurobonds

In this part we lay out the economy in which both countries can issue a bond with joint liability. The endogenous aggregate states consists of the vector of countries' debt holdings, $\{b_i\}_{\forall i}$. Therefore, the economy's state space, that consists endogenous and exogenous states, is defined as: $S = \{b_1, b_2, y_1, y_2\}$. The countries' repayment strategy is denoted by, $\{h_i'\}_{\forall i}$. The repayment strategy is a binary variable, where $h_i' = 0$ stands for good credit, while $h_i' = 1$ stands for bad credit.

Based on the assumption that when a country $i$ chooses to default then it stays in permanent autarky. Therefore, it is redundant to analyze the case that a country $i$ has bad credit history in the past, since we have analyzed these cases in ch.2.1. This is because the country $i$ stays in permanent autarky while country $i^-$ decides either to repay the aggregate amount of Eurobonds, in the period that country $i$ decides to default and then return to the Benchmark case or to Default.

As a result, in this part we analyze the case that both countries have good credit record and the option to default or to repay back its liabilities. Moreover, $V_i^E(S)$ is the associated value function for Eurobonds for each country $i$, given that both countries have good credit history. Hence, we have four possible scenarios:

- Scenario I - both countries choose to repay:

$$W_i^{rr}(S; b_{i^-}') = \max_{c_i, {b_i}'} \; u(c_i) + \beta E_{y_i'|y_i, y_{i^-}'|y_{i^-}} V_i^E(S') \tag{10}$$
$$\text{s.t.} \quad c_i + q_E(b_i^{'}, b_{i^-}^{'}, y_i, y_{i^-}) \cdot b_i^{'} = y_i + b_i$$

where, $W_i^{rr}(S; b'_{i^-})$ is the payoff function when both countries choose to repay, given the arbitrary debt strategy $b'_{i^-}$ for country $i^-$. It is vital to know the level of debt for country $i^-$, since it influences the Eurobonds' price $q_E(b_i^{'}, b_{i^-}^{'}, y_i, y_{i^-})$. Next period since both countries choose to repay, they will be able to borrow again with Eurobonds.

- Scenario II/III - country $i$ chooses to repay while country $i^-$ chooses to default:

$$W_i^{rd}(S) = \max_{c_i, b_i^{'}} \ u(c_i) + \beta E_{y_i'|y_i} V_i(b_i^{'}, y_i') \tag{11}$$

$$\text{s.t. } c_i + q_i(b_i{'}, y_i) \cdot b_i{'} = y_i + (b_i + b_{i^-})$$

where, $W_i^{rd}(S)$ is the payoff function when country $i$ chooses to repay while country $i^-$ chooses to default. In this scenario, country $i$ has to pay the sum of all the Eurobonds, while next period it will be in the Benchmark case. The price that country $i$ receives today is derived from the Benchmark case, since it reflect the probability that the country $i$ will default on the debt $b_i'$, given the income $y_i$.

- Scenario IV - country $i$ chooses to default:

$$W_i^{def}(y_i) = \max_{c_i^{def} = g(y_i)} \ u(c_i^{def}) + \beta E_{y_i'|y_i} W_i^{def}(y_i') \tag{12}$$

where, $W_i^{def}(y_i)$ is the payoff when the country $i$ chooses to default and it is identical with ch. 2.1, thus country $i$ has to face an exclusion from the financial markets.

We develop an intra-period game to derive the optimal strategy of repayment and borrowing for each country $i$, since it internalizes the effects of its strategies and the other's country strategies. Hence, the structure of the subgame depends on the aggregate state space $S$, as well as the repayment and borrowing decisions of both countries. The equilibrium strategies of repayment and borrowing $\{b_i'(S) = b_i^{BR'}(S, b_{i^-}^{BR'}, h_{i^-}^{BR'}) \ , \ h_i'(S) = h_i^{BR'}(S, h_{i^-}^{BR'}, b_{i^-}^{BR'})\}_{\forall i}$ are Nash and they reflect the best response of country $i$ given the best response of country $i^-$.

The best response for the repayment strategy of country $i$, given the arbitrary current strategies $\{h_{i^-}^{'}, b_{i^-}^{'}\}$ is defined:

$$h_i^{BR'}(S; h'_{i-}, b'_{i-}) = \underset{h'_i \in \{0,1\}}{\text{argmax}} \begin{cases} (1-h'_i) \cdot W_i^{rr}(S; b'_{i-}) + h'_i \cdot W_i^{def}(y_i) & \text{,if } h'_{i-} = 0 \\ \\ (1-h'_i) \cdot W_i^{rd}(S) + h'_i \cdot W_i^{def}(y_i) & \text{,if } h'_{i-} = 1 \end{cases} \tag{13}$$

The best response for the debt strategy of country $i$, given the arbitrary current strategies $\{h'_{i-}, b'_{i-}\}$ is defined:

$$b_i^{BR'}(S; b'_{i-}, h'_{i-}) = \underset{b'_i \in B}{\text{argmax}} \begin{cases} W_i^{rr}(S; b'_{i-}) & \text{,if } h_i^{BR'} = 0 \ \& \ h'_{i-} = 0 \\ \\ W_i^{rd}(S) & \text{,if } h_i^{BR'} = 0 \ \& \ h'_{i-} = 1 \\ \\ 0 & \text{,if } h_i^{BR'} = 1 \end{cases} \tag{14}$$

Moreover, $\tilde{V}_i^E(S; \{b'_i, h'_i\}_{\forall i})$ is the payoff function of country $i$, given the arbitrary current strategies $\{b'_i, h'_i\}_{\forall i}$

$$\tilde{V}_i^E(S; \{b'_i, h'_i\}_{\forall i}) = \begin{cases} W_i^{rr}(S; b'_{i-}) & \text{,if } h'_i = 0 \ \& \ h'_{i-} = 0 \\ \\ W_i^{rd}(S) & \text{,if } h'_i = 0 \ \& \ h'_{i-} = 1 \\ \\ W_i^{def}(y_i) & \text{,if } h'_i = 1 \end{cases} \tag{15}$$

**Definition 3:** Given the future value functions $\{V_i^E(S'), V_i(b'_i, y'_i)\ , V_i^{def}(y'_i)\}$ and the prices $\{q_i(b'_i, y_i), q_E(b'_1, b'_2, y_1, y_2)\}$, the intra-period Nash Equilibrium consists the best response strategies for debt and repayment $\{b_i^{BR'}(S; b_{i-}^{BR'}, h_{i-}^{BR'}), h_i^{BR'}(S; h_{i-}^{BR'}, b_{i-}^{BR'})\}_{\forall i}$ s.t.:

1. The best response strategies satisfy equations 14 & 13, while $\{b'_i(S) = b_i^{BR'}(S; b_{i-}^{BR'}, h_{i-}^{BR'})$ , $h'_i(S) = h_i^{BR'}(S; h_{i-}^{BR'}, b_{i-}^{BR'})\}_{\forall i}$

2. The equilibrium pay-off value function $V_i^E(S)$ is derived by the equilibrium strategies $\{b_i^{BR'}(S, b_{i-}^{BR'}, h_{i-}^{BR'}),\ h_i^{BR'}(S, h_{i-}^{BR'}, b_{i-}^{BR'})\}_{\forall i}$ and equation 15 s.t.:
   $V_i^E(S) = \tilde{V}_i^E(S; \{b_i^{BR'}, h_i^{BR'}\}_{\forall i})$

Given the outcome of the intra-period Nash Equilibrium, let $D(b_1, b_2)$ be the set, for which both countries choose to default simultaneously:

$$D(b_1, b_2) = \{y_1 \in Y \ \& \ y_2 \in Y : h_1'(S) \cdot h_2'(S) = 1\} \tag{16}$$

Following the same methodology as in the benchmark case, the default probability for Eurobonds is:

$$\phi_E(b_1', b_2', y_1, y_2) = \iint_{D(b_1', b_2')} d\mu_1(y_1'|y_1) d\mu_2(y_2'|y_2) \tag{17}$$

To derive the equilibrium prices we use Eq. 2, and we get:

$$q_E(b_1', b_2', y_1, y_2) = \frac{1 - \phi_E(b_1', b_2', y_1, y_2)}{1 + r} \tag{18}$$

Note that this price reflects the probability that both countries will default simultaneously, and the analysis is similar to the benchmark case.

**Definition 4:** Given the price function $q_i(b_i', y_i)$ and the value function $V_i(b_i, y_i)$ from definition 1 and the value function $W_i^{def}(y_i)$ from definition 2 , a Markov Perfect Equilibrium for this economy consists of: *(i)* policy function for repayment, borrowing, consumption $\{h_i'(S), b_i'(S)$ $, c_i(S)\}_{\forall i}$ and value functions $\{V_i^E(S)\}_{\forall i}$ ; *(ii)* a price function for bonds $\{q_E(S)\}$ st:

1. Given the prices $\{q_i(b_i', y_i), q_E(b_i', b_{i-}', y_i, y_{i-})\}$ and the equilibrium value functions from definition 1 & 2, the policy functions and the value functions are the solution to the equations 10 - 15 and satisfy definition 3.

2. Taking as given both countries' policies functions and values functions, the bond price function $\{q_E(b_i', b_{i-}', y_i, y_{i-})\}$ satisfies the maximization problem of the intermediaries 18.

# 3 Quantitative Analysis

## 3.1 Calibration

In this paper we borrow the parameters from Arellano & Bai (2014), as a first approximation of our results and we assume that the countries are symmetric.

| | | Value | Target |
|---|---|---|---|
| Country's discount factor | $\beta$ | 0.88 | |
| Country's risk aversion | $\sigma$ | 2 | Standard |
| Output cost after default | $\gamma$ | 0.984 | |
| Output | $y$ | $\{9, 9.5, 10, 10.5, 11\}$ | |

## 3.2 Simulation Results

This section first analyzes the policy functions for the Eurobonds model and then compares the quantitative results between the two models.

In the Eurobonds model, the repayment strategy is a function of the level of income and the inherited asset level for both countries. Figure 1, shows the repayment strategies for both countries, given the level of their incomes. The x-axis and y-axis measure the level of asset holding over the average income level for country 1 and 2, respectively. Moreover, in this case country 2 has relatively better income than country 1.

The red region represents the combination of the inherited debt level for which both countries decide to default simultaneously. In the dark green area both choose to repay, while in the light green area we come across with multiple Nash equilibrium in which both countries choose either to repay or default. More specifically, in case of multiple equilibrium we choose the outcome that yields the highest aggregate welfare, which is the scheme that both countries choose to repay. The dark blue region shows the synthesis of debt level for which country 1 defaults while the other repays the sum of Eurobonds and then issues individual bonds. Finally, in the white area we have no pure strategy N.E. for this reason we solve for the mixed strategy Nash Equilibrium.

The solid yellow line exhibits the threshold at which countries would default bellow that level of debt for this specific income in the benchmark case. This line is at -0.2 debt to income for country 1 and -0.6 for the other country. In this particular case, we can notice that the risk sharing mechanism works for country 1 since there is some green region bellow the vertical yellow line. More specifically, although country 1 faces a severe income shock, the risk sharing instrument allows to borrow at better interest rate and this reduces its incentives to become insolvent. This is happening because country 2 has a lower negative income shock with relatively limited level of debt. Therefore, that encourage the financial intermediaries to provide a better interest rate for the Eurobonds, since the default probability is more depressed compared to the benchmark case.

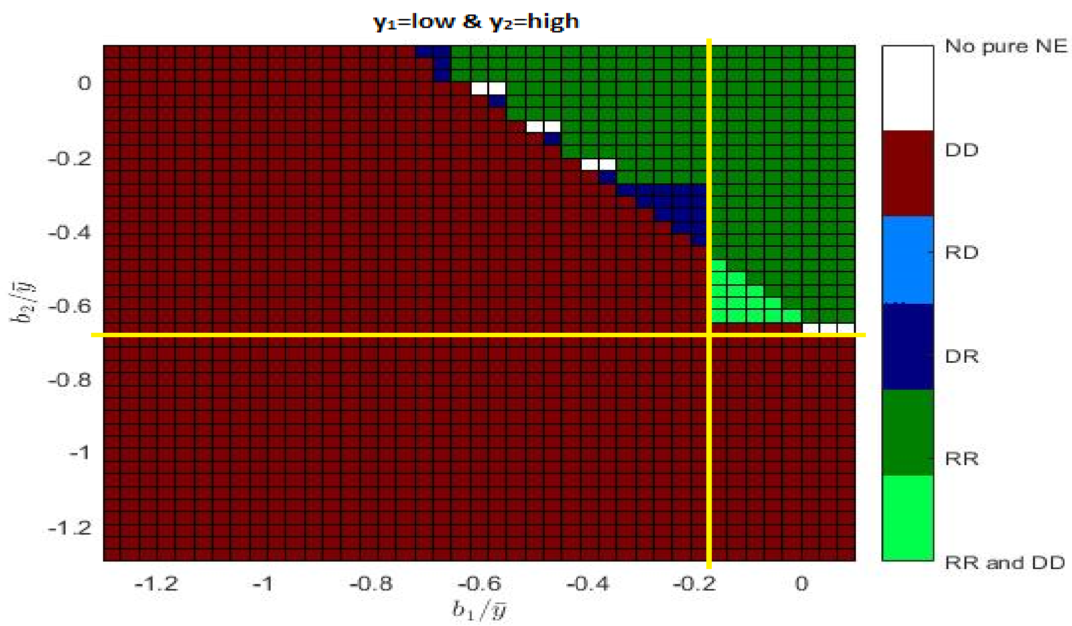


Figure 1: **Repayment Strategies**

Furthermore, it can be observed that there is a section of red blocks above the horizontal yellow line. More specifically, country 2 defaults in the Eurobonds, although this would not happen in the benchmark case. This phenomenon happens because there is a domino effect and country 2 does not have deep enough pockets to cover the loss from the default of country 1. In addition, in the white blocks country 2 would prefer to pay the sum of Eurobonds and then issue individual bonds. The main reason for this incident is because of the moral hazard effect. Country 1 receives a better price, since country 2 has relatively higher income, and this provides the incentives to increase its debt. However this affects negatively the price for country 2 and in this particular case it would prefer to issue individual bonds.

In Table 1 compares the Real Business Cycles statistics for both models. It is observed that although the debt to GDP has been increased after the introduction of Eurobonds there is a significant reduction on the annual spreads. Moreover, there is a modest increase in the welfare for both countries because of the fact that there is easier access to the financial markets.

Table 1: **RBC Statistics**

| | **Benchmark** | | **Eurobonds** | |
|---|---|---|---|---|
| | Country 1 | Country 2 | Country 1 | Country 2 |
| **Debt/Y** | -1.26 | -1.26 | -1.64 | -1.63 |
| **Spread** | 0.019 | 0.018 | 0.002 | 0.002 |
| **TB/Y** | 0.015 | 0.015 | 0.021 | 0.021 |
| **Welf** | -6.82 | -6.82 | -6.81 | -6.81 |

# 4 Conclusion

Europe faces the dilemma weather to step forward to a higher level of unification or not. This paper analyzes a mechanism that promotes a further unification to the Eurozone. More specifically, it develops a model, where countries issue bonds with full joint liability and they interact strategically. Finally, it compares the results with the benchmark economy, which is Arellano (2008). This paper finds that the economy with joint liability bonds faces risk spreads below those in the benchmark economy, although there is a modest increase in the Debt to GDP ratio. Moreover, countries experience higher welfare, they have cheaper access to the financial markets, and the moral hazard problem is quantitatively small.

An interesting extension of this model would be the analysis of partial joint liability -i.e. countries can issue debt with joint liability up to a percentage level of their GDP. If the countries need to issue additional debt beyond this threshold, they have to sell individual bonds, as Delpla & von Weizsacker (2010) proposal.

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# Appendix - Computational Algorithm

We first discretize the endowment space $y = (y_1; y_2)$ into 25 pairs using Tauchen & Hussey (1991) method and the debt space $b = (b_1; b_2)$ into 2,025 pairs. Define the state space as $S = (b_1, b_2, y_1, y_2)$. Then we compute two models: Benchmark model and Eurobonds model. We need to compute first the Benchmark model because we use the equilibrium results to calculate the Eurobonds model.

1. Benchmark model

   (a) Solve for the value functions $\{V^{def}(y_i), V(b_i, y_i)\}$ and the prices $q(b_i, y_i)$ in the Benchmark case by using the same methodology as Arellano (2008).

2. Eurobonds model

   (a) Calculate the pay-off function $W_i^{rd}(S)$ for the scenario that country $i$ repays while country $i^-$ defaults, given the value functions and prices from part 1a. At this point I want to mention that $W_i^{rd}(S)$ is one shot problem because in the first period country $i$ has to pay the sum of Eurobonds and after that it will continue as a single country in the Benchmark case, therefore there are no strategic interactions.

   (b) Given prices $\{q_E(S), q(b_i, y_i)\}_{\forall i}$ and the value functions $\{V^{def}(y_i), V(b_i, y_i), W_i^{rd}(S)\}_{\forall i}$, we apply value function iteration and we solve for the intra-period Nash Equilibrium by using backward induction.

      i. Assuming that both countries choose to repay, we calculate the pay-off function $\{W_i^{rr}(S; b'_{i^-})\}_{\forall i}$, for all the arbitrary debt decisions of country $i^-$. Then we derive for the best response of debt policy by looking for the fixed point, thus we will have $\{b_i^{BR'}(S; b_{i^-}^{BR'}, 0)\}_{\forall i}$.

      ii. We take as given the best response debt policy function for both countries in case that both choose to repay. Then we calculate the optimal repayment decision of both countries by looking for the fixed point that satisfies the following: $\{h_i^{BR'}(S; h_{i^-}^{BR'}, b_{i^-}^{BR'}), b_i^{BR'}(S; h_{i^-}^{BR'}, b_{i^-}^{BR'})\}_{\forall i}$.

iii. Given the optimal best response policy function for debt and repayment we update the value function for Eurobonds, $\{V_i^E(S) = \tilde{V}_i^E(S; \{b_i^{BR'}, h_i^{BR'}\}_{\forall i})\}_{\forall i}$, and go back to step 2.b.i until convergence.

(c) Finally, we use the optimal best response repayment policy function for both countries in order to update the prices $\{q_E(S)\}$, then we go back to step 2.b until convergence.