The Economics of Sovereign Debt, Bailouts and the Eurozone Crisis*

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Abstract

Despite a formal 'no-bailout clause', we estimate significant transfers from the European Union to Cyprus, Greece, Ireland, Portugal and Spain, ranging from roughly 0% (Ireland) to 43% (Greece) of output during the recent sovereign debt crisis. We propose a model to analyze and understand bailouts in a monetary union, and the large observed differences across countries. We characterize bailout size and likelihood as a function of the economic fundamentals (economic activity, debt-to-gdp ratio, default costs). Because of collateral damage to the union in case of default, these bailouts are ex-post efficient. Our model embeds a *'Southern view'* of the crisis (assistance was insufficient) and a *'Northern view'* (assistance weakens fiscal discipline). Ex-post, bailouts do not improve the welfare of the recipient country, since creditor countries get the entire surplus from avoiding default. Ex-ante, bailouts generate risk shifting with an incentive to over-borrow by fiscally fragile countries. While a stronger no-bailout commitment reduces risk-shifting, we find that it may not be ex-ante optimal from the perspective of the creditor country, if there is a risk of immediate insolvency. Hence, the model provides some justification for the often decried policy of *'kicking the can down the road'*.

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1 Introduction.

The markets are deluding themselves when they think at a certain point the other member states will put their hands on their wallets to save Greece.
ECB Executive Board member, Júrgen Stark (January 2010)

The euro-region treaties don't foresee any help for insolvent countries, but in reality the other states would have to rescue those running into difficulty.
German finance minister Peer Steinbrueck (February 2009)

No, Greece will not default. Please. In the euro area, the default does not exist.
Economics Commissioner Joaquin Almunia (January 2010)

These quotes illustrate the uncertainty and the disagreements on sovereign defaults and bailouts in the Eurozone and also the distance between words and deeds. The eurozone crisis has highlighted the unique features of a potential default on government debt in a monetary union comprised of sovereign countries. Compared to the long series of defaults the world has experienced, the costs and benefits that come into play in a decision to default inside a monetary union such as the eurozone are magnified for both debtor and creditor countries. Because a monetary union facilitates financial integration, cross-border holdings of government debts (in particular by banks) inside the monetary union, and therefore potential capital losses in the event of a default, are very large. In addition, a sovereign default inside the eurozone has been interpreted by many policy makers and economists as a first step towards potential exit of the defaulter from the monetary union. Such a dramatic event would in turn impair the credibility of the monetary union as a whole, that may come to be seen as a mere fixed exchange rate regime, leading to a significant re-assessment of risks. The costs of default for the creditor countries inside the eurozone are therefore not only the direct capital losses due to non-repayment but the collateral damage in the form of contagion costs to other member countries as well as the potential disruption of trade and financial flows inside a highly integrated union. For the defaulting party, being part of a monetary union also magnifies the costs of a sovereign default. First, as for creditor countries, the financial and trade disruptions are made worse because of the high level of integration of the eurozone. As illustrated by the Greek case, a sovereign default would endanger the domestic banks which hold large amounts of domestic debt used as collateral to obtain liquidity from the European Central

Bank. A potential exit from the eurozone (and even according to several analysts from the European Union) would entail very large economic and political costs with unknown geopolitical consequences. The political dimension of the creation of the euro also transforms a potential default inside the eurozone into a politically charged issue.[1] These high costs of a default for both the creditors and the debtors and of a potential exit were supposed to be the glue that would make both default and euro exit impossible. They may also have led to excessive debt accumulation.

A distinctive feature of a monetary union comprised of sovereign countries is the way in which debt monetization affects member countries. While benefits and costs of inflation are borne by all members, their distribution is not uniform. Surprise inflation reduces the ex-post real value of debt for all members, benefiting disproportionately highly indebted countries, while the costs of inflation are more uniformly distributed. There is therefore a significant risk that the European Central Bank (ECB) may be pressured to use monetary policy to prevent a default in fiscally weak countries via debt monetization. This was well understood at the time of the creation of the euro and Article 123 of the Treaty on the Functioning of the European Union (TFEU) expressly prohibits the European Central Banks' direct purchase of member countries' public debt.[2]

In addition, Article 125 of the TFEU which prevents any form of liability of the Union for Member States debt obligations.[3] This clause is often referred to as the *'no bail-out clause'*, making bail-outs illegal even in case of a sovereign default. For others (see De Grauwe, 2009), the no-bail-out clause only says that the Union shall not be liable for the debt of Member States but does not forbids Member States themselves from providing financial assistance to another member state.[4] Indeed, at various points during the Eurozone sovereign debt crisis, Greece, Ireland, Portugal,

[1] The political dimension of the creation of the euro was highlighted by former president of the European Commission Jacques Delors in this declaration of 1997: "people forget too often about the political objectives of European construction. The argument in favor of the single currency should be based on the desire to live together in peace," cited in Prior-Wandersforde and Hacche (2005).

[2] Article 123 stipulates 'Overdraft facilities or any other type of credit facility with the European Central Bank or with the central banks of the Member States (hereinafter referred to as 'national central banks') in favour of Union institutions, bodies, offices or agencies, central governments, regional, local or other public authorities, other bodies governed by public law, or public undertakings of Member States shall be prohibited, as shall the purchase directly from them by the European Central Bank or national central banks of debt instruments.'

[3] Article 125 stipulates 'The Union shall not be liable for or assume the commitments of central governments, regional, local or other public authorities, other bodies governed by public law, or public undertakings of any Member State, without prejudice to mutual financial guarantees for the joint execution of a specific project. A Member State shall not be liable for or assume the commitments of central governments, regional, local or other public authorities, other bodies governed by public law, or public undertakings of another Member State, without prejudice to mutual financial guarantees for the joint execution of a specific project.'

[4] Article 122 of the TFEU Treaty stipulates "..Where a Member State is in difficulties or is seriously threatened with severe difficulties caused by natural disasters or exceptional occurrences beyond its control, the Council, on a proposal from the Commission, may grant, under certain conditions, Union financial assistance to the Member State concerned.'

Spain and Cyprus lost market access and had to ask for the support of other eurozone members in order to avoid a default or a collapse of their domestic banking sector. This financial support was mainly provided through the creation of the European Financial Stability Fund (EFSF) and its successor the European Stability Mechanism (ESM) who lent large amounts to these countries.

How much, if any, of this financial support constitutes a transfer to the recipient country? The answer depends on the risk profile of funding programs and the interest rate charged by these institutions. If the ESM or EFSF are providing funding at the market risk-free rate and are fully repaid, there is no implicit subsidy. If instead the ESM charges a concessional rate below the market risk-free rate, or charges the risk-free rate but does not expect full repayment, there is an expected transfer component. This paper provides estimates of the implicit transfers arising from official European Union financing to five crisis countries: Cyprus, Greece, Ireland, Portugal and Spain. The key assumption to obtain our estimates is the use of the IMF internal rate of return on lending to these countries as an estimate of the true risk-free rate.[5] This is justified by the evidence that IMF programs almost always get repaid and do not incorporate a substantial transfer component, except when lending is concessional (Joshi and Zettelmeyer (2005)). Importantly, this assumption yields a *lower bound* on the size of the transfers from the European Union for three reasons. First IMF programs are relatively short term (between three and nine years) compared to ESM and EFSF programs with duration ranging from 10 years to 30 years. Adjusting the IMF internal rate for a term premia would increase estimates of the transfers. Second, IMF programs are super-senior and their super-seniority is acknowledged by the ESM. Therefore the proper risk-free rate for European Union programs is likely to be higher than the IMF. Lastly, we ignore any potential transfer component arising from European Central Bank policies (namely the Security Market Program, or the Asset Purchase Program).

Our estimates indicate substantial variation in the implicit transfers, from roughly zero percent of output (or even slightly negative) for Ireland to a very substantial 43 percent of output for Greece. It is clear, based on these estimates, that the transfers can be far from zero – so the no bail-out rule did not apply– and their variation across countries suggests that they were a key element of the resolution of the eurozone crisis. The purpose of this paper is to understand better the trade-off between ex-post bailouts and ex-ante borrowing incentives, the determinants of the likelihood of a bailout as well as its size, potentially accounting to the observed variation across countries, and finally to understand who -of the lender, the borrower or the rest of the world- ultimately benefit from these bailouts.

[5]Spain did not have an IMF program, so we use an average of the IMF's internal rate of return for the other four countries.

To answer these questions, we present a two-period model of strategic default that integrates these different features unique to the eurozone. The model features two eurozone countries, one fiscally strong and one fiscally fragile, and a third country that represents the rest of the world. Each region issues sovereign debt and private portfolio holdings are determined endogenously. A sovereign default inflicts direct costs on bondholders, but also indirect costs on both the defaulting country and its eurozone partner. The structure of these collateral costs, together with the realization of output and the composition of portfolios determine the conditions under which the fiscally strong country may prefer to bailout its fiscally weak partner. We show that while the bailout allows the union to achieve (ex-post) efficiency, it does so by transferring all the surplus to the fiscally strong country, leaving the debtor country no better off with a bailout (and no default) than with a default (and no bailout). We call this the *'Southern view'* of the crisis: financial assistance may come, but it does not help the afflicted country. That financial assistance to a country that is close to default does not improve its fate may seem surprising. However, in absence of political integration, there is no reason creditor countries would offer more than the minimal transfer required that leaves the debtor country indifferent between default and no default. Hence, even though Greece received a very large transfer (which we estimate above 40% of its GDP), this transfer does not make it better off ex-post in our analysis.

What the possibility of a bailout does, however, is distort the ex-ante incentives of the fiscally weak country and generate excessive borrowing in the first period. We establish this result with a risk neutral borrower, so the incentive to borrow arises exclusively from the expected ex-post transfer. In effect, the likelihood of transfers lowers the cost of borrowing for the weak country below the risk free rate, at the expense of the fiscally strong country. The debtor country then trades off the increased riskiness of debt against the likelihood of a bailout. We call this the *'Northern view'* of the crisis: the ability to obtain a bailout weakens fiscal discipline. In the context of the Eurozone crisis, this position has been articulated many times by the German Treasury. Thus our analysis reconciles the 'Northern' and 'Southern' views of the crisis as the two sides of the same coin: risk shifting by the debtor country occurs in the first period because of the transfer, even if ex-post the creditor country captures all the efficiency gains from avoiding a default.

This suggests a simple fix: if the creditor country could credibly commit to a no bail-out clause, this would eliminate ex-ante risk shifting and overborrowing. Yet we show that such commitment may not be optimal, even from the perspective of the creditor country. Instead, we find that, under certain conditions, the creditor country may prefer an imperfect commitment to the no-bailout clause. This is more likely to be the case if the debtor country has an elevated level of debt to rollover. Under a strong no-bailout clause, the debtor country may be immediately insolvent. In-

stead, if a future bailout is possible, the debtor country might be able to roll-over its debt in the initial period. Of course, this will lead to some risk shifting and excessive borrowing, but the scope for excessive borrowing is less significant the larger is the initial debt to roll-over. Hence the creditor country faces a meaningful trade-off between immediate insolvency and the possibility of a future default. Thus the model provides conditions under which it is optimal for creditor countries to 'gamble for resurrection' or 'kick the can down the road' in official EU parlance and remain evasive about the strength of the no bailout clause. This part of the model captures well what happened between 2000 and 2008 when spreads on sovereign debts were severely compressed.

Finally, we also characterize the impact of a debt monetization through higher inflation in the monetary union. Debt monetization differs from transfers in the sense that the distortion cost is borne by all Member States. We first show that if debt monetization generates a surplus for the monetary union, it is captured by creditor countries. As in the case of bailouts, the ECB may prefer, ex-post, to monetize the debt rather than let a default occur. Yet because inflation is more distortionary than a direct bailout, our model implies a pecking order in terms of policies : direct fiscal transfers should be used first before debt monetization.

Our paper relates to several literature The theoretical literature on sovereign debt crisis has focused on the following question: why do countries repay their debt? Two different approaches have emerged (see the recent survey by Bulow and Rogoff (2015)). On the one hand, Eaton and Gersovitz (1981) focus on the reputation cost of default for countries that value access to international capital markets to smooth consumption. On the other hand, Cohen and Sachs (1986), Bulow and Rogoff (1989b), Bulow and Rogoff (1989a) and Fernandez and Rosenthal (1990) focus on the direct costs of default in terms of disruption of trade for example. Our model clearly belongs to this second family of models as we emphasize output loss for the country that defaults which comes from trade and financial disruptions but also which may come from the risk of exit of the eurozone. Empirically, Rose (2005) shows that debt renegotiation entail a decline in bilateral trade of around 8 percent a year which persists for around 15 years.

Collateral damage of a sovereign default plays an important role in our analysis of the euro crisis and the existence of efficient ex post transfers. We are not the first to make this point. A related argument can be found in Bulow and Rogoff (1989a) who show that because protracted debt renegotiation can harm third parties, the debtor country and its lenders can extract side-payments. Mengus (2014) shows that if the creditor's government has limited information on individual domestic portfolios, direct transfers to residents cannot be perfectly targeted so that it may be better off honoring the debtor's liabilities. Tirole (2015) investigates ex ante and ex post forms of solidarity. As in our paper, the impacted countries may stand by the troubled country be-

cause they want to avoid the collateral damage inflicted by the latter. A related paper is Farhi and Tirole (2016) which adds a second layer of bailout in the form of domestic bailouts of the banking system by the sovereign to analyze the 'deadly embrace' or two-way link between sovereign and financial balance sheets. The main differences with our paper are that the first paper focuses on the determination of the optimal debt contract, that both rule out strategic default as well as legacy debt and possible debt monetization. Dovis and Kirpalani (2017) also analyze how expected bailouts change the incentives of governments to borrow but concentrate on the conditions under which fiscal rules can correct these incentives in a reputation model. Niepmann and Schmidt-Eisenlohr (2013) analyze how bank bailouts are affected by cross-border contagion costs. Broner, Erce, Martin and Ventura (2014) analyze the eurozone sovereign crisis through a model which features home bias in sovereign debt holdings and creditor discrimination. Our model shares with Broner et al. (2014) the first feature but not the second. In their model, creditor discrimination provides incentives for domestic purchases of debt which itself generate inefficient crowding-out of productive private investment. Uhlig (2013) analyzes the interplay between banks holdings of domestic sovereign debt, bank regulation, sovereign default risk and central bank guarantees in a monetary union. Contrary to this paper, we do not model banks explicitly but the home bias in sovereign bonds plays an important role in the incentive to default. A related paper is also Dellas and Niepelt (2016) who show that higher exposure to official lenders improves incentives to repay due to more severe sanctions but that it is also costly because it lowers the value of the sovereign's default option. Our model does not distinguish private and official lenders

Since the seminal paper of Calvo (1988), a large part of the literature on sovereign default has focused on an analysis of crisis as driven by self-fulfilling expectations (see for example Cole and Kehoe (2000)). This view has been very influential to analyze the euro crisis: this is the case for example of de Grauwe (2012), Aguiar, Amador, Farhi and Gopinath (2015) and Corsetti and Dedola (2014)) for whom the crisis can be interpreted as a rollover crisis where some governments (Spain for example) experienced a liquidity crisis. In this framework, the crisis abates once the ECB agrees to backstop the sovereign debt of eurozone members. For example, Corsetti and Dedola (2014)) analyze a model of sovereign default driven by either self-fulfilling expectations, or weak fundamentals, and analyze the mechanisms by which either conventional or unconventional monetary policy can rule out the former. We depart from this literature and do not focus on situations with potential multiple equilibria and on liquidity issues. This is not because we believe that such mechanisms have been absent but in a framework where the crisis is solely driven by self-fulfilling expectations, the bad equilibrium can be eliminated by a credible financial backstop and transfers should remain "off the equilibrium path". However, we will show in the next section

that transfers (from the EFSF/ESM) to the periphery countries have been substantial and not only to Greece. An important difference between Aguiar et al. (2015) and our work is that they exclude the possibility of transfers and concentrate on the lack of commitment on monetary policy that makes the central bank vulnerable to the temptation to inflate away the real value of its members' nominal debt. We view the lack of commitment on transfers as an distinctive feature of a monetary union and analyze the interaction between the monetary policy and transfers in a situation of possible sovereign default.

The remaining of the paper is organized as follows. In Section 2, we review how bailouts unfolded during the eurozone debt crisis in the different countries and estimate transfers implicit in lending from European countries to Greece, Ireland, Portugal, Cyprus and Spain. The possibility of such transfers is a key element of our theoretical model which we present in section 3. Section 4 analyzes the incentives for defaults and bailouts and section 5 studies how these incentives shape optimal debt issuance. Section 6 then extends the model into two directions: first, the possibility that a country could default but still remain in the eurozone and second the possibility that the ECB monetises the debt. Section 7 concludes.

2 Bailouts and implicit transfers during the Euro area crisis

In this section, we document the lending 'Programmes' for the major borrowers (Cyprus, Greece, Ireland, Portugal, and Spain) which are the basis for our implicit transfer estimates. Corsetti, Erce and Uy (2017) provide a more detailed analysis and description of the development of a euro area crisis resolution framework.

2.1 Bailout programmes

2.1.1 Greece

Greece received three rounds of bailouts. The first round (Programme 1) came from the Eurogroup via the Greek Loan Facility (GLF) and the International Monetary Fund (IMF) between 2010-2011. A second round (Programme 2) came from the European Financial Stability Fund (EFSF) and the IMF between 2012-2015. Finally, a third round (Programme 3), which is still ongoing, came from the European Stability Mechanism (ESM) and began in 2015.

For Programme 1, disbursements by the IMF totaled €20.1 Billion over six tranches.[6] The

[6]The IMF lends in Special Drawing Rights (SDRs). We convert these amounts to Euros by using the EUR/SDR

European Member states committed a total of €80 Billion, although not all was disbursed (Eurogroup, 2010) The first disbursement of Programme 1 occurred in May 2010, and the sixth and final disbursement took place in December 2011. Actual Programme 1 disbursements totaled €52.9 Billion, with Germany (€15.17 Billion), France (€11.39 Billion), and Italy (€10.00 Billion) contributing the most.(**?**).[7]

The original loan agreement stipulated the structure of principal repayment and interest. The maximum maturity was initially set to 5 years. Repayments of principal were subject to a Grace Period during which no repayments had to be made. This Grace Period was initially 3 years from Disbursement Date. As for lending rates, the bilateral loans would be pooled by the European Commission and then disbursed to Greece. The variable lending rate was thus originally based on the 3-month Euribor (to represent borrowing costs), with a margin of 300 basis points for the first three years and 400 basis points thereafter.

The original loan agreement was amended three times: in June 2011, February 2012, and December 2012. (European Financial Stability Fund, 2014, 2015; European Stability Mechanism, 2017) These amendments altered the Grace Period, the maturity structure, and the interest rates. The June 2011 agreement extended the Grace Period to 4.5 years, the maximum maturity to 10 years, and lowered the interest rate margin by 100bp in all years. The February 2012 agreement extended the Grace Period to 10 years, the maximum maturity to 15 years, and lowered the margin to 150 basis points for all years. Finally, the December 2012 agreement extended the maturity to 30 years and lowered the interest rate margin to only 50 basis points each year.

The IMF's lending structure is discussed at length in Joshi and Zettelmeyer (2005). The countries involved in the Eurocrisis are not low-income countries, which means their lending has mostly come through non-concessional facilities. Greece originally borrowed through a Stand-By Arrangements (SBA) where repayment is typically due within 3-5 years. However, eventually all of their borrowing came through the Extended Fund Facility (EFF), which allows for repayment within 4-10 years. Both of these facilities come with conditionality on achieving structural improvements.(International Monetary Fund, 2016) EFF loans permit the maximum amount a country can borrow is 145% of a their quota annually or 435% over the lifetime of a program. Greece was permitted to go over this quota due to special circumstances. The lending rate on all non-concessional facilities is tied to the Basic Rate of Charge, which is the SDR rate plus some premium depending on the size of the loan relative to a country's quota. The margin is 100bp

exchange rate prevailing during the month of the disbursement/repayment/interest payment.

[7] Originally, Ireland and Portugal were slated to contribute to Programme 1. However, their own fiscal struggles caused them to eventually drop out. Slovakia never participated.

for loans less than 187.5% of Quota, 200bp for credit above 187.5% of Quota, and 300bp for credit above 187.5% of Quota for more than 51 months. (International Monetary Fund, 2017)

For Programme 2, actual disbursements by the IMF totalled €8.33 Billion over four tranches, with planned contributions of €28 Billion. The first loan was in 2010 and the last one in May 2010 through Stand-By Arrangements (SBA). The last IMF loan was on June 3, 2014 from the Extended Fund Facility (EFF). The EFSF, on the other hand, committed a total of €144.7 Billion to Programme 2 over 2012-2014. (?) A total of approximately €141.8 Billion was disbursed, although €10.9 Billion was returned, leaving a net outstanding of €130.9 Billion as of May 2017.[8]

Lending rates were calculated as the EFSF cost of funding. The agreement allowed some margin over this cost of funding, which was instituted for some disbursements, although by eventually all such margins were eliminated.[9] Interest payments were also deferred for 10 years for EFSF Loans. In January 2017, the ESM approved a number of adjustments to the EFSF loans. Most importantly, the maturity of the loans was lengthened to "update" the weighted average maturity back to the maximum permitted 32.5 years. However, the agreement also reduced interest rate risk via bond exchanges, swap arrangements, and matched funding.[10]

Greece received one bridge loan from the European Financial Stability Mechanism (EFSM) when it missed a payment on its loans to the IMF in July 2015. This was a three-month loan for €7.16 Billion given to allow Greece time to transition to the third Programme and receive assistance from the ESM. This loan was therefore repaid when ESM assistance was received.

Programme 3 began in 2015 and concluded in August 2018. This programme consists of new loans by the ESM only (although debt relief on earlier loans by other officials has also occurred). The ESM has committed €86 Billion to Greece and has disbursed €31.7 thus far.[11]

On June 22, 2018 the Eurogroup released a statement regarding additional debt relief measures pertaining to the EFSF and ESM programmes for Greece. These measures include two significant changes that affect our calculations. First, for the EFSF programme, interest and amortization is deferred for another 10 years, and the maximum weighted average maturity (WAM) is extended to 42.5 years.[12] Second, for the ESM programme, the step-up margin related to the debt buy-back

[8] The €10.9 Billion consisted of bonds that were to be used to recapitalize Greek banks through the Hellenic Financial Stability Fund.

[9] Originally, interest payments on the debt buyback scheme would be subject to a margin of 200bps per annum beginning in January 2017 (The "Step-Up" Scheme), although this was waived temporarily in January 2017.

[10] Note that we do not take this second factor into account in our calculation of transfers.

[11] There was one cashless loan for bank recapitalization of €5.4 Billion. Note that for this loan, €2.2 Billion has an interim maturity in 2018.

[12] Note that this affects all loans except for the €34.6 billion that included private sector involvement. This is because modifications to these loans would involve negotiations with the private sector.

tranche is eliminated. This step-up margin had been temporarily waived, but now was abolished. The third major change, which is not included in our calculations, is the transfer of approximately €2 billion in profits from the ESM segregated account to Greece. The details of these measures have not been released, and so to implement this agreement in our calculations we adjust the amortization schedule in order to maintain the same linearly increasing rate of the path of redemption for EFSF disbursements to match the new WAM of 42.5 years for all non-private sector disbursements. The accumulated interest payments that are deferred are then bundled into a new disbursement at the end of the deferral period, thereby raising the overall size of the programme.

2.1.2 Ireland

Ireland requested funding in November 2010 and was approved for assistance in December 2010. Total commitments were €85 Billion, comprised of €17.7 Billion from the EFSF, €22.5 Billion from the EFSM, €22.5 Billion from the IMF, and €4.8 Billion from Bilateral Loans (United Kingdom, Sweden, and Denmark).[13] This means €67.5 Billion was committed externally. All committed funds were eventually disbursed.

In February 2011, the EFSF disbursed its first tranche of funding. In December 2013, the final disbursement occurred and the EFSF programme was concluded. The EFSM disbursed its first tranche of funding in January 2011, and their last tranche was disbursed in March 2014. The IMF programme began in January 2011, and the last disbursement was December 2013. Finally, there were also bilateral loans to Ireland. Sweden committed and disbursed €600 Million in four tranches in 2012 and 2013. The United Kingdom committed €3,830 Million (£3.23) in December 2010 and disbursed this amount between October 2011 and September 2013 in 8 disbursements of £403,370,000 each. Denmark offered a loan of €400 Million in four tranches between March 2012 and November 2013. Sweden offered a loan of €600 Million in four tranches between June 2012 and November 2013.

Interest Rates for the EFSM loans were originally equal to cost of funding plus 292.5bp. In October 2011, all EFSM margins were cancelled and average maturities were extended to 12.5 years.(Council of European Union, 2011c) The EFSF loans had interest rates of cost of funding and, like Greece, optional margins set to zero.

For bilateral loans, the interest rate for the UK loans was the "the semi-annual swap rate for Sterling swap transactions.." plus a margin of 229bp per annum.(UK Treasury, 2010) In 2012, the

[13] Ireland also had to commit €17.5 Billion itself, which they pulled from, among other sources, their Pension program.

interest rate was reduced to a service fee of 18bp per annum plus the cost of funding.(UK Treasury, 2012) £7,668,903.59 was rebated to Ireland as a consequence by reducing the interest payment due at the following interest payment date. The interest rate on Sweden and Denmark loans was tied to the 3-month Euribor rate plus a margin of 100bp.

2.1.3 Portugal

Portugal requested aid from the EFSF, the IMF, and the European Union via the EFSM in April, 2011 and was approved for a programme in May 2011. Portugal officially exited in June 2014 when they allowed the programme to lapse without taking the final tranche of funding available. The three groups each committed approximately €26 Billion for a total of €78 Billion. (European Commission, 2016)

Lending Rates for the EFSF were equal to the EFSF Cost of Funding plus a Margin, which was equal to 0. For the EFSM, the original agreement in May 2011 stipulated the loans would have an average maturity of 7.5 years and a margin of 215bp on top of the EU's cost of funding. In 2011 Portugal the average maturities of Portugal's EFSM loan were extended to 12.5 years and margins were eliminated.(Council of European Union, 2011b) In 2013, the averag maturities were again extended to 19.5 years.(Council of European Union, 2011a) IMF lending terms are described above.

2.1.4 Cyprus

Cyprus officially asked for assistance in 2012 and was approved for a programme in April/May 2013. Cyprus officially exited its programme in March 2016. The program's total financing envelope was €10 Billion, with the ESM committing €9 Billion and the IMF committing approximately €1 Billion. In total, The ESM disbursed €6.3 Billion between May 2013 - October 2015, while the IMF disbursed all of its commitment.(European Stability Mechanism, 2016) IMF lending terms are described above.

2.1.5 Spain

Spain received assistance from only the ESM. Loans were approved in July 2012, with two disbursements in December 2012 and February 2013. The committed €100 Billion, although only €41.3 Billion was used. The assistance came in the form of bonds, which were used to recapitalize the banking sector. Spain has made some voluntary early repayments on these loans.(European Stability Mechanism, 2013)

2.2 Transfers estimates

2.2.1 Methodology

To estimate transfers implicit in the programs described above, we follow Joshi and Zettelmeyer (2005) who perform a similar exercise for transfers implicit in IMF programs and use the data on interest payments of Corsetti et al. (2017). A key issue the extent of default risk on these loans and therefore what is the appropriate interest rate to discount cash flows. A first estimate of transfers was attempted by the European Stability Mechanism itself (see European Stability Mechanism (2014) and European Stability Mechanism (2015) reports). The discount rate they used was the market interest rate that crisis countries would have paid had they been able to cover their financing needs from private investors. Using these market rates, however, overlooks the possibility that ESM loans are less risky than loans by private creditors and therefore produces estimates of transfers which we believe are too large. In fact, if the ESM loans are risk free and the ESM charges a risk-free rate, then there is no implicit transfer, regardless of the market rate on risky loans. Contrary to the ESM, we assume that the default risk of European loans to crisis countries is similar to the default risk on IMF loans to these countries during the crisis. Hence, we first compute the internal rate of return of the IMF loans for each country under an IMF program and use it to discount cash flows of European loans.

There are two reasons why this approach will provide a lower bound of the implicit transfer. First, IMF programs are relatively short to medium term (3 to 9 years for Cyprus, Greece, Ireland and Portugal) while European loans have a longer duration (10 to 30 years). To the extent that there is a positive term premium, we are underestimating the net-present value of the program. Second, if anything, the risk of default on IMF loans is lower than that of European loans. Therefore, the correct discount rate on European loans should be higher than the IMF internal rate, further increasing the net present value.[14]

To estimate the NPV of total transfers $Tr_t^{i,j}$ for borrower i and creditor j at time t, we calculate the difference between the present value of the sequence of net transfers discounted at some benchmark internal rate of return and the present value of the sequence of net transfers discounted at its actual internal rate of return. By definition, this latter term is zero, and so we

[14]The similarity of seniority status of ESM and IMF loans is explicit in the ESM Treaty but it also recognises that IMF loans are more senior: "ESM loans will enjoy preferred creditor status in a similar fashion to those of the IMF, while accepting preferred creditor status of the IMF over the ESM."

can write the transfer as

$$Tr_{t_0}^{i,j} = \sum_{t=t_0}^{T} \frac{1}{(1+irr^{i,IMF})^t} NT_t^{i,j} \tag{1}$$

where t_0 is 2010 and T is the date of the last net transfer flow (always a repayment). As explained above we use the internal rate of return on the IMF's lending for borrower i during the Eurozone crisis, $irr^{i,IMF}$, as the discount rate. $NT_t^{i,j}$ are net transfers from lender j to borrower i at time t.

We follow Joshi and Zettelmeyer (2005) and construct net transfers as:

$$NT_t^{i,j} = D_t^{i,j} - R_t^{i,j} - i_{t-1}^{i,j}(D^o)_{t-1}^{i,j} - \ldots - i_{t-\tau}^{i,j}(D^o)_{t-\tau}^{i,j}$$

where $R_t^{i,j}$ are repayments and $D_t^{i,j}$ disbursements. τ denotes the maturity of each disbursement. D^o is the *outstanding* balance remaining on each disbursement. Then, the internal rate of return $irr^{i,j}$ is the value that sets the sequence of net transfers to zero. The series of net transfers $NT_t^{i,j}$ is also used to calculate the size of the present discounted value of the transfer.

To calculate the internal rates of return, we follow Joshi and Zettelmeyer (2005). We begin by establishing a *lending cycle* for each country-lender pair. A lending cycle is a sequence of disbursements, repayments, and interest payments between a lender and a borrower during which the level of outstanding debt is positive. Unlike Joshi and Zettelmeyer (2005), who in some cases have multiple lending cycles per country-IMF pair, we only have one lending cycle for each country as, once a country requested assistance, they have since maintained an outstanding balance.

We compile data on disbursements, repayments, and interest payments for five borrowing countries, four official international lenders[15]. The borrowing countries are Cyprus, Greece, Ireland, Portugal, and Spain, who each requested assistance from at least one European multilateral institution. The four international lenders are the International Monetary Fund (IMF), European Financial Stability Fund (EFSF), European Stability Mechanism (ESM), and the European Financial Stability Mechanism (EFSM). We also compile data on the bilateral loan agreements that constituted the first round of financing for Greece from the Greek Loan Facility. More information can be found in Appendix A.

We make two key assumptions when calculating the internal rates of return. The first key assumption is that the current specification of repayments and interest rates will coincide with the realized outcome, and there will be no more debt renegotiations. Any changes to the current

[15]There were also bilateral loans to Ireland during the crisis from the United Kingdom, Sweden, and Denmark. These loans small relative to the other assistance, and so we leave them out of the analysis for now.

agreement that makes the terms more favorable for Greece, such as delaying interest payments or extending the overall maturity, would result in a larger transfer than we calculate. The second key assumption is that for loans with variable interest rates that depend on the international institutions borrowing rate, we assume that they can roll over debt at the same interest rate. Whether the current environment featuring low global interest rates is here to stay is beyond the scope of this paper, but if global interest rates were to rise, both the IMF and the Europeans lenders would most likely be affected similarly. Hence, it is unlikely that these changes in the interest rate are a source of concern in our estimation.

2.2.2 Results

Our results are given in Table 1. The first column shows the calculated internal rate of return for the given borrower-lender pair i, j. The second column reports the IMF internal rate of return for borrower i, which is used in our calculations as discount rate. Note that this is simply repeated for reference from the IMF row by country. The third column shows the difference between the IMF internal rate of return and the loan's internal rate of return, and is simply the second column minus the first column. With the notable exception of the EFSF loan to Ireland, the IMF internal rate of return is always higher, which implies a transfer element from European institutions.[16]

The fourth column displays the duration of the lending cycle, d, following the methodology in Joshi and Zettelmeyer (2005). The duration of the lending cycle between borrower i and lender j, $d^{i,j}$, is calculated as

$$d^{i,j} = \sum_{t=1}^{T} \frac{\text{Repayment}^{i,j} \text{in Period t}}{\text{Total Repayment}^{i,j}} \cdot t$$

For all countries, we know that the IMF has lent at a much shorter duration even in those cases where they have lent a similar nominal amount to other European lenders. The maturity differences also suggest a transfer element. The next column shows the sum of all nominal disbursements $\sum D^{i,j}$, in €Billion.

The last two columns shows our estimate of the NPV transfers from Equation 1, first in billions of Euros and then as a percentage of the country's 2010 GDP. A striking element is that transfers differ substantially from one country to another. Two countries stand out. First, Ireland which received no transfer. We even estimate a very small negative one. However, remember that our estimates can be considered as lower bounds so we interpret the Irish case as one without transfer. At the other extreme, Greece received a very substantial transfer which amounts (putting together

[16] For Spain, who did not receive any IMF loans, we take the simple average of the other IMF rates.

Borrower i	Lender j	$irr^{i,j}$	$irr^{i,IMF}$	$\Delta irr^{i,j}$	$d^{i,j}$	$\sum D^{i,j}$	$Tr^{i,j}$	$Tr^{i,j}/GDP^i$
Cyprus	ESM	0.89	1.71	0.82	15.48	6.30	0.66	3.25%
Cyprus	IMF	1.71	1.71		8.78	0.95		
Greece	EC	1.06	3.16	2.09	20.66	52.90	15.49	6.85%
Greece	EFSF	0.69	3.16	2.47	30.06	167.05	66.39	28.01%
Greece	EFSF_PreJune	0.98	3.16	2.18	29.37	154.23	57.98	24.46%
Greece	ESM	1.63	3.16	1.52	33.81	61.90	17.47	7.67%
Greece	IMF	3.16	3.16		6.82	31.99		
Ireland	EFSF	2.28	2.48	0.20	21.98	17.70	0.54	0.31%
Ireland	EFSM	3.17	2.48	-0.70	16.04	22.50	-1.84	-1.07%
Ireland	IMF	2.48	2.48		5.37	22.61		
Portugal	EFSF	2.08	3.29	1.21	21.92	26.00	4.43	2.38%
Portugal	EFSM	3.04	3.29	0.25	15.64	24.30	0.66	0.36%
Portugal	IMF	3.29	3.29		7.15	26.39		
Spain	ESM	0.83	2.66	1.82	9.14	41.33	5.87	0.51%

Table 1: Implicit Transfers from European Union Funding Programs

The table reports the internal rate of return ($irr^{i,j}$) for each recipient country i and funding agency j, the duration of the program ($d^{i,j}$), the total (nominal) amount disbursed ($\sum D^{i,j}$), the implicit transfer $Tr^{i,j}$ in billions of euros and scaled by 2010 nominal GDP.

RC, EFSF, and ESM lending) to more than 40% of GDP. For Portugal and Cyprus the transfer is positive and a bit more than 3% of GDP. In the case of Spain, where lending was directed towards bank recapitalization and therefore is different in nature from other countries, the transfer is less than 1% of GDP.

Our lower bounds estimates of implicit transfers during the euro crisis show that transfers, of very different size to different countries, were a central part of the crisis resolution. We now present a model that analyzes how these transfers emerge during a crisis.

3 Model

3.1 Assumptions

The baseline model is similar to Calvo (1988). Consider a world with 2 periods, $t = 0, 1$ and three countries. We label the countries g, i and u. g and i belong to a monetary union, unlike u. g is a fiscally strong country in the sense that its government debt is risk-free. Instead, i is fiscally fragile: the government may be unable or unwilling to repay its debts either in period 0 or period

1. Countries can have different sizes, denoted ω^j with $\sum_j \omega^j = 1$.

Each country/region j receives an exogenous endowment in period t denoted y_t^j. The only source of uncertainty in the model is the realization of the endowment in i in period 1, y_1^i. We assume that $y_1 = \bar{y}_1^i \epsilon_1^i$ where $E[\epsilon_1^i] = 1$, so $\bar{y}_1^i$ represents expected total output in i, and we can interpret ϵ_1^i as the output gap in i in period 1. Lastly, we assume that ϵ_1^i is distributed according to some cdf $G(\epsilon)$ and pdf $g(\epsilon)$, with a bounded support $[\epsilon_{\min}, \epsilon_{\max}]$, with $0 < \epsilon_{\min} < \epsilon_{\max} < \infty$.

In each country j, a representative agent has preferences defined over aggregate consumption c_t^j and government bond-holdings $\{b_t^{k,j}\}_k$ as follows:

$$U^j = c_0^j + \beta E[c_1^i] + \omega^j \lambda^s \ln b_1^{s,j} + \omega^j \lambda^{i,j} \ln b_1^{i,j}$$

The first part of these preferences is straightforward: households are risk neutral over consumption sequences. In addition, we assume that government bonds provide 'money-like' liquidity services that are valued by households (cf. evidence for US Treasuries from Krishnamurthy and Vissing-Jorgensen). We model these liquidity services in a very simple way, by including bond-holdings in the utility function. Crucially, we consider that bonds from different countries provide different levels of liquidity services, depending on how 'safe' or 'money-like' these bonds are perceived to be for different classes of investors. One potential interpretation is that different government bonds can be used as collateral in various financial transactions and are therefore valued by market participants beyond their financial yield. We don't propose here a theory of what makes some government bonds safe and others not, we simply take as given that:

- u and g bonds are perceived as equally safe and liquid. It follows that they are perfect substitutes and we can consider the total demand for *safe* assets by households in country j, denoted $b_1^{s,j} \equiv b_1^{g,j} + b_1^{u,j}$. Given our assumptions, if aggregate safe bond holdings increase by 1%, aggregate utility in country j increases by $\omega^j \lambda^s / 100$.
- We denote the demand for i-bonds from investors in country j by $b_1^{i,j}$. i-bonds may offer different degrees of liquidity to u investors, g investors and i investors. A reasonable assumption is that i-bonds provide higher liquidity services to i investors, then g investors, then u investors. That is, we assume that $\lambda^{i,i} > \lambda^{i,g} > \lambda^{i,u}$.

It seems quite natural that i investors perceive i debt as more liquid/safe than other investors. For instance, one could argue that i banks optimally discount the states of the world where their

own government defaults because they themselves would have to default. The next section provides a fleshed out model of this risk-shifting. The assumption that g bond holders get more liquidity from i debt holdings than u investors could reflect the fact that g banks can obtain liquidity against i bonds from the common monetary authority at favorable terms. In other words, we view the assumption that $\lambda^{i,g} < \lambda^{i,u}$ as a consequence of the monetary union between i and g.[17] We will consider later how changes in perceptions of the liquidity services provided by i bonds (circa 2008-2009) affects equilibrium debt and bailout dynamics.

In order to simplify a number of expressions, we will often consider the *bondless limit* that obtains when $\lambda^s \to 0$ and $\lambda^{i,j} \to 0$, while keeping the ratios $\omega^j \lambda^{i,j} / \sum_k \omega^k \lambda^{i,k}$ constant.[18] In this limit, as we will see, the bond portfolios remain well defined, but the liquidity services become vanishingly small, so the level of debt does not directly affect utility.

Countries i and g differ in their fiscal strength. We assume that g is fiscally sound, so that its debt is always safe. Instead, i is fiscally fragile: it needs to refinance some external debt in period $t = 0$, and can decide to default in period $t = 1$. Should a default occurs, we follow the literature and assume that i suffers an output loss equal to Φy_1^i with $0 \leq \Phi \leq 1$. This output loss captures the disruption to the domestic economy from a default. There are many dimensions to the economic cost of a default. In particular, for i, a default may force the country to exit the monetary union, potentially raising default costs substantially. One way to capture this dimension is to assume that $\Phi = \Phi_d + \Phi_e$ where Φ_d is the share of lost output if the country defaults but remains in the currency union, and Φ_e is the additional share of lost output from a potential exit, conditional on a default. While Φ_d might be low, Φ_e could be much larger.[19] We assume that the default cost is proportional to output, so that, everything else equal, a default is less likely when the economy is doing well.

In case of a default, we assume that creditors can collectively recover an amount ρy_1^i where $0 \leq \rho < 1$. This assumption captures the fact that i's decision not to repay its debt does not generally result in a full expropriation of outstanding creditor claims. Importantly, the amount recovered is proportional to output, and not to the outstanding debt, capturing the idea that i can

[17] Note that it is not necessarily the case that a monetary union implies that i debt is more valuable to g investors than u investors. In practice, though, this seems to have been the case. See Buiter et al. (XXX)

[18] The terminology here is by analogy with Woodford's cashless limit where the direct utility gains from money holdings become vanishingly small.

[19] Section 6.2 considers separately the possibility of a sovereign default and an exit from the currency union.

only commit to repay a fraction of its output. An alternative interpretation is that ρy_1^i represents the collateral value of the outstanding debt. The recovery payment is distributed *pari passu* among all creditors , domestic and foreign, in proportion to their initial debt holdings. We assume that $\Phi + \rho < 1$ so that the country always has enough resources for the recovery amount in case of default.[20]

In addition, we assume that g also suffers a collateral cost from a default in i, equal to κy_1^g, with $0 \leq \kappa \leq 1$, while u does not suffer any collateral damage. There are two ways to interpret this assumption. First, it captures the idea that the economies of countries g and i are deeply intertwined since they share a currency, so that a default in i would disrupt economic activity in g as well, to a greater extent than u. In addition, we can imagine that the contagion cost would be much higher if, as a consequence of its default, i is forced to exit the common currency. By analogy with the cost of default for i, we could write $\kappa = \kappa_d + \kappa_e$, where κ_e captures the expected cost of an exit, conditional on a default. Countries outside the monetary union would not face the higher levels of economic disruption caused by a collapse of the monetary union.

As in Tirole (2015), the contagion cost creates a *soft budget constraint* for country i. Our interpretation is that this 'collateral damage' was at the heart of the discussions regarding bailout decisions in the Eurozone. For instance, the decision to bailout Greece in 2010 and avoid a debt restructuring was directly influenced by the perception that a Greek debt restructuring could have propagated the fiscal crisis to other economies in the Eurozone. For instance, it was argued that the economies of Spain, Italy, Portugal or Ireland could have suffered an adverse market reaction. It was also argued that a Greek restructuring could hurt France or Germany through the exposure of their banking system to Greek sovereign risk. Implicitly, a common perception at the time was that bailing out Greece -so that the Greek government could in turn repay French and German banks– was preferable to a default event where German and French governments would have needed to directly recapitalize the losses of their domestic banks on their Greek portfolio. The term κy_1^g captures the additional cost of a default for g above and beyond the direct portfolio exposure $b_1^{i,g}$.

Finally, we allow for ex-ante and ex-post voluntary transfers τ_t from g to i. Crucially, we consider an environment where g can make ex-post transfers to i conditional on the realization of

[20] This condition also ensures that i's consumption is always positive.

output, and also on i's default decision. Because these transfers are voluntary, they must satisfy: $\tau_t \geq 0$. Since there is no reason for g to make a transfer to i in case of a default, the optimal transfer in that case is zero.

3.2 Budget Constraints

3.2.1 Households

The budget constraints of the households of the different regions are as follows. First consider i's household in period $t = 0$:

$$c_0^i + b_1^{i,i}/R^i + b_1^{s,i}/R^* \quad = \quad y_0^i - T_0^i + b_0^{i,i} + b_0^{s,i}$$

while in period $t = 1$:

$$\begin{cases} c_1^i = y_1^i - T_1^i + b_1^{i,i} + b_1^{s,i} & \text{if } i \text{ repays} \\ c_1^i = y_1^i(1-\Phi) - T_1^i + \rho y_1^i \dfrac{b_1^{i,i}}{b_1^i} + b_1^{s,i} & \text{if } i \text{ defaults} \end{cases}$$

In period $t = 0$, i's representative household consumes, invests in domestic and safe debt. Its revenues consist of after tax income $y_0^i - T_0^i$ where T_0^i denotes lump-sum taxes levied by i's government. R^i denotes the yield on the Italian debt, while R^* is the yield on safe debt. In period $t = 1$, the household consumes after tax income, and liquidates its bond portfolio. In case of default, it suffers the direct cost Φy_1^i and recovers only $\rho y_1^i / b_1^i$ per unit of domestic bond purchased. Note that period 1 taxes T_1^i are state contingent and can depend on the realization of output and the decision to default.

Now consider g's household. Using similar notation, the budget constraint in period $t = 0$ is:

$$c_0^g + b_1^{i,g}/R^i + b_1^{s,g}/R^* \quad = \quad y_0^g - T_0^g + b_0^{i,g} + b_0^{s,g}$$

and that in period $t = 1$ takes the form:

$$\begin{cases} c_1^g = y_1^g - T_1^g + b_1^{i,g} + b_1^{s,g} & \text{if } i \text{ repays} \\ c_1^g = y_1^g(1-\kappa) - T_1^g + \rho y_1^i \dfrac{b_1^{i,g}}{b_1^i} + b_1^{s,g} & \text{if } i \text{ defaults} \end{cases}$$

As in the case of i, taxes raised in $t = 1$, T_1^g, are state contingent.

A similar set of budget constraints hold for investors from the rest of the world. We omit them from simplicity.

3.2.2 Governments

We now write the budget constraints of the governments in i and g.[21]

The budget constraints for i's government in periods $t = 0$ and $t = 1$ are respectively:

$$T_0^i + b_1^i/R^i + \tau_0 \quad = \quad b_0^i$$

and

$$\begin{cases} T_1^i + \tau_1 = b_1^i & \text{if } i \text{ repays} \\ T_1^i = \rho y_1^i & \text{if } i \text{ defaults} \end{cases}$$

In these expressions, τ_t is the direct unilateral transfer from g's government to i's government in period t. As discussed previously, ex-post transfers τ_1 can be made conditional on the decision to default by i. In principle, g's government can make a transfer to i either *ex-ante*, so as to reduce the debt overhang that i is likely to face, or *ex-post* once i is facing the possibility of default.

The budget constraints for g's government are:

$$T_0^g + b_1^g/R^* \quad = \quad b_0^g + \tau_0$$

and

$$\begin{cases} T_1^g = b_1^g + \tau_1 & \text{if } i \text{ repays} \\ T_1^g = b_1^g & \text{if } i \text{ defaults} \end{cases}$$

3.3 Market Clearing

The markets for safe bonds and i-bonds clear. The following equilibrium conditions obtain:

$$\sum_j b_1^{i,j} = b_1^i \quad ; \quad \sum_j b_1^{s,j} = b_1^s \tag{2}$$

[21] There is no role for the government in the rest of the world so we ignore it. One can check that under the assumption that $\alpha^{i,g} \geq \alpha^{i,u}$ and $\kappa \geq 0$, it is never optimal for u to make a transfer. The proof consists in checking that u never wants to make a transfer when g doesn't.

3.4 Optimal Portfolios without Discrimination

Denote $\mathcal{P}^j \leq 1$ the expected payment per unit of i's sovereign debt for j's household, given the optimal choice of default rate in period $t = 1$. If i cannot discriminate between different types of bondholders when defaulting, this expected payoff is the same for all investors: $\mathcal{P}^j = \mathcal{P}$. It follows that the first-order conditions for the choice of debt by households are:

$$\begin{aligned} \frac{1}{R^i} - \beta\mathcal{P} &= \frac{\omega^i \lambda^{i,i}}{b_1^{i,i}} = \frac{\omega^g \lambda^{i,g}}{b_1^{i,g}} = \frac{\omega^u \lambda^{i,u}}{b_1^{i,u}} \\ \frac{1}{R^*} - \beta &= \frac{\omega^i \lambda^{s}}{b_1^{s,i}} = \frac{\omega^g \lambda^{s}}{b_1^{s,g}} = \frac{\omega^u \lambda^{s}}{b_1^{s,u}} \end{aligned}$$

Denote $\bar{\lambda}^i \equiv \sum_k \omega^k \lambda^{i,k}$. Using the bond market clearing condition, the aggregate share $\alpha^{i,j}$ of i's debt held by country j satisfies:

$$\alpha^{i,j} \equiv \frac{b_1^{i,j}}{b_1^i} = \frac{\omega^j \lambda^{i,j}}{\bar{\lambda}^i} \tag{3}$$

Similarly derivations for safe bonds yield:

$$\alpha^{s,j} = \omega^j \tag{4}$$

In the absence of selective default, the model implies that equilibrium portfolio shares are proportional to relative liquidity benefits of i debt across investor classes. To understand the intuition for this result, observe that all investors expect the same payment per unit of debt, $\beta\mathcal{P}$, and pay the same price, $1/R^i$. Hence, difference in equilibrium portfolios must arise entirely from differences in the relative liquidity services provided by the bonds, i.e. $\omega^j \lambda^{i,j}/\bar{\lambda}^i$. These shares don't depend on the riskiness of i's debt and remain well defined in the *bondless limit*.

For safe assets, liquidity services are the same, up to size differences. It follows that equilibrium portfolios only reflect size differences with larger countries holding more safe assets.[22]

[22] Since equilibrium portfolios are constant regardless of the riskiness of the bonds, our benchmark portfolio allocation cannot replicate the large shifts in cross-border bond holdings observed first after the introduction of the Euro (globalization), then following the sovereign debt crisis (re-nationalization). In the benchmark version of the model, this re-nationalization can only occur if the liquidity services provided by i's debt to i's banks ($\lambda^{i,i}$) increases, or if the liquidity services provided by i's debt to foreign banks ($\lambda^{i,g}$ or $\lambda^{i,u}$) decrease. A possible extension, left for future

Finally, we can rewrite the equilibrium conditions as:

$$\frac{1}{R^*} = \beta + \frac{\lambda^s}{b_1^s} \quad ; \quad \frac{1}{R^i} = \beta\mathcal{P} + \frac{\bar{\lambda}^i}{b_1^i} \tag{5}$$

The first expression indicates that the yield on safe debt can be lower than the inverse of the discount rate $1/\beta$ because of a liquidity premium that is a function of λ^s/b_1^s. As the supply of safe debt increases, this liquidity premium decreases, as documented empirically by Krishnamurthy and Vissing-Jorgensen (2012). Similarly, the yield on i's debt decreases with the liquidity services equal to $\bar{\lambda}^i/b_1^i$, but increases as the expected payoff per unit of i's debt $\mathcal{P}$ decreases.

In the *bondless limit* these expressions simplify and we obtain:

$$R^* = \beta^{-1} \quad ; \quad R^i = (\beta\mathcal{P})^{-1}$$

In that limit case, portfolio holdings remain determined by (3) and (4) but the liquidity premium on safe debt disappears and the premium on i's debt reflects entirely default risk ($\mathcal{P} \leq 1$).

4 Defaults and Bailouts in $t = 1$

We solve the model by backward induction, starting at $t = 1$. In the final period, i's government can unilaterally decide to repay its debt or default after observing the realization of the income shock ϵ_1^i, taking as given the transfer τ_1 it would receive from g's government if it decides to repay. Consolidating the budget constraint of i's government and households, a government maximizing the welfare of domestic agents will decide to repay its debts when:

$$y_1^i \left[\Phi + \rho(1 - \alpha^{i,i})\right] + \tau_1 \geq b_1^i(1 - \alpha^{i,i}) \tag{6}$$

This equation has a natural interpretation. The left hand side captures the cost of default for i's government. This cost has three components. First there is the direct disruption to the domestic economy captured by Φy_1^i. Second there is the fact that, even if default occurs, the country will have to repay a fraction ρ of output to foreign investors, holding a fraction $1 - \alpha^{i,i}$ of marketable debt. Lastly there is the foregone transfer τ_1. Against these costs, the benefit of default consists in not repaying the outstanding debt to foreign investors, both insider the monetary union and

work, would allow for either discrimination in default or differential bailout policies, so that $\mathcal{P}^i \neq \mathcal{P}^j$.

in the rest of the world: $b_1^i(1-\alpha^{i,i})$. Intuitively, default is more likely if the direct cost of default is low, the recovery rate is low, transfers are low, and a larger fraction of the public debt is held abroad.

Condition (6) puts a floor under the promised transfer necessary to avoid a default:

$$\tau_1 \geq b_1^i(1-\alpha^{i,i}) - y_1^i\left[\Phi + \rho(1-\alpha^{i,i})\right] \equiv \underline{\tau}_1$$

Since transfers are voluntary, there is a minimum realization of the shock ϵ_1^i such that repayment is optimal, even in the absence of transfer:

$$\epsilon_1^i \geq \frac{(1-\alpha^{i,i})b_1^i/\bar{y}_1^i}{\Phi + \rho(1-\alpha^{i,i})} \equiv \bar{\epsilon} \tag{7}$$

Intuitively, $\bar{\epsilon}$ increases with the ratio of debt held by foreigners to expected output, $\left(1-\alpha^{i,i}\right) b_1^i/\bar{y}_1^i$, and decreases with the cost of default Φ or the recovery rate ρ. A larger fraction of i's public debt held by domestic investors makes default less appealing to i's government since a default becomes a zero sum transfer from domestic bondholders and domestic taxpayers. In the limit where i's debt is entirely held domestically, ($\alpha^{i,i}=1$), there is never any incentive to default regardless of the realization of output: $\bar{\epsilon}=0$.

This result suggests one important implication of the re-nationalization of bond markets: everything else equal, it decreases the ex-post likelihood of default. Hence in our model there is no *deadly embrace* between sovereigns and bondholders. In Farhi and Tirole (2016), the deadly embrace arises from the distorted incentives of domestic banks to hold debt issued by their own sovereign, creating an enhanced contagion channel from banks to sovereigns and vice versa, a channel that is absent in this paper.

Let's now consider the choice of optimal ex-post transfers by g. When $\epsilon_1^i < \bar{\epsilon}$, a transfer becomes necessary to avoid default. Given our assumptions, g makes the minimum transfer required to avoid a default: $\tau_1 = \underline{\tau}_1$.[23] Substituting $\underline{\tau}_1$ into g's consolidated budget constraint, we find that g's government will prefer to make a transfer as long as:

$$\Phi y_1^i + \kappa y_1^g \geq \alpha^{i,u}\left(b_1^i - \rho y_1^i\right) \tag{8}$$

[23] We assume that if i is indifferent between default and no-default, it chooses not to default.

The left hand side of (8) measures the overall loss from default for the monetary union. It consists of the sum of the direct cost Φy_1^i for i and the contagion cost κy_1^g for g. The right hand side measures the overall benefit of default: from the point of view of the monetary union, the benefits of default consists in not repaying the rest of the world and economizing $\alpha^{i,u}(b_1^i - \rho y_1^i)$.

Equation (8) makes clear that g's transfers are *ex-post efficient* from the joint perspective of g and i. The difference between the left and right hand side of equation (8) represents the surplus from avoiding a default. Under our assumption that g makes a take-it-or-leave-it offer to i, g is able to appropriate the entirety of the ex-post surplus from avoiding default.[24]

We can solve equation (8) for the minimum realization of ϵ_1^i such that a transfer (and no-default) is optimal. This defines a threshold $\underline{\epsilon}$ below which default is jointly optimal:

$$\epsilon_1^i \leq \frac{\alpha^{i,u} b_1^i/\bar{y}_1^i - \kappa y_1^g/\bar{y}_1^i}{\Phi + \rho\alpha^{i,u}} \equiv \underline{\epsilon} \tag{9}$$

Based on the discussion above, we make the following observations about equation (9):

- First, it can be immediately checked that $\underline{\epsilon} \leq \bar{\epsilon}$ as long as $\alpha^{i,g} \geq 0$ or $\kappa \geq 0$. In other words, as long as g is exposed directly (through its portfolio) or indirectly (through contagion) to i's default, it has an incentive to offer ex-post transfers.
- It follows immediately that an ex-ante no-transfer commitment - such as a no-bailout clause- is not *renegotiation proof* and therefore will be difficult to enforce.
- It is also immediate from (8) that g will always be willing to bailout i, regardless of its debt level, if $\alpha^{i,u} = 0$, that is if all of i's debt is held within the monetary union, as long as i's default is costly, either for i or g.[25]

[24] One could imagine an alternative arrangement where i and g bargain over the surplus from avoiding default. Depending on its bargaining weight, i may be able to extract a share of the surplus, reducing the gain to g. In that case, ex-post efficiency would still obtain, but i's utility would increase relative to default. We analyze this extension in section 6.1. If output is observable, we believe that it is reasonable to assume that g has the strongest bargaining power. We can rationalize this assumption by noting that a larger bargaining weight for creditor countries would arise naturally in a repeated bargaining environment a la Rubinstein and the creditor country is more patient than the debtor country. A related argument arises if a lengthy bargaining process was more costly for the debtor than for the creditor country both politically and economically. Alternatively, one could consider what happens if ϵ_1^i is not perfectly observable. In that case, i would like to claim a low realization of output in order to extract a larger bailout. It would then be in the interest of g to verify the realization of the state whenever i would request a bailout. In practice, this is often what happens (cf. Greece and the monitors from the 'Troika').

[25] Of course, in anticipation of the next section, in that case i would want to issue so much debt in period $t = 0$

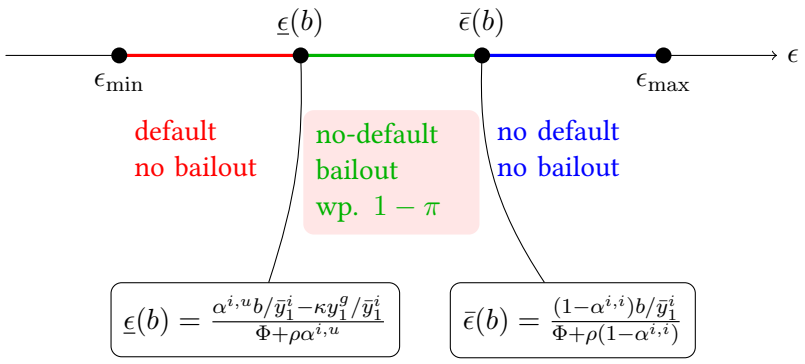


Figure 1: Optimal Ex-Post Bailout Policy.

- The threat of collateral and direct damage to g from i's default relaxes ex-post i's budget constraint, a point emphasized also by Tirole (2012).

- Lastly, because g offers the minimum transfer $\underline{\tau}_1$ to avoid a default, it becomes a residual claimant and captures the entire surplus from avoiding default. When $\underline{\epsilon} \leq \epsilon_1^i < \bar{\epsilon}$, i receives a positive transfer but achieves the same utility as under default. In these states of the world, i's consumption in period $t = 1$ is given by

$$c_1^i = y_1^i(1 - (\Phi + \rho(1 - \alpha^{i,i}))) + b_1^{s,i}$$

  This captures an important effect in our model, which we call the *Southern view* of the crisis: the ex-post support that i receives from g does not make i better off. It avoids the deadweight losses imposed by a default, but g captures *all* the corresponding efficiency gains.

The previous discussion fully characterizes the *optimal* ex-post transfer τ_1, default decisions and consumption patterns in both countries and is summarized in Figure 1.

We already noted that the transfer τ_1 is ex-post optimal from the point of view of g. However, it is important to recognize that it may be difficult for g to implement such transfers. For instance, the institutional framework may prevent direct transfers from one country to another. It may also make be difficult for an institution like the Central Bank to implement such a transfer on behalf

that this would eventually threaten g's fiscal capacity. In what follows we always assume that $\alpha^{i,u} > 0$ and that g has sufficient fiscal capacity to make the necessary transfers.

of g (we explore this possibility in more details in the next section).

These 'no-bailout' clauses have repeatedly been invoked and played an important role in shaping the response to the Eurozone crisis. For instance, the legality of proposed bailout programs has often been questioned and referred to the German constitutional court (the Karlsruhe court), or the European Court of Justice. From pour point of view, the important observation is that the political process contains a certain amount of uncertainty, since it is not known ex-ante how the legal authorities will rule on these matters.

We also note that, even though a bailout from g to i is renegotiation proof in our static model, it may not be optimal from a dynamic perspective. Indeed we will see that in some cases g may prefer ex-ante to commit not to bailout i ex-post.

We capture both the political uncertainty and the attempt to achieve some form of ex-ante commitment with an exogenous parameter π, denoting the probability that ex-post transfers will *not* be implemented, even when they are ex-post in the best interest of both parties. By varying π, we nest the polar cases of full commitment ($\pi = 1$) and full discretion ($\pi = 0$).

The following table summarizes the transfers in period $t = 1$ depending on the realization of the shock ϵ_1.

	ex-post transfer	default	ex-post transfer τ_1
$\epsilon_1 < \underline{\epsilon}$		yes	0
$\underline{\epsilon} \leq \epsilon_1 < \bar{\epsilon}$	ruled out	yes	0
$\underline{\epsilon} \leq \epsilon_1 < \bar{\epsilon}$	authorized	no	$b_1^i(1-\alpha^{i,i}) - y_1^i \left[\Phi + \rho(1-\alpha^{i,i})\right]$
$\bar{\epsilon} \leq \epsilon_1$		no	0

Observe that the optimal transfer is discontinuous at $\epsilon_1^i = \underline{\epsilon}$. The reason is that a large transfer to i is necessary to avoid a default at that point. A default occurs either if $\epsilon < \underline{\epsilon}$ or when $\underline{\epsilon} < \epsilon_1^i \leq \bar{\epsilon}$ and ex-post transfers are ruled to be illegal. The ex-ante probability of default is then given by:

$$\pi_d = G(\underline{\epsilon}) + \pi(G(\bar{\epsilon}) - G(\underline{\epsilon})) \tag{10}$$

5 Debt Rollover Problem at $t = 0$

5.1 The Debt Laffer Curve.

We now turn to the choice of optimal debt issuance at period $t = 0$, taking the ex-ante transfer τ_0 and initial debt level b_0 as given. If debt with notional value b_1^i has been issued at $t = 0$, then the expected repayment $\mathcal{P}b_1^i$ is given by:

$$\mathcal{P}b_1^i = (1 - \pi_d)b_1^i + \rho\bar{y}_1^i \left(\int_{\epsilon_{\min}}^{\underline{\epsilon}} \epsilon dG(\epsilon) + \pi \int_{\underline{\epsilon}}^{\bar{\epsilon}} \epsilon dG(\epsilon) \right)$$

This expression has three terms. First, if country i does not default (with probability $1 - \pi_d$), it repays at face value. If default occurs, investors recover instead ρy_1^i. This can happen either because default is ex-post optimal (when $\epsilon_1^i < \underline{\epsilon}$) or when a transfer is needed but fails to materialize (with probability π when $\underline{\epsilon} \leq \epsilon_1^i < \bar{\epsilon}$).

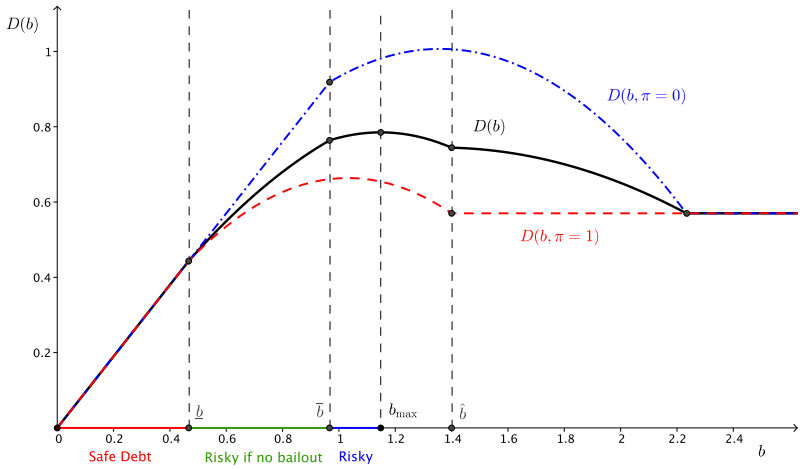
Substituting this expression into condition (5), we obtain an expression for the fiscal revenues $D(b_1^i) \equiv b_1^i / R^i$ raised by the government of country i in period $t = 0$:

$$\begin{aligned} D(b_1^i) &= \beta \mathcal{P} b_1^i + \overline{\lambda}^i \\ &= \beta b_1^i (1 - \pi_d) + \beta\rho\bar{y}_1^i \left(\int_{\epsilon_{\min}}^{\underline{\epsilon}} \epsilon dG(\epsilon) + \pi \int_{\underline{\epsilon}}^{\bar{\epsilon}} \epsilon dG(\epsilon) \right) + \overline{\lambda}^i \end{aligned} \tag{11}$$

This *Laffer curve* plays an important role in the analysis of the optimal choice of debt. We report a full characterization in appendix B. Heuristically, we have the following cases, also illustrated on Figure 2:[26]

- When $b_1^i \leq \underline{b} \equiv y_{\min}^i \left(\Phi / (1 - \alpha^{i,i}) + \rho \right)$. In that case, the debt level is so low that i repays in full without transfers, for all realizations of output. The debt is safe, there is no default risk and no transfers.
- When $\underline{b} < b_1^i \leq \bar{b} \equiv ((\Phi + \rho\alpha^{i,u})y_{\min}^i + \kappa y_1^g)/\alpha^{i,u}$. In that case, the level of debt is sufficiently low that it is optimal for g to bailout i when output is too low. Default might occur if this bailout is not allowed with probability $\pi > 0$. In that region, the Laffer curve with discretionary bailout ($\pi = 0$, in blue on the figure) lies strictly above the Laffer curve under no bailout ($\pi = 1$, in red on the figure): this is a consequence of the soft budget

[26] This figure is drawn under the assumption that the shocks are uniformly distributed.



$D(b)$ for $\pi = 0$ (max bailout), $\pi = 0.5$ and $\pi = 1$ (no bailout).
[Uniform distribution with $\rho = 0.6$, $\Phi = 0.2$, $\kappa = 0.05$, $\epsilon_{\min} = 0.5$, $\beta = 0.95$, $\bar{y}_1^i = 1$, $y_1^g = 2$, $\alpha^{i,i} = 0.4$, $\alpha^{i,g} = \alpha^{i,u} = 0.3$. $\underline{b} = 0.47$, $\bar{b} = 0.97$ and $\hat{b} = 1.4$]

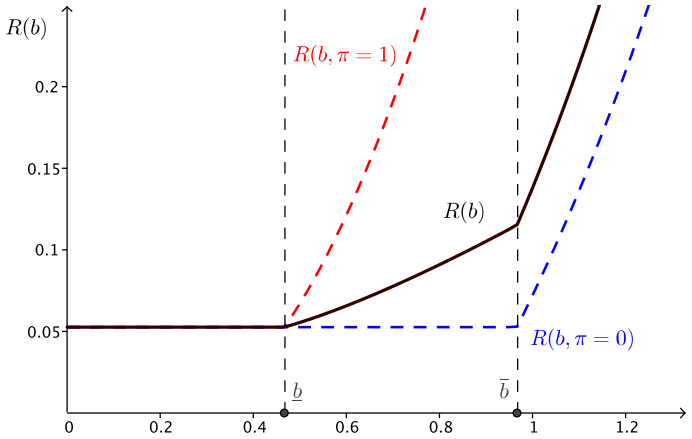
Figure 2: The Debt-Laffer Curve

constraint that is induced by the transfers. Under the assumptions specified in appendix B, the Laffer curve is increasing (at a decreasing rate) over that range.

- When $\bar{b} < b_1^i \leq \hat{b} \equiv y_{\max}^i(\Phi/(1-\alpha^{i,i}) + \rho)$, it becomes optimal for g to let i default when the realizations of output are sufficiently low. This increases default risk and the yield on i's debt. Under the assumptions specified in Appendix B, the Laffer curve is convex in this region and reaches its peak at $b = b_{\max}$ strictly below $\hat{b}$.
- For $\hat{b} < b \leq \tilde{b}$, we enter a region where default would occur with certainty in the absence of transfers. With transfers, it is possible for default to be avoided, if output is sufficiently high. Under the assumptions in the appendix, the Laffer curve slope down over that region.
- Finally, for $b > \tilde{b} \equiv ((\Phi + \rho\alpha^{i,u})y_{\max}^i + \kappa y_1^g)/\alpha^{i,u}$, i always defaults regardless of the realization of output. There are no transfers and investors expected repayment is amount $\rho\bar{y}_1^i$.[27]

Appendix B provides a full characterization of the cut-offs and a set of necessary conditions to ensure that the Laffer curve is convex over the relevant range: $[0, \hat{b})$. The fact that the country

[27] There is also another case where $\tilde{b} < \hat{b}$. We view this case as unintuitive: it corresponds to a situation where it would always be ex-post efficient to bail out i. We assume parameter configurations that rule out this case.



Yields for $\pi = 0$, $\pi = 1$ and $\pi = 0.2$.
[Uniform distribution with $\rho = 0.6$, $\Phi = 0.2$, $\kappa = 0.05$, $\epsilon_{\min} = 0.5$, $\beta = 0.95$, $\bar{y}_1^i = 1$, $y_1^g = 2$, $\alpha^{i,i} = 0.4$, $\alpha^{i,g} = \alpha^{i,u} = 0.3$. $\underline{b} = 0.47$ and $\bar{b} = 0.97$]

Figure 3: Yields

can choose its repayment level b_1^i implies that it will never choose to locate itself on the 'wrong side' of the Laffer curve, i.e. it will only consider levels of debt level such that $b \leq b_{\max} < \hat{b}$. This eliminates Calvo (1988)-like rollover crises and multiple equilibria.

Over the relevant range, the Laffer curve is convex, continuous and exhibits two non-differentiable points, at $b = \underline{b}$ and $b = \bar{b}$.

Figure 3 reports the contractual yield R^i on i's debt and shows how it varies with the probability of enforcement of no-bailout clause π. The interesting range is for $\underline{b} < b \leq \bar{b}$ where the yield remains equal to $1/\beta$ if the bailouts are allowed, but increases very rapidly –together with the ex-post probability of default– when bailouts are prohibited. This figure illustrates one possible channel for the rapid surge in yields when the crisis erupted: the perception that implicit bailout guarantees were removed (i.e. a switch from $\pi = 0$ to $\pi = 1$). Similarly, one can interpret the decline in yields following President Draghi's famous pronouncement that the ECB would do 'Whatever it takes' to preserve the Euro, as a sign that bailout guarantees would be reinstated, i.e. a switch from $\pi = 1$ to $\pi = 0$.

5.2 Optimal Debt Issuance

We now consider the optimal choice of debt b_1^i in the *bondless limit* where bond holdings provide infinitesimal liquidity services. This allows us to ignore the direct impact of the debt level on the utility of the agents via liquidity services. Recall that bond portfolios remain pinned down and invariant to the level of debt so we can take the portfolio shares $\alpha^{j,k}$ as given.

The consolidated budget constraint for i in period 0 is:

$$c_0^i + \alpha^{i,i} b_1^i / R^i + \alpha^{s,i} b_1^s / R^* \quad = \quad (y_0^i + \tau_0 + b_0^{i,i} - b_0^i + b_0^{s,i}) + b_1^i / R^i$$

And the consolidated budget constraint for period 1 is:

$$\begin{cases} c_1^i = y_1^i - b_1^i(1-\alpha^{i,i}) + \alpha^{s,i} b_1^s & \text{if } \epsilon_1^i \geq \bar{\epsilon} \ (i \text{ repays, no transfer}) \\ c_1^i = y_1^i(1-\Phi) - \rho y_1^i (1-\alpha^{i,i}) + \alpha^{i,s} b_1^s & \text{if } \epsilon_1^i < \bar{\epsilon} \ (i \text{ defaults or receives a transfer}) \end{cases}$$

where we substituted the optimal transfer.

It follows that country i's government solves the following program:[28]

$$\begin{aligned} \max_{b_1^i} \quad & c_0^i + \beta \left(\int_{\epsilon_{\min}}^{\bar{\epsilon}} c_1^i dG(\epsilon) + \int_{\bar{\epsilon}}^{\epsilon_{\max}} c_1^i dG(\epsilon) \right) \\ \text{s.t.} \quad & c_0^i \geq 0 \\ & b_1^i / R^i = D(b_1^i) \\ & 0 \leq b_1^i \leq b_{\max} \end{aligned}$$

where c_0^i and c_1^i are defined above.

Denoting ν_0 the multiplier on period 0 consumption and μ_1 the multiplier on $b_1^i \geq 0$, the first-order condition is:[29]

$$\begin{aligned} 0 \quad \in \quad & \mu_1 + (1-\alpha^{i,i}) \partial D(b_1^i)(1+\nu_0) - \beta(1-G(\bar{\epsilon}))(1-\alpha^{i,i}) \\ & \nu_0 c_0^i = 0 \\ & \mu_1 b_1^i = 0 \end{aligned}$$

where $\partial D(b)$ denotes the sub-differential of $D(b)$.[30]

[28] We do not need to impose the constraint that $c_1^i \geq 0$: it is always satisfied under the assumption that $\Phi + \phi \leq 1$.

[29] The constraint $b \leq b_{\max}$ does not need to be imposed.

[30] The sub-differential is the derivative of $D(b)$ where that derivative exists. It is the convex set $[D(b^-), D(b^+)]$

Consider first an interior solution ($c_0^i \geq 0$ and $b_1^i \geq 0$) where the revenue curve is differentiable. The first-order condition becomes:

$$D'(b_1^i) = \beta \left(1 - G(\bar{\epsilon})\right) \tag{12}$$

This first-order condition equates the marginal gain from one additional unit of debt (at face value), $D'(b_1^i)$, with its marginal cost. Equation (12) establishes that this marginal cost is equal to the probability of repayment without transfer $1 - G(\bar{\epsilon})$, discounted back at the risk free rate $1/R^* = \beta$. In other words, i only considers as relevant the states of the world where it is repaying the debt without default or bailout. In case of default, the repayment is proportional to output (and therefore not a function of the debt level). In case of a bailout, the debt is -at the margin- repaid by g. A change in b_1^i also has an effect on the thresholds $\bar{\epsilon}$ and $\underline{\epsilon}$, but since these thresholds are optimally chosen, the Envelope theorem ensures that i does not need to consider their variation.

Substituting the general expression for $D'(b_1^i)$ from equation (11) into equation (12) we obtain:

$$\left(G(\bar{\epsilon}) - G(\underline{\epsilon})\right)(1 - \pi) = (b_1^i - \rho \bar{y}_1^i \underline{\epsilon})(1 - \pi) g(\underline{\epsilon}) \frac{d\underline{\epsilon}}{db} + (b_1^i - \rho \bar{y}_1^i \bar{\epsilon}) \pi g(\bar{\epsilon}) \frac{d\bar{\epsilon}}{db} \tag{13}$$

The left hand side of this equation has a very natural interpretation. It represents the probability that i will receive a transfer from g, a benefit for i. Recall that i obtains a bailout from g with probability $1 - \pi$ when $\underline{\epsilon} \leq \epsilon < \bar{\epsilon}$. By issuing more or less debt in period 0, i can influence the likelihood of a bailout. The right hand side represents the cost of issuing more debt. It has two components. Let's consider each in turn. The first term captures the cost of an increase in debt due to a change in $\underline{\epsilon}$. Recall that i defaults below $\underline{\epsilon}$, and receives no bailout. An increase in b_1^i increases $\underline{\epsilon}$, making outright default more likely. If $\epsilon = \underline{\epsilon}$, lenders loose b_1^i and receive instead $\rho y_1^i \underline{\epsilon}$, with probability $g(\underline{\epsilon})(1 - \pi)$. The second term captures the cost of an increase in debt due to a change in $\bar{\epsilon}$. Recall that, above $\bar{\epsilon}$, i repays its debts and default does not occur. Below $\bar{\epsilon}$, a default can occur when bailouts are not allowed. An increase in debt increases $\bar{\epsilon}$, again making default more likely. At $\epsilon = \bar{\epsilon}$, lenders are now at risk of loosing b_1^i and receiving instead $\rho y_1^i \bar{\epsilon}$, in case a bailout does not materialize, i.e. with probability $g(\bar{\epsilon})\pi$. The increased riskiness of i's debt is reflected into a higher yield, reducing $D'(b)$. Equation (13) makes clear that the possibility of

where that derivative does not exist, at $b = \underline{b}$ and $b = \bar{b}$.

a bailout in period 1 induces i to choose excessively elevated debt levels in period 0. We call this the *Northern view* of the crisis. Note also that a lower collateral cost of default for g, a lower κ, reduces the probability i will receive a transfer from g (the left hand side of (13)) and therefore the incentive to issue debt. Hence, reducing κ has a direct positive impact on g but also serves to discipline i. This resonates with some German proposals to introduce orderly restructuring in case of a default in the eurozone that can be interpreted in the context of our model as lower collateral costs of default.

Equation (13) highlights that i trades off the increased riskiness of debt –and therefore higher yields– against the likelihood of a bailout. In the absence of ex-post transfers (e.g. when $\pi = 1$), the left hand side of (13) is identically zero. The only interior solution is $\bar{\epsilon} \leq \epsilon_{\min}$, so that $g(\bar{\epsilon}) = 0$: i has no incentives to issue risky debt. By contrast, once $\pi > 0$, i may choose to issue risky debt (i.e. $\bar{\epsilon} > \epsilon_{\min}$) in order to maximize the chance of a bailout in period 1. This risk shifting result is a common feature of moral hazard models. Ex-post bailouts partially shield borrowers from the fiscal consequences of excessive borrowing. Not surprisingly, this provides an incentive to borrow excessively.

Appendix C provides a full description of the optimal level of debt issued in period 0. In particular, we show that, under some mild regularity conditions, the optimal choice of debt is either $b \leq \underline{b}$, i.e. a safe level of debt, or $b_{opt} \leq b \leq b_{\max}$, where b_{opt} denotes the unique optimal level of risky debt that obtains when the funding needs are smaller than $D(b_{opt})$.

Define $x_0^i = (b_0^i(1-\alpha_0^{i,i}) + \alpha^{s,i} b_1^s/R^* - y_0^i - \tau_0 - b_0^{s,i})/(1-\alpha^{i,i})$. x_0^i represents the *funding needs* of country i. It increases with the net amount of debt to be repaid $b_0^i(1-\alpha_0^{i,i})$, and decreases with the amount of resources available in period 0, $y_0^i + \tau_0^i$. The optimal choice of debt as a function of the initial funding needs x_0^i can be summarized as follows:

- For $x_0^i > D(b_{\max})$, i is insolvent in period 0 and must default. No level of debt can ensure solvency.
- For $D(b_{\max}) \geq x_0^i > D(b_{opt})$, i issues a level of debt $b_{\max} \geq b > b_{opt}$ such that $D(b) = x_0^i$ and there is no consumption in period 0. There is no risk shifting in the sense that debt issuance is fully constrained by i's funding in period 0.
- For $D(b_{opt}) \geq x_0^i > \beta \underline{b}$, i chooses to issue b_{opt}. In that range, the possibility of a bailout

leads i to issue excessive amounts of debt in the sense that $D(b_{opt}) > x_0^i$ and consequently the probability of default is excessively high.

- Finally, for $x_0^i < \beta \underline{b}$, i can choose to issue either a safe amount debt $x_0^i/\beta \leq b_1^i \leq \underline{b}$ or the risky amount b_{opt}. If i prefers to issue risky debt, then the amount of risk shifting is *maximal*. This will be the case if i achieves a higher level of utility at b_{opt} then by keeping the debt safe. The utility gain from risk shifting is given by $U(b_{opt}) - U_{safe}$, equal to:

$$\begin{aligned} U(b_{opt}) - U_{safe} &= (1-\alpha_1^{i,i})(1-\pi)\beta\left[G(\bar{\epsilon}) - G(\underline{\epsilon})\right]\left(b_{opt} - \rho\bar{y}_1^i E[\epsilon|\underline{\epsilon} \leq \epsilon \leq \bar{\epsilon}]\right) \\ &\quad -\beta\Phi G(\bar{\epsilon})\bar{y}_1^i E[\epsilon|\epsilon < \bar{\epsilon}] \end{aligned}$$

The first term represents the expected net gain from the bailout (since $b_{opt} > \rho\bar{y}_1^i\bar{\epsilon}$, it follows that $b_{opt} > \rho\bar{y}_1^i E[\epsilon|\underline{\epsilon} < \epsilon < \bar{\epsilon}]$). The second term represents the expected discounted cost of default for i. This cost is borne by i as soon as $\epsilon < \bar{\epsilon}$ since the bailout does not affect i's utility. It follows that i will issue excessively high levels of debt when the following condition holds:

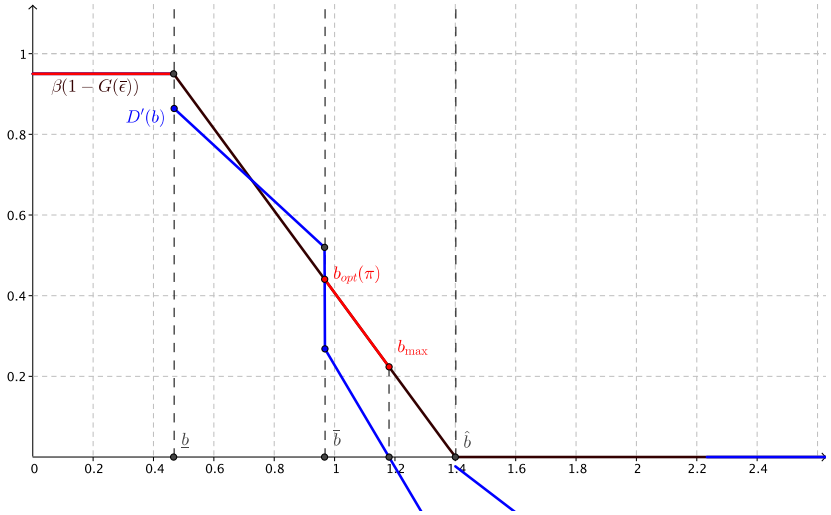
$$(1-\alpha_1^{i,i})(1-\pi)\left[G(\bar{\epsilon}) - G(\underline{\epsilon})\right]\left(b_{opt} - \rho\bar{y}_1^i E[\epsilon|\underline{\epsilon} \leq \epsilon \leq \bar{\epsilon}]\right) > \Phi G(\bar{\epsilon})\bar{y}_1^i E[\epsilon|\epsilon < \bar{\epsilon}] \quad (14)$$

Inspecting equation (14), it is immediate that there is no risk shifting when $\pi = 1$ or when i holds most of its own debt ($\alpha^{i,i} \approx 1$). Risk shifting is more likely the higher is the optimal debt output ratio $b_{opt}/\bar{y}_1^i$ and the lower the cost of default Φ.

These results are summarized in Figure 4. The figure reports, for the case of a uniform distribution the function $\beta(1 - G(\bar{\epsilon}(b)))$ (in black) and the function $D'(b)$ (in blue). There are two discontinuities of the function $D'(b)$ at $b = \underline{b}$ and $b = \bar{b}$. In red, the figure reports the possible optimal equilibrium debt levels. For $b \leq \underline{b}$ the debt is safe and any level -if sufficient to rollover the debt– provides equivalent level of utility; $b_{opt} \geq \bar{b}$ is the optimal level of risky debt when the rollover constraint ($c_0^i \geq 0$) does not bind. Finally, $b_{opt} < b \leq b_{\max}$ obtains when the rollover constraint binds (i.e. $c_0^i = 0$ and $D(b) = x_0^i$.[31]

Figure 5 reports the Laffer curve and the optimal debt levels. It illustrates the extent of risk shifting that occurs when i chooses to issue at b_{opt} instead of a safe level $b < \underline{b}$.

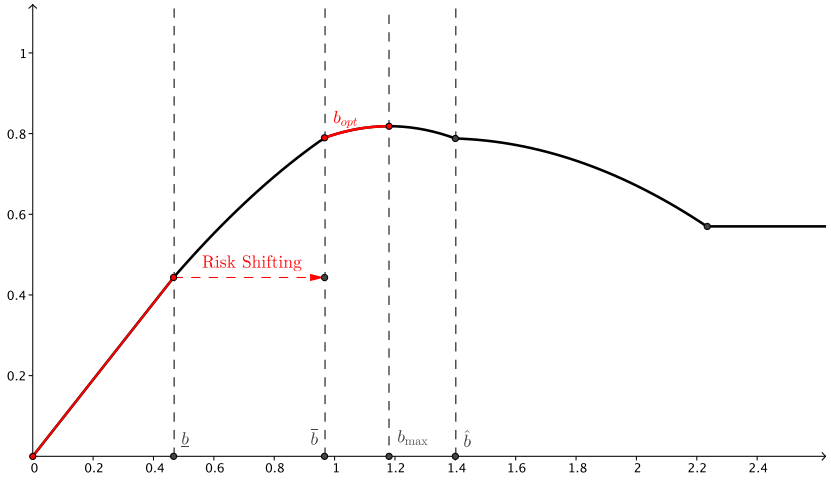
[31] As can be seen on the figure, there is another solution to the first order condition between $\underline{b}$ and $\bar{b}$. However, this solution does not satisfy the second-order conditions.



$D'(b)$ and $\beta(1-G(\bar{\epsilon}))$ for $\pi = 0.5$.

[Uniform distribution with $\rho = 0.6$, $\Phi = 0.2$, $\kappa = 0.05$, $\epsilon_{\min} = 0.5$, $\beta = 0.95$, $\bar{y}_1^i = 1$, $y_1^g = 2$, $\alpha^{i,i} = 0.4$, $\alpha^{i,g} = \alpha^{i,u} = 0.3$. $\underline{b} = 0.47$, $\bar{b} = 0.97$ and $\hat{b} = 1.4$]

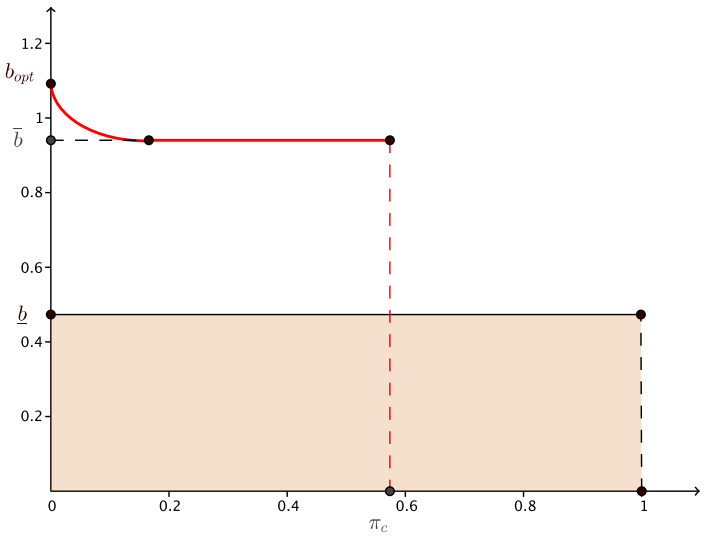
Figure 4: Optimal Debt Issuance



Optimal Debt Issuance for $\pi = 0.5$.

Uniform distribution with $\rho = 0.6$, $\Phi = 0.2$, $\kappa = 0.05$, $\epsilon_{\min} = 0.5$, $\beta = 0.95$, $\bar{y}_1^i = 1$, $y_1^g = 2$, $\alpha^{i,i} = 0.4$, $\alpha^{i,g} = \alpha^{i,u} = 0.3$. $\underline{b} = 0.47$, $\bar{b} = 0.97$ and $\hat{b} = 1.4$

Figure 5: Optimal Debt Issuance: Risk Shifting



Plot of the set of unconstrained solutions $0 \leq b \leq \underline{b}$ and b_{opt} as a function of π. There is a critical value π_c above which risk shifting disappears.

Figure 6: The Effect of No-Bailout Clauses

Making i's debt safe: Optimal ex-ante bailout policy for g. The previous analysis makes clear that the extent of risk shifting depends on the likelihood of a bailout, $1 - \pi$. When bailouts are very likely ($\pi \approx 0$), and under the regularity conditions described in appendix B and C, b_{opt} is larger than $\bar{b}$. In other words, i chooses a level of risky debt sufficiently high so that there might be a possibility of default, even when ex-posts bailouts are almost guaranteed. In that case, the extent of risk shifting is maximal.

As π increases, this optimal level of risky debt decreases until it reaches $b_{opt} = \bar{b}$. Appendix C shows that there is a critical level of π, denoted π_c such that for $\pi > \pi_c$, the optimal level of debt falls discontinuously from $\bar{b}$ to $b \leq \underline{b}$ and debt becomes safe. This is represented in Figure 6 where we report b_{opt} as a function of π. This analysis indicates that it is not necessary for g to enforce a strict no-bailout policy ($\pi = 1$) to eliminate risk shifting in period 0. Any level π superior to π_c will result either in a safe debt level, or the minimum level of debt necessary to cover funding needs, i.e. $D(b_1^i) = x_0^i$.

It does not necessarily follow that g is indifferent between any bailout policy with $\pi \geq \pi_c$,

since higher levels of π reduce ex-post efficiency. Suppose g can choose a commitment technology π in period 0. A higher π reduces the amount of risk shifting. For $\pi > \pi_c$ risk shifting is eliminated entirely. However, this also reduces resources available to i in the ex-post stage and makes a default more likely. It also makes i less solvent, so that, depending on the initial funding needs x_0^i, it could also force i to default in period 0. In other words, there is an option value to wait and see if i's output level will be sufficiently high to allow repayment without transfer and it can be in the interest of g to allow for a possible bailout, even as of $t = 0$.

In the bondless limit, g's utility can be expressed as a function of the optimal debt $b(\pi)$ issued by i under a no-bailout probability π (after substitution of the optimal transfer when $\underline{\epsilon} \leq \epsilon < \bar{\epsilon}$):

$$\begin{aligned} U_g(b(\pi), \pi) &= c_0^g + \beta E[c_1^g] \\ &= y_0^g - b_0^g + b_0^{i,g} + b_0^{s,g} + \beta y_1^g + \Psi(b(\pi); \pi) \end{aligned}$$

where $\Psi(b; \pi)$ denotes the net utility gain to g from i's sovereign default decision and is defined as:

$$\begin{aligned} \Psi(b, \pi) &= -\beta\kappa y_1^g G(\bar{\epsilon}) \\ &\quad - (1-\pi)\alpha^{ig}\beta b\left(G(\bar{\epsilon}) - G(\underline{\epsilon})\right) \\ &\quad + (1-\pi)\beta \int_{\underline{\epsilon}}^{\bar{\epsilon}} \left(y_1^i\left(\Phi + \rho\left(1-\alpha^{ii}\right)\right) - \alpha^{iu} b\right) dG(\epsilon) \\ &\quad + (1-\pi)\beta\kappa y_1^g \left(G(\bar{\epsilon}) - G(\underline{\epsilon})\right) \end{aligned}$$

The term on the first line represents the expected utility loss to g due to collateral damage when i defaults and there is no bailout ($\pi = 1$). Notice that this loss is not impounded in the borrowing rate since it is not a private loss for g investors. The next three lines represent the gains/losses when π is different from 1, i.e. in the presence of bailouts. The second line represents the fact that g makes a transfer to i. The third line represents the fact that g captures the efficiency gains from avoiding a default and the last line captures the gain from avoiding collateral damage. It is immediate to check that if i's debt is safe, then $\Psi(b; \pi) = 0$.

The optimal choice of commitment technology satisfies

$$\frac{d\Psi(b(\pi); \pi)}{d\pi} = \frac{\partial \Psi(b(\pi); \pi)}{\partial \pi} + \frac{\partial \Psi(b(\pi); \pi)}{\partial b}\frac{db}{d\pi} = 0$$

The appendix provides a full discussion of the optimal choice of commitment technology and establishes that g always prefers to choose a level of commitment that rules out risk shifting, i.e. $\pi\ geq\pi_c$. The intuition is simple: when $\pi \geq \pi_c$, the optimal debt level does not depend anymore on π: $db/d\pi = 0$. It follows that the optimal choice of π over that range is controlled by the sign of $\partial\Psi/\partial\pi$. But since i's debt is safe $\Psi = 0$ and therefore g is indifferent. For lower levels of commitment, if a default with transfer is possible, it must lower the utility of g. Hence it is strictly preferable to eliminate risk shifting, to the extent possible.

But this analysis is valid as long as i remains solvent. Denote $b_{\max}(\pi)$ the level of debt that maximizes revenues for i as a function of the commitment level. It is immediate that $dD(b_{\max};\pi)/d\pi \leq 0$. Once $D(b_{\max}(\pi);\pi) < x_0^i$, i cannot honor its debts and is forced to default in the initial period. By analogy with the analysis of period 1, suppose that a default in period 0 has a direct contagion cost κy_0^g on g. In addition, i's bondholders recover a fraction ρ of i's output. Assume also that i is unable to borrow, so $b_1^i = 0$. It follows that g will choose $\pi(x_0^i)$ defined implicitly such that $D(b_{opt};\pi(x_0^i)) = x_0^i$, and will prefer to let i default if the following condition is satisfied:

$$\kappa y_0^g + \alpha_0^{i,g}(b_0^i - \rho y_0^i) + \Psi(b_{opt}, \pi(x_0^i)) \geq 0 \tag{15}$$

Condition (15) states that it can be optimal ex-ante for g to allow ex-post bailouts if these allow i to avoid an immediate default. The logic is quite intuitive: by allowing the possibility of a future bailout, g allows the monetary union to gamble for resurrection: in the event that i's output is sufficiently hight in period 1, debts will be repaid and a default will be avoided in both periods. Even if a bailout is required, the cost to g as of period 0 is less than one for one.

This discussion highlights that g is more likely to adopt an ex-ante lenient position on future bailouts (i.e. a low π) when i has initially a high debt level or a low output level. This provides an interpretation of the early years following the creation of the Eurozone. Countries were allowed to join the Eurozone with vastly different levels of initial public debt. The strict imposition of a no bailout guarantee could have pushed these countries towards an immediate default and debt restructuring. Instead, it may have been optimal to allow these countries to rollover their debt on the conditional belief that a bailout might occur in the future. The fiscal cost to g of an immediate default may have exceeded the expected costs from possible future bailouts. Notice however, that we specify the optimal policy such that $D(b_{opt};\pi) = x_0^i$. In other words, while g is willing to let i roll over its debts, it is still able to avoid risk-shifting, in the sense of avoiding excessive debt issuance at period 0.

Summarizing the main points of the baseline model. The previous analysis makes a number of interesting points for the analysis:

- First, if the probability of bailout $1-\pi$ is sufficiently small, there is no 'risky' equilibrium and the only possible solutions are either to issue safe debt (when rollover needs are small enough) or issue the amount necessary to exactly roll over the debt (i.e. $c_0^i = 0$). In other words, when the probability of bailout is too small, there is no risk shifting equilibrium anymore.
- when π is sufficiently small (high probability of bailout), as long as the funding needs are not too high, country i chooses a unique level of debt b_{opt} regardless of the funding needs. We also know that this optimal level of debt is such that $\bar{b} \leq b_{opt} < b_{\max}$, i.e. it occurs for levels of debt sufficiently elevated that default might occur.

6 Extensions

In the baseline model, we excluded the possibility that (i) the countries could bargain over the surplus; (ii) a country could default but still remain a member of the eurozone and that (iii) a third institution, for instance the European Central Bank, could intervene to alter the real value of public debt. We now analyze these three possibilities separately.

6.1 Bargaining over the surplus

In the main model, we assumed that all the bargaining power was in the hand of the creditor country. Even though it is plausible that the creditor country has a larger bargaining weight, our assumption of a 'take it or leave it' offer may be too strong. Hence, in this section we relax it and assume that the bargaining weight of i is $0 < \gamma < 1$, and that of country g is $1-\gamma$ The baseline case corresponds to $\gamma = 0$. This changes the size of the transfer that i receives as it can obtain a share γ of the total surplus generated by avoiding the default. The transfer to i is now:

$$\underline{\tau}_1(\gamma) = \left(b_1^i\left(1-\alpha^{i,i}\right) - y_1^i\left[\Phi + \rho(1-\alpha^{i,i})\right]\right) + \gamma\left(\Phi y_1^i + \kappa y_1^g - \alpha^{i,u}(b_1^i - \rho y_1^i)\right). \tag{16}$$

The first term on the right hand side corresponds to the previous expression for the transfer, i.e. when i has no bargaining power. The second term represents the share of the total surplus $\Phi y_1^i + \kappa y_1^g - (b_1^i - \rho\alpha^{i,u})$ that goes to i. It increases with the collateral damage κ inflicted on g in

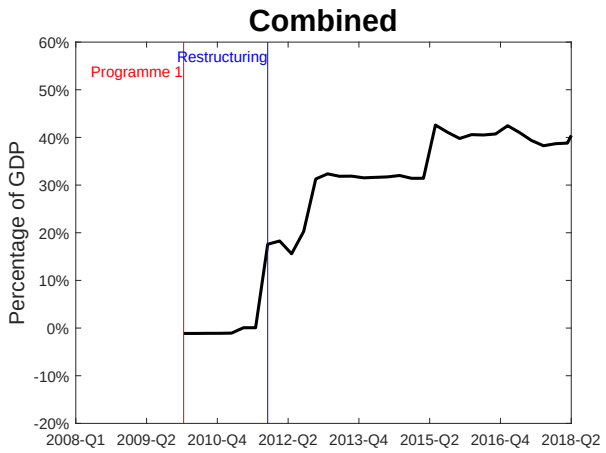
case of default. While the transfer increases with γ, the threshold levels $\underline{\epsilon}$ and $\overline{\epsilon}$ remain unchanged. At $\underline{\epsilon}$ the surplus is zero, hence there is no transfer and default becomes optimal. At $\overline{\epsilon}$, i unilaterally prefers not to default even without transfers. As long as income realizations are observable, no transfer is needed. This implies a downward discontinuity in consumption for i at $\epsilon = \overline{\epsilon}$: a slight increase in income makes default non-credible and therefore eliminates the transfer.

The expectation that i has some strictly positive bargaining weight in period 1 also modifies the incentive to issue debt in period 0. Because the thresholds are unchanged, the probability of default is also unaffected. Hence the Laffer curve is also unchanged. However, the level of debt issued b_1^i affects the expected transfer along two margins. First, there is the marginal effect of an increase in debt on the overall surplus which is now shared between the two countries. A higher debt issuance reduces the total surplus from not defaulting on the rest of the world. This reduces the transfer that i can expect to receive and is akin to an increase in the marginal cost of issuing debt. Ceteris paribus, this increase in the marginal cost of debt issuance should reduce the optimal debt level and risk shifting. However, there is another effect, related to the discontinuity in consumption at $\overline{\epsilon}$: increasing the level of debt raises $\overline{\epsilon}$ and therefore makes it more likely that a transfer will be needed. This second effect increases risk shifting.

CHARACTERIZATION OF THE OPTIMAL DEBT ISSUANCE WITH BARGAINING TO BE COMPLETED.

6.2 Default vs. Exit

In July 2012, Greece restructured its debt, implementing one of the largest sovereign haircuts in modern history. Yet, the country remained in the eurozone, and agreed to the terms of a bailout that was described in section 2. In our baseline model, in the event that the borrower defaults, it should not receive any bailout. To make this point explicitly, Figure 7 reports the timeline of NPV transfers to Greece, estimated between 2010 and 2018 using the methodology of section 2 and using the planned sequence of disbursements and repayments at each point in time. The figure indicates that the transfers to Greece were minimal between 2010 and 2012 and jumped to 20% of GDP in 2012, precisely at the time at which Greece defaulted on its sovereign debt. Through the lens of the model, Greece should have received a transfer in 2010-11 and no transfer post-default. We now extend the model to account for the pattern we see in the data. To do so, we consider an extension of the model were a country can decide to default and/or exit the monetary union altogether. In this extension, members of a monetary union may now find it in their interest to support financially one of their neighbors, so as to avoid a default, an exit from the



The figure reports the timeline of combined transfers in present value from the GLF, the EFSF, the ESM and the IFM to Greece, between 2010 and 2018, were the NPV at each point in time depend on the planned sequence of disbursements and repayments in place at that time. Fraction of 2010 Greek GDP. *Source*: Authors calculations from ESM, IFM data. See online appendix for details.

Figure 7: The Time Line of Greek Transfers. Percent of 2010 Greek GDP

currency union, or both. In particular, we characterize the conditions under which it is optimal to let a country default, yet provide a transfer so as to avoid an exit from the currency union. We provide a characterization of the optimal transfers and discuss the implications of the model in the context of the recent Eurozone crisis. A direct implication of our analysis is that any transfer from European institutions to Greece post 2012 must have served to prevent an implosion of the Eurozone. However, as in the baseline model, our model still implies that the surplus from these ex-post transfers are mostly captured by the rest of the monetary union.

The extended model differentiates between the direct cost of a default for country i, denoted Φ_d, and that of an exit, denoted Φ_e. Similarly, we differentiate between the collateral cost for country g in the event of a default, denoted κ_d, and that in the event of an exit, denoted κ_e. As in the baseline model, these costs represent the net economic disruption associated with a default, and an exit respectively on i and g. We also assume that a decision to simultaneously default and exit the currency union imposes *additive* costs $\Phi_d+\Phi_e$ on i and $\kappa_d+\kappa_e$ on g.[32] The decision to exit the currency union brings in additional benefits to i. Most importantly, it allows i to regain some

[32]This assumption is made mostly for simplicity. An alternative assumption which we do not explore in this paper is that the cost function is superadditive in default and exit.

monetary autonomy, and debase the value of local currency debt held externally.[33] We assume that this additional benefit is proportional to the outstanding stock of debt held abroad and express it as $\Delta b_1^i(1-\alpha_1^{ii})$ where $\Delta > 0$, with a corresponding loss for g of $\Delta b_1^i \alpha^{i,g}$.[34] Nevertheless, we restrict the parameters so that i always prefers to default before exiting the currency union. This is summarized in the following assumption.[35]

Assumption 1 *: Country i always prefers to default before exiting.*

$$\frac{\Delta}{\Phi_e} < \frac{1}{\Phi_d + \rho}$$

This condition is satisfied if the cost of exit per unit of output Φ_e is large, and or the benefits per unit of debt held abroad Δ are small.

In period 1, country i decides whether to repay or default and whether to stay or exit the currency union. Country g can then decide to make a unilateral transfer conditional on i's decision and the realization of i's output. We further assume that g cannot commit to a no-bailout clause, so i and g will always achieve ex-post efficiency.[36] We begin by characterizing the decision choices of country i in the absence of transfers. This is summarized in the following proposition.

Proposition 1 (Optimal Default and Exit Decisions without Bailouts) *Under Assumption 1, and in the absence of transfers, country i's default and exit decisions in period $t = 1$ are characterized by a default threshold $\bar{\epsilon}^d$ and an exit threshold $\bar{\epsilon}^e$ such that $\bar{\epsilon}^d > \bar{\epsilon}^e$ and:*

1. *i repays and stays in the currency union if and only if:*

$$\epsilon_1^i \geq \bar{\epsilon}^d \equiv \frac{(1-\alpha^{i,i})b_1^i/\bar{y}_1^i}{\Phi_d + \rho(1-\alpha^{i,i})}$$

2. *i defaults but remains in the currency union if and only if:*

$$\bar{\epsilon}^d > \epsilon_1^i \geq \bar{\epsilon}^e \equiv \frac{\Delta(1-\alpha^{i,i})b_1^i/\bar{y}_1^i}{\Phi_e}$$

[33] While the debt is initially issued in the common currency, part of it may be re-denominated in local currency in the event of an exit.

[34] Monetary autonomy may also confer benefits to i that are proportional to its output, but these are already subsumed in Φ_e. In addition, one could imagine that exiting the currency union would also confer some flexibility to g. However, we consider in what follows that the gains from this increased autonomy are negligible from g's perspective, possibly because g has more control over the currency union's policies, including monetary policy.

[35] The alternative assumptions, that i would either default and exit jointly or always prefer to exit before defaulting, strike us as counterfactual. After all, Greece defaulted in 2012, yet remained in the Eurozone.

[36] In terms of the baseline model, we assume that $\pi = 0$.

3. *i defaults and exits the currency union if and only if:*

$$\bar{\epsilon}^e > \epsilon_1^i$$

Proof. See the Appendix. ■

The intuition for the result is as follows. First, because the gains and costs of default and exit are additive, it is easy to check that default is preferred whenever $\bar{\epsilon}^d > \epsilon_1^i$, independently of the decision to exit, while exit is preferred whenever $\bar{\epsilon}^e > \epsilon_1^i$, regardless of the decision to repay. Second, Assumption 1 ensures that $\bar{\epsilon}^d > \bar{\epsilon}^e$ so that the country always prefers to default first, for a given initial debt level, as domestic economic conditions deteriorate.

Figure 8 provides a graphical illustration of i's decision to default and/or exit, as a function of the ratio of debt to potential output, $b_1^i/\bar{y}_1^i$, on the horizontal axis, and the output gap ϵ_1^i on the vertical axis. The cut-offs $\bar{\epsilon}^d$ and $\bar{\epsilon}^e$ represent rays through the origin that partition the state space into the three regions described in the proposition. Higher realizations of output and lower initial debt levels make it more likely that debts will be repaid and that the country will remain in the currency union.

Next, we consider the optimal transfers from g to i. As before, we assume that g makes the minimal transfer needed to avoid default and/or exit from i. Given the additivity assumption, we can consider three possible transfers: a transfer $\underline{\tau}_1^d$ to avoid a default, another transfer $\underline{\tau}_1^e$ to avoid an exit, and a transfer $\underline{\tau}_1^{de} = \underline{\tau}_1^d + \underline{\tau}_1^e$, to avoid both default and exit.

Proposition 2 (Optimal Ex-post Transfers and Default/Exit Decisions) *Under Assumption 1, country g implements the following optimal ex-post bailout policy:*

1. *When $\epsilon_1^i \geq \bar{\epsilon}^d$, there is no bailout: $\tau_1 = 0$; Country i repays and stays in the currency union;*
2. *When $\bar{\epsilon}^d > \epsilon_1^i \geq \underline{\epsilon}^d$, where*

$$\underline{\epsilon}^d = \frac{\alpha^{i,u} b_1^i/\bar{y}_1^i - \kappa_d y_1^g/\bar{y}_1^i}{\Phi_d + \rho\alpha^{i,u}} < \bar{\epsilon}^d$$

country g makes a transfer to avoid default and exit. Country i repays and stays in the currency union;

3. *When* $\underline{\epsilon}^d > \epsilon_1^i \geq \underline{\epsilon}^e$, *where*

$$\underline{\epsilon}^e = \frac{\Delta\alpha^{i,u} b_1^i/\bar{y}_1^i - \kappa_e y_1^g/\bar{y}_1^i}{\Phi_e},$$

country g *makes a minimal transfer to avoid exit. Country* i *defaults and stays in the currency union;*

4. *When* $\underline{\epsilon}^e > \epsilon_1^i$, *country* g *does not make any transfer:* $\tau_1 = 0$; *Country* i *defaults and exits.*

Proof. See the Appendix. ■

The intuition for the result is as follows. First, when $\epsilon_1^i \geq \bar{\epsilon}^d$, country i prefers to repay and stay in the currency union even in the absence of transfer. Therefore, $\tau_1 = 0$. When $\epsilon_1^i = \bar{\epsilon}^d$, country i is indifferent between defaulting and repaying, but prefers to stay in the currency union. Yet, because a default inflicts collateral damage on g, the latter is willing to make a minimal transfer $\underline{\tau}_1^d$ as long as $\bar{\epsilon}^d > \epsilon_1^i \geq \underline{\epsilon}^d$. The intuition is the same as in the baseline model: g prefers to make an ex-post transfer as long as the joint surplus from not-defaulting remains positive. There is one difference with the previous case. When $\bar{\epsilon}^d > \epsilon_1^i \geq \bar{\epsilon}^e$, it is sufficient to transfer $\underline{\tau}_1^d$ since i prefers not to exit. However, when $\bar{\epsilon}^e > \epsilon_1^i > \underline{\epsilon}^d$, g must transfer $\underline{\tau}_1^d + \underline{\tau}_1^e$. Finally, when $\underline{\epsilon}^d > \epsilon_1^i$, g is not willing to make a transfer to avoid repayment. However, as long as $\epsilon_1^i > \underline{\epsilon}^e$, it will make a transfer $\underline{\tau}_1^e$ to avoid exit.

Proposition 2 illustrates an important result: it is possible for g to make transfers to avoid a default, or an exit, or both. Figure 8 illustrates the optimal choice of default and exit in the presence of the optimal transfers. The transfers are also not monotonic in output. For moderate levels of debt, it is optimal to make transfers so that i never defaults or exits. However, the transfers vary non-monotonically with the level of output. As output decreases, i's preference for a joint default and exit forces g to increase discretely its transfer from $\underline{\tau}_1^d$ to $\underline{\tau}_1^d + \underline{\tau}_1^e$.[37] For higher levels of debt, transfers go through two phases as a function of output. A first transfer $\underline{\tau}_1^d$ is implemented when output is moderately high, to avoid a default. For moderate levels of output, it becomes optimal to let i default and remain in the union. However, as output decreases, g then initiates transfers $\underline{\tau}_1^e$ to avoid an exit from the currency union. Finally, if output becomes really low, it is optimal to let i default and exit.

This extension allows us to think about the determinants of ex-post bailouts both prior to a default episode, or, in the case of Greece after 2012, post default, but before an exit.

[37] This discontinuity is a consequence of the fact that output is perfectly observed by g.

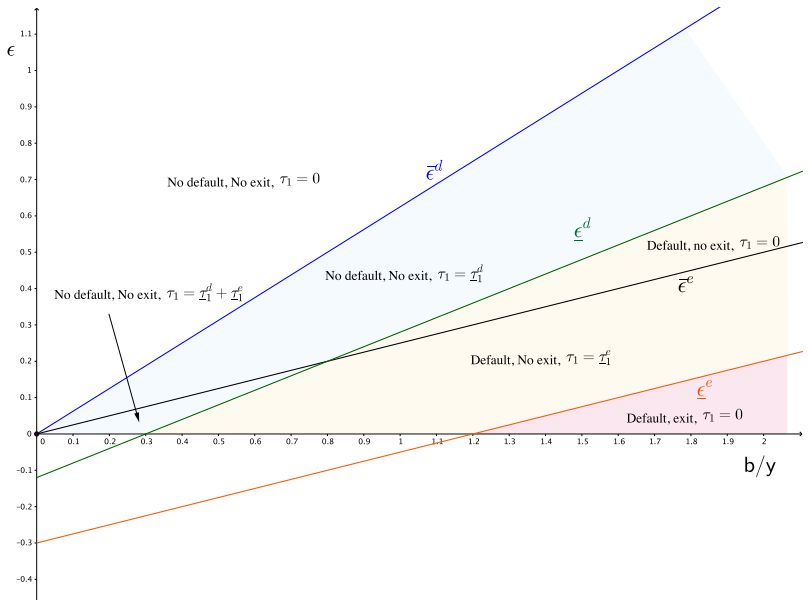


Figure 8: Optimal Ex-Post Bailout and Default vs. Exit Decisions

6.3 Debt monetization

Debt monetization is an alternative to default which we have excluded so far. Even though article 123 of the Treaty of the European Union forbids ECB direct purchase of public debt, debt monetization can still take place through inflation and euro depreciation. In this section, we analyze in a very simplified framework how the interaction of transfers and debt monetization affects the probability of default and how the ECB may be overburdened when transfers are excluded. To facilitate the analysis of this extension we simplify the model by assuming a zero recovery rate ($\rho = 0$) and by focusing on two polar cases where transfers are always possible ($\pi = 0$) and where transfers are excluded ($\pi = 1$).

There are now three players: i, g and the ECB. In addition to g's decision on the transfer, i's decision on default, the ECB decides how much and whether to monetize the debt. We assume the ECB can choose the inflation rate for the monetary union as a whole. This would be the case for example with Quantitative Easing (QE) which generates higher inflation and euro depreciation that both reduce the real value of public debt. Importantly, all public debts are inflated away at the same rate in the monetary union so that g also stands to benefit from it. However, both countries also suffer from the inflation distortion cost that are proportional to output. If z is the inflation

rate, the distortion cost is $\delta z y_1^h$ for $h = i, g$. We also assume that the inflation rate is between 0 and a maximum rate $\overline{z}$ above which distortion costs are infinite.

The ECB can also implement targeted purchases of public debt. In this case, it would be possible to buy public debt of a specific country without any inflation cost for example if it was sterilized by sales of other eurozone countries debt. The Outright Monetary Transactions (OMT) program announced in September 2012 is close to such a description. This program however resembles a transfer in the sense that part of the debt of i is taken off the market and that to sterilize this intervention the ECB would sell g debt. A condition of the OMT program is that the country needs to have received financial sovereign support from the eurozone's bailout funds EFSF/ESM. This strengthens our interpretation of the OMT program as a financial support program, i.e. a transfer. Remember that the OMT was never put into place but remains a possibility. The Securities Markets Programme (SMP) program was put into place in May 2010 by the ECB and terminated in September 2012 to be replaced by OMT. The aim was to purchase sovereign bonds on the secondary markets. At its peak, the programme's volume totalled around 210 billion euros. The Eurosystem central banks that purchased sovereign bonds under this programme hold them to maturity. The programme initially envisaged that central bank money created from the purchase of securities would be sterilised. This description suggests that the (never implemented) OMT and the (now terminated) SMP programmes are close to the way we interpret transfers. However, the OMT rules imply that such a transfer can not take place without support from the eurozone's bailout funds EFSF/ESM. Hence, we keep the assumption that the transfer τ_1 is decided by g. On the other hand, debt monetization at the inflation rate z is the sole responsibility of the ECB. Inflation in this version of the model looks very much like a partial default, except that the total cost for the eurozone is $\delta\overline{z}\left(y_1^i + y_1^g\right)$ in case of inflation and $\Phi y_1^i + \kappa y_1^g$ in case of default. We reasonably assume that Φ and κ are larger than $\delta\overline{z}$, so that,in proportion to output, the costs of default are both larger than the marginal distortionary cost of inflation.

6.3.1 The case with transfers

We first analyze the case where transfers by g are possible and not subject to political risk i.e. $\pi = 0$. Remember that in presence of transfers by g to i, g captures the entire surplus of i not defaulting: g's transfers are ex-post efficient from the joint perspective of g and i. This implies that the objective of the ECB and g are perfectly aligned if, as we assume, the ECB maximizes the whole EMU welfare. The ECB will choose either zero or maximum inflation rate $\overline{z}$ depending whether the marginal benefit of inflating the eurozone debt held in the rest of the world is below

or above its marginal distortion cost. In the case of no default, the ECB will inflate the debt if:

$$b_1^i \alpha^{i,u} + b_1^g \alpha^{g,u} > \delta \left(y_1^i + y_1^g \right) \tag{17}$$

so that the ECB chooses a zero inflation rate if i output realization is such that:

$$\epsilon_1^i > \frac{b_1^i \alpha^{i,u} + b_1^g \alpha^{g,u}}{\delta \overline{y}_1^i} - \frac{y_1^g}{\overline{y}_1^i} \equiv \overline{\overline{\epsilon}} \tag{18}$$

Weak fiscal dominance, which we concentrate on in this section, applies when the ECB never inflates in case of default of i but may inflate for low levels of i output realizations (below $\overline{\overline{\epsilon}}$). There are several conditions on output realizations and parameters for such a situation to exist which we detail in appendix E. We exclude situations such that the ECB inflates even in case of default of i (fiscal dominance) which apply when g debts are very high and situations where the ECB never inflates (monetary dominance) which apply when distortion costs δ are very high. This later case is identical to the main model.

In the case of monetization, the transfer necessary to make i indifferent between default and no default becomes:

$$\tau_1 = b_1^i \left(1 - \alpha_1^{i,i} \right) (1 - \overline{z}) - y_1^i \left[\Phi - \delta \overline{z} \right] + \overline{z} b_1^g \alpha^{g,i} \tag{19}$$

We can compare the transfer with monetization and without monetization ($\overline{z} = 0$). The first element on the right hand side reduces the required transfer because debt monetization weakens the incentive of i to default. However, the second term, the inflation distortion (proportional to y_1^i) must be compensated by a higher transfer given that in default there is no such inflation distortion. The last term is the inflation tax on the g debt held by i which also must be compensated by a higher transfer. Hence, debt monetization allows to reduce the transfer for low levels of g debt which is the case we concentrate on. The threshold level of i output below which g prefers a default is also affected by the possibility of ECB monetization:

$$\epsilon_1^i < \frac{\alpha^{iu} b_1^i (1 - \overline{z}) - \alpha^{gu} b_1^g \overline{z} - y_1^g (\kappa - \delta \overline{z})}{(\Phi - \delta \overline{z}) \overline{y}_1^i} \equiv \underline{\epsilon}' \tag{20}$$

It can be shown that ECB monetization, if it takes place, always reduces the likelihood of default in the sense that $\frac{\partial \underline{\epsilon}'}{\partial \overline{z}} < 0$, i.e. the output realization below which i defaults falls with debt monetization. The intuition is that the net gain of inflating the debt for the eurozone is eliminated when de-

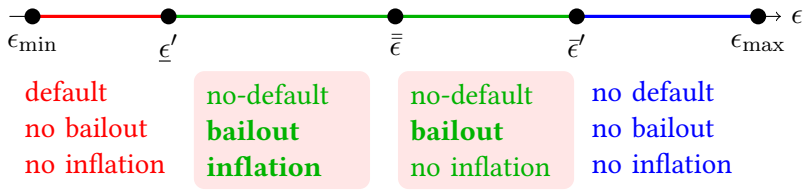


Figure 9: Bailout and Inflation under Weak Fiscal Dominance

fault occurs. Hence, monetization, because it taxes agents from outside the eurozone, produces an additional gain of not defaulting. A related and interesting result is that the whole benefit of debt monetization (on the part of debt held outside the eurozone), if it occurs, is captured by g. The increase in consumption by g due to debt monetization is indeed: $\overline{z}\left[b_1^i\alpha^{i,u} + b_1^g\alpha^{g,u} - \delta\left(y_1^i + y_1^g\right)\right]$ which represents the surplus of monetization of the whole eurozone debt held by the rest of the world (net of distortion costs).

Under reasonable parameters (see appendix) Figure 9 depicts how the equilibrium changes with i output realizations. As they deteriorate, the equilibrium moves from a situation with 1) no default, no transfer, no inflation, ; 2) no default, transfer, no inflation; 3) no default, inflation, transfer; 4) default, no inflation, no transfer.

6.3.2 When transfers are excluded: the overburdened ECB

The situation we described is one where a fiscal union or a strong cooperative agreement exists such that fiscal transfers are possible with full discretion ($\pi = 0$). This meant that there were two instruments for two objectives: transfers to avoid default and inflation to monetize the debt held outside the eurozone. This is an efficient use of these two instruments.

These transfers may actually be hard to implement for political and legal reasons which we captured in the previous analysis with $\pi > 0$. They may not be possible also because of the difficulty to get an agreement with multiple eurozone creditor countries who share the cost of the transfer and its benefit, i.e the absence of default. Such a situation would generate a prisoner's dilemma because avoiding i default is a public good. The Nash equilibrium may be characterized by the absence of transfers. We analyze the simplest version of this situation with $\pi = 1$.

Because ex-post efficient transfers to avert a default are not possible, the ECB may now use monetary policy to avert a costly default. To make the analysis as simple and as stark as possible we assume that the ECB may choose positive inflation only because transfers are not possible and in order to avoid a default of i. In addition, we assume that $b_1^g = 0$ as we concentrate on the

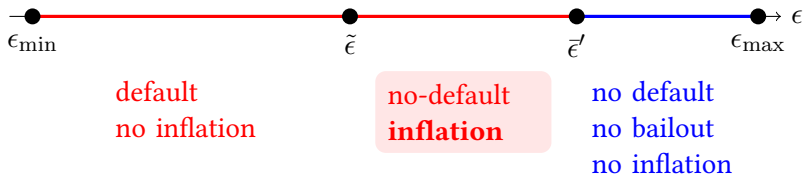


Figure 10: Bailout with Overburdened Central Bank

incentive to avert a default of i. The minimum inflation rate necessary to avoid a default is the one that leaves i indifferent between default and no default:

$$\tilde{z} = \frac{b_1^i \left(1 - \alpha^{i,i}\right) - \Phi y_1^i}{b_1^i \left(1 - \alpha^{i,i}\right) - \delta y_1^i} \tag{21}$$

This also defines a threshold level of shock $\bar{\epsilon} = \frac{b_1^i\left(1-\alpha^{i,i}\right)}{\Phi \overline{y}_1^i}$ above which i does not require any monetization and does not default. It can be shown that for $\Phi > \kappa > \delta$ the ECB is willing to accept such monetization at rate $\tilde{z}$ to avert a default but the constraint that it is below the maximum rate $\bar{z}$ defines a level of shock below which the ECB prefers to let the country default rather than monetize it:

$$\tilde{\epsilon} \equiv \frac{\left(1 - \alpha^{i,i}\right) b_1^i \left(1 - \overline{z}\right)}{\left(\Phi - \delta \overline{z}\right) \overline{y}_1^i}$$

Figure 10 shows that when transfers are impossible, the ECB inflates the debt for intermediate level of output realizations to avoid default. The inflation rate is maximum just above the threshold $\tilde{\epsilon}$. Contrary to transfers, inflation generates distortion costs. Hence, using inflation rather than transfers to avoid default, a situation where the ECB is "overburdened", is innefficient.

7 Conclusion

The objective of our paper was to shed light on the specific issues of sovereign debt in a monetary union. We analysed the impact of collateral damages of default and exit. Because of collateral damages of default, the no bailout clause by governments is not ex-post efficient. This provides an incentive to borrow by fiscally fragile countries. This is a "Northern" narrative of the crisis. We showed however that the efficiency benefits of transfers and debt monetization that prevent a default are entirely captured by the creditor country. There is no solidarity" in the transfers

made to prevent a default. Our model interprets our estimate of a very large transfer in the case of Greece, more than 40% of its GDP, not as a gesture that helped Greece but as the logical consequence of large collateral damages in case of exit, high debt and relatively high net gains for Greece to exit. This is the "Southern" narrative of the crisis. Our model shows that the two narratives are two sides of the same coin. One may think that a policy implication would be to strengthen the no-bailout commitment. We have shown that this may not be the case because doing so may precipitate immediate insolvency. In addition, this may put pressure on the ECB to step in and prevent a default through debt monetization which is less efficient than simple transfers. Some current discussions on eurozone reforms resonate with our analysis. For example, German policy makers and economists have made proposals to introduce orderly restructuring in case of a default in the eurozone. This can be interpreted in the context of our model as both lower cost of default for the debtor country and lower collateral damage of default for creditor countries. In our model, that would increase the probability of default but also strengthen "market discipline" through a higher yield for fiscally fragile countries. Similarly to the strengthening of the no-bailout clause though, an increase in market discipline that reduces risk shifting must be handled with care to avoid immediate insolvency. Finally, policies of the ESM and of the ECB which aim to reduce the risk of contagion to other fragile countries during financial stress episodes can also be interpreted as lower collateral damage that increases the probability of default and market discipline.

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Appendices

A Construction of the Dataset

- IMF Data for Cyprus, Greece, Ireland, and Portugal comes from the IMF website, which reports actual and projected disbursements, repayments of principal, and interest payments. Spain did not receive IMF assistance
- EFSF and ESM Disbursements and Repayment schedules for Cyprus, Greece, Ireland, Portugal, and are available from the EFSF and ESM websites. For interest payments, we apply the blended rate for August 2015 to the series of outstanding debt over the lifetime of the lending cycle. We are grateful to Corsetti et al. (2017) for sharing this data.
- EFSM data for Ireland come from the Irish Treasury website. EFSM data for Portugal come from the European Commission website. Interest payments are calculated by applying the three-month euribor rate at the time of disbursement.
- Bilateral loan data to Ireland come from the United Kingdom, Sweden, and Denmark Treasury websites.

B Characterizing the Laffer Curve

This appendix provides a full characterization of the Laffer curve in the basic model.

The Laffer curve satisfies :

$$D(b) = \beta b\left(1-\pi_d(b)\right)+\beta\rho\bar{y}_1^i\left(\pi\int_{\underline{\epsilon}(b)}^{\bar{\epsilon}(b)}\epsilon dG\left(\epsilon\right)+\int_{\epsilon_{\min}}^{\underline{\epsilon}(b)}\epsilon dG\left(\epsilon\right)\right)+\overline{\lambda}^i$$

where the cut-offs are defined as:

$$\begin{aligned}\bar{\epsilon}(b) &= \frac{(1-\alpha^{i,i})b/\bar{y}_1^i}{\Phi+\rho(1-\alpha^{i,i})}\\ \underline{\epsilon}(b) &= \frac{\alpha^{i,u}b/\bar{y}_1^i-\kappa y_1^g/\bar{y}_1^i}{\Phi+\rho\alpha^{i,u}}\end{aligned}$$

and the probability of default is:

$$\pi_d(b)=G(\underline{\epsilon}(b))+\pi(G(\bar{\epsilon}(b))-G(\underline{\epsilon}(b)))$$

There are a number of cases to consider:

- When $b \leq \underline{b} \equiv y^i_{\min}\left(\Phi/(1-\alpha^{i,i})+\rho\right)$. In that case $\bar{\epsilon} \leq \epsilon_{\min}$ and i's output is always sufficiently high that i prefers to repay even without any transfer from g. This makes i's debt riskless and

$$D\left(b\right) = \beta b + \bar{\lambda}^i$$

- If $\bar{b} \equiv ((\Phi+\rho\alpha^{i,u})y^i_{\min} + \kappa y^g_1)/\alpha^{i,u} \leq \hat{b} \equiv y^i_{\max}\left(\Phi/(1-\alpha^{i,i})+\rho\right)$. This is a condition on the parameters. It can be rewritten as:

$$\kappa y^g_1/\bar{y}^i_1 \leq \alpha^{i,u}\rho(\epsilon_{\max}-\epsilon_{\min}) + \Phi/(1-\alpha^{i,i})(\alpha^{i,u}\epsilon_{\max} - \epsilon_{\min}(\alpha^{i,u}+\alpha^{i,g}))$$

  - When $\underline{b} < b \leq \bar{b} < \hat{b}$. In that case, we have $\underline{\epsilon} \leq \epsilon_{\min} < \bar{\epsilon} < \epsilon_{\max}$. When $b = \bar{b}$, $\underline{\epsilon} = \epsilon_{\min} < \bar{\epsilon} < \epsilon_{\max}$. Default can occur if $\epsilon^i_1 \leq \bar{\epsilon}$ and ex-post transfers are forbidden. It follows that

$$D\left(b_1\right) = \beta[b_1\left(1-\pi G\left(\bar{\epsilon}\right)\right) + \rho\bar{y}^i_1\pi\int_{\epsilon_{\min}}^{\bar{\epsilon}} \epsilon dG\left(\epsilon\right)] + \bar{\lambda}^i$$

    and the slope of the Laffer curve is given by

$$D'\left(b_1\right) = \beta\left[1-\pi G\left(\bar{\epsilon}\right) - \frac{\pi\bar{\epsilon}g\left(\bar{\epsilon}\right)\Phi}{\Phi+\rho(1-\alpha^{i,i})}\right]$$

    For these intermediate debt levels, default is a direct consequence of the commitment *not* to bail-out country i in period $t=1$. The derivative of the Laffer curve is discontinuous at $b=\underline{b}$ if the distribution of shocks is such that $g\left(\epsilon_{\min}\right) > 0$ and the can write the discontinuity as:

$$\begin{aligned} D'(\underline{b}^+) - D'(\underline{b}^-) &= \beta\left(-\underline{b}+\rho y^i_{\min}\right)\pi g(\epsilon_{\min})\left.\frac{d\bar{\epsilon}}{db}\right|_{b=\underline{b}} \\ &= -\beta\frac{\pi\epsilon_{\min}g(\epsilon_{\min})\Phi}{\Phi+\rho(1-\alpha^{i,i})} \leq 0 \end{aligned}$$

    The intuition for the discontinuity is that at $b=\underline{b}$, a small increase in debt increases the threshold $\bar{\epsilon}$ beyond $\epsilon_{\min}$, so a default is now possible. This happens with probability $\pi g(\epsilon_{\min})d\bar{\epsilon}$. In that case, investors' discounted net loss is $\beta(-\underline{b}+\rho y^i_{\min})$.

    It is possible for the Laffer curve to *decrease* to the right of $\underline{b}$ if $\pi\epsilon_{\min}g(\epsilon_{\min})\Phi/(\Phi+\rho(1-\alpha^{i,i})) > 1$. In that case the increase in default risk is so rapid that the interest rate rises rapidly and i's revenues $D(b)$ decline as soon as $b > \underline{b}$. Given that i can always choose to be on the left side of the Laffer curve by choosing a lower b^i_1, there would never be any default or bailout. We view this case as largely uninteresting.

This case can be ruled out my making the following assumption *sufficient* to ensure $D'(\underline{b}^+) > 0$:

Assumption 2 *We assume the following restriction on the pdf of the shocks and the probability of bailout*

$$\pi \epsilon_{\min} g(\epsilon_{\min}) < 1$$

[Note: (a) this condition cannot be satisfied with a power law and $\pi = 1$ (i.e. no transfers); (b) this condition is satisfied for a uniform distribution if $\pi < \epsilon_{\max}/\epsilon_{\min} - 1$. A sufficient condition for this is $\epsilon_{\min} < 2/3$.[38]]

The second derivative of the Laffer curve is:

$$D''(b) = -\beta\pi \frac{d\bar{\epsilon}}{db}\left[g(\bar{\epsilon}) + \frac{\Phi}{\Phi + (1-\alpha^{i,i})\rho}(g(\bar{\epsilon}) + \bar{\epsilon}g'(\bar{\epsilon}))\right]$$

If we want to ensure that $D''(b) < 0$ a *sufficient* condition is:

Assumption 3 *We assume that g satisfies*

$$\frac{\epsilon g'(\epsilon)}{g(\epsilon)} > -2$$

[Note: we can replace this condition by a condition on the slope of the monotone ratio: $\pi g(\epsilon)/(1 - \pi G(\epsilon))$.]

[Note: (a) that sufficient condition is not satisfied for $\rho = 0$ and a power law; (b) it is always satisfied for a uniform distribution since $g'(\epsilon) = 0$.]

The value of $D'(\bar{b}^-)$ is:

$$D'(\bar{b}^-) = \beta\left[1 - \pi G\left(\bar{\epsilon}(\bar{b})\right) - \frac{\pi\Phi\bar{\epsilon}(\bar{b})g\left(\bar{\epsilon}(\bar{b})\right)}{\Phi + \rho(1-\alpha^{i,i})}\right]$$

We can ensure that this is positive (so that the peak of the Laffer curve has not been reached) by assuming that:

$$1/\pi > G\left(\bar{\epsilon}(\bar{b})\right) + \frac{\Phi\bar{\epsilon}(\bar{b})g\left(\bar{\epsilon}(\bar{b})\right)}{\Phi + \rho(1-\alpha^{i,i})}$$

This condition is always satisfied when there is no default ($\pi = 0$). Otherwise, a *sufficient* condition is:

[38] To see this, observe that since $E[\epsilon] = 1$ we can solve for $\epsilon_{\min} < 2/(2+\pi)$.

Assumption 4 *We assume that the distribution of shocks satisfies:*

$$1 > G\left(\bar{\epsilon}(\bar{b})\right) + \bar{\epsilon}(\bar{b})g\left(\bar{\epsilon}(\bar{b})\right)$$

[Note: with a uniform distribution, the condition above becomes $\bar{\epsilon}(\bar{b}) < \epsilon_{\max}/2$. Substituting for $\bar{\epsilon}(\bar{b})$, this can be ensured by choosing $\epsilon_{\min}$ such that

$$\frac{1-\alpha^{i,i}}{\Phi+(1-\alpha^{i,i})\rho}\frac{(\Phi+\rho\alpha^{i,u})\epsilon_{\min}+\kappa y_1^g/\bar{y}_1^i}{\Phi+\rho\alpha^{i,u}} < 1-\frac{\epsilon_{\min}}{2}$$

This can be ensured with $\epsilon_{\min}$ sufficiently small, provided $(\Phi+(1-\alpha^{i,i})\rho)\alpha^{i,u} > (\Phi+\rho\alpha^{i,u})(1-\alpha^{i,i})\kappa y_1^g/\bar{y}_1^i$.]

Under assumptions 2 -4, the Laffer curve is upward sloping, decreasing in b, discontinuous at $\underline{b}$ and has not yet reached its maximum at $\bar{b}$.

– When $\bar{b} < b \leq \hat{b}$ then we have $\epsilon_{\min} < \underline{\epsilon} < \bar{\epsilon} \leq \epsilon_{\max}$. It's now possible to default even with optimal transfers and the Laffer curve satisfies

$$D\left(b_1\right) = \beta\left[b_1\left(1-G\left(\underline{\epsilon}\right)-\pi\left(G\left(\bar{\epsilon}\right)-G\left(\underline{\epsilon}\right)\right)\right)+\rho\bar{y}_1^i\left(\pi\int_{\underline{\epsilon}}^{\bar{\epsilon}}\epsilon dG\left(\epsilon\right)+\int_{\epsilon_{\min}}^{\underline{\epsilon}}\epsilon dG\left(\epsilon\right)\right)\right]+\bar{\lambda}^i$$

with slope:

$$D'\left(b_1\right) = \beta\left[1-\pi_d-\frac{\pi g(\bar{\epsilon})\bar{\epsilon}\Phi}{\Phi+\rho(1-\alpha^{i,i})}-(1-\pi)g(\underline{\epsilon})\frac{\Phi\underline{\epsilon}+\kappa y_1^g/\bar{y}_1^i}{\Phi+\rho\alpha^{i,u}}\right]$$

One can check immediately that the slope of the Laffer curve is discontinuous at $b=\bar{b}$ as well, if $\pi<1$ and $g(\epsilon_{\min})>0$, with:

$$\begin{aligned} D'(\bar{b}^+)-D'(\bar{b}^-) &= \beta\left(-\bar{b}+\rho y_{\min}^i\right)(1-\pi)g(\epsilon_{\min})\left.\frac{d\underline{\epsilon}}{db}\right|_{b=\bar{b}} \\ &= -\beta(1-\pi)g(\epsilon_{\min})\frac{\Phi\epsilon_{\min}+\kappa y_1^g/\bar{y}_1^i}{\Phi+\rho\alpha^{i,u}} \leq 0 \end{aligned}$$

The interpretation is the following: when $b=\bar{b}$, a small increase in debt makes default unavoidable, i.e. default probabilities increase from π to 1, since the debt level is too high for transfers to be optimal. The probability of default jumps up by $(1-\pi)g(\epsilon_{\min})d\underline{\epsilon}$. The discounted investor's loss in case of default is $\beta(-\bar{b}+\rho y_{\min}^i)$.

The second derivative of the Laffer curve is:

$$\begin{aligned} D''(b) &= -\beta\pi\frac{d\bar{\epsilon}}{db}\left[g(\bar{\epsilon})+\frac{\Phi}{\Phi+(1-\alpha^{i,i})\rho}(g(\bar{\epsilon})+\bar{\epsilon}g'(\bar{\epsilon}))\right] \\ &\quad -\beta(1-\pi)\frac{d\underline{\epsilon}}{db}\left[g(\underline{\epsilon})+\frac{\Phi}{\Phi+\rho\alpha^{i,u}}g(\underline{\epsilon})+g'(\underline{\epsilon})\frac{\Phi\underline{\epsilon}+\kappa y_1^g/\bar{y}_1^i}{\Phi+\rho\alpha^{i,u}}\right] \end{aligned}$$

The first term is negative under assumption 3. The second term is also negative under assumption 3, unless $g'(\epsilon)$ becomes too negative.

Assumption 5 *The parameters of the problem are such that $D''(b)<0$ for $b<\hat{b}$.*

[Note: with a uniform distribution, this condition is satisfied since $g'(\underline{\epsilon})=0$.]

We can check that:

$$D'(\hat{b}^-) = \beta\left[(1-\pi)(1-G(\underline{\epsilon}))-\frac{\pi g(\epsilon_{\max})\epsilon_{\max}\Phi}{\Phi+\rho(1-\alpha^{i,i})}-(1-\pi)g(\underline{\epsilon})\frac{\Phi\underline{\epsilon}+\kappa y_1^g/\bar{y}_1^i}{\Phi+\rho\alpha^{i,u}}\right]$$

– As $\hat{b}<b\leq\tilde{b}$ where $\tilde{b}\equiv((\Phi+\rho\alpha^{i,u})y_{\max}^i+\kappa y_1^g)/\alpha^{i,u}$, we have $\epsilon_{\min}<\underline{\epsilon}\leq\epsilon_{\max}<\bar{\epsilon}$ and now the only way for i to repay its debts is with a transfer from g.

$$D(b)=\beta\left(b(1-\pi)(1-G(\underline{\epsilon}))+\rho\bar{y}_1^i\left(\pi\int_{\underline{\epsilon}(b)}^{\epsilon_{\max}}\epsilon dG(\epsilon)+\int_{\epsilon_{\min}}^{\underline{\epsilon}(b)}\epsilon dG(\epsilon)\right)\right)+\overline{\lambda}^i$$

The derivative satisfies:

$$D'(b)=\beta\left[(1-\pi)(1-G(\underline{\epsilon}))-(1-\pi)g(\underline{\epsilon})\frac{\Phi\underline{\epsilon}+\kappa y_1^g/\bar{y}_1^i}{\Phi+\rho\alpha^{i,u}}\right]$$

Evaluating this expression at $b=\hat{b}^+$, there is an *upwards discontinuity* in the Laffer curve:

$$\begin{aligned} D'(\hat{b}^+)-D'(\hat{b}-) &= \beta\left(\hat{b}-\rho y_{\max}^i\right)\pi g(\epsilon_{\max})\left.\frac{d\bar{\epsilon}}{db}\right|_{b=\hat{b}} \\ &= \beta\pi\frac{\Phi g(\epsilon_{\max})\epsilon_{\max}}{\Phi+\rho(1-\alpha^{i,i})}\geq 0 \end{aligned}$$

This upwards discontinuity arises because, at $b=\hat{b}$, an infinitesimal increase in debt pushes $\bar{\epsilon}$ above $\epsilon_{\max}$. The increase in the threshold becomes inframarginal and does not affect the value of the debt anymore (since the realizations where $\epsilon>\bar{\epsilon}$ cannot be achieved anymore).

At $b = \tilde{b}$, the derivative of the Laffer curve satisfies:

$$D'(\tilde{b}^-) \quad = \quad -\beta(1-\pi)g(\epsilon_{\max})\frac{\Phi\epsilon_{\max} + \kappa y_1^g/\bar{y}_1^i}{\Phi + \rho\alpha^{i,u}} \leq 0$$

so the peak of the Laffer curve occurs necessarily at or before $\tilde{b}$.

The second derivative satisfies:

$$D''(b) \quad = \quad -\beta(1-\pi)\frac{d\underline{\epsilon}}{db}\left[g(\underline{\epsilon}) + \frac{\Phi}{\Phi + \rho\alpha^{i,u}}g(\underline{\epsilon}) + g'(\underline{\epsilon})\frac{\Phi\underline{\epsilon} + \kappa y_1^g/\bar{y}_1^i}{\Phi + \rho\alpha^{i,u}}\right]$$

which is still negative under assumption 5.

The discontinuity at $\hat{b}$ could be problematic for our optimization problem. Consequently, we make assumptions to ensure that the peak of the Laffer curve occurs at or before $\hat{b}$. A sufficient assumption is that $D'(\hat{b}^+) < 0$.

Assumption 6 *We assume that the parameters of the problem are such that*

$$D'(\hat{b}^+) = \beta(1-\pi)\left[1 - G(\underline{\epsilon}) - g(\underline{\epsilon})\frac{\Phi\underline{\epsilon} + \kappa y_1^g/\bar{y}_1^i}{\Phi + \rho\alpha^{i,u}}\right] < 0$$

Under this assumption, the Laffer curve reaches its maximum at $0 < b_{\max} < \hat{b}$ such that $0 \in \partial D(b_{\max})$, where $\partial D(b)$ is the sub-differential of the Laffer curve at b. The peak of the Laffer curve cannot be reached at $\hat{b}$ or beyond since $D'(\hat{b}^-) < D'(\hat{b}^+) < 0$, so $0 \notin \partial D(\hat{b})$ and $D''(b) < 0$ for $b < \tilde{b}$. It follows immediately that $b_{\max} < \hat{b}$.

The economic interpretation of this assumption is that we restrict the problem so that the maximum revenues that i can generate by issuing debt in period 0 do not correspond to levels of debt so elevated that no realization of ϵ would allow i to repay on its own. In other words, the implicit transfer and the recovery value of debt are limited.

– As $b > \tilde{b}$ we have $\epsilon_{\max} < \underline{\epsilon}$ so that default is inevitable, even with transfers and the Laffer curve becomes:

$$D(b) = \beta\rho\bar{y}_1^i + \overline{\lambda}^i$$

which does not depend on the debt level. Note that there is an upwards discontinuity at $\tilde{b}$ since $D'(b) = 0$ for $b > \tilde{b}$.

To summarize, under assumptions 2-6, the Laffer curve reaches its peak at $b_{\max}$ with $\bar{b} \leq b_{\max} < \hat{b}$. The Laffer curve is continuous, convex and exhibits two (downward) discontinuities of $D'(b)$ on the interval $[0, b_{\max}]$. Since i will never locate itself on the 'wrong side' of the Laffer curve ($b > b_{\max}$), we can safely ignore the non-convexity associated with the upward discontinuities of the $D'(b)$ at

$\hat{b}$ and $\tilde{b}$.

- For the sake of completeness, the remaining discussion describes what happens if $\bar{b} > \hat{b}$ (the reverse condition on the parameters). In that case, as b increases, the country stops being able to repay on its own first. This leads to a somewhat implausible case where the only reason debts are repaid is because of the transfer. We would argue that this is not a very interesting or realistic case.

  - When $\underline{b} < b \leq \hat{b} < \bar{b}$. In that case, we have $\underline{\epsilon} < \epsilon_{\min} \leq \bar{\epsilon} < \epsilon_{\max}$. When $b = \hat{b}$, $\underline{\epsilon} < \epsilon_{\min} < \bar{\epsilon} = \epsilon_{\max}$. Default can occur if $\epsilon_1^i \leq \bar{\epsilon}$ and ex-post transfers are forbidden. It follows that

$$D\left(b_1\right) = \beta[b_1\left(1 - \pi G\left(\bar{\epsilon}\right)\right) + \rho \bar{y}_1^i \pi \int_{\epsilon_{\min}}^{\bar{\epsilon}} \epsilon dG\left(\epsilon\right)] + \bar{\lambda}^i$$

    and the slope of the Laffer curve is given by

$$D'\left(b\right) = \beta\left[1 - \pi G\left(\bar{\epsilon}\right) - \frac{\pi \bar{\epsilon} g\left(\bar{\epsilon}\right) \Phi}{\Phi + \rho(1 - \alpha^{i,i})}\right]$$

    As before, default is a direct consequence of the commitment *not* to bail-out country i in period $t = 1$. The derivative of the Laffer curve is discontinuous at $b = \underline{b}$ if the distribution of shocks is such that $g\left(\epsilon_{\min}\right) > 0$ and $\pi > 0$.[39]

    Under the same assumptions as before, the Laffer curve slopes up at $b = \underline{b}$.

    The second derivative of the Laffer curve is:

$$D''(b) = -\beta\pi \frac{d\bar{\epsilon}}{db}\left[g(\bar{\epsilon}) + \frac{\Phi}{\Phi + (1 - \alpha^{i,i})\rho}(g(\bar{\epsilon}) + \bar{\epsilon} g'(\bar{\epsilon}))\right]$$

    and we can to ensure that $D''(b) < 0$ with:

$$\frac{\epsilon g'(\epsilon)}{g(\epsilon)} > -2$$

  - When $\hat{b} < b < \bar{b}$, we have $\underline{\epsilon} \leq \epsilon_{\min} < \epsilon_{\max} < \bar{\epsilon}$. It follows that

$$D(b) \quad = \quad \beta b(1 - \pi) + \beta\pi\rho\bar{y}_1^i + \overline{\lambda}^i$$

    which has a constant positive slope $\beta(1 - \pi)$. At $b = \hat{b}$ the slope is discontinuous, with

$$D'\left(\hat{b}^-\right) = \beta\left[1 - \pi - \frac{\pi \epsilon_{\max} g\left(\epsilon_{\max}\right) \Phi}{\Phi + \rho(1 - \alpha^{i,i})}\right]$$

[39] To see this, observe that: $D'(\underline{b}^+) = \beta\left[1 - \frac{\pi \epsilon_{\min} g(\epsilon_{\min}) \Phi}{\Phi + \rho(1 - \alpha^{i,i})}\right] < \beta$ when $g(\epsilon_{\min}) > 0$ and $\pi > 0$.

so there is an upwards discontinuity in the slope at $b = \hat{b}$.

– for $\bar{b} < \tilde{b}$ we have $\epsilon_{\min} < \underline{\epsilon} < \epsilon_{\max} < \bar{\epsilon}$ and it is now possible to default even with optimal transfers. The Laffer curve satisfies

$$D\left(b_1\right) = \beta\left[b_1\left((1-\pi)(1-G\left(\underline{\epsilon}\right)\right) + \rho\bar{y}_1^i\left(\pi\int_{\underline{\epsilon}}^{\epsilon_{\max}} \epsilon dG\left(\epsilon\right) + \int_{\epsilon_{\min}}^{\underline{\epsilon}} \epsilon dG\left(\epsilon\right)\right)\right] + \bar{\lambda}^i$$

with slope:

$$D'\left(b_1\right) \quad = \quad \beta(1-\pi)\left[(1-G(\underline{\epsilon}) - g(\underline{\epsilon})\frac{\Phi\underline{\epsilon} + \kappa y_1^g/\bar{y}_1^i}{\Phi + \rho\alpha^{i,u}}\right]$$

One can check that the slope of the Laffer curve is discontinuous also at $b = \bar{b}$ as long as $\pi < 1$ and $g(\epsilon_{\min}) > 0$ with:

$$D'(\bar{b}^+) - D'(\bar{b}^-) = -\beta(1-\pi)g(\epsilon_{\min})\frac{\Phi\epsilon_{\min} + \kappa y_1^g/\bar{y}_1^i}{\Phi + \rho\alpha^{i,u}} < 0$$

At $b = \tilde{b}$, the derivative satisfies:

$$D'(\tilde{b}^-) \quad = \quad -\beta(1-\pi)g(\epsilon_{\max})\frac{\Phi\epsilon_{\max} + \kappa y_1^g/\bar{y}_1^i}{\Phi + \rho\alpha^{i,u}} < 0$$

so the peak of the Laffer curve *needs* to occur before $\tilde{b}$.

The second derivative satisfies:

$$D''(b) \quad = \quad -\beta(1-\pi)\frac{d\underline{\epsilon}}{db}\left[g(\underline{\epsilon}) + \frac{\Phi}{\Phi + \rho\alpha^{i,u}}g(\underline{\epsilon}) + g'(\underline{\epsilon})\frac{\Phi\underline{\epsilon} + \kappa y_1^g/\bar{y}_1^i}{\Phi + \rho\alpha^{i,u}}\right]$$

which is still negative as long as $g'(\underline{\epsilon})$ is not too negative.

– As $b > \tilde{b}$ we have $\epsilon_{\max} < \underline{\epsilon}$ so that default is inevitable, even with transfers and the Laffer curve becomes:

$$D(b) = \beta\rho\bar{y}_1^i + \overline{\lambda}^i$$

which does not depend on the debt level.

C Optimal Debt

Let's consider the rollover problem of country i. The first order condition is

$$\begin{aligned} 0 \quad \in \quad & \mu_1 + (1-\alpha^{i,i})\partial D(b_1^i)(1+\nu_0) - \beta(1-G(\bar{\epsilon}))(1-\alpha^{i,i}) \\ & \nu_0 c_0^i = 0 \\ & \mu_1 b_1^i = 0 \end{aligned}$$

We consider first an interior solution and ignore the non-continuity of $D'(b)$ at $\underline{b}$ and $\bar{b}$. The first-order condition becomes:

$$D'(b_1^i) = \beta\,(1 - G(\bar{\epsilon})) \tag{C.1}$$

Both sides of this equation are decreasing in b.

- Consider first the region $0 \leq b_1^i < \underline{b}$. Over that range, debt is safe: $D'(b) = \beta$ and $G(\bar{\epsilon}) = 0$. The first order condition is trivially satisfied: since debt is safe, risk neutral agents price the debt at β and i is indifferent as to the amount of debt it issues as long as it can ensure positive consumption.
- Consider now the interval $\underline{b} < b_1^i < \bar{b}$. We need to consider two cases.
  - when $\pi = 0$, g always bails out i and i's debt is safe. This implies $D'(b_1^i) = \beta$ and

    $$D'(b) - \beta(1 - G(\bar{\epsilon})) = \beta G(\bar{\epsilon}) > 0$$

    so there is no solution in that interval: i would always want to issue more debt.
  - when $\pi = 1$, i defaults when $b > \underline{b}$. Going back to the definition of $D'(b_1^i)$ and $\bar{\epsilon}$ we can check that

    $$D'(b) - \beta(1 - G(\bar{\epsilon})) = -\beta \frac{\Phi}{\Phi + \rho(1-\alpha^{i,i})} g(\bar{\epsilon})\bar{\epsilon} < 0$$

    from which it follows that there is no solution in that interval: i would always want to issue less debt to remain safe.
  - In the intermediate case where $0 < \pi < 1$, it is possible to find a solution to the first-order condition. However, under reasonable conditions the second-order condition of the optimization problem will not be satisfied. This will be the case if $D'(b) - \beta(1 - G(\bar{\epsilon})$ is increasing. A sufficient condition is that g/G is monotonously decreasing. To see this, observe that for $\underline{b} < b \leq \bar{b}$, we have $\underline{\epsilon} < \epsilon_{\min}$ and therefore we can write:

    $$D'(b) - \beta(1 - G(\bar{\epsilon})) = \beta(1-\pi)G(\bar{\epsilon}) \left[1 - \frac{\pi}{1-\pi}(b - \rho\bar{y}_1^i\bar{\epsilon}) \frac{g(\bar{\epsilon})}{G(\bar{\epsilon})} \frac{d\bar{\epsilon}}{db}\right]$$

    The term in brackets is increasing in $\bar{\epsilon}$ when g/G is decreasing. If this condition is satisfied,

then there is no solution in the interval $(\underline{b}, \bar{b})$. [Note: this condition is satisfied for a uniform distribution.]

- Consider next the interval $\bar{b} \leq b < \hat{b}$. We already know under the assumptions laid out in section B that we only need to consider the subinterval $(\bar{b}, b_{\max})$ where $b_{\max}$ is the value of the debt that maximizes period 1 revenues. Let's consider the various values of π again:

  - for $\pi = 0$, we have $D'(\bar{b}^-) = \beta$ and $D'(b_{\max}) = 0$. Since $D'(b) - \beta(1 - G(\bar{\epsilon}))$ is continuous over that interval, then there is at least one solution to the first-order condition, possibly at $b = \bar{b}$. This solution is unique if $D'(b) - \beta(1 - G(\bar{\epsilon}))$ is strictly decreasing over that interval. Recall that over that interval we have:

$$\begin{aligned} D'(b) - \beta(1 - G(\bar{\epsilon})) &= \beta \left[G(\bar{\epsilon}) - G(\underline{\epsilon}) - g(\underline{\epsilon})(b - \rho \bar{y}_1^i \underline{\epsilon}) \frac{d\underline{\epsilon}}{db} \right] \\ &= \beta \left[G(\bar{\epsilon}) - G(\underline{\epsilon}) - g(\underline{\epsilon}) \frac{\Phi \underline{\epsilon} + \kappa y_1^g / \bar{y}_1^i}{\Phi + \rho \alpha^i, u} \right] \end{aligned}$$

    The condition that $D'(b) - \beta(1 - G(\bar{\epsilon}))$ is decreasing over this range is satisfied for a uniform distribution if $\alpha^{i,g}$ is not too high.

    Let's denote the unique solution b_{opt}. If $D'(\bar{b}^+) < \beta(1 - G(\bar{\epsilon}))$ then the solution is $b_{opt} = \bar{b}$.

  - for $\pi = 1$ (no bailout), we can check that in that interval we can write

$$D'(b) - \beta(1 - G(\bar{\epsilon})) = -\beta g(\bar{\epsilon})(b - \rho \bar{y}_1^i \bar{\epsilon}) \frac{d\bar{\epsilon}}{db} < 0$$

    Since $D'(\bar{\epsilon}^+) < \beta(1 - G(\bar{\epsilon}))$, it follows that there is no solution over that interval.

  - For intermediate values of π, as long as π is not too high, we will have a unique solution b_{opt} as before. b_{opt} is decreasing in π for $\pi < \pi_c$. Above this critical value, this equilibrium disappears and the only remaining solutions are for $b \leq \underline{b}$. π_c is characterized by the condition that $D'(\bar{b}^-) = \beta(1 - G(\bar{\epsilon}))$. Substituting, we obtain:

$$\pi_c = \frac{G(\bar{\epsilon})}{G(\bar{\epsilon}) + \frac{\Phi g(\bar{\epsilon}) \bar{\epsilon}}{\Phi + \rho(1 - \alpha^{i,i})}}$$

    In the case where there is no recovery, the formula for π_c simplifies to

$$\pi_c = \frac{1}{1 + g(\bar{\epsilon}) \bar{\epsilon} / G(\bar{\epsilon})}$$

D Exit and Default

D.1 Proof of Proposition 1.

Proof. Denote D/ND the decision to default/repay and E/NE the decision to exit/stay in the currency union. Denote $\hat{b}$ the amount of debt held abroad, scaled by potential output: $\hat{b} = (1-\alpha^{i,i})b_1^i/\bar{y}_1^i$. Denote also $\hat{\rho} = \rho(1-\alpha^{i,i})$ the foreign debt holder's recovery rate per unit of output. i prefers ND/NE to D/NE whenever:

$$-\Phi_d\epsilon_1^i + \hat{b} - \hat{\rho}\epsilon_1^i \leq 0 \iff \epsilon_1^i \geq \bar{\epsilon} = \frac{\hat{b}}{\Phi_d + \hat{\rho}}$$

Similarly, i prefers ND/E to D/E whenever

$$-\Phi_e\epsilon_1^i + \Delta\hat{b} \geq -(\Phi_d + \Phi_e) + (1+\Delta)\hat{b} - \hat{\rho} \iff \epsilon_1^i \geq \bar{\epsilon}^d$$

It follows that $\bar{\epsilon}^d$ represents the cut-off for default decisions, regardless of exit decisions.

Now, by a similar reasoning, we can show that i chooses to stay in the currency union whenever $\epsilon_1^i \geq \bar{\epsilon}^e$, regardless of the decision to default.
Under the assumption $\Delta/\Phi_e > 1/(\Phi_d + \rho)$, we have $\bar{\epsilon}^d > \bar{\epsilon}^e$ for all $\hat{b}$ and the proposition follows. ■

D.2 Proof of Proposition 2

Proof. Let's define the minimal transfer to avoid a default $\underline{\tau}_1^d$ and the minimal transfer to avoid an exit $\underline{\tau}_1^e$. They satisfy:

$$\begin{aligned}
\underline{\tau}_1^d &= (b_1^i - \rho y_1^i)(1-\alpha^{i,i}) - \Phi_d y_1^i \\
\underline{\tau}_1^e &= \Delta b_1^i(1-\alpha^{i,i}) - \Phi_e y_1^i
\end{aligned}$$

Now, define $U_g(ND, NE, \tau_1)$ the utility of g if there is no default (ND), no exit (NE) and transfer τ_1. It satisfies:

$$U_g(ND, NE, \tau_1) = x_1^g + b_1^i\alpha^{i,g} - \tau_1$$

where $x_1^g = y_1^g + b_1^{s,g} - b_1^g$ is constant regardless of the transfers and i's decision. Similarly, we can define:

$$\begin{aligned}
U_g(D, NE, \tau_1) &= x_1^g - \kappa_d y_1^g + \rho y_1^i\alpha^{i,g} - \tau_1 \\
U_g(ND, E, \tau_1) &= x_1^g - \kappa_e y_1^g + b_1^i\alpha^{i,g} - \Delta b\alpha^{i,g} - \tau_1 \\
U_g(D, E) &= x_1^g - (\kappa_d + \kappa_e)y_1^g + \rho y_1^i\alpha^{i,g} - \Delta b\alpha^{i,g}
\end{aligned}$$

where we note that g will never make a transfer if i defaults and exits. Consider now the following cases:

- When $\epsilon_1^i \geq \bar{\epsilon}^d$. Since i does not want to default or exit, no transfer is necessary: $\tau_1 = 0$.
- When $\bar{\epsilon}^d > \epsilon_1^i \geq \bar{\epsilon}^e$, i prefers to default and exit. To prevent this, g must make a transfer $\underline{\tau}_1^d$. This is optimal as long as $U_g(ND, NE, \underline{\tau}_1^d) > U_g(D, NE, 0)$. This condition takes the form:

$$\Phi_d y_1^i + \kappa_d y_1^g \geq (b_1^i - \rho y_1^i)\alpha^{i,u}$$

  or equivalently:

$$\epsilon_1^i \geq \underline{\epsilon}^d \equiv \frac{\alpha^{i,u} b_1^i / \bar{y}_1^i - \kappa_d y_1^g / \bar{y}_1^g}{\Phi_d + \rho\alpha^{i,u}}$$

  where $\underline{\epsilon}^d < \bar{\epsilon}^d$. It follows that:

  - When $\bar{\epsilon}^d > \epsilon_1^i \geq \underline{\epsilon}^d$, g makes the transfer $\underline{\tau}_1^i$ and there is no default
  - When $\underline{\epsilon}^d > \epsilon_1^i \geq \bar{\epsilon}^e$, g does not make a transfer ($\tau_1 = 0$), i defaults, but without exiting.

- $\bar{\epsilon}^e > \epsilon_1^i$, i prefers to default and exit without transfer. g can consider two types of transfer: $\underline{\tau}_1^e$ to avoid the exit (but not the default) or $\underline{\tau}_1^d + \underline{\tau}_1^e$ to avoid both default and exit. Consider first a transfer to avoid exit. This is optimal as long as $U_g(D, NE, \underline{\tau}_1^e) > U_g(D, E)$. This condition takes the form:

$$\Phi_e y_1^i + \kappa_e y_1^g > \Delta b \alpha^{i,u}$$

  or equivalently

$$\epsilon_1^i \geq \underline{\epsilon}^e \equiv \frac{\Delta\alpha^{i,u} b_1^i / \bar{y}_1^i - \kappa_e y_1^g / \bar{y}_1^i}{\Phi_e}$$

  where $\underline{\epsilon}^e < \bar{\epsilon}^e$, and it yields the following utility for g:

$$U_g(D, NE, \underline{\tau}_1^e) = x_1^g - \kappa_d y_1^g + \rho y_1^i \alpha^{i,g} - \Delta b_1^i (1 - \alpha^{i,i}) + \Phi_e y_1^i$$

  Now, within that region, g prefers to make a transfer $\underline{\tau}_1^d + \underline{\tau}_1^e$, to avoid both default and exit as long as $U_g(ND, NE, \underline{\tau}_1^d + \underline{\tau}_1^e) \geq U_g(D, NE, \underline{\tau}_1^e)$ which takes the form:

$$\Phi_d y_1^i + \kappa_d y_1^g \geq (b_1^i - \rho y_1^i)\alpha^{i,u}$$

  or equivalently:

$$\epsilon_1^i \geq \underline{\epsilon}^d$$

  It follows that:

  - When $\bar{\epsilon}^e > \epsilon_1^i > \underline{\epsilon}^e$ and $\epsilon_1^i \geq \underline{\epsilon}^d$, g prefers to make the transfer $\underline{\tau}_1^d + \underline{\tau}_1^e$ to avoid default and exit.

- When $\overline{\epsilon}^e > \epsilon_1^i > \underline{\epsilon}^e$ and $\epsilon_1^i < \underline{\epsilon}^d$, g makes the transfer $\underline{\tau}_1^e$, i defaults but stays in the currency union
- When $\underline{\epsilon}_1^e > \epsilon_1^i$, g makes no transfer ($\tau_1 = 0$), i defaults and exits.

■

E Debt Monetization

This appendix provides a full characterization of the different cases that arise with possible debt monetization within a monetary union. They depend on the output shock realization ϵ_1^i and on the ranking of the output thresholds. We first analyze the decision to default of i for a given transfer and inflation/monetization rate. If i repays the ECB chooses the rate z and if i defaults it chooses the rate $\hat{z}$. The budget constraint in period 1 of the i households becomes:

$$\begin{aligned} c_1^i &= y_1^i - T_1^i + \left(b_1^{i,i} + b_1^{g,i}\right)(1-z) - \delta z y_1^i + b_1^{u,i} \quad \text{if } i \text{ repays} \\ c_1^i &= y_1^i(1-\Phi) - T_1^i + b_1^{g,i}(1-\hat{z}) - \delta \hat{z} y_1^i + b_1^{u,i} \quad \text{if } i \text{ defaults} \end{aligned}$$

Government i constraint in $t = 1$ is:

$$\begin{aligned} T_1^i + \tau_1 &= b_1^i(1-z) \quad \text{if } i \text{ repays} \\ T_1^i &= 0 \quad \text{if } i \text{ defaults} \end{aligned}$$

Consolidating the private and public budget constraints, we again proceed by backward induction. At $t = 1$, i can decide to default after the shock ϵ_1^i has been revealed and the transfer τ_1 announced. Taking b_1^i and τ_1 as given, i repays if and only if:

$$y_1^i\left[\Phi - \delta(z - \hat{z})\right] \geq b_1^i\left(1 - \alpha^{i,i}\right)(1-z) + (z-\hat{z})\, b_1^g \alpha^{g,i} - \tau_1 \tag{E.1}$$

For g, the budget constraint is:

$$\begin{aligned} c_1^g &= y_1^g - T_1^g + \left(b_1^{i,g} + b_1^{g,g}\right)(1-z) - \delta z y_1^g + b_1^{u,g} \quad \text{if } i \text{ repays} \\ c_1^g &= y_1^g(1-\kappa) - T_1^g + b_1^{g,g}(1-\hat{z}) - \delta \hat{z} y_1^g + b_1^{u,g} \quad \text{if } i \text{ defaults} \end{aligned}$$

and g government constraint in $t = 1$ is:

$$\begin{aligned} T_1^g - \tau_1 &= b_1^g(1-z) \quad \text{if } i \text{ repays} \\ T_1^g &= b_1^g(1-\hat{z}) \quad \text{if } i \text{ defaults} \end{aligned}$$

We now detail the different relevant thresholds:

- **No default, no monetization, no transfer**. Comparison made when $z = 0$ in no default and default. Necessary conditions on output shock:

$$\begin{aligned}
\epsilon_1^i &> \frac{b_1^i \alpha^{iu} - \kappa y_1^g}{\Phi \overline{y}_1^i} \equiv \overline{\epsilon}'' \quad \text{ECB and g prefer no default to default with } z = 0 \text{ in both cases} \\
\epsilon_1^i &> \frac{b_1^i \alpha^{iu} + b_1^g \alpha^{gu}}{\delta \overline{y}_1^i} - \frac{y_1^g}{\overline{y}_1^i} \equiv \overline{\overline{\epsilon}} \quad \text{ECB prefers } z = 0 \text{ in no default} \\
\epsilon_1^i &> \frac{\alpha^{gu} b_1^g - \delta y_1^g}{\delta \overline{y}_1^i} \equiv \hat{\epsilon} \quad \text{ECB chooses } z = 0 \text{ in case of default} \\
\epsilon_1^i &> \frac{b_1^i \left(1 - \alpha^{ii}\right)}{\Phi \overline{y}_1^i} \equiv \overline{\epsilon}' \quad i \text{ repays with zero transfer and } z = 0
\end{aligned}$$

- **No default, no monetization, positive transfer** Necessary conditions on output shock:

$$\begin{aligned}
\epsilon_1^i &> \overline{\epsilon}'' \quad \text{ECB and g prefer no default to default with } z = 0 \text{ in both cases} \\
\epsilon_1^i &> \overline{\overline{\epsilon}} \quad \text{ECB prefers } z = 0 \text{ in case of no default} \\
\epsilon_1^i &< \overline{\epsilon}' \quad i \text{ repays only with transfer and } z = 0
\end{aligned}$$

- **No default, monetization at maximum rate, no transfer** Comparison made when $z = \overline{z}$ in no default and $z = 0$ in case of default.

$$\begin{aligned}
\epsilon_1^i &< \overline{\overline{\epsilon}} \quad \text{ECB prefers } z = \overline{z} \text{ in no default} \\
\epsilon_1^i &> \frac{\left(1 - \alpha^{ii}\right) b_1^i \left(1 - \overline{z}\right) + \alpha^{gi} b_1^g \overline{z}}{\left(\Phi - \delta \overline{z}\right) \overline{y}_1^i} \equiv \tilde{\epsilon} \quad i \text{ repays with zero transfer with } z = \overline{z}
\end{aligned}$$

- **No default, monetization at maximum rate, positive transfer** Comparison made when $z = \overline{z}$ in no default and $z = 0$ in case of default.

$$\begin{aligned}
\epsilon_1^i &< \overline{\overline{\epsilon}} \quad \text{ECB prefers } z = \overline{z} \text{ in no default} \\
\epsilon_1^i &> \frac{\alpha^{iu} b_1^i \left(1 - \overline{z}\right) - \alpha^{gu} b_1^g \overline{z} - y_1^g \left(\kappa - \delta \overline{z}\right)}{\left(\Phi - \delta \overline{z}\right) \overline{y}_1^i} \equiv \underline{\epsilon}' \quad g \text{ prefers no default, transfer and } z = \overline{z} \\
\epsilon_1^i &< \frac{\left(1 - \alpha^{i,i}\right) b_1^i \left(1 - \overline{z}\right) + \alpha^{gi} b_1^g \overline{z}}{\left(\Phi - \delta \overline{z}\right) \overline{y}_1^i} \equiv \tilde{\epsilon} \quad i \text{ repays only with transfer with } z = \overline{z}
\end{aligned}$$

In this case, the transfer is the minimum that leaves i indifferent between default and no default (see equation 19).

- **Default, no monetization, no transfer**

  Comparison made when $z = \overline{z}$ in no default and $z = 0$ in case of default.

$$\begin{aligned}
\epsilon_1^i &< \overline{\overline{\epsilon}} \quad \text{ECB prefers } z = \overline{z} \text{ in no default} \\
\epsilon_1^i &< \frac{\alpha^{iu} b_1^i (1 - \overline{z}) - \alpha^{gu} b_1^g \overline{z} - y_1^g (\kappa - \delta \overline{z})}{(\Phi - \delta \overline{z}) \overline{y}_1^i} \equiv \underline{\epsilon}' \quad g \text{ prefers default, no transfer} \\
\epsilon_1^i &> \frac{\alpha^{gu} b_1^g - \delta y_1^g}{\delta \overline{y}_1^i} \equiv \hat{\epsilon} \quad \text{ECB chooses } z = 0 \text{ in default}
\end{aligned}$$

- **Default, monetization, no transfer**

  Comparison made with $z = \overline{z}$ in both cases:

$$\begin{aligned}
\epsilon_1^i &< \frac{\alpha^{iu} b_1^i (1 - \overline{z}) - \kappa y_1^g}{\Phi \overline{y}_1^i} \equiv \underline{\epsilon}'' \quad g \text{ prefers default, no transfer and } z = \overline{z} \\
\epsilon_1^i &< \frac{\alpha^{g,u} b_1^g - \delta y_1^g}{\delta \overline{y}_1^i} \equiv \hat{\epsilon} \quad \text{ECB chooses } z = \overline{z} \text{ in default}
\end{aligned}$$

There are therefore 7 thresholds for output realizations: $\overline{\overline{\epsilon}}; \overline{\epsilon}'; \overline{\epsilon}''; \hat{\epsilon}; \tilde{\epsilon}; \underline{\epsilon}'; \underline{\epsilon}''$. In addition, we assume there is a minimum and maximum output realization ϵ^{max} and ϵ^{min}.

We can rank some of them under the assumption that $\Phi > \kappa > \delta$: $\underline{\epsilon}' < \overline{\epsilon}'; \underline{\epsilon}'' < \overline{\epsilon}''; \hat{\epsilon} < \overline{\epsilon}'; \underline{\epsilon}'' < \underline{\epsilon}'; \tilde{\epsilon} > \underline{\epsilon}'$

To simplify the analysis, we focus on parameter configurations that are most interesting and most plausible for the situation of the eurozone, we rank these thresholds based on the following general assumptions : b_1^g is small relative y_1^g and to b_1^i.

Assumptions on parameters: We can compare different cases with different degrees of fiscal dominance. **Fiscal dominance** would apply if the ECB inflates the eurozone debt even if i defaults so that only g debt remains. This is not a very interesting or plausible case so we ignore it and assume $\hat{\epsilon} < \epsilon^{min}$ which means that we concentrate as before on relatively low levels of debt to GDP levels in g and relatively high levels of the distortion costs δ. Another polar case is one of **monetary dominance**. This is a situation with low levels of g debt relative to GDP and high distortion costs δ. A sufficient condition is: $\overline{\overline{\epsilon}} < \epsilon^{min}$. The ECB never inflates the debt in a situation where transfers are possible because transfers are sufficient and the ECB would never want to avert a default if it was not in g interest which is also the interest of the Eurozone as whole. This case is identical to the one analyzed in section (4) where the role of the ECB was ignored.

- $\hat{\epsilon} < \epsilon^{min}$ which insures that the ECB will choose a zero inflation rate in the case of default. This

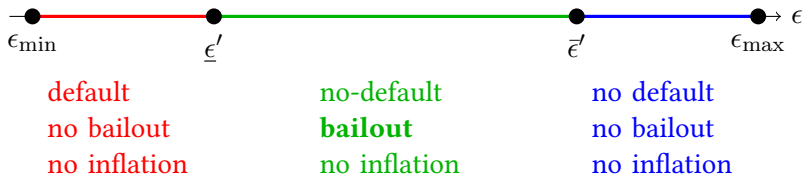


Figure 11: Bailout under Monetary Dominance

excludes the case of strong fiscal dominance.

$$\frac{b_1^g}{y_1^g} < \frac{\delta}{\alpha^{gu}}\left(1 + \frac{y_1^i}{y_1^g}\epsilon^{min}\right)$$

The condition on parameters is such that the debt to GDP ratio for g is small enough.

We then examine two cases: monetary dominance and weak fiscal dominance/.

- Monetary dominance: If $\overline{\overline{\epsilon}} < \underline{\epsilon}'$, then when transfers are possible, the ECB never chooses positive inflation. This case is valid with high y_1^g and δ, and low b_1^g.
- Weak fiscal dominance: If $\overline{\epsilon}' > \overline{\overline{\epsilon}} > \underline{\epsilon}'$, then when transfers are possible, the ECB may choose positive inflation. This is the case with intermediate levels of y_1^g and δ, and low b_1^g.

Under monetary dominance, the possible equilibria are shown in figure 11. Only binding thresholds are indicated. Monetary policy does not affect transfers and the decision whether to default or not.

Under weak fiscal dominance, possible equilibria are shown in figure 9. In this case, when output realization in i is sufficiently high ($\epsilon_1^i > \overline{\epsilon}'$), there is no default, no inflation and no transfer. If it is lower, i requires a transfer in order not to default ($\overline{\epsilon}' > \epsilon_1^i > \overline{\overline{\epsilon}}$) but there is no inflation. For $\overline{\overline{\epsilon}} > \epsilon_1^i > \underline{\epsilon}'$), the ECB partly inflates the debt, g makes a transfer to avoid the default. For $\epsilon_1^i < \underline{\epsilon}'$, the default is optimal and there is no more incentive to inflate the debt.

There are several conditions on output realizations and parameters for such a situation to exist:

$$\begin{aligned}
\epsilon_1^i &< \overline{\overline{\epsilon}} \\
\epsilon_1^i &> \frac{\alpha_1^{i,u} b_1^i (1-\overline{z}) - \alpha_1^{gu} b_1^g \overline{z} - y_1^g (\kappa - \delta\overline{z})}{(\Phi - \delta\overline{z})\,\overline{y}_1^i} \equiv \underline{\epsilon}' \\
\epsilon_1^i &< \frac{\left(1 - \alpha_1^{i,i}\right) b_1^i (1-\overline{z}) + \alpha_1^{g,i} b_1^g \overline{z}}{(\Phi - \delta\overline{z})\,\overline{y}_1^i} \equiv \tilde{\epsilon} \\
\hat{\epsilon} &< \epsilon^{min} < \underline{\epsilon}' < \overline{\overline{\epsilon}} < \tilde{\epsilon}
\end{aligned}$$

The first condition says that the output realization is such that the ECB sets $z = \overline{z}$, the second that g prefers no default and transfer and the third that indeed i requires a transfer when $z = \overline{z}$. These conditions apply for intermediate levels of the output realization i. The last condition on the ranking of thresholds requires in particular intermediate levels of debt (see appendix for details).

Finally, when transfers are excluded (and $\overline{\overline{\epsilon}} < \underline{\epsilon}'$ so that monetary dominance applies with zero inflation in presence of transfers) the possible equilibria are shown in figure 10. When output realization in i is sufficiently high ($\epsilon_1^i > \overline{\epsilon}'$), there is no default and no inflation. If it is lower, i requires a positive inflation rate in order not to default ($\overline{\epsilon}' > \epsilon_1^i > \tilde{\epsilon}$). For $\epsilon_1^i < \tilde{\epsilon}$, the default is optimal and there is no more incentive to inflate the debt.

F ONLINE DATA APPENDIX. Not for Publication

To be completed.

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