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ESBies: Safety in the Tranches

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ESBies: Safety in the tranches*

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Abstract

The euro crisis was fueled by the diabolic loop between sovereign risk and bank risk, coupled with cross-border flight-to-safety capital flows. European Safe Bonds (ESBies), a union-wide safe asset without joint liability, would help to resolve these problems. We make three contributions. First, numerical simulations show that ESBies would be at least as safe as German bunds and approximately double the supply of euro safe assets when protected by a 30%-thick junior tranche. Second, a model shows how, when and why the two features of ESBies—diversification and seniority—can weaken the diabolic loop and its diffusion across countries. Third, we propose a step-by-step guide on how to create ESBies, starting with limited issuance by public or private-sector entities.

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1 Introduction

The creation of the euro in 1999 was a landmark in the European integration process. Since 2009, however, the euro area has been roiled by financial crisis, with heightened sovereign default risk, a weakened banking sector, and a stagnating macroeconomy.

Why did this happen? Among many factors, the euro area lacked institutional features necessary for the success of a monetary union, including emergency funding for sovereigns and common banking supervision and resolution (Brunnermeier, James & Landau, 2016). While some of these deficiencies have since been addressed, one crucial feature remains missing. The euro area as a whole does not have a safe asset: one that guarantees a payoff at virtually any point in time and state of the world, including crises (see Section 2). By storing value in safe assets, rather than the risky sovereign bonds of the nation-state in which they reside, banks can avoid the diabolic loop between their own solvency and that of their sovereign. Moreover, in a cross-border currency area, union-wide safe assets ensure that flight-to-safety capital flows occur across assets (i.e. from risky to risk-free assets) rather than countries, thereby avoiding fire sales of sovereign bonds.

To fill this gap, Brunnermeier, Garicano, Lane, Pagano, Reis, Santos, Thesmar, Van Nieuwerburgh & Vayanos (2011) propose "European Safe Bonds",[1] formed from the senior tranche of a diversified portfolio of euro area sovereign bonds (see Section 3). ESBies entail no joint liability among sovereigns, in contrast to most other proposals.[2] Sovereigns remain responsible for their own bonds, which would still be traded at a market price, exerting discipline on borrowing decisions. One sovereign could default on its own obligations without others bearing any bail-out responsibility and without holders of ESBies bearing any losses. Also, in contrast with other proposals that require treaty change, ESBies entail little downside political risk: if they ultimately failed to function, society would not bear losses relative to the *status quo*.

[1] European Safe Bonds are eponymous: they are "European" in that they are backed by the sovereign bonds of all euro area members; they are "safe" as expected loss rates are minimal; and they are "bonds" in that they are fixed-income instruments that investors may trade and hold.

[2] Other proposals for union-wide safe assets engender some form of joint liability, rendering them susceptible to political problems (since fiscal union requires political union to ensure democratic accountability) and incentive issues (since joint liability implies moral hazard), as documented by Claessens, Mody & Vallée (2012) and Tumpel-Gugerell (2014). Common issuance of eurobonds, contemplated by the European Commission (2011) and Ubide (2015), implies joint liability. The blue-red proposal of Von Weizsacker & Delpla (2010) entails joint liability for the first 60% of a sovereign's debt stock (relative to GDP). The "eurobills" proposal of Philippon & Hellwig (2011) involves joint issuance of short-maturity bills of up to 10% of a country's GDP. Even the German Council of Economic Experts' (2012) proposal for a "European Redemption Pact" involves some degree of joint liability, albeit with strict conditionality, and without leading to the creation of a union-wide safe asset. Hild, Herz & Bauer (2014) envisage a security similar to ESBies, namely a synthetic security backed by a GDP-weighted portfolio of sovereign bonds, but with partial joint liability among nation-states. To our knowledge, the only proposal for a pooled security that does not engender joint liability is that of Beck, Wagner & Uhlig (2011), whose "synthetic eurobond" is comparable to ESBies without tranching. Our simulations in Section 4 and our model in Section 5 show that tranching is critical to ESBies' safety.

We advocate Brunnermeier et al.'s proposal for a union-wide safe asset in three ways. First, in Section 4, simulations gauge ESBies' safety. With a subordination level of 30%, ESBies have an expected loss rate slightly lower than German bunds. At the same time, they would approximately double the supply of safe assets relative to the *status quo*. The corresponding junior securities would be attractive investments, thanks to their embedded leverage and expected loss rates similar to those of vulnerable euro area sovereign bonds.

These simulations take default probabilities as given. In fact, underlying default probabilities can be expected to change endogenously in response to banks' safer sovereign bond portfolios. In Section 5, we extend a workhorse model of the diabolic loop between sovereign risk and bank risk developed by Brunnermeier, Garicano, Lane, Pagano, Reis, Santos, Thesmar, Van Nieuwerburgh & Vayanos (2016). We show that the diabolic loop is less likely to arise if banks hold ESBies rather than domestic sovereign bonds or a diversified portfolio with no tranching. ESBies are thus a "positive sum game".

Third, in Sections 6 and 7, we propose a step-by-step guide on how to create ESBies. At present, their creation is stymied by regulatory and market (coordination) failures. To remove these roadblocks, policymakers should announce their intention to change the prudential treatment of banks' sovereign exposures, to be implemented once the market for ESBies is up and running. They should also set common standards for the new securities in an *ESBies' Handbook*, including with respect to their subordination level and underlying portfolio composition, and decide which institution(s) should be licensed to issue ESBies. Following these steps, issuance should start with limited experimentation before deepening the market with a centralized swap mechanism, such as an auction, accompanied by strong signals from the European Central Bank regarding the treatment and use of ESBies in its collateral framework and asset purchase program.

2 The crisis without a union-wide safe asset

Modern financial systems rely on safe assets. They lubricate financial transactions, which often entail a contractual requirement to post as collateral some asset deemed as safe (Giovannini, 2013). Safe assets allow market participants to transfer risks, like liquidity or market risk, without creating new risks, like counterparty credit risk. To comply with liquidity regulations, banks need to hold safe assets to meet their funding needs in a stress scenario (Basel Committee on Banking Supervision, 2013). And central banks need safe assets with which to conduct monetary policy, exchanging money, whether currency or reserves, for quasi-money in the form of safe assets (Brunnermeier & Sannikov, 2016).

A safe asset is liquid, maintains value even in crises, and is denominated in a currency with stable purchasing power. Relative to investors' demand for safe assets, there is scarce global supply of securities that possess all three characteristics of safety (Caballero, 2010). The most widely held safe asset, US Treasury bills and bonds, earns a large "safe haven" premium of 0.7% per year on average (Krishnamurthy & Vissing-Jorgensen, 2012). Acute safe asset scarcity has negative macroeconomic effects by increasing risk premia and pushing the economy into a "safety trap" (Caballero, Farhi & Gourinchas, 2016).

The euro area does not supply a safe asset on a par with US Treasuries, despite encompassing a similarly large economy and developed financial markets. Instead, euro area nation-states issue bonds with heterogeneous risk and liquidity characteristics. Monetary policy is conducted by an external authority (the European Central Bank), which is constrained in its ability to target credit and liquidity to specific member countries.[3] Just three euro area nation-states—Germany, the Netherlands and Luxembourg—are rated triple-A. The face value of the general government gross debt of these nation-states stood at €2.6tn in 2015, equal to 25% of euro area GDP. By contrast, the general government gross debt of the United States, which is also rated triple-A, stood at $19tn (i.e. €17.5tn) in 2015, equal to 105% of US GDP. The relative scarcity and asymmetric supply of euro-denominated safe assets creates two problems, which we explain next.

2.1 Diabolic loop

Euro area banks hold €1.9tn of euro sovereign bonds, many of which are quite risky. This is facilitated by regulation: in calculating capital requirements, bank regulators assign a zero risk-weight to banks' claims on EU members states, regardless of their fiscal situation (see Subsection 6.1). Banks are therefore incentivized to hold sovereign bonds to economize on capital, particularly during crises when capital is scarce and sovereign risk and yields are elevated (European Systemic Risk Board, 2015).

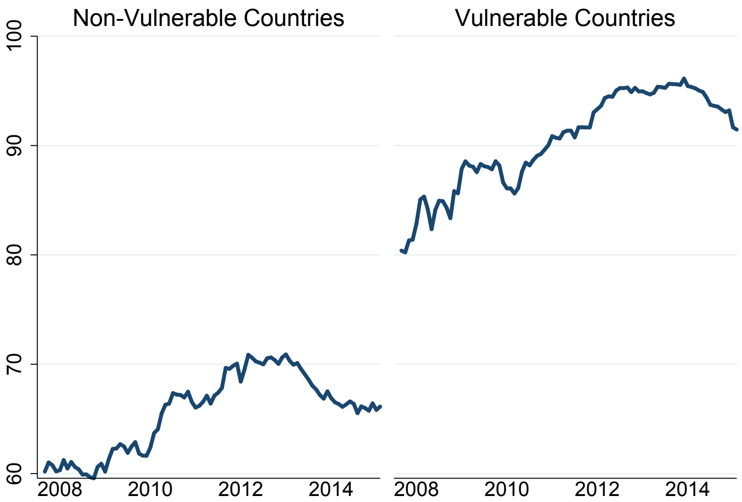
Although the zero risk-weight applies to banks' claims on any EU member state, banks prefer to hold claims on their own sovereign, particularly during crises (Figure 1).[4] Banks' home bias in their sovereign bond portfolios creates a potent diabolic loop between sovereign risk and bank risk. The loop works as follows. Initially, sovereign risk

[3] The Lisbon Treaty (Article 123) prohibits eurosystem central banks from extending credit facilities to public authorities or directly purchasing debt instruments from them. This constraint has led Goodhart (2013) to describe euro sovereign bonds as effectively "sub-sovereign", since they are issued in a currency over which the issuer has no control (de Grauwe, 2013).

[4] Battistini, Pagano & Simonelli (2014) find that banks in vulnerable countries increased their domestic sovereign debt holdings in response to increases in sovereign risk, reflecting distorted incentives. Near-insolvent banks were attempting to earn "carry" on the interest rate spread in a gamble for resurrection (Acharya & Steffen, 2015; Acharya, Eisert, Eufinger & Hirsch, 2016; Buch, Koetter & Ohls, 2016). They were also responding to moral suasion by governments: domestic publicly-owned banks and recently bailed-out banks reacted to sovereign stress by increasing their holdings of domestic public debt significantly more than other banks (Becker & Ivashina, 2014; De Marco & Macchiavelli, 2016; Ongena, Popov & Van Horen, 2016). Altavilla, Pagano & Simonelli (2016) find that the evidence is consistent with both the "carry trade" and the "moral suasion" hypotheses, and that the increase in banks' exposure to domestic sovereign risk exacerbated their own solvency risk; consequently, these banks reduced their lending volumes and increased their lending rates relative to other banks.

increases owing to a shock, such as a productivity shock, asset price collapse, or a sunspot-driven shift in investors' expectations. The shock reduces the marked-to-market value of sovereign bonds, causing banks' book and market equity value to fall.

Figure 1: Mean of banks' domestic sovereign bond holdings as a percentage of their total

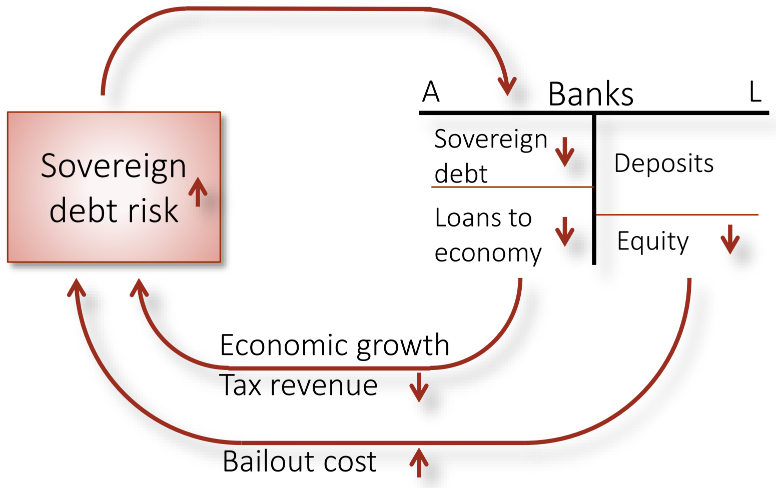


Note: Figure plots the mean of euro area banks' holdings of their own sovereign's debt as a proportion of their total sovereign debt holdings. Banks are split into two subsamples: those resident in "non-vulnerable" countries (i.e. Austria, Belgium, Germany, Estonia, Finland, France, Luxembourg, Malta, Netherlands) and those in "vulnerable" countries (i.e. Spain, Ireland, Italy, Portugal, Cyprus, Slovenia, Greece). Source: ECB; Altavilla et al. (2016).

Two propagation channels follow. First, the increase in bank leverage raises the probability that the home sovereign will bail-out the bank's bondholders, insofar as the bank is deemed too important (or politically connected) to fail (Acharya, Drechsler & Schnabl, 2014). Second, in response to their increase in leverage, banks shed assets in an attempt to return to their target leverage ratio (Adrian & Shin, 2014). This includes cuts in loans to firms and households; the attendant credit crunch reduces economic activity (Altavilla et al., 2016). These two channels—through government bail-outs and the real economy—respectively increase the public debt stock and reduce tax revenue, exacerbating the initial rise in sovereign risk and completing the diabolic loop (Figure 2).

This loop was the quintessential characteristic of the euro area sovereign debt crisis. In some countries—particularly Ireland and Spain—widespread bank insolvencies endangered the sustainability of sovereign debt dynamics. In other countries—Greece, Italy, Portugal and Belgium—long run public debt accumulation and slow growth generated sovereign debt dynamics that threatened banks' solvency. In both cases, domestic governments' guarantees became less credible. As a result, the interaction of sovereign risk and bank risk amplified the crisis after 2009. To weaken the diabolic loop, the euro area needs a safe asset that banks can hold without being exposed to domestic sovereign risk.

Figure 2: The sovereign-bank diabolic loop



Note: Figure depicts the diabolic loop between sovereign risk and bank risk. The first loop operates via a bail-out channel: the reduction in banks' solvency raises the probability of a bail-out, increasing sovereign risk and lowering bond prices. The second loop operates via the real economy: the reduction in banks' solvency owing to the fall in sovereign bond prices prompts them to cut lending—reducing real activity, lowering tax revenues, and increasing sovereign risk further. Source: Brunnermeier et al. (2011).

2.2 Flight to safety

The asymmetric provision of safe assets creates distortions. In the euro area, this asymmetry and the resulting distortions are particularly pronounced, since Germany supplies 83% of triple-A rated euro-denominated sovereign debt.

During the 2003-07 boom, capital flowed from non-vulnerable to vulnerable countries, attracted by the perceived relative abundance of investment opportunities and the absence of foreign exchange risk.[5] This compressed sovereign bond spreads; investors effectively treated all euro area nation-states' bonds as safe. After 2009, investors began to question the solvency of some euro area sovereigns and to perceive a risk that euro-denominated securities in certain countries might be redenominated into a new currency at a devalued exchange rate. Short-term capital flows from non-vulnerable to vulnerable countries reversed, as investors sought safety above all else (Lane, 2013).

In the absence of a union-wide safe asset, non-vulnerable sovereigns' debt partially satisfied investors' newfound demand for safety. The capital flow reversal depressed non-vulnerable nation-states' borrowing costs below the level justified by fundamentals—and, in proportion, elevated vulnerable sovereigns' borrowing costs. Hence, flight-to-safety

[5] These boom-era capital flows fueled credit expansion in vulnerable countries, raising asset prices and therefore attracting more flows, financing greater expansion. In the presence of financial frictions, this credit expansion led to a slump in productivity and an appreciation of the real exchange rate because it came with a misallocation of resources towards low productivity sectors (Reis, 2013), especially real estate and other non-tradable sectors (Benigno & Fornaro, 2014).

capital flowed from high-risk to low-risk countries. With ESBies, such cross-border flows would not occur: in the event of a crisis, the flight to safety would instead take place from high-risk to low-risk European assets.

With ESBies, the safe haven premium enjoyed during crises by the euro area's pre-eminent safe asset—German bunds—would dissipate. This dissipation is desirable: the safe haven premium is the corollary of expectations-driven runs on sovereign debt elsewhere in the euro area. From a German point of view, the loss of the safe haven premium would be more than adequately compensated in two ways. First, the probability of crises would diminish with ESBies, as we show in Section 5. Crises are strictly worse than good states of the world, particularly for Germany's export-oriented economy, and regardless of the safe haven premium. Second, conditional on being in a crisis, bail-out requirements would be smaller, as banks would be less exposed to sovereign risk.

3 Designing European Safe Bonds

ESBies are the senior tranche of a diversified portfolio of euro area sovereign bonds. Their construction, as proposed by Brunnermeier et al. (2011), works as follows. A public or private entity purchases a diversified portfolio of euro area sovereign bonds,[6] weighted according to a strict, well-defined rule, such as euro area countries' relative GDPs or contributions to ECB capital.[7] To finance this purchase, the entity issues two types of securities: European Safe Bonds (ESBies) and European Junior Bonds (EJBies).[8] ESBies are senior to EJBies. The tranching point at which the junior tranche is subordinated to the senior tranche is set according to a pre-defined standard. Our base case is for the subordination level to be set at 30%, such that the junior tranche represents 30%, and the senior tranche 70%, of the underlying face value.

As a result of this construction, ESBies and EJBies would be fully collateralized by the underlying portfolio, such that the combined face value of ESBies and EJBies equals the sum of the face values of the national sovereign bonds against which ESBies and EJBies are issued. The resulting balance sheet of the ESB-issuer is shown in Figure 3.[9]

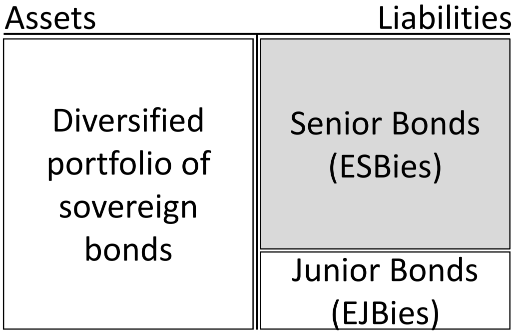
[6] We define sovereign bonds with reference to general government debt, which is the standard measure of public debt used by the "Maastricht criteria" governing the European monetary union. However, the portfolio could in principle comprise only a sub-category of public debt, such as central government debt.

[7] For brevity, this paper considers only the securitization of euro area nation-states' sovereign bonds. However, the concept of ESBies could in principle be extended to other jurisdictional units, such as the wider European Union. With broader coverage, ESB-issuers would need to manage exchange rate risk, for example by increasing the subordination level or using foreign exchange derivatives.

[8] In a variant of their core proposal, Brunnermeier et al. (2011) consider further protection for the senior tranche in the form of a state-guaranteed "credit enhancement". However, as we show in Section 4, the credit enhancement is unnecessary to ensure the safety of the senior tranche. Thus ESBies need not encompass any state guarantee; this is critical for their political feasibility.

[9] Note that ESBies are fundamentally different from more opaque securitized assets such as mortgage-backed securities (MBSs). They would be backed by standardised assets (sovereign bonds) that are traded

Figure 3: Balance sheet of an ESB securitization vehicle



Note: Figure shows the balance sheet of an ESB securitization vehicle, whereby its diversified portfolio of sovereign bonds is financed by the issuance of two securities, with ESBies senior to EJBies.

Tranching is key to the safety of ESBies: losses arising from sovereign default would first be borne by holders of the junior bond; only if they exceed the subordination level, such that EJBies are entirely wiped out, would ESBies begin to take any losses. This eventuality is highly unlikely, as we show numerically in Section 4.

ESBies couple the protection due to tranching with the benefit of diversification. With these two features, ESBies meet the criteria of a union-wide safe asset defined in Section 2. Insofar as banks hold ESBies as a safe store of value, the diabolic loop between sovereign risk and bank risk would be weakened. The next sections explore the quantitative properties of ESBies, their effect on the diabolic loop, and their practical implementation.

4 Simulating the quantitative properties of ESBies

This section answers three related questions through a series of numerical simulations. Would ESBies be as safe as the paragons of euro-denominated safe assets: the AAA-rated sovereign bonds of Germany, the Netherlands and Luxembourg? Would their supply be adequate for banks to use them as a safe store of value? And would there be enough demand for EJBies?

The results lead us to answer "yes" to all three questions. First, with an appropriate subordination level, ESBies can be designed such that they are at least as safe as German sovereign bonds. Second, ESBies could more than double the supply of AAA-rated safe assets relative to the *status quo*, without deviating from the fundamental principle that they should be backed by the sovereign bonds of all euro area member states. Third,

on liquid secondary markets. By contrast, MBSs are backed by a multitude of heterogeneous mortgages that have no liquid secondary market and for which prices are not directly observable. This makes MBSs opaque and complex, allowing issuers to milk their reputation by engaging in lax screening (Keys, Mukherjee, Seru & Vig, 2010), and credit rating agencies to assign noisy and biased ratings (Efing & Hau, 2015). ESB-issuers would have no scope to engage in such reputation-milking.

in our benchmark scenario, EJBies have an expected loss rate comparable to those of vulnerable euro area sovereign bonds. We obtain these results by comparing four cases:

Status quo: In this case, each country issues its own sovereign bond; these bonds are neither pooled across nation-states, nor tranched for safety.

National tranching: Each national sovereign bond is tranched into a senior and junior component at a given subordination level. In this case, there is no pooling.

Pure pooling: National sovereign bonds are pooled, with weights equal to countries' relative GDP over 2010-2014.[10] This pool is financed by the issuance of a single synthetic bond to benefit from diversification. In this case, there is no tranching.

Pooling and tranching: The pooled portfolio is tranched into a senior component (ESBies) and a junior component (EJBies) at a given subordination level.

In what follows, we first describe the methodological design of our simulations (Subsection 4.1). We then analyze the securities' quantitative properties under a benchmark scenario (Subsection 4.2) and an adverse one (Subsection 4.3). Finally, we ask how the exclusion of certain nation-states would affect these properties (Subsection 4.4).

These simulations are intended to provide rough guidance rather than precise answers. They take the distribution of default and loss-given-default rates as given, and therefore turn off general equilibrium effects. Yet by expanding the volume of safe assets that may be held by banks, ESBies endogenously reduce the number of states in which the diabolic loop can operate. Because this mechanism is hard to quantify empirically, Section 5 writes down a theoretical model that captures it. For now, though, by not considering this general equilibrium effect, our simulations are conservative in that they understate the risk reduction that ESBies can achieve.

4.1 Designing the simulations

The two main inputs are a stochastic model of default and a distribution of loss-given-default rates for each euro area sovereign. Model calibration is guided by the principle of conservatism regarding the potential benefits of ESBies. We use a simple and transparent two-level hierarchical model. The first hierarchical level concerns the aggregate state of the euro area economy. We simulate 2,000 five-year periods, in each of which the aggregate state can take one of three values:

[10] We constrain the scheme to buy no more than 100% of each nation-state's outstanding debt. When this constraint binds, we re-scale remaining weights so that they sum to 100%. This affects Luxembourg, Latvia, Lithuania, Slovakia, and Slovenia. Portfolio weights are listed in column 3 of Table 1.

State 1: A severe recession occurs; default and loss-given-default rates are very high for all nation-states, and particularly for those with worse credit ratings. In this scenario, the expected default rate over five years is listed in column 4 of Table 1; expected loss-given-default rates, are shown in column 7.

State 2: A mild recession occurs; default and loss-given-default rates are elevated in all nation-states. Expected five-year default rates are given in column 5 of Table 1; expected loss-given-default rates are 80% of those in state 1.

State 3: The economy expands; default risk is low for most nation-states (column 6 of Table 1); loss-given-default rates are 50% of those in state 1.

The random variable determines that the euro area economy is in the good state 70% of the time and in one of the two recessionary states 30% of the time. This 70:30 split between expansions and recessions accords with NBER data on the US business cycle spanning 1854-2010. Of the 30% recessionary states, similarly long time-series data gathered by Reinhart & Rogoff (2009) and Schularick & Taylor (2012) suggest that about one-sixth are severe. We match these historical patterns by assuming that mild recessions occur 25% of the time and severe recessions occur 5% of the time. Robustness checks are provided in a web appendix, available at `www.euro-nomics.com`.

The second hierarchical level concerns the possible default of each euro area sovereign. Within each five-year period, conditional on the aggregate state in that period (drawn in the first hierarchical level of the model), we take 5,000 draws of the sovereigns' stochastic default process. The random variable that determines whether a sovereign defaults, and which can be interpreted as the "sunspot" in the theoretical model in Section 5, is assumed to have a fat-tailed distribution (Student-t with 4 degrees of freedom), making defaults far more likely than under a normal distribution. In each state of the economy, nation-states' default probabilities increase with their numerical credit score (higher scores indicate worse ratings). Any two nation-states with the same credit rating are assumed to have the same (or similar) independent probabilities of default in each aggregate state of the world. With 2,000 five-year periods and 5,000 draws within each period, our calibration uses a total of 10 million draws.

To check that our calibrated expected default rates in the benchmark scenario are consistent with market prices, we compare them to CDS spreads. According to calculations by Deutsche Bank, which infers default probabilities from CDS spreads by assuming a constant loss-given-default rate of 40%, annual default probabilities were 0.20% for Germany and 0.30% for the Netherlands in December 2015; by comparison, our model calculates 0.07% and 0.15% respectively. This difference can be accounted for the counterparty credit risk and liquidity premia that inflate CDS spreads, particularly for highly rated reference entities. For other countries for which data are available our model calculates precisely the same default probabilities as those implied by CDS spreads in December 2015. This cross-check with CDS spreads allows us to establish nation-states' relative riskiness; later, in Subsection 4.3, we subject loss rates to a stress test by building in further cross-country dependence with four additional contagion assumptions. Further robustness checks are provided in a web appendix.

Average loss-given-default rates in our simulations range from 36-38% for the AAA-rated nation-states to 55% for France and 69% for Italy. According to Moody's data on sovereign defaults over 1983-2010, most of which were by emerging or developing economies, issuer-weighted loss-given-default rates were 47% when measured by the post-default versus pre-distress trading price, and 33% based on the present value of cash flows received as a result of the distressed exchange compared with those initially promised. On a value-weighted basis, average loss given default rates were 69% and 64% respectively.

4.2 Benchmark scenario

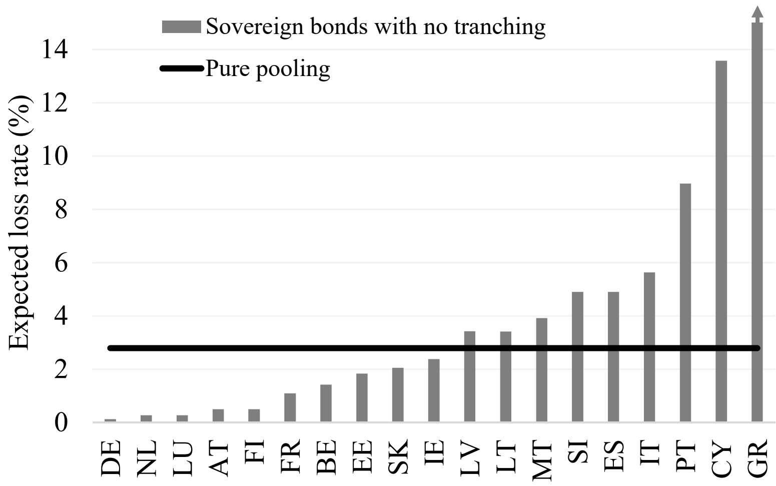
The purpose of our simulations is to compare the four cases along two dimensions: the five-year expected loss rates of the different securities, calculated as average loss rates over the simulations of the default process; and the total economy-wide volume of safe debt. We do so in the context of a benchmark scenario, in which the model is calibrated to give the average default and loss-given-default rates in Table 1, yielding the cross-country correlations in default probabilities shown in Panel A of Table 2. Later, in Subsection 4.3, we impose additional contagion assumptions which lead to the aggravated correlations shown in Panel B of Table 2. Alternative scenarios are reported in a web appendix.

4.2.1 The effects of pooling and tranching on safety

We begin by comparing *pure pooling* with the *status quo*, before turning to tranched securities. The horizontal line in Figure 4 marks the pooled security's five-year expected loss rate of 2.79%, which is slightly higher than that of Irish sovereign bonds (2.38%). By comparison, in the *status quo* (with no tranching), only German, Dutch, Luxembourgish, Austrian and Finnish bonds are safe.

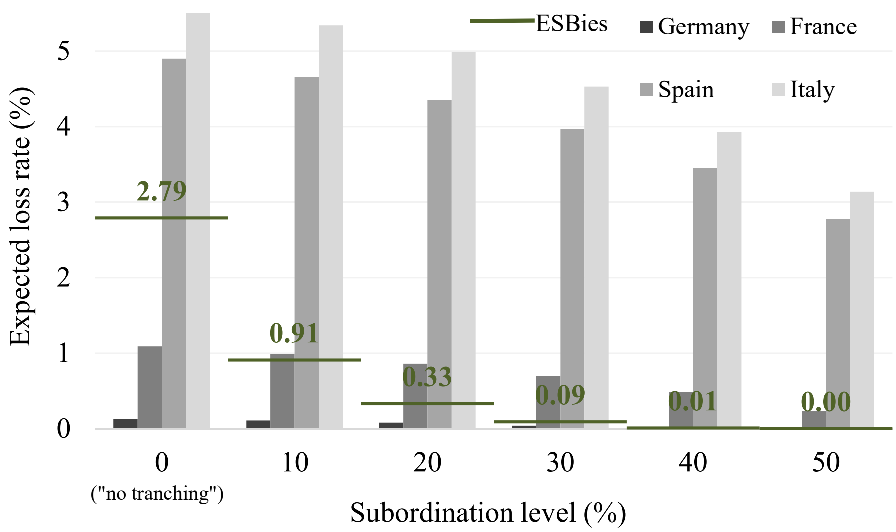
Figure 5 and Table 3 show the effects of tranching by comparing the expected loss rates of ESBies with the senior tranches of securitized national sovereign bonds. With *national tranching*, the reduction in expected loss rates is minimal: no additional nation-state clears the 0.5% safety hurdle at 10% subordination. ESBies, by comparison, benefit more from tranching. The expected loss rate of the pooled security (2.79%) falls to 0.91% with tranching at 10% subordination. In our base case of 30% subordination, ESBies' expected loss rate falls to 0.09%, which is slightly lower than untranched German bunds.

Figure 4: Untranched bonds' five-year expected loss rates



Note: Figure shows the expected loss rates of national sovereign bonds versus that of the pooled euro area security without tranching. The vertical axis is truncated at 15% for presentational purposes; the expected loss rate on Greek sovereign bonds is 34.16%. The data presented in this figure correspond to those reported in Table 3.

Figure 5: Senior tranches' five-year expected loss rates by subordination level



Note: Figure shows the expected loss rates of the senior tranche of national sovereign bonds versus that of the pooled euro area security. When the subordination level is 0%, there is no tranching: national sovereign bonds correspond to the *status quo*, and the pooled security corresponds to *pure pooling* (as in Figure 4). When the subordination level is greater than 0%, national sovereign bonds correspond to *national tranching*, and the pooled portfolio corresponds to ESBies. For brevity, this figure displays only the largest four nation-states; data for others are shown in Table 3.

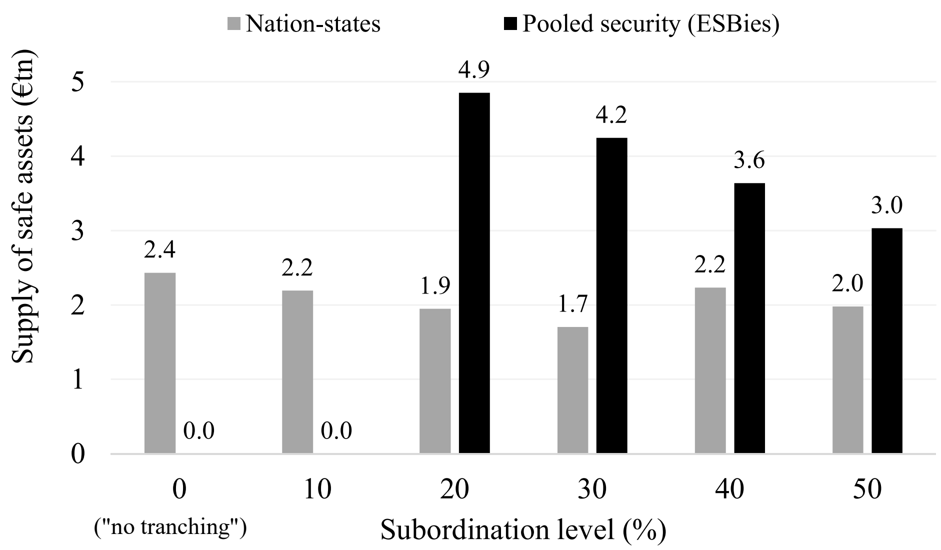
4.2.2 The supply of safe debt

Given the global scarcity of safe assets, maximizing their supply is a valuable policy goal, subject to the proviso that the safe asset is backed by all euro area sovereign bonds.

We define an asset as safe if its five-year expected loss rate is 0.5% or less, so that it would correspond approximately to a triple-A credit rating (according to the simulation results in Table 3). We include in the securitization sovereign bonds up to 60% of national GDP, amounting to €6.06tn (using 2014 GDP). This figure is used just for illustrative purposes—in principle, the face value of the underlying portfolio could be higher or lower.

Figure 6 shows the volume of safe assets supplied by the different securities. With no pooling or tranching, only German, Dutch, Luxembourgish, Austrian and Finnish bonds are safe, leading to a safe asset supply of €2.43tn. By contrast, *pure pooling* leads safe asset supply to become zero, since the expected loss rate stands at 2.79%.

Figure 6: Supply of safe assets



Note: Gray bars refer to nation-states (i.e. the *status quo* when the subordination level is 0% and *national tranching* when the subordination level is greater than 0%), and black bars refer to the pooled euro area portfolio (i.e. *pure pooling* when the subordination level is 0% and ESBies when the subordination level is greater than 0%). The supply of safe assets is calculated by setting the face value of the underlying portfolio equal to 60% of euro area GDP, i.e. €6.06tn in 2014 prices.

Introducing *national tranching* with uniform subordination has two opposing effects on safe asset supply. On one hand, it increases supply because the senior tranche of additional nation-states may become safe. On the other hand, it lowers supply because with $(1 - f)\%$ subordination only $f\%$ of safe nation-states' debt is safe. Figure 6 shows that only the second effect is present until 40% subordination, when the senior tranche of French bonds become safe, leading to a modest increase in safe asset supply. To turn off the second effect, one could "optimize" *national tranching* by minimizing $(1 - f)\%$, such that each nation-state's senior tranche just meets the 0.5% safety threshold. For Germany, this minimum is 0%; for France, 40%; for Italy, 77%. Overall, optimized *national tranching* generates safe asset supply of €3.79tn. This is the best that *national tranching* can achieve.

ESBies do better. They are safe at a subordination level of 16%, generating €5.07tn of safe assets—more than double safe asset supply in the *status quo*, and one-third greater than under *national tranching* with optimized subordination levels. This quantifies the benefit of tranching interacted with diversification.

The subordination level is a key policy variable: it affects the senior tranche's safety and the volume of safe assets that is generated. Our simulations point to 30% as a reasonable middle-ground between minimizing expected loss rates and maximizing safe asset supply: at this level, ESBies are slightly safer than the untranched German bund; safe asset supply is nearly two times greater than the *status quo*, and over 40% greater than *national tranching* with equivalent expected loss rates of 0.09%.

4.2.3 The attractiveness of EJBies

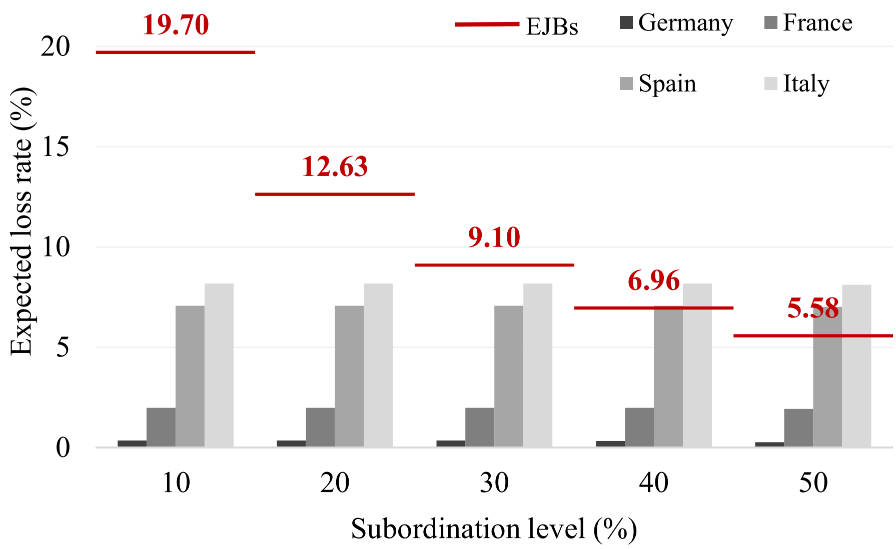
One might worry that the safety of ESBies comes at the expense of very risky EJBies that no investor would want to buy. This worry is fundamentally misplaced: if investors hold sovereign bonds, then they will also hold synthetic securities backed by these bonds.

The junior bond allows investors to leverage their exposure to sovereign risk more cheaply than by using on-balance sheet leverage to fund a pooled portfolio of sovereign debt. This is because the first-loss piece comes with embedded leverage, which amplifies returns without investors using costly on-balance sheet leverage. The advantage of embedded leverage can be illustrated with a simple example. Take the case of a hedge fund seeking exposure to a diversified portfolio of sovereign bonds. Imagine that the hedge fund wishes to enhance its return using leverage. It has two options. It could buy a pool of sovereign bonds on margin; the prime broker would set the cost of this margin funding at the interest rate of the hedge fund's external funding. Alternatively, the hedge fund could buy EJBies, in which leverage is already embedded. In this case, the leverage is implicitly financed at the safe interest rate of ESBies, rather than at the hedge fund's marginal rate of external funding, which is likely to be much higher. The hedge fund can therefore lever its portfolio more cheaply by using the leverage embedded in EJBies.

Notwithstanding the attractiveness of EJBies borne by embedded leverage, one might still wish to gauge the riskiness of EJBies and therefore the price at which investors would be willing to buy them. To see this, we analyze the expected loss rates of EJBies, and compare them with those of existing sovereign bonds.

Expected five-year loss rates of the junior tranche decrease monotonically as the subordination level increases (Figure 7 and Table 4), since a larger junior tranche is available to bear the same quantity of losses. As with the senior tranche, the interaction of diversification and tranching means that EJBies' expected loss rates fall significantly as the subordination level increases—much more than for the junior tranches of national sovereign bonds. At 10%, EJBies' expected loss rate is high, at 19.70%, because losses are absorbed by a small junior tranche. But in our base case of 30% subordination, EJBies have a five-year expected loss rate of 9.10% and a face value of €1.82tn.

Figure 7: Junior tranches' five-year expected loss rates by subordination level



Note: Figure shows the expected loss rates of the junior tranche of national sovereign bonds versus that of the pooled euro area security. The data presented in this figure correspond to those reported in Table 4.

By comparison, the bonds of the four lowest rated nation-states—Italy, Portugal, Cyprus, and Greece—have a weighted average expected loss rate of 9.32% and a face value of €2.7tn. Non-euro area nation-states rated BB or BBB had outstanding debt of €4.1tn in 2012. In light of these numbers, the market will have the capacity to absorb EJBies, particularly given that they partially supplant the stock of low-rated national sovereign bonds actively traded on secondary markets.

4.2.4 Sub-tranching EJBies to cater to different investors

In principle, the EJB component could be sub-tranched or re-packaged in ways that make them more desirable to investors with different risk appetites. For instance, it is possible to sub-tranche the junior bond into a first-loss "equity" piece and a mezzanine tranche, each catering to a different clientele, as envisaged by Corsetti, Feld, Koijen, Reichlin, Reis, Rey & Weder Di Mauro (2016). Risk-averse investors, such as insurance companies and pension funds, would be attracted to the mezzanine tranche; others specialized in high-yield debt, such as hedge funds, would prefer the first-loss piece.

We consider three sub-tranching types: a 50/50 split, whereby the equity piece comprises 15%, and the mezzanine tranche 15%, of the underlying face value; a two-thirds/one-third split, whereby the equity piece comprises 20% and the mezzanine tranche 10%; and a third case in which the equity piece comprises 25% and the mezzanine tranche 5%.

With the 50/50 split, the mezzanine tranche has an expected loss rate of 2.68%. This is slightly lower than that of untranched Latvian sovereign bonds and slightly higher than Irish sovereign bonds, and maps to a credit rating of approximately A (i.e. ranked 6 on a 1-22 rating scale), which is firmly investment grade. The equity tranche has an expected loss rate of 15.52%, which is slightly higher than that of untranched Cypriot sovereign bonds, and would be assigned a credit rating of B+ (i.e. ranked 14 on a 1-22 rating scale), making it a "speculative" high-yield security.

As the size of the equity tranche increases, such that the mezzanine tranche is protected by a larger first-loss piece, the expected loss rate of the mezzanine tranche falls. With a 10% mezzanine tranche and a 20% equity tranche, the expected loss rate of the mezzanine falls to 2.40%, which is similar to that of *status quo* Irish sovereign bonds and maps to a credit rating of approximately A+ (i.e. ranked 5 on a 1-22 rating scale). With a 5% mezzanine tranche and a 25% equity tranche, the expected loss rate of the mezzanine falls to 1.54%, which is similar to that of untranched Belgian bonds and maps to a rating of AA (i.e. ranked 3 on a 1-22 rating scale).

Similarly, the expected loss rate of the equity tranche decreases as its size increases, since the same quantum of losses is spread over a larger tranche. With a 5%/25% split between the mezzanine and equity tranches, the equity tranche has an expected loss rate of 10.61%, which is slightly below that of untranched Portuguese sovereign bonds and below investment grade. At this level of riskiness, the equity tranche would be an attractive investment proposition for hedge funds and other specialized investors in high-yield debt.

4.3 Adverse scenario

In the benchmark scenario, defaults are idiosyncratic events. All commonality in defaults comes from credit ratings conditional on the aggregate state, namely whether the euro area economy is in the catastrophic state 1, bad state 2, or good state 3. To consider a more adverse scenario, we build in further cross-country dependence. This provides a pessimistic robustness check and allows us to evaluate how ESBies would perform in an adverse scenario relative to other security designs. We make four additional contagion assumptions, imposed sequentially in the following order:

1. Whenever there is a German default, others default with 50% probability.

2. Whenever there is a French default, other nation-states default with 40% probability, except the five highest rated nation-states, which default with 10% probability.

3. Whenever there is an Italian default, the five highest rated nation-states default with 5% probability; the next three nation-states (France, Belgium and Estonia) default with 10% probability; and the other nation-states default with 40% probability—unless any of these nation-states had defaulted at step 1 or 2.

4. Whenever there is a Spanish default, the five highest rated nation-states default with 5% probability; the next three nation-states default with 10% probability; and the other nation-states default with 40% probability—unless any of these nation-states had defaulted at step 1, 2 or 3.[11]

These contagion assumptions substantially increase the correlation of defaults across nation-states, as is evident in Panel B (relative to Panel A) of Table 2. The first principal component of defaults now explains 42% of covariation in default rates, compared with 29% in the benchmark scenario, and the first three principal components account for 64% of the covariation compared to 57% before. Table 5 shows the conditional default probabilities, which given the way we built the adverse scenario have the feature that euro area nation-states are very sensitive to the default of Germany, France, Italy or Spain.

Five-year expected loss rates for *status quo* sovereign bonds are much higher than in the benchmark scenario (Table 6). Now, only untranched German sovereign bonds are safe, so that safe asset supply stands at €1.70tn, down from €2.43tn in the benchmark scenario. France's expected loss rate increases from 0.50% in the benchmark to 1.94% in the adverse scenario; Spain's from 4.90% to 6.80%; and Italy's from 5.63% to 7.22%.

Only pooling or only tranching does not increase safe asset supply. The expected loss rate of the pooled security rises from 2.79% in the benchmark scenario to 3.84% in the adverse scenario. With *national tranching*, only the five highest rated nation-states' senior bonds are safe with 30% subordination, so total safe debt is €1.70tn. One must increase the subordination rate to 50% for French senior bonds to qualify, and even then the peak amount of safe debt is only €1.86tn.

Again, ESBies make a significant difference. In our base case of 30% subordination, the expected loss rate is 0.42%, compared with 0.09% in the benchmark scenario. Therefore, even in this adverse scenario, ESBies would be slightly safer than untranched German bunds. In terms of safe asset supply, ESBies are even more beneficial (relative to the *status quo*) in the adverse scenario than in the benchmark scenario, since they generate €4.22tn of safe debt in either.

[11] These four additional contagion assumptions are applied sequentially in the order in which they are described. For example, if there is a German default at step 1, all other nation-states default with a probability of 50%. If France then defaults at step 2—which if Germany defaults happens with 50% probability, but if Germany does not default happens with probability pd1=25%, pd2=3% or pd3=0.05%—the nation-states with a credit rating superior to France's default with probability 10%, if they had not already defaulted, while those with an inferior rating default with probability 40%. After this second step, we add the default events to those from the first step. So if a nation-state had not defaulted after step 1, but defaults in step 2 after France's default, then it has defaulted after steps 1 and 2 taken together.

ESBies' safety is ensured by the junior tranche, which naturally is riskier in the adverse scenario than in the benchmark one. With 30% subordination, EJBies' five-year expected loss rate is 11.81%, compared with 9.10% in the benchmark scenario. Nevertheless, EJBies could still be sub-tranched to create an investment grade 15%-thick mezzanine tranche with an expected loss rate of 6.38%, protected by a 15%-thick first-loss piece with an expected loss rate of 17.24%.

4.4 Exclusion of certain nation-states from the securitization

The premise of ESBies is that they should be created out of a diversified portfolio that comprises the sovereign bonds of all euro area member states. This ensures that ESBies eliminate cross-border flight-to-safety capital flows. Excluding certain nation-states from the securitization would negate some of the welfare improvement from creating ESBies.

This section abstracts from these welfare considerations to investigate the marginal effect on the properties of ESBies of excluding certain nation-states. There are two effects of such an exclusion: a *volume effect*, by which the face value of the senior tranche is reduced (holding the subordination level fixed), and a *risk effect*, which captures the change in the size of the senior tranche owing to the change in subordination required to keep ESBies' expected loss rate constant. The volume effect of excluding any nation-state is always negative; the risk effect is negative for low risk nation-states, and positive for riskier nation-states. The volume effect always dominates the risk effect, even for risky nation-states such as Greece; consequently, the exclusion of any nation-state unambiguously reduces the supply of safe assets for given cross-country default correlations. Note that if correlations were to increase endogenously following the inclusion of a nation-state, the positive risk effect may dominate the negative volume effect. The mechanism that could yield such an increase in correlations is opaque to us, however, and in Section 5 we find that union-wide ESBies would have the opposite effect, resulting in a decrease in cross-country correlations.

To see why the volume effect dominates the risk effect, we compare our base case—in which ESBies with 30% subordination generate €4.22tn of safe assets in the benchmark scenario—with alternative synthetic securities that exclude Italy and, in a separate exercise, Spain. These two countries are chosen arbitrarily for their size and moderate riskiness; in unreported results, we conduct similar exercises for other countries, with qualitatively similar findings.

Without Italy, safe asset supply stands at €3.54tn; Spain's exclusion puts it at €3.78tn (holding the subordination level constant at 30%). These reductions of €0.68tn and €0.44tn (relative to the €4.22tn benchmark) represent the negative volume effect. In both cases, however, the same level of safety can be achieved with a lower subordination level: 24% without Italy, and 28% without Spain. These adjustments lead to positive risk effects of €0.30tn and €0.11tn respectively, resulting in safe asset supply of €3.84tn without Italy and €3.89tn without Spain. The volume effect dominates the risk effect, such that the overall impact on safe asset supply of excluding any given nation-state from the securitization is negative for a fixed correlation structure. This conclusion holds even if the excluded nation-state's debt were individually tranched.[12]

The key insight is that there is no trade-off between the union-wide, proportionate provision of the safe asset and maximization of the volume of safe assets for fixed correlation structures. This is because each nation-state's debt contains a component, however small, that with tranching can be made safe. We conclude that ESBies should be backed by all euro area nation-states. This engenders two benefits: first, it turns off distortionary flight-to-safety flows of capital during crises; second, it maximizes the supply of safe assets.

5 Modeling the diabolic loop

The simulations presented in the previous section are based on fixed estimates of sovereign default probabilities and correlations. However, probabilities would change if euro area banks were to reduce the home bias of their sovereign portfolios, either by holding a diversified pool of bonds or by holding ESBies. Since there is no historical case of such portfolio rebalancing, we turn to theoretical analysis to understand how default probabilities and their correlations would change with different compositions of banks' sovereign portfolios.

The structure of banks' sovereign portfolios affects sovereign default probabilities for the reasons described in Section 2. Insofar as banks hold fewer domestic sovereign bonds, home-grown sovereign risk is less likely to destabilize the banks, which in turn mitigates concerns about sovereigns' solvency. On the other hand, if banks hold more foreign sovereign bonds, they become more exposed to the solvency risk of foreign sovereigns, so that shocks may spread across borders via the balance sheets of banks.

We analyze these issues through the lens of a model of the diabolic loop. Brunnermeier et al. (2016) focus on the polar cases in which banks hold only domestic sovereign debt, equally-weighted domestic and foreign sovereign debt, or ESBies. We extend their model to a continuum of portfolios, spanning the entire spectrum from complete home bias to complete diversification, either via pooling or pooling-cum-tranching. This extension is important from a policy perspective because future prudential regulation is unlikely to induce complete diversification, even if it reduces the extent of banks' home bias.

Our analysis uncovers three main results. First, without tranching, international diversification of banks' sovereign portfolios can be a blessing (if banks are well capitalized)

[12] The minimum subordination level at which the Italian (Spanish) senior tranche is safe is 77% (76%). Safe asset supply with *national tranching* is therefore €0.23bn for Italy and €0.16bn for Spain. Even if we were to add these figures to the positive risk effect, the negative volume effect still dominates.

or a curse (if they are weakly capitalized). Second, ESBies reduce the number of states in which contagion can occur and expands those in which no diabolic loop can occur. Third, the extent to which ESBies have this effect depends on their design: greater subordination enhances the safety of ESBies, as shown numerically in Section 4, and therefore reduces the number of states in which the diabolic loop can occur.

5.1 The model

Here, we present the layout of the model and its main results graphically, and leave the detailed presentation of assumptions and derivations to the Mathematical Appendix.

In the model, there are two countries, each populated by four agents: (i) the government, which prefers higher to lower output, as this is associated with greater tax revenue; (ii) dispersed depositors, who run on insolvent banks if the government does not bail them out, and also pay taxes; (iii) bank equity holders, who hold all of their capital in initial bank equity, so that they cannot recapitalize banks subsequently; and (iv) investors in government bonds, whose beliefs determine the price of sovereign debt.[13] The two countries are identical, so there is no loss of generality in focusing the analysis only on one of them, which we shall refer to as the domestic country.

Initially, there is a unit-size outstanding supply of zero-coupon domestic sovereign bonds with face value $\underline{S} > 0$. Domestic banks are endowed with a sovereign bond portfolio that may include domestic sovereign bonds, a pooled security (comprising domestic and foreign sovereign bonds in equal weights), or some combination of both. We express banks' holdings of domestic sovereign bonds as a fraction α of the total face value $\underline{S}$, so that the face value of banks' domestic holdings is $\alpha\underline{S}$. Likewise, we express banks' holdings of the pooled security as a fraction β of $\underline{S}$, so that the face value of banks' holdings of the pooled security is $\beta\underline{S}$.[14] The total face value of banks' overall sovereign portfolio is then $(\alpha + \beta)\underline{S} = \gamma\underline{S}$. Note that β can be interpreted as an indicator of the extent to which banks' portfolios are diversified. Beside sovereign debt securities, banks' assets include loans L_0 to the real economy. Their liabilities are formed by deposits D_0 and equity. The market value of equity depends on the market price of sovereign debt.

Now consider the case in which the pooled security is tranched. Banks hold some portion of the senior tranche (ESBies), while the junior tranche (EJBies) is held exclusively

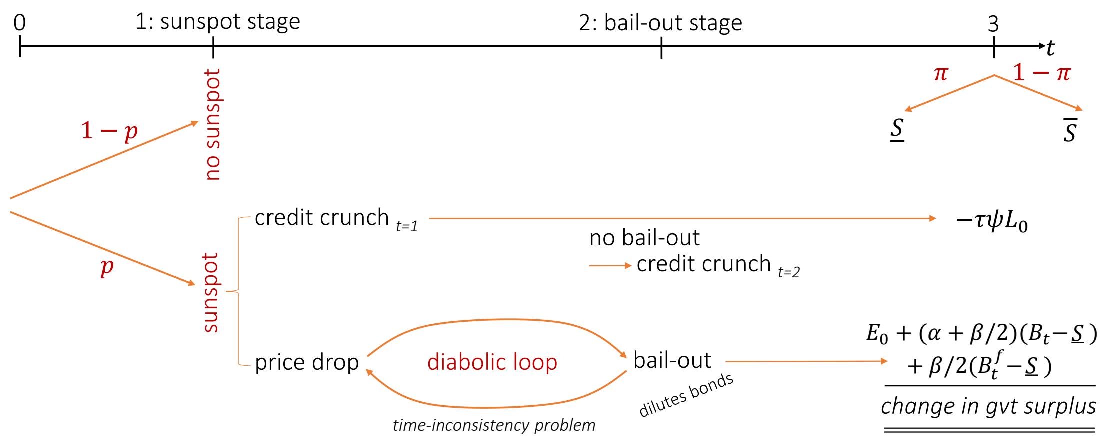
[13] For simplicity, we assume that all agents are risk neutral. There is no discounting, so the risk-free interest rate is zero. Short-term deposits yield extra utility compared to long-term government debt due to their convenience value in performing transactions. This is necessary to justify the demand for bank deposits backed by sovereign debt. Otherwise, banks would not need to hold sovereign debt.

[14] We normalize one unit of the pooled security to face value $\underline{S}$. This is only a normalization: it does not imply that the total face value of the pooled security is $\underline{S}$. For example, if only a small amount of the pooled security is created, its face value will be much smaller than that of the outstanding supply of domestic sovereign bonds.

by non-bank investors.[15] In this case, we still denote the face value of banks' holdings of ESBies by $\beta \underline{S}$. Hence, the total face value of banks' overall sovereign portfolio remains $(\alpha+\beta)\underline{S} = \gamma \underline{S}$. Note that face value $\beta \underline{S}$ of ESBies is obtained by tranching face value $\frac{\beta \underline{S}}{f}$ of the pooled security, where f is one minus the subordination level.

The model is composed of four periods (0, 1, 2, 3), shown in Figure 8. At $t = 0$, government bonds in both countries trade at price B_0. A fraction α of each country's bonds are owned by domestic banks, and some may be pooled with the bonds issued by the foreign country, and possibly tranched, with banks holding a fraction β of this pooled security. The marked-to-market value of banks' equity in periods $t = 0$ and $t = 1$ is equal to a constant E_0 plus the capital gains on banks' sovereign bond holdings relative to their book value, i.e. $E_0 + (\alpha + \frac{\beta}{2})(B_t - \underline{S}) + \frac{\beta}{2}(B_t^f - \underline{S})$, where we reserve the notation B_t for the market price of the domestic bond and use B_t^f for the price of the foreign bond. (The two prices can differ in period 1.) We assume that $0 < E_0 < (\alpha+\beta)\underline{S}$; this implies that if the market value of the banks' entire portfolio of sovereign debt were to become zero, banks would have negative equity.

Figure 8: Model timeline



Note: At $t = 1$, a sunspot occurs with probability p independently in each country. If it occurs, sovereign bonds fall in value; when the price drop is sufficiently large, banks cannot roll over their lending to the real economy. At $t = 2$, the government decides whether to bail out the banks. At $t = 3$, the government's surplus is revealed. The payoff to bondholders is the size of that surplus minus any reduction in tax revenue (owing to the credit crunch) at $t = 1$ and the cost of the bail-out (if it took place) at $t = 2$.

At $t = 1$, a sunspot—i.e. a confidence crisis—occurs with probability p independently in each country. This sunspot carries no fundamental information, and can be interpreted as the random variable that governs whether each nation-state defaults in each draw of the simulation in Section 4. If the sunspot occurs, non-bank investors become pessimistic

[15] In Subsection 6.1.3, we envisage allowing banks to hold EJBies, subject to a punitive risk weight. Our modeling assumption—that non-banks are the exclusive holders of EJBies—can be interpreted in the sense that risk weights would be so punitive that banks decide not to hold any EJBies.

about the government's ability to repay its obligations at $t = 3$. This causes the price of government bonds at $t = 1$, B_1, to drop, reducing the marked-to-market value of banks' equity. If this repricing renders the market value of banks' equity negative, banks cannot roll-over maturing loans of size ψL_0, leading to an equal output loss that reduces the government's revenue by $\tau\psi L_0 \geq 0$ at $t = 3$. Hence, investors' pessimism can by itself generate a credit crunch that weakens the government's fiscal position.

At $t = 2$, if a sunspot occurred at $t = 1$, the government must decide whether to bail out banks, before discovering its tax revenue at $t = 3$. If the government chooses not to bail out, insolvent banks are unable to roll-over a further ψL_0 of maturing loans, resulting in a deeper credit crunch and even lower tax revenues at $t = 3$. If instead the government bails out the banks, it must issue additional government bonds, which are given to the banks as extra assets.

Finally, at date $t = 3$, the government's fiscal surplus is realized, and all consumption takes place. If no sunspot occurred, the surplus is just the stochastic variable S, which is low ($\underline{S}$) with probability π and high ($\overline{S} > \underline{S}$) with probability $1 - \pi$. If a sunspot occurred at $t = 1$ and a bail-out occurred at $t = 2$, the surplus is equal to S, minus the tax loss $\tau\psi L_0$ due to the credit crunch at $t = 1$, minus the cost of recapitalizing the banks. For example, in the case in which banks hold only domestic bonds ($\beta = 0$), they are in need of recapitalization if the reduction in the value of their bonds, $\alpha(B_0 - B_1)$, is greater than their equity at $t = 0$, $E_0 + \alpha(B_0 - \underline{S})$, or equivalently if their equity at $t = 1$, $E_0 + \alpha(B_1 - \underline{S})$, is negative. The probability that the government defaults at $t = 3$ is the probability that the fiscal surplus is lower than $\underline{S}$.

5.2 The diabolic loop in equilibrium

In the absence of any pooling or tranching, and under suitable parameter restrictions, there are two possible equilibria. If investors do not expect the government to bail out the domestic banks, they will also expect that the government will be able to repay the promised amount $\underline{S}$, even with a low realization of the surplus. As a result, banks will not suffer a capital loss regardless of their portfolio composition.

But if banks' initial equity is sufficiently low, a second equilibrium—the diabolic loop—can arise. Investors expect the government to bail out banks, eroding the value of government bonds at $t = 1$. This erosion triggers the need to recapitalize the banks, which—in tandem with the recessionary effect of the attendant credit crunch—validates the initial bail-out expectation, leading to a sovereign default in the bad state (when $S = \underline{S}$). The sunspot picks this bad equilibrium with probability p. Note the time-inconsistency problem at the root of this bad equilibrium: if the government could credibly commit to never bail out banks, the diabolic loop could not arise.

Importantly, the diabolic loop equilibrium can occur if the fraction of domestic sovereign debt held by banks exceeds a threshold value relative to banks' equity. In this case, if investors become pessimistic due to the sunspot, the sovereign debt repricing will make banks insolvent, prompting the government to bail them out, which in turn precipitates sovereign default and justifies the investors' pessimism. Policymakers can reduce the probability of a diabolic loop, or even exclude it entirely, by increasing bank equity requirements and reducing the fraction α of domestic sovereign bonds that banks are permitted to hold. However, if banks are not well capitalized, reducing the fraction α of domestic sovereign bonds held by banks and increasing the fraction of β of the pooled security held by banks increases their vulnerability to a foreign sunspot.

This is best understood with graphs; the Mathematical Appendix contains the underlying analysis. Domestic banks are initially endowed with a fraction α of domestic sovereign bonds and β of the pooled security, with the overall size of their sovereign bond portfolio, $\alpha + \beta$, held constant. In Figure 9, the parameter E_0 that characterizes bank equity is on the horizontal axis, and the degree of diversification of banks' sovereign portfolio, β, is on the vertical axis. The parameter $\gamma \equiv \alpha + \beta$, which characterizes the overall size of banks' sovereign bond portfolio, is held constant. Complete home bias corresponds to $\beta = 0$; complete diversification (in which domestic banks hold an equal-weighted portfolio of domestic and foreign sovereign bonds) corresponds to $\beta = \gamma$.

Consider first the case of no tranching, shown in Panel A of Figure 9. When E_0 exceeds the critical value $\gamma\pi\tau\psi L_0$, banks are so well capitalized that the diabolic loop cannot occur, even if banks' sovereign debt portfolios are composed entirely of domestic debt (i.e. $\beta = 0$), and regardless of the subordination level. In this case, a sovereign bond sell-off would be unjustified even following a global sunspot, because banks' initial equity is so large that the government could recapitalize them without defaulting. Hence, in equilibrium no bond repricing would occur at date $t = 1$.

For values of E_0 below $\gamma\pi\tau\psi L_0$ (but not too low), if banks hold a well-diversified portfolio of sovereign debt (i.e. with sufficiently high β), a local sunspot—that is, a loss of confidence in the solvency of the home country only—cannot trigger the diabolic loop. In this *diversification* region, the repricing of banks' sovereign portfolios following a local sunspot is so limited that they do not become insolvent. However, the benefits of diversification are absent in the event of a global sunspot, when a simultaneous diabolic loop in both countries can still occur, although only with probability p^2.

For even lower values of E_0 or lower levels of diversification β, there exists the *uncorrelated diabolic loop* region, in which diversification is too limited to bring either benefit or harm. In this region, a country-specific sunspot will trigger the diabolic loop only in the country concerned. Hence, the probability of a diabolic loop occurring in the domestic country being triggered is simply that of a sunspot occurring there, i.e. p.

For even lower E_0 or higher β, one enters the *contagion* region, in which diversification turns from a blessing into a curse. Here, a country-specific sunspot triggers a global diabolic loop: given banks' weak capitalization and diversified portfolios, a sunspot in either country brings down the banks and sovereign in both countries. In this region, from the perspective of each country, the probability of the diabolic loop being triggered, i.e. $p^2 + p(1-p)$, is larger than in the region with uncorrelated diabolic loops, where the probability is p. In the spirit of Wagner (2010), full diversification (without tranching) by individual institutions can facilitate contagion across countries. The policy lesson is that simply increasing banks' diversification (without ESBies) may be harmful rather than beneficial if they are poorly capitalized, as it will increase contagion.

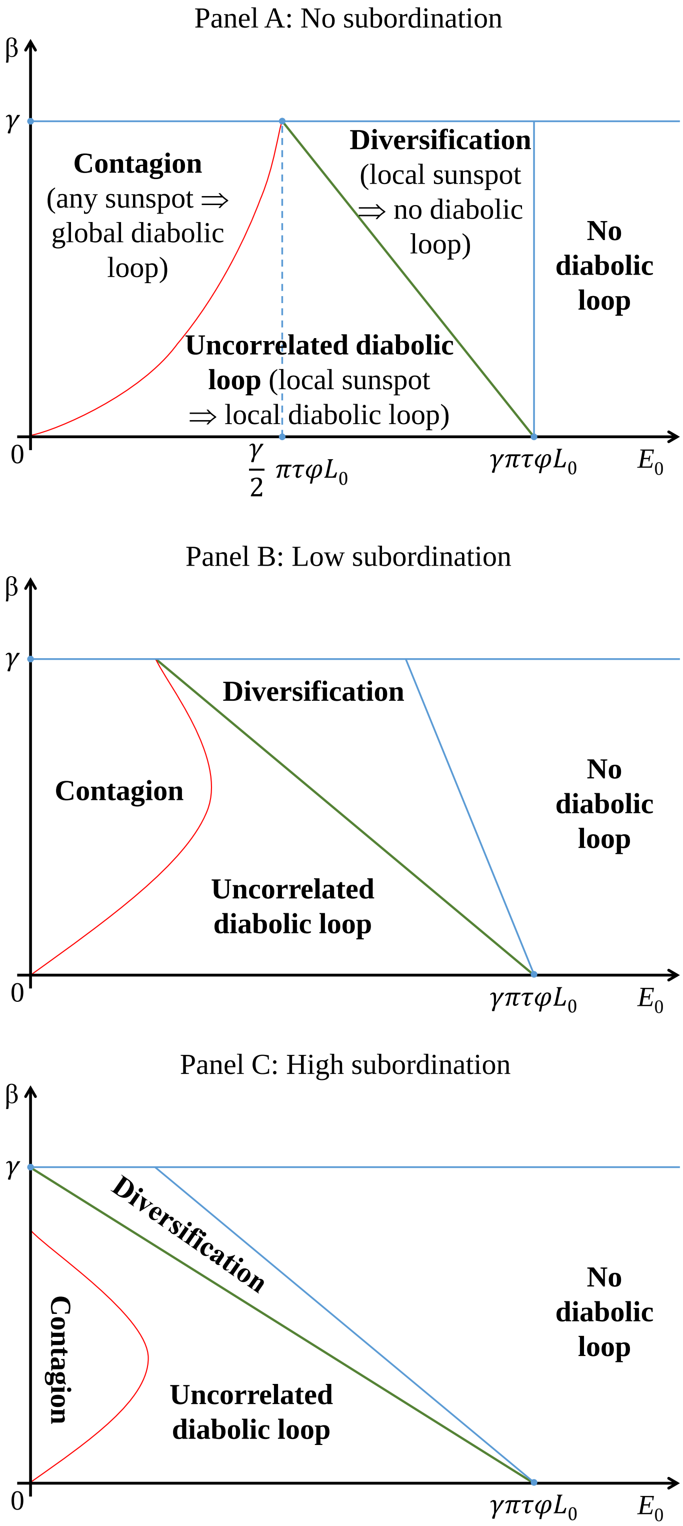
5.3 ESBies: shift to a new equilibrium

Figure 9 shows that if banks were to use ESBies to diversify their sovereign portfolios, the contagion region would shrink compared to the case of no tranching, and the region in which no diabolic loop can occur would expand at the expense of the diversification region. As such, the potential for a local sunspot triggering a global crisis would decrease, and so would its ability to trigger a local crisis. The intuition for this result is that tranching shifts default risks to junior bond holders outside of the banking sector. Tranching is thus a positive sum game, as it reduces the endogenous risk of a diabolic loop.

The extent of these beneficial effects of ESBies is determined by their degree of subordination, which increases from Panel B to C in Figure 9. In fact, if subordination were very high, both the contagion and the diversification regions are eliminated. Of course, as we know from the simulations in Section 4, choosing a very high degree of subordination also reduces the supply of ESBies, so it does not come as a free lunch.

These figures illustrate that the probability of sovereign defaults and their cross-country correlation are both affected by the structure of banks' balance sheets. Specifically, the probability of default depends on bank capitalization; the diversification of banks' sovereign portfolios; and whether diversification takes place with or without tranching. The diabolic loop equilibrium can be avoided if banks are adequately capitalized. At lower levels of bank equity, the possibility of a diabolic loop equilibrium can still be avoided if banks hold ESBies. Without tranching, diversification can increase the probability of a diabolic loop by facilitating cross-country contagion. Accordingly, by introducing ESBies and incentivizing banks to hold them, policymakers would lower the probability of sovereign defaults and reduce their cross-country correlation.

Figure 9: Diabolic loop regions by ESBies' subordination level



Note: Figure analyzes the case in which there is tranching at no (Panel A), low (Panel B) and high (Panel C) levels of subordination. As subordination increases, the *no diabolic loop* region increases, while the other regions shrink. In the limit, when subordination is very high, the *contagion* and *diversification* regions disappear.

6 Laying the groundwork for ESBies

ESBies are innovative sovereign debt securities. In this section, we describe how the new securities would function in financial markets, and the decisions that policymakers would need to take to lay the groundwork for their creation. We ask and answer: (i) How would ESBies integrate with banking regulation? (ii) To what standards should their issuance adhere? (iii) Who would issue ESBies? (iv) How would they interact with sovereign bond issuance? (v) How would sovereign debt restructuring change in the presence of ESBies?

6.1 Future reform of banking regulation

Breaking the diabolic loop between sovereign risk and bank risk is a major aim of regulatory reform in Europe (Juncker, Tusk, Dijsselbloem, Draghi & Schulz, 2015). To date, policymakers have pursued this objective by improving the resilience of banks and sovereigns in isolation. Banks are subject to tighter capital requirements and stricter resolution rules, and sovereigns have improved their fiscal balance and acquired access to emergency lending facilities. These measures weaken the diabolic loop, but they are not sufficient because they do not reduce banks' exposures to their domestic sovereign.

6.1.1 *Status quo* in EU banking regulation

Banking regulation facilitates home bias in banks' sovereign bond portfolios by setting risk weights on exposures to central governments at zero and exempting these portfolios from normal large exposure limits (European Systemic Risk Board, 2015).[16] As a result, euro area banks may hold sovereign bonds without funding them with any equity (as long as the leverage ratio requirement does not bind). This is logically inconsistent with the "no-bail-out" clause in the Lisbon Treaty, which is founded on the premise that the commitments of governments are risky, and in certain states of the world might be defaulted upon. The absence of any capital charge incentivizes banks to hold risky sovereign bonds rather than other assets of similar riskiness, particularly when capital requirements bind. Furthermore, zero risk weights create a double moral hazard problem when sovereign risk increases: politicians encourage local banks to buy local sovereign bonds, and banks realize that holding these sovereign bonds allows them to collectively correlate their risks (Farhi & Tirole, 2016). In sum, the regulatory *status quo* gives banks a strong incentive to load up on sovereign risk in a socially inefficient way.

[16] See 114(4) and 400(1a) of the EU Capital Requirements Regulation (CRR). While the 0% risk weight applies only to exposures denominated and funded in domestic currency, 114(5) grants a transitional exemption until end-2017 for holdings denominated in foreign currency. And although 114(4) pertains only to the standardized approach, article 150 provides authorities with the discretion to grant internal ratings-based banks a "permanent partial use" of the standardized approach. Competent authorities may revoke permission for this "permanent partial use", but few have done so.

6.1.2 ESBies as the complement of regulatory reform

If these regulations are so damaging, why do they persist? Why not assign risk weights to sovereign debt or impose limits on concentrated holdings?

Without ESBies, the implementation of such reforms would clash with liquidity regulation. To satisfy the liquidity coverage ratio requirement, banks must hold enough high quality liquid assets to meet their outflows over a 30-day stress scenario. In a new regulatory regime, these holdings would be subject to a capital charge. If capital charges were set as a function of the measured riskiness of sovereign debt, banks would prefer to satisfy liquidity requirements by holding low-risk sovereign debt. The interaction of liquidity requirements with risk-based capital charges could therefore generate a regulatory-driven flight to safety from vulnerable to less vulnerable nation-states.

ESBies would avoid this outcome. Banks could satisfy liquidity requirements by holding a zero risk-weighted synthetic security that is backed by the sovereign bonds of all euro area nation-states. This security would be liquid and safe, and should not be subject to any capital charge, as we explain in the next section. Moreover, the increase in safe asset supply from issuing ESBies ensures that banks could satisfy their latent demand for a liquid and safe store of value without needing to grapple with safe asset scarcity.

Another argument against risk-based capital charges rests on their procyclicality and its systemic implications. Mechanically raising the risk weight on sovereign debt in a crisis might lead banks to sell bonds, which in turn might lower the price of these bonds and amplify risky sovereigns' troubles. With a union-wide safe asset there would be no fire sales of sovereign bonds by banks in a crisis: ESBies' safety ensures that banks would not suffer capital losses when their sovereign encounters difficulties.

Alternatively, regulators could set capital charges as a function of banks' concentration in individual sovereign issuers, or hard limits on banks' exposures to issuers. In this regime, banks are incentivized to diversify their portfolios, avoiding a regulatory-driven flight to safety. However, this would come with two side effects. First, banks would hold a diversified portfolio of sovereign debt without the seniority offered by tranching. The numerical simulations in Section 4 revealed that such a portfolio would not, in fact, be safe. Tranching is necessary to achieve safety. Additionally, the theoretical model in Section 5 showed that diversification without tranching can facilitate cross-border contagion. When banks are weakly capitalized, such contagion can strengthen, rather than weaken, the diabolic loop between sovereign risk and bank risk.

The second side effect of concentration-based capital charges or large exposure limits is that they might incentivize only partial diversification. Banks may decide to diversify into only the most liquid sovereign bond markets, given that the five largest nation-states together account for more than four-fifths of euro area GDP. With a partially diversified portfolio comprised of five nation-states' sovereign bonds, the marginal diversification benefit of adding an extra issuer to that portfolio would be minimal. Relatively small frictions in banks' ability to operate in other sovereign bond markets might therefore be sufficient to dissuade them from achieving full diversification. Consequently, smaller nation-states with relatively illiquid sovereign bond markets would be penalized by concentration-based capital charges. The existence of ESBies would solve this conundrum, as they represent a highly liquid security that banks could buy with minimal transaction costs. As ESBies are proportionally backed by the sovereign bonds of all euro area nation states, smaller countries would not be penalized by regulatory reform.

In sum, ESBies are the missing piece that would enable the completion of bank regulatory reform, with either risk-based or concentration-based capital charges or limits on banks' holdings of sovereign debt. As part of that reform, bank regulators would need to decide on how to treat ESBies (such that banks are incentivized to hold them rather than national sovereign debt) and EJBies (such that regulatory arbitrage is precluded). We turn to that question next.

6.1.3 Risk weights on ESBies and EJBies

The defining characteristic of ESBies is that they are safe. To reflect this, and to encourage their issuance, bank regulators should exempt ESBies from ordinary capital charges and exposure limits. This regulatory choice is analogous to that made in the United States, where federal Treasuries have a zero risk weight but municipal and state bonds do not.

EJBies, instead, are risky securities and should be treated by regulators as such. If they were not, banks would be able to arbitrage regulation (by holding EJBies rather than ESBies or national sovereign bonds) and the diabolic loop would partly remain. Take a bank holding a portfolio with a share f of ESBies and a share $1-f$ of EJBies, where $1-f$ is the subordination level. This is equivalent to holding the portfolio of the underlying sovereign bonds. Therefore, if the weighted-average risk weight of directly held sovereign bonds were $X\%$, and since the risk weight of ESBies is fixed at zero, the risk weight of the EJBies must be $\frac{X}{1-f}\%$, so that $0f + \frac{X}{1-f}(1-f) = X\%$. Importantly, this application of the "look-through principle" takes into account the tranching structure embedded in the asset-backed security. Similar considerations apply to the regulation of insurers, investment funds, and other financial institutions.

6.2 The *ESBies' Handbook*

ESBies must be homogeneous. This is important for them to be highly liquid and transparent. Homogeneity can be ensured by a process of ESB-certification that is trusted by market participants. Each authorized ESB-issuer must adhere to common guidelines laid out in an *ESBies' Handbook*. A security created according to these guidelines would then be awarded a "license number" that certifies it as a legitimate ESB. The *Handbook* could be developed by an existing public body in collaboration with stakeholders including countries' Debt Management Offices, potential ESB-issuers and would-be purchasers of ESBies and EJBies, and the licensing scheme could be run by the same institution.

Three features of ESBies are particularly important to standardize: the subordination level, the portfolio weights, and the allocation of the arbitrage margin resulting from different liquidity premia. These features should be fixed and revised only infrequently, and should be applied strictly without scope for deviation.

6.2.1 Subordination level

The subordination level determines the safety of ESBies and the volume of safe debt that may be issued. The *Handbook* should set this level so that it is the same across ESBies.[17] As we highlight in Section 4, the choice of the subordination level embeds a trade-off between ESBies' safety and the volume of safe debt that can be issued. Our base case subordination level is 30%, at which ESBies would be slightly safer than German bunds, while doubling the supply of safe assets.

6.2.2 Portfolio weights

To reflect ESBies' status as a union-wide asset, portfolio weights should be set according to nation-states' relative contributions to euro area GDP.[18] To avoid sudden changes in weights, owing for example to a severe recession in one country, it would be preferable to calculate a moving average of countries' relative GDPs with a window of, say, five years; similarly, one could assign weights in proportion to national central banks' shares in the ECB's capital, which is slow-moving by design. In general, weight recalculations should be done infrequently, preserving a high degree of homogeneity among outstanding ESBies.

One problem with the GDP-weighting or ECB capital rule is that several nation-states in the euro area have little public debt outstanding relative to their GDP. As of 2015, the nation-state with the lowest debt-to-GDP ratio was Estonia (at 10%), followed by Luxembourg (21%), Latvia (36%), Lithuania (43%) and Slovakia (53%), as shown in column 2 of Table 1. A simple solution would be to modify the portfolio weights

[17] Alternatively, the *Handbook* could specify that ESBies must have a modeled expected loss rate of, say, 0.5% over five years. We prefer to harmonize the subordination level, as it is a transparent and objective characteristic of the securitization. By contrast, risk modeling is a subjective exercise that could be subject to manipulation by ESB-issuers.

[18] Some commentators have suggested that the weights should instead be set according to nation-states' outstanding public debt, thereby reflecting the "market portfolio". If implemented, such a weighting scheme would embed a severe moral hazard problem. By issuing more debt, nation-states could increase their weighting in the securitization, and thereby increase the demand for their debt from ESB-issuers. This might induce a "race to the top" in public debt issuance which in the limit could generate unsustainable debt dynamics.

once ESBies include all of a nation-state's outstanding bonds, with the weights on the remaining elements of the portfolio being scaled up proportionally.

The problem with this simple re-weighting scheme is that ESB-issuers would buy all of the outstanding debt of certain nation-states, such that price formation could no longer take place. For other nation-states, ESB-issuers would buy most of the outstanding bonds, so that price formation might be distorted by low market liquidity. To overcome this problem, the *ESBies' Handbook* could adopt the rule followed by the ECB in the implementation of its public sector purchase program. In the case of ESBies, this means that the underlying pool would include only up to $k\%$ of a nation-state's outstanding bonds, with the ESB-issuer purchasing these bonds at the market price of the $1-k\%$ that would still be traded on secondary markets. When the $k\%$ constraint binds, the weights on the remaining elements of the portfolio would be scaled up proportionally so that the weights sum to 100%. Higher k would reduce the need for weight recalculations, but at the expense of making secondary markets for national sovereign bonds thinner.

6.2.3 Market liquidity

Thinner secondary markets for national sovereign bonds would feature higher liquidity premia (Foucault, Pagano & Röell, 2013). But these higher liquidity premia in national markets would be offset by the creation of new, much larger and therefore highly liquid markets for ESBies and EJBies. As a result, the liquidity premium on ESBies and EJBies would be lower than the weighted-average liquidity premia on the national sovereign bonds from which they are created. In securitizations, this mismatch is called the "excess spread" or "arbitrage margin".

The accrual and allocation of this arbitrage margin should be regulated in the *ESBies' Handbook*. One possibility would be to deposit in a residual interest tranche all of the arbitrage margin accrued over the life of the securitization. If a default occurs, this residual interest tranche would cover the first loss, providing additional protection to EJB holders. If no default occurs, then the residual interest tranche could be disbursed to nation-states. Disbursement could take place according to nation-states' weights in the securitization. Alternatively, a more refined disbursement arrangement would compensate nation-states in proportion to the cost that they bear in terms of higher liquidity premia following the advent of ESBies. In this way, ESBies could be Pareto improving in terms of the overall liquidity premium paid by each nation-state.

6.3 Who would issue ESBies?

ESBies can, in principle, be issued by any entity. The two most likely candidates are either the securitization vehicles of private financial institutions, such as large banks or asset managers; or a public institution, such as the European Stability Mechanism, European Investment Bank or European Central Bank, or even a new "European Debt Agency" (EDA). This choice does not need to be exclusive: ESBies could be issued by some combination of private and public entities. Our proposal is consistent with any of these options.

6.3.1 Public versus private

Assigning responsibility for issuing ESBies to a single public institution would ensure that the instruments possess homogeneous characteristics. The *ESBies' Handbook* would be fully respected, as the public institution would have no incentive to deviate from the *Handbook*'s specifications or engage in market manipulation. Moreover, a public institution could be depended upon for continuous issuance even during banking crises, when some private financial institutions might have their functions impaired.

A public ESB-issuer must be independent from political interference with respect to the design of ESBies. This creates a governance challenge, requiring substantial investment of political capital, and perhaps new EU legislation.[19] By contrast, issuance by private financial institutions would not require any legal change, and would exploit the fact that many of these institutions have pre-existing expertise in securitizations. In fact, they are likely to find ESB-issuance attractive: securitization is more complex than market-making in sovereign bond markets by primary dealers, such that the ESB-issuers could charge appropriate fees. Private-sector issuers could also compete to design differently sub-tranched junior securities that are most attractive to investors, while ensuring that ESBies are designed in accordance with the *Handbook*.

Each prospective issuer must obtain prior authorization to issue ESBies from a public licensing body. In the case of public issuance, the public institution would receive its authority directly from legislation. In the case of private issuance, a licensing body, which could well be an existing institution, would authorize private-sector ESB-issuers. If both private and public issuance were to co-exist, then the licensing body could be the same as the public issuer.

Licenses for ESB-issuance would be given to reputable private financial institutions that fulfill some requirements. The institution must have the necessary financial expertise and experience, and demonstrate capacity to continue to issue ESBies during crises. Beyond these basic requirements, it is important to ensure that the holders of ESBies do not face counterparty credit risk.

[19] One might be concerned that the EDA might be unable to place EJBies during a stress scenario. But the EDA could always place EJBies at some market-clearing price: EJBies would remain attractive to high-yield investors owing to their embedded leverage and high liquidity. Moreover, the EDA should be required by law to place EJBies as soon as the securitization takes place.

6.3.2 Minimizing counterparty risk

Counterparty risk might arise due to risk of default by the issuer, legal risk, or moral hazard in forming and monitoring the portfolio of bonds.

Counterparty default risk: ESB securitizations can be made bankruptcy-remote from the issuer's own balance sheet by using special purpose vehicles to hold the underlying portfolios of bonds. Thus, in case of default of the issuer, resolution procedures would be able to easily extract the ESB operations of the issuer from the rest of its activities, and carry on servicing and honoring previously issued ESBies.

Counterparty legal risk: The public licensing body could require ESB-issuers to operate only in jurisdictions with reliable legal frameworks. The body could even require issuance to take place in a single jurisdiction, so that all ESBies are subject to the same laws.

Counterparty moral hazard: Issuers of asset-backed securities are usually subject to two types of moral hazard. The first is in selecting the underlying asset pool. This risk is absent in the case of ESBies because the issuers would have no discretion with respect to asset selection. The second source of moral hazard is in monitoring the corresponding debtors and enforcing payments. Because the underlying pool is made of sovereign bonds that continue to be traded in markets, the collection of payments takes minimal effort. Therefore, it is not necessary to have the ESB-issuer hold "skin in the game", by holding a tranche junior to all others, in order to align their incentives with EJB holders.

6.4 Dealing with diversity in sovereign bond issuance

ESB-issuers could purchase sovereign bonds on the primary or secondary markets (or a combination of both). Their activity on secondary markets would be facilitated by European issuers' tendency to top-up on-the-run bonds, which improves liquidity (in combination with relatively active futures markets). Primary markets, however, are characterized by substantial cross-country heterogeneity in terms of the timing and characteristics of issues. Therefore, relying only on primary markets may complicate the process of securitization, although some ingenuity by ESB-issuers and coordination among Debt Management Offices (DMOs) can overcome this diversity. Only one form of heterogeneity would be fatal to ESBies: that is, if a nation-state were to issue bonds that are senior to the bonds underlying the ESBies. Such activity should be prohibited; if it were to take place, the portfolio underlying ESBies would need to be changed accordingly.

6.4.1 Heterogeneity in the timing of issues

Heterogeneity in the timing of issues creates warehousing risk for the ESB-issuer that must hold sovereign bonds for a short period of time, subject to market and credit risk, until it assembles the complete pool of underlying securities and places the corresponding ESBies and EJBies. Warehousing risk is most severe during financial crises, when market volatility is high and credit risk elevated. To some extent, warehousing risk is inevitable in any securitization activity, and is compensated by the fees and spreads that accrue to the issuer. In the case of ESBies, it is mitigated by the liquidity of the underlying sovereign bonds, easing the process of buying them in secondary markets. Moreover, issuers could sell "to-be-announced" securities—whereby an issuer sells forward contracts for delivery of ESBies and EJBies on a pre-agreed date—using the proceeds to buy the underlying national bonds. This reduces warehousing risk by placing the ESBies and EJBies at the same time as the underlying sovereign bonds are being purchased.

Warehousing risk could be significantly reduced if purchases were to happen mostly at primary issuance. This would be facilitated by coordination among debt management offices (DMOs), as proposed by Giovannini (2000). DMOs would have strong incentives to coordinate, since ESB-issuers would provide a large and steady demand for national bonds. While this is not necessary for ESBies to be created, it would simplify matters.

6.4.2 Heterogeneity in bond maturities

Almost all nation-states in the euro area issue plentiful 1-year, 5-year and 10-year nominal bonds. This may be a good place to start, and possibly even remain, in terms of ESBies' maturities. Still, in any one month, or even quarter, several nation-states might not issue any bonds in one of these maturity buckets. This problem could be overcome by the ESB-issuer buying sovereign bonds also in secondary markets.

One obstacle would be if the quantity constraint were to bind: in a certain time interval, some nation-states may not issue enough bonds of a given maturity, leading to ESBies of different maturities but with the same origination date having potentially different pool weights. There are two possible solutions to this problem. One would be to re-open issues at later dates. National DMOs could re-open previous issues of 10-year bonds (e.g., by re-opening it and adding more of a 9-year bond identical to it) to help provide a supply of underlying assets. A second solution to this problem could be for ESB-issuers to engage in *time tranching*, on top of the credit tranching that is at the heart of ESBies. Time tranching, which is standard in the issuance of mortgage-backed securities, consists of buying bonds of different maturities and then using their payouts to service synthetic securities of different maturities.

6.4.3 Heterogeneity in other bond characteristics

Euro area sovereign bonds differ in their coupons, indexing and other characteristics. Again, greater coordination among DMOs on these bond characteristics would simplify ESB-issuance. However, nation-states have different cash-flow requirements and preferences, so some degree of heterogeneity in bond characteristics is unavoidable. This need not be a roadblock to the creation of ESBies, since issuers would have the technical capability to group sovereign bonds with slightly different characteristics. These institutions have faced and overcome greater challenges with respect to the heterogeneity underlying the securitizations of private securities.

6.5 Governance during restructuring

The ESB-issuer holds underlying bonds. Yet, having sold all tranches, the issuer would have no incentive to act in accordance with the interests of ESB- and EJB-holders during a restructuring procedure.

A standard solution to this problem is to require the issuer to retain a fraction of the junior bond, so that it votes on restructuring proposals with interests aligned with those of the EJB holders. However, this is not the only solution, nor is it necessary. An alternative is to employ a special servicer that adheres to a servicing standard and maximizes value on behalf of all investors. In private-sector securitizations, the special servicer is typically controlled by the most junior investors in the deal, who can vote to replace the special servicer.[20] Once a tranche is wiped out, control shifts to the next most junior class. The problem with this model is that it would concentrate considerable power in a small number of agents, who would likely be subject to lobbying by special interests.

A third alternative is available, by which one applies the "look-through principle" to the voting rights of ESB- and EJB-holders in proportion to the underlying face value of the securitization. By distributing votes to both ESB- and EJB-holders, one avoids any bias in favor of either holding-out or restructuring.[21] Another advantage of applying the "look-through principle" to voting rights is that it would ensure that veto power is not assigned to ESB-issuers: thus, the market could sustain only a few ESB-issuers, without engendering an excessive concentration of power in those issuers.

[20] In post-crisis securitizations in the US, the special servicer is complemented with an operating advisor, appointed by the senior investors, to balance any bias that the special servicer might have in favor of junior bondholders.

[21] With an uneven distribution, such bias arises from the fact that junior and senior bondholders have a conflict of interest in restructuring procedures. Junior bondholders favor holding-out to preserve their control and any remaining upside in their claim—although in euro sovereign debt their capacity to do so is constrained by the existence of collective action clauses, which are required by the European Stability Mechanism Treaty (paragraph 3, article 12). By contrast, senior bondholders have a "pro-restructuring" bias, because a partial absorption of losses by EJB-holders improves the safety of the senior tranche. This conflict of interest can therefore be dealt with by an even distribution of voting rights.

7 Catalyzing the market for ESBies

As with any new market, and especially one that would involve a large-scale, highly-standardized, issuance program, it might take a while for ESBies to emerge. Reform of the regulatory treatment of banks' sovereign exposures (Subsection 6.1), the enforcement of an *ESBies' Handbook* (Subsection 6.2), the certification of ESB-issuers (Subsection 6.3), and coordination of sovereign bond issuance (Subsection 6.4) all provide for a large steady-state demand and supply in this market. However, policy intervention is necessary to kickstart the market for ESBies. We envision this process taking place in three stages.

7.1 Stage one: limited experimentation

At first, ESB-issuance could be limited, with asset purchases taking place in secondary markets. This would give a chance for mistakes in design to be corrected, and for details of the contracts to be perfected. Issuance could increase gradually over time. On the buy side, this gradual approach would allow investors—both banks and non-banks—to learn about ESBies' utility as a safe store of value. On the sell side, potential ESB-issuers would have the opportunity to acquire information regarding the marginal cost of ESB-issuance, and to charge fees accordingly. This process could take only a few months.

7.2 Stage two: a centralized swap mechanism

After the initial experimentation stage, policymakers could encourage large-scale ESB-issuance within a relatively short time-frame. This would help to give the market a critical mass—both microeconomically (in terms of liquidity) and macroeconomically (in terms of safe asset creation).

In a reformed regulatory regime, banks would want to hold ESBies rather than national sovereign bonds. In transitioning to this steady state, however, banks may fear the market risk of selling their sovereign bonds at potential fire-sale discounts, and buying new securities at volatile prices. Policymakers and ESB-issuers could ease this transition by arranging for a centralized swap mechanism, by which banks could swap a portfolio of sovereign bonds for ESBies and EJBies. This swap could occur either at pre-set prices, such as an average of historical prices, or through an auction mechanism whereby bank and non-banks participants would submit a price schedule for euro area sovereign bonds as well as ESBies and EJBies. This auction mechanism could be designed to elicit truthful revelation of value. After the auction, ESB-issuers would hold the sovereign bonds that underlie the synthetic security; banks would end up with ESBies and maybe some EJBies; and non-bank investors would acquire primarily EJBies. While this auction may seem involved, it is much simpler than the famous spectrum auctions (used in selling frequencies to telecommunications companies).

7.3 Stage three: transition to the new regulatory regime

Once the market for ESBies attains a critical mass, the new banking regulations could be introduced gradually, allowing banks to comply within a transition period. In this transition, lower-than-adequate risk weights for national sovereign debt and EJBies would persist for a short while. Nevertheless, markets may put pressure on banks to engage in front-running, as happened with capital requirements. Banks may try to move quickly to meet the future regulatory requirements and use the swap auction to immediately satisfy the new steady-state regulation. Such front-running is acceptable as long as there is a well-functioning, liquid market for ESBies to facilitate banks' portfolio rebalancing. This underscores the importance of establishing the market for ESBies *before* changing the prudential treatment of national sovereign bonds.

7.4 The role of the European Central Bank

The ECB is a big player in sovereign debt markets. The central bank would benefit from the presence of ESBies, which provide for a union-wide safe asset with which to perform monetary policy operations, thereby simplifying risk management decisions. The ECB could catalyze the market for ESBies in two ways.

First, the ECB could announce that it would accept ESBies as collateral in monetary policy operations, as suggested by Brunnermeier et al. (2011) and Garicano & Reichlin (2014). As a general rule, banks should have no reason to hold sovereign bonds instead of ESBies; changing the ECB's collateral rules to reflect ESBies' relative safety would be consistent with this principle. The haircut rate at which the ECB would accept ESBies as collateral in monetary policy operations should reflect ESBies' superior safety relative to national sovereign bonds. These new haircuts for ESBies would send a powerful signal to markets regarding their treatment in the new regime.

Second, the ECB could use ESBies as its preferred security for open market operations or quantitative easing. If the ECB wanted to expand its balance sheet, it could purchase ESBies to pursue its mandate without bearing default risk. In the short run, with the national sovereign bonds that it already owns and following the rules in the *ESBies' Handbook*, the ECB could itself issue and place ESBies and EJBies in the market.

8 Conclusion

Safe assets allow banks and other financial institutions to store value without being exposed to default risk. In a cross-border currency area, the union-wide provision of safe assets precludes distortionary flight-to-safety flows of capital across country borders. Despite their importance for the smooth functioning of financial markets, euro-denominated safe assets are inadequately and asymmetrically supplied.

Following Brunnermeier et al. (2011), we advocate a solution: European Safe Bonds. ESBies are the senior tranche of a diversified portfolio of euro area sovereign bonds. They eliminate cross-border flight-to-safety capital flows because they pool the sovereign bonds of all euro area member-states. They weaken the diabolic loop by providing banks with a safe and liquid store of value. And they promise to approximately double the supply of AAA-rated euro-denominated financial instruments.

Crucially, ESBies are designed with political reality in mind. They entail no joint liability among sovereigns and require no significant change in treaties or legislation. The inclusion of all nation-states in the securitization means that ESB-issuers would provide a large and steady demand for national sovereign bonds. This is an attractive proposition for heavily indebted nation-states, as it ensures a smooth transition towards greater diversification in banks' sovereign bond portfolios.

In this paper, we make three main contributions. First, we assess ESBies' safety via numerical simulations, and show that the interaction between pooling and tranching achieves better outcomes than either of these two separately. We discuss the trade-off between ESBies' safety and the size of their supply to conclude that, with a subordination level of 30%, ESBies would be safe even under adverse conditions and would more than double the supply of euro safe assets. At the same time, the junior tranche would have risk characteristics and embedded leverage that would be attractive to high-yield investors.

Second, we show theoretically that the simulations understate the benefits that ESBies engender in equilibrium. In a model of banks and financial markets, we show analytically that the sovereign-bank diabolic loop can be avoided thanks to banks' safer bond portfolios, thereby lowering the chance of a crisis.

Third, we outline the operational steps necessary to implement ESBies. Policymakers should set common standards for ESBies and kickstart their issuance through initial experimentation followed by a centralized swap mechanism, strong signals from the ECB, and ultimately changes to banking regulation. The fact that ESBies have not yet been created by financial markets speaks to the importance of these steps in overcoming the regulatory and market failures that currently inhibit their creation.

With these three contributions, we hope to advance the policy debate on the merits of ESBies, and eventually to make them a reality in euro area financial markets.

Table 1: Simulation inputs

	(1) Rating	(2) Debt/GDP	(3) Weight	(4) pd1	(5) pd2	(6) pd3	(7) lgd1
Germany	1	71	28.16	5	0.5	0	40
Netherlands	1	65	6.61	10	1	0	40
Luxembourg	1	21	0.18	10	1	0	40
Austria	1.5	86	3.21	15	2	0	45
Finland	1.5	63	2.02	15	2	0	45
France	3	96	21.25	25	3	0.05	60
Belgium	3.5	106	3.93	30	4	0.1	62.5
Estonia	4.5	10	0.03	35	5	0.1	67.5
Slovakia	5	53	0.66	35	6	0.1	70
Ireland	6.5	94	1.80	40	6	0.12	75
Latvia	7	36	0.17	50	10	0.3	75
Lithuania	7	43	0.25	50	10	0.3	75
Malta	7.5	64	0.07	55	11	0.4	78
Slovenia	9	83	0.37	60	15	0.4	80
Spain	9	99	10.77	60	15	0.4	80
Italy	9.5	133	16.52	65	18	0.5	80
Portugal	12	129	1.77	70	30	2.5	85
Cyprus	13.5	109	0.19	75	40	10	87.5
Greece	19	177	2.01	95	75	45	95
Average	4.58	91		31.30	8.07	1.12	59.47

Note: This table reports the inputs used in the numerical simulations described in Section 4. In the table, nation-states are ordered in terms of their sovereign credit ratings as of December 2015. Letter grades are converted into a numerical score (1 is AAA, 19 is CCC-) and averaged across S&P and Moody's; this average credit rating is listed in column 1. Column 2 refers to consolidated general government gross debt (following the Maastricht criteria) in 2015 as a percentage of GDP. Column 3 refers to the percentage weight of each sovereign in the pooled euro area portfolio, corresponding to nation-states' relative GDPs (with the constraint that the pooled portfolio cannot include more than 100% of nation-states' outstanding debt). Columns 4-6 describe the five-year default probabilities (in %) in states 1, 2 and 3 respectively. Column 7 describes the five-year loss-given-default rates (in %) in state 1; in state 2, loss-given-default rates are 80% of those in state 1, and in state 3 they are 50% of those in state 1.

Table 2: Correlations between nation-states' default probabilities

Panel A: Benchmark scenario

DE																		
0.04	NL																	
0.04	0.06	LU																
0.05	0.07	0.07	AT															
0.05	0.07	0.07	0.08	FI														
0.06	0.09	0.09	0.11	0.11	FR													
0.07	0.1	0.1	0.11	0.11	0.15	BE												
0.07	0.1	0.1	0.12	0.12	0.16	0.17	EE											
0.07	0.1	0.1	0.12	0.12	0.15	0.16	0.18	SK										
0.08	0.11	0.11	0.13	0.13	0.17	0.18	0.19	0.19	IE									
0.08	0.11	0.12	0.14	0.14	0.18	0.19	0.2	0.2	0.22	LV								
0.08	0.11	0.11	0.14	0.14	0.18	0.19	0.2	0.2	0.22	0.23	LT							
0.09	0.12	0.12	0.14	0.14	0.18	0.2	0.21	0.21	0.23	0.24	0.24	MT						
0.09	0.12	0.12	0.14	0.14	0.19	0.2	0.21	0.21	0.23	0.25	0.25	0.26	SI					
0.09	0.12	0.12	0.14	0.14	0.18	0.2	0.22	0.21	0.23	0.25	0.25	0.26	0.27	ES				
0.09	0.12	0.12	0.15	0.15	0.19	0.2	0.22	0.22	0.23	0.25	0.25	0.27	0.27	0.27	IT			
0.08	0.11	0.11	0.13	0.13	0.17	0.18	0.2	0.2	0.21	0.23	0.23	0.24	0.26	0.26	0.27	PT		
0.06	0.09	0.09	0.1	0.1	0.13	0.15	0.16	0.16	0.17	0.19	0.19	0.2	0.21	0.21	0.22	0.22	CY	
0.04	0.05	0.06	0.07	0.07	0.09	0.1	0.1	0.11	0.11	0.13	0.13	0.13	0.14	0.14	0.15	0.16	0.14	GR

Panel B: Adverse scenario

DE																		
0.77	NL																	
0.77	0.68	LU																
0.72	0.64	0.64	AT															
0.72	0.64	0.64	0.61	FI														
0.37	0.37	0.37	0.36	0.36	FR													
0.31	0.34	0.34	0.34	0.34	0.81	BE												
0.3	0.34	0.34	0.34	0.34	0.79	0.73	EE											
0.31	0.35	0.35	0.35	0.35	0.51	0.51	0.51	SK										
0.31	0.35	0.35	0.36	0.35	0.51	0.51	0.51	0.81	IE									
0.3	0.34	0.34	0.35	0.35	0.49	0.49	0.49	0.77	0.77	LV								
0.3	0.34	0.34	0.35	0.35	0.49	0.49	0.49	0.77	0.77	0.74	LT							
0.3	0.34	0.34	0.34	0.34	0.48	0.49	0.49	0.76	0.76	0.73	0.73	MT						
0.29	0.33	0.33	0.34	0.34	0.47	0.48	0.48	0.73	0.73	0.71	0.71	0.7	SI					
0.33	0.37	0.37	0.37	0.37	0.56	0.55	0.55	0.79	0.79	0.75	0.75	0.74	0.72	ES				
0.33	0.36	0.37	0.37	0.37	0.56	0.55	0.55	0.77	0.77	0.74	0.74	0.73	0.71	0.75	IT			
0.24	0.29	0.29	0.29	0.29	0.4	0.42	0.42	0.62	0.62	0.61	0.61	0.6	0.59	0.61	0.61	PT		
0.2	0.23	0.23	0.24	0.24	0.33	0.34	0.34	0.5	0.5	0.49	0.49	0.49	0.49	0.5	0.49	0.45	CY	
0.11	0.13	0.13	0.13	0.13	0.18	0.19	0.19	0.26	0.26	0.26	0.27	0.27	0.27	0.26	0.27	0.26	0.22	GR

Note: Matrices show the correlations between nation-states' probabilities of default in the benchmark (Panel A, described in Subsection 4.2) and adverse (Panel B, described in Subsection 4.3) scenarios. Correlations are much higher in the adverse scenario owing to the additional contagion assumptions.

Table 3: Senior tranches' five-year expected loss rates in the benchmark scenario (%)

Subordination	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
Germany	0.13	0.11	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.27	0.22	0.15	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.27	0.22	0.15	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Austria	0.50	0.42	0.32	0.19	0.06	0.00	0.00	0.00	0.00	0.00
Finland	0.50	0.42	0.32	0.19	0.06	0.00	0.00	0.00	0.00	0.00
France	1.09	0.99	0.86	0.70	0.49	0.23	0.00	0.00	0.00	0.00
Belgium	1.42	1.29	1.14	0.94	0.69	0.34	0.09	0.00	0.00	0.00
Estonia	1.83	1.70	1.53	1.32	1.05	0.67	0.30	0.00	0.00	0.00
Slovakia	2.05	1.91	1.74	1.52	1.23	0.83	0.40	0.00	0.00	0.00
Ireland	2.38	2.25	2.09	1.88	1.61	1.24	0.68	0.30	0.00	0.00
Latvia	3.42	3.22	2.97	2.65	2.24	1.68	0.85	0.38	0.00	0.00
Lithuania	3.41	3.21	2.96	2.64	2.23	1.68	0.85	0.38	0.00	0.00
Malta	3.92	3.72	3.46	3.13	2.70	2.14	1.30	0.67	0.00	0.00
Slovenia	4.90	4.65	4.35	3.96	3.45	2.78	1.77	0.91	0.00	0.00
Spain	4.90	4.66	4.35	3.97	3.45	2.78	1.77	0.91	0.00	0.00
Italy	5.63	5.34	4.99	4.53	3.93	3.14	1.97	0.98	0.00	0.00
Portugal	8.97	8.52	7.95	7.23	6.26	5.16	3.62	1.59	0.80	0.00
Cyprus	13.58	12.75	11.70	10.35	8.56	6.90	5.06	1.99	1.28	0.00
Greece	34.16	31.80	28.85	25.06	20.01	14.47	11.92	7.67	3.24	2.16
Pooled	**2.79**									
ESBies		**0.91**	**0.33**	**0.09**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Note: Table shows the senior tranches' five-year expected loss rates (in %) in the benchmark scenario described in Subsection 4.2. It corresponds to the summary data presented in Figure 4 and Figure 5. The first row of the table refers to the subordination level, which defines the size of the junior tranche. 0% subordination refers to the special case of no tranching. The remaining rows refer to the bonds of nation-states and, in the penultimate row, the GDP-weighted securitization of the 19 euro area sovereign bonds (without tranching), and in the final row ESBies (i.e. the senior tranche of the pooled security). Numbers in black denote five-year expected loss rates below 0.5%, which is the threshold below which we deem bonds to be safe, while numbers in gray denote loss rates above this safety threshold.

Table 4: Junior tranches' five-year expected loss rates in the benchmark scenario (%)

Subordination	10%	20%	30%	40%	50%	60%	70%	80%	90%
Germany	0.36	0.36	0.36	0.34	0.27	0.22	0.19	0.17	0.15
Netherlands	0.73	0.73	0.73	0.67	0.54	0.45	0.38	0.34	0.30
Luxembourg	0.72	0.72	0.72	0.67	0.54	0.45	0.38	0.33	0.30
Austria	1.22	1.22	1.22	1.17	1.00	0.84	0.72	0.63	0.56
Finland	1.22	1.22	1.22	1.17	1.00	0.84	0.72	0.63	0.56
France	1.99	1.99	1.99	1.98	1.94	1.81	1.55	1.36	1.21
Belgium	2.52	2.52	2.52	2.50	2.49	2.30	2.02	1.77	1.57
Estonia	3.02	3.02	3.02	3.01	3.00	2.85	2.62	2.29	2.03
Slovakia	3.29	3.29	3.29	3.29	3.27	3.16	2.93	2.57	2.28
Ireland	3.53	3.53	3.53	3.53	3.51	3.50	3.26	2.97	2.64
Latvia	5.21	5.21	5.21	5.19	5.16	5.13	4.72	4.28	3.80
Lithuania	5.19	5.19	5.19	5.17	5.14	5.11	4.70	4.26	3.79
Malta	5.76	5.76	5.76	5.75	5.70	5.66	5.31	4.90	4.36
Slovenia	7.07	7.07	7.07	7.07	7.02	6.98	6.60	6.12	5.44
Spain	7.07	7.07	7.07	7.07	7.02	6.98	6.61	6.12	5.44
Italy	8.18	8.18	8.18	8.18	8.12	8.07	7.62	7.04	6.25
Portugal	13.03	13.03	13.03	13.03	12.78	12.53	12.13	11.01	9.96
Cyprus	21.11	21.11	21.11	21.11	20.26	19.26	18.55	16.66	15.09
Greece	55.39	55.39	55.39	55.39	53.85	48.99	45.51	41.89	37.72
EJBies	**19.70**	**12.63**	**9.10**	**6.96**	**5.58**	**4.65**	**3.99**	**3.49**	**3.10**

Note: Table shows the junior tranches' five-year expected loss rates (in %) in the benchmark scenario described in Subsection 4.2. It corresponds to the summary data presented in Figure 7. The first row of the table refers to the subordination level, which defines the size of the junior tranche. The remaining rows refer to the bonds of nation-states and, in the final row, EJBies (i.e. the junior tranche of the pooled security). Numbers in black denote five-year expected loss rates below 7%, which represents the approximate threshold below which bonds would be rated investment grade, while numbers in gray denote loss rates above this threshold.

Table 5: Conditional default probabilities (%)

	Benchmark scenario *conditional on a default by:*				**Adverse scenario** *conditional on a default by:*			
	Germany	France	Spain	Italy	Germany	France	Spain	Italy
Germany	100	3	2	2	100	18	12	11
Netherlands	7	6	4	4	26	19	14	14
Luxembourg	7	6	4	4	25	20	14	14
Austria	10	9	7	7	28	22	16	16
Finland	10	9	7	7	28	22	16	16
France	17	100	11	11	46	100	28	27
Belgium	20	19	14	13	44	45	31	30
Estonia	24	22	16	16	46	47	32	32
Slovakia	24	23	17	16	70	69	62	61
Ireland	28	25	19	18	70	70	63	62
Latvia	35	33	25	24	72	72	65	64
Lithuania	35	33	25	24	72	72	65	64
Malta	39	36	28	27	73	73	66	65
Slovenia	44	41	32	31	75	74	68	67
Spain	43	40	100	31	81	77	100	67
Italy	47	44	35	100	84	79	72	100
Portugal	56	52	44	43	80	79	74	73
Cyprus	62	59	52	51	82	82	77	77
Greece	88	86	82	81	93	93	91	91

Note: Table shows the default probabilities of euro area nation-states (given in the rows of the table) conditional on the default of Germany, France, Spain or Italy (given in the columns). These conditional default probabilities are shown for the benchmark scenario (Subsection 4.2) and the adverse scenario (Subsection 4.3). In the benchmark scenario, correlations between nation-states' default probabilities arise entirely out of the state of the euro area economy and similarity in credit ratings. Default probabilities are otherwise independent. Conditional default probabilities are shown for the benchmark scenario for comparison with those of the adverse scenario, in which there are four additional contagion assumptions governing the correlation matrix of default probabilities. Owing to these additional contagion assumptions, default probabilities conditional on the default of Germany, France, Spain or Italy increase monotonically in the adverse scenario relative to the benchmark scenario. If Italy defaults, for example, Spain then has a probability of default of 67% in the adverse scenario, up from 31% in the benchmark scenario. This underscores the severity of the adverse scenario.

Table 6: Five-year expected loss rates in the adverse scenario (%)

Subordination	0%	10%		20%		30%		40%		50%	
Tranche		**S**	J	**S**	J	**S**	J	**S**	J	**S**	J
Germany	0.50	0.40	1.43	0.27	1.43	0.11	1.42	0.00	1.26	0.00	1.01
Netherlands	0.69	0.55	1.94	0.38	1.94	0.16	1.93	0.00	1.73	0.00	1.38
Luxembourg	0.69	0.55	1.94	0.38	1.94	0.16	1.93	0.00	1.73	0.00	1.38
Austria	0.96	0.80	2.41	0.60	2.41	0.35	2.40	0.09	2.27	0.00	1.93
Finland	0.96	0.80	2.41	0.60	2.41	0.35	2.40	0.09	2.27	0.00	1.93
France	1.94	1.75	3.66	1.51	3.66	1.20	3.66	0.81	3.63	0.33	3.54
Belgium	2.64	2.40	4.80	2.10	4.80	1.71	4.80	1.22	4.76	0.54	4.74
Estonia	3.10	2.87	5.23	2.57	5.23	2.19	5.23	1.70	5.20	1.03	5.18
Slovakia	5.58	5.16	9.30	4.65	9.30	3.98	9.30	3.13	9.25	1.97	9.19
Ireland	6.05	5.68	9.40	5.21	9.40	4.62	9.40	3.83	9.37	2.80	9.30
Latvia	6.81	6.38	10.66	5.85	10.66	5.16	10.66	4.26	10.62	3.09	10.53
Lithuania	6.80	6.37	10.64	5.84	10.64	5.15	10.64	4.26	10.61	3.08	10.52
Malta	7.32	6.91	11.04	6.39	11.04	5.73	11.04	4.85	11.03	3.72	10.92
Slovenia	8.17	7.74	12.05	7.20	12.05	6.51	12.05	5.59	12.05	4.41	11.94
Spain	6.80	6.45	9.94	6.02	9.94	5.46	9.94	4.71	9.94	3.75	9.86
Italy	7.22	6.85	10.58	6.38	10.58	5.78	10.58	4.98	10.58	3.96	10.49
Portugal	11.80	11.21	17.12	10.47	17.12	9.52	17.12	8.25	17.12	6.78	16.82
Cyprus	16.07	15.12	24.61	13.93	24.61	12.41	24.61	10.37	24.61	8.41	23.73
Greece	35.19	32.79	56.77	29.79	56.77	25.94	56.77	20.80	56.77	15.15	55.23
Pooled	**3.84**										
ESBies / EJBies		**2.02**	**20.24**	**1.02**	**15.13**	**0.42**	**11.81**	**0.15**	**9.38**	**0.03**	**7.64**

Note: Table shows the five-year expected loss rates (in %) in the adverse scenario described in Subsection 4.3. The first row refers to the subordination level, which defines the size of the junior tranche. The second row refers to the tranche type; "S" (in black) denotes the senior tranche and "J" (in gray) the junior tranche. The cell referring to 0% subordination is blank, since there is no tranching in this case: all bonds are *pari passu*. The remaining rows refer to the bonds of nation-states and, in the final row, the pooled security, which represents a GDP-weighted securitization of the 19 euro area nation-states' sovereign bonds.

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Mathematical Appendix

A No Pooling or Tranching

We start with the special case in which banks hold only domestic bonds ($\beta = 0$). This case illustrates our model's basic mechanics without the complexities of pooling and tranching. When banks hold only domestic bonds, the relevant sunspot is the one observed domestically.

We make three parametric assumptions, which we carry over to the cases of pooling and tranching. First, the government's primary surplus before bail-out costs remains positive:

$$\underline{S} - \tau\psi L_0 \geq 0. \tag{1}$$

Second, banks' aggregate equity is sufficiently small that the diabolic loop occurs at least if exposure is maximal, such that domestic banks hold all outstanding domestic sovereign bonds (i.e. $\alpha = 1$):

$$E_0 < \pi\tau\psi L_0. \tag{2}$$

Third, if the surplus is high, the government can still fully repay its debt even after a bail-out at $t = 2$ for any α (even for $\alpha = 1$):[22]

$$\overline{S} - \underline{S} \geq \tau\psi L_0 - E_0. \tag{3}$$

If the sunspot is observed at $t = 1$ and a bail-out occurs at $t = 2$, the government surplus at $t = 3$ is $S - \tau\psi L_0 + \alpha\left(B_1 - \underline{S}\right) + E_0 =: S \; - \; C$, where C is the implied (endogenous) bail-out cost. Assumption 3 ensures that when $S = \overline{S}$ the debt is fully repaid. When $S = \underline{S}$, only $\underline{S} - C$ is repaid. Hence, the price of domestic bonds at $t = 1$ if the sunspot is observed at $t = 1$ and a bail-out is expected to occur at $t = 2$ is $B_1 = \underline{S} - \pi C$, so $\pi C \equiv \Delta_1$ is the price discount relative to the face value $\underline{S}$. Recalling the definition of the bail-out cost C and using $B_1 = \underline{S} - \Delta_1$, we find that the discount Δ_1 is

$$\begin{aligned}\Delta_1 &= \pi\left[\tau\psi L_0 - \alpha(B_1 - \underline{S}) - E_0\right] \qquad (4)\\ &= \frac{\pi(\tau\psi L_0 - E_0)}{1 - \alpha\pi}.\end{aligned}$$

Hence, banks are left with negative equity if

$$\begin{aligned}&\alpha(B_1 - \underline{S}) + E_0 < 0 \qquad (5)\\ &\Leftrightarrow E_0 < \alpha\pi\tau\psi L_0.\end{aligned}$$

When banks are left with negative equity, the government bails them out if the capital shortfall is smaller than the cost $\tau\psi L_0$ of not bailing them out, i.e.,

$$\begin{aligned}&\alpha(B_1 - \underline{S}) + E_0 + \tau\psi L_0 > 0 \qquad (6)\\ &\Leftrightarrow E_0 > \left(2\alpha\pi - 1\right)\tau\psi L_0.\end{aligned}$$

If banks' equity is below the threshold in (5), and the bail-out condition (6) holds, then the domestic sunspot leads to the domestic diabolic loop equilibrium. Equation (5) can hold for some parameter values because of (2). Moreover, (5) and (6) can hold simultaneously for a subset of these values because $\alpha\pi < 1$.

[22] This assumption is only used to simplify calculations, but can be relaxed without changing the conclusions.

Conversely, if banks' equity is above the threshold in (5), then the domestic sunspot does not lead to the domestic diabolic loop equilibrium.

B Pooling

When a sunspot is observed in one country it may be the case that only that country must recapitalize its banks. We denote by Δ_{11} the value of Δ_1 for the recapitalizing country: this is the difference between the face value $\underline{S}$ of that country's bond and the bond's price B_1 in period 1. Alternatively, it may be the case that both countries must recapitalize their banks. We denote by Δ_{12} the value of Δ_1 when recapitalization must take place in both countries (regardless of whether this is the outcome of the sunspot being observed in one or both countries): this is the difference between the face value $\underline{S}$ of the bond of either country and the bond price B_1. To compute banks' equity at $t = 1$, we note that their portfolio of $\alpha\underline{S}$ face value of the domestic bond and $\beta\underline{S}$ face value of the pooled security is equivalent to $\left(\alpha + \frac{\beta}{2}\right)\underline{S}$ face value of the domestic bond and $\frac{\beta}{2}\underline{S}$ face value of the foreign bond.

When only one country recapitalizes its banks, the cost for that country is

$$\begin{aligned} C_1 &= \tau\psi L_0 - \left(\alpha + \frac{\beta}{2}\right)(B_1 - \underline{S}) - E_0 \qquad (7) \\ &= \tau\psi L_0 + \left(\alpha + \frac{\beta}{2}\right)\Delta_{11} - E_0. \end{aligned}$$

Combining (7) with $\Delta_{11} = \pi C_1$, we find

$$\begin{aligned} C_1 &= \tau\psi L_0 + \left(\alpha + \frac{\beta}{2}\right)\pi C_1 - E_0 \qquad (8) \\ &= \frac{\tau\psi L_0 - E_0}{1 - \left(\alpha + \frac{\beta}{2}\right)\pi}. \end{aligned}$$

Hence, banks in the recapitalizing country are left with negative equity if

$$\begin{aligned} &-\left(\alpha + \frac{\beta}{2}\right)\Delta_{11} + E_0 < 0 \qquad (9) \\ &\Leftrightarrow E_0 < \left(\alpha + \frac{\beta}{2}\right)\pi\tau\psi L_0. \end{aligned}$$

On the other hand, banks in the non-recapitalizing country are left with non-negative equity if

$$\begin{aligned} &-\frac{\beta}{2}\Delta_{11} + E_0 \geq 0 \qquad (10) \\ &\Leftrightarrow E_0 \geq \frac{\frac{\beta}{2}}{1 - \alpha\pi}\pi\tau\psi L_0. \end{aligned}$$

When both countries recapitalize their banks, the cost per country is

$$\begin{aligned} C_2 &= \tau\psi L_0 - \left(\alpha + \frac{\beta}{2}\right)(B_1 - \underline{S}) - \frac{\beta}{2}(B_1 - \underline{S}) - E_0 \qquad (11) \\ &= \tau\psi L_0 + (\alpha + \beta)\Delta_{12} - E_0. \end{aligned}$$

Combining (11) with $\Delta_{12} = \pi C_2$, we find

$$C_2 = \tau\psi L_0 + (\alpha+\beta)\,\pi C_2 - E_0 \tag{12}$$

$$= \frac{\tau\psi L_0 - E_0}{1-(\alpha+\beta)\pi}.$$

Hence, banks in either country are left with negative equity if

$$-\alpha\Delta_{12} + E_0 < 0 \tag{13}$$

$$\Leftrightarrow E_0 < (\alpha+\beta)\pi\tau\psi L_0.$$

Based on the above analysis, we can divide the parameter space into four regions:

- $E_0 \geq (\alpha+\beta)\pi\tau\psi L_0$. Equity is large enough that the sunspot, whether observed in one or both countries, does not lead to the diabolic loop equilibrium.
- $(\alpha+\beta)\pi\tau\psi L_0 > E_0 \geq \left(\alpha+\frac{\beta}{2}\right)\pi\tau\psi L_0$. When the sunspot is observed in both countries, it leads to the diabolic loop equilibrium. When it is observed in one country only, and the bond prices in the other country do not move, then the diabolic loop equilibrium does not arise even in the country observing the sunspot. This is the *diversification region*.
- $\left(\alpha+\frac{\beta}{2}\right)\pi\tau\psi L_0 > E_0 \geq \frac{\frac{\beta}{2}}{1-\alpha\pi}\pi\tau\psi L_0$. When the sunspot is observed in both countries, it leads to the diabolic loop equilibrium. When it is observed in one country only, it leads to the diabolic loop equilibrium only in that country.
- $\frac{\frac{\beta}{2}}{1-\alpha\pi}\pi\tau\psi L_0 > E_0$. When the sunspot is observed in both countries, it leads to the diabolic loop equilibrium. When it is observed in one country only, it leads to the diabolic loop equilibrium in both countries. This is the *contagion region*.

We can fix $\gamma := \alpha+\beta$, and plot the four regions in the (E_0, β) space. This is done in Figure 9.

C Pooling and Tranching

As in the case of pooling and no tranching, we distinguish cases depending on whether one or both countries recapitalize their banks. The analysis is more complicated than in the case of pooling and no tranching because we must also distinguish cases depending on whether or not the senior tranche incurs losses. We denote by $B_1^{\mathcal{E}}$ the period 1 price of an ESBies security produced by tranching face value $\underline{S}$ of the pooled security. We also denote by $\Delta_{11}^{\mathcal{E}}$ the difference between the face value $f\underline{S}$ of that ESBies security and the price $B_1^{\mathcal{E}}$ when only one country recapitalizes, and by $\Delta_{12}^{\mathcal{E}}$ the same difference when both countries recapitalize.

C.1 Only one country recapitalizes

When only one country recapitalizes its banks, the cost for that country is

$$C_1 = \tau\psi L_0 - \alpha(B_1 - \underline{S}) - \frac{\beta}{f}(B_1^{\mathcal{E}} - f\underline{S}) - E_0 \tag{14}$$

$$= \tau\psi L_0 + \alpha\Delta_{11} + \frac{\beta}{f}\Delta_{11}^{\mathcal{E}} - E_0.$$

To compute the equilibrium, we must distinguish two cases.

Case a: The senior tranche incurs no losses. Combining (14) with $\Delta_{11} = \pi C_1$ and $\Delta_{11}^{\mathcal{E}} = 0$, we find

$$\begin{aligned} C_1 &= \tau\psi L_0 + \alpha\pi C_1 - E_0 \\ &= \frac{\tau\psi L_0 - E_0}{1-\alpha\pi}. \end{aligned} \tag{15}$$

Banks in the recapitalizing country are left with negative equity if

$$\begin{aligned} &-\alpha\Delta_{11} + E_0 < 0 \\ &\Leftrightarrow E_0 < \alpha\pi\tau\psi L_0. \end{aligned} \tag{16}$$

The senior tranche incurs no losses if

$$\begin{aligned} &\underline{S} - \frac{C_1}{2} \geq \underline{S} f \\ &\Leftrightarrow \underline{S}(1-f) \geq \frac{\tau\psi L_0 - E_0}{2(1-\alpha\pi)}. \end{aligned} \tag{17}$$

Case b: The senior tranche incurs losses in the state in which the recapitalizing country has primary surplus $\underline{S}$.[23] Combining (14) with $\Delta_{11} = \pi C_2$ and $\Delta_{11}^{\mathcal{E}} = \pi\left[\frac{C_2}{2} - \underline{S}(1-f)\right]$, we find

$$\begin{aligned} C_2 &= \tau\psi L_0 + \alpha\pi C_2 + \frac{\beta}{f}\pi\left[\frac{C_2}{2} - \underline{S}(1-f)\right] - E_0 \\ &= \frac{\tau\psi L_0 - E_0 - \frac{\beta}{f}\pi\underline{S}(1-f)}{1-\left(\alpha + \frac{\beta}{2f}\right)\pi}. \end{aligned} \tag{18}$$

Banks in the recapitalizing country are left with negative equity if

$$\begin{aligned} &-\alpha\Delta_{11} - \frac{\beta}{f}\Delta_{11}^{\mathcal{E}} + E_0 < 0 \\ &\Leftrightarrow -\alpha\pi C_2 - \frac{\beta}{f}\pi\left[\frac{C_2}{2} - \underline{S}(1-f)\right] + E_0 < 0 \\ &\Leftrightarrow E_0 < \left(\alpha + \frac{\beta}{2f}\right)\pi\tau\psi L_0 - \frac{\beta}{f}\pi\underline{S}(1-f). \end{aligned} \tag{19}$$

Banks in the non-recapitalizing country are left with non-negative equity if

$$\begin{aligned} &-\frac{\beta}{f}\Delta_{11}^{\mathcal{E}} + E_0 \geq 0 \\ &\Leftrightarrow E_0 \geq \frac{\frac{\beta}{2f}}{1-\alpha\pi}\pi\tau\psi L_0 - \frac{\beta}{f}\pi\underline{S}(1-f). \end{aligned} \tag{20}$$ [24]

[23] Note that we do not need to distinguish cases according to the primary surplus of the non-recapitalizing country because that country always repays $\underline{S}$ on its bonds.

[24] Note that we do not need to check this condition in Case a because banks in the non-recapitalizing country can be affected only through their exposure in the senior tranche, and the senior tranche incurs no losses.

The senior tranche incurs losses in the state in which the recapitalizing country has primary surplus $\underline{S}$ if

$$\underline{S} - \frac{C_2}{2} < \underline{S}f \tag{21}$$

$$\Leftrightarrow \underline{S}(1-f) < \frac{\tau\psi L_0 - E_0}{2(1-\alpha\pi)}.$$

C.2 Both countries recapitalize

When both countries recapitalize their banks, the cost per country is

$$C_2 = \tau\psi L_0 - \alpha(B_1 - \underline{S}) - \frac{\beta}{f}(B_1^{\mathcal{E}} - f\underline{S}) - E_0 \tag{22}$$

$$= \tau\psi L_0 + \alpha\Delta_{12} + \frac{\beta}{f}\Delta_{12}^{\mathcal{E}} - E_0.$$

To compute the equilibrium, we must distinguish three cases.

Case a: The senior tranche incurs no losses. Combining (22) with $\Delta_{12} = \pi C_2$ and $\Delta_{12}^{\mathcal{E}} = 0$, we find

$$C_2 = \tau\psi L_0 + \alpha\pi C_2 - E_0 \tag{23}$$

$$= \frac{\tau\psi L_0 - E_0}{1-\alpha\pi}.$$

Banks in either country are left with negative equity if

$$-\alpha\Delta_{12} + E_0 < 0 \tag{24}$$

$$\Leftrightarrow E_0 < \alpha\pi\tau\psi L_0.$$

The senior tranche incurs no losses if

$$\underline{S} - C_2 \geq \underline{S}f \tag{25}$$

$$\Leftrightarrow \underline{S}(1-f) \geq \frac{\tau\psi L_0 - E_0}{1-\alpha\pi}.$$

Case b: The senior tranche incurs losses only in the state in which both countries have primary surplus $\underline{S}$. Combining (22) with $\Delta_{12} = \pi C_2$ and $\Delta_{12}^{\mathcal{E}} = \pi^2\left[C_2 - \underline{S}(1-f)\right]$, we find

$$C_2 = \tau\psi L_0 + \alpha\pi C_2 + \frac{\beta}{f}\pi^2\left[C_2 - \underline{S}(1-f)\right] - E_0 \tag{26}$$

$$= \frac{\tau\psi L_0 - E_0 - \frac{\beta}{f}\pi^2\underline{S}(1-f)}{1-\alpha\pi - \frac{\beta}{f}\pi^2}.$$

Banks in either country are left with negative equity if

$$-\alpha\Delta_{12} - \frac{\beta}{f}\pi^2\Delta_{12}^{\mathcal{E}} + E_0 < 0 \tag{27}$$

$$\Leftrightarrow -\alpha\pi C_2 - \frac{\beta}{f}\pi^2\left[C_2 - \underline{S}(1-f)\right] + E_0 < 0$$

$$\Leftrightarrow E_0 < (\alpha\pi + \frac{\beta}{f}\pi^2)\tau\psi L_0 - \frac{\beta}{f}\pi^2\underline{S}(1-f).$$

The senior tranche incurs losses in the state in which both countries have primary surplus $\underline{S}$ if

$$\underline{S} - C_2 < \underline{S}f \tag{28}$$

$$\Leftrightarrow \underline{S}(1-f) < \frac{\tau\psi L_0 - E_0}{1-\alpha\pi}.$$

It incurs no losses in the state in which only one country has primary surplus $\underline{S}$ if

$$\underline{S} - \frac{C_2}{2} \geq \underline{S}f \tag{29}$$

$$\Leftrightarrow \underline{S}(1-f) \geq \frac{\tau\psi L_0 - E_0}{2 - 2\alpha\pi - \frac{\beta}{f}\pi^2}.$$

Case c: The senior tranche incurs losses also in the states where only one country has primary surplus $\underline{S}$. Combining (22) with $\Delta_{12} = \pi C_2$ and

$$\Delta_{12}^{\mathcal{E}} = \pi^2\left[C_2 - \underline{S}(1-f)\right] + 2\pi(1-\pi)\left[\frac{C_2}{2} - \underline{S}(1-f)\right],$$

we find

$$\begin{aligned} C_2 &= \tau\psi L_0 + \alpha\pi C_2 + \frac{\beta}{f}\left[\pi C_2 - \pi(2-\pi)\underline{S}(1-f)\right] - E_0 \\ &= \frac{\tau\psi L_0 - E_0 - \frac{\beta}{f}\pi(2-\pi)\underline{S}(1-f)}{1-(\alpha+\frac{\beta}{f})\pi}. \end{aligned} \tag{30}$$

Banks in either country are left with negative equity if

$$-\alpha\Delta_{12} - \frac{\beta}{f}\Delta_{12}^{\mathcal{E}} + E_0 < 0 \tag{31}$$

$$\Leftrightarrow E_0 < (\alpha + \frac{\beta}{f})\pi\tau\psi L_0 - \frac{\beta}{f}\pi(2-\pi)\underline{S}(1-f).$$

The senior tranche incurs losses in the state in which only one country has primary surplus $\underline{S}$ if

$$\underline{S} - \frac{C_2}{2} < \underline{S}f \tag{32}$$

$$\Leftrightarrow \underline{S}(1-f) < \frac{\tau\psi L_0 - E_0}{2 - 2\alpha\pi - \frac{\beta}{f}\pi^2}.$$

C.3 Parameter regions

Based on the above analysis, we can divide the parameter space into regions, in a way analogous to that in Subsection B. We distinguish cases according to the value of $\underline{S}(1-f)$.

Case 1 (low subordination): $\frac{\tau\psi L_0}{2} > \underline{S}(1-f)$. There are four regions, as follows:

- No diabolic loop: $E_0 \geq (\alpha + \frac{\beta}{f})\pi\tau\psi L_0 - \frac{\beta}{f}\pi(2-\pi)\underline{S}(1-f)$.
- Diversification region: $(\alpha+\frac{\beta}{f})\pi\tau\psi L_0 - \frac{\beta}{f}\pi(2-\pi)\underline{S}(1-f) > E_0 \geq \left(\alpha + \frac{\beta}{2f}\right)\pi\tau\psi L_0 - \frac{\beta}{f}\pi\underline{S}(1-f)$.
- Uncorrelated diabolic loop: $\left(\alpha + \frac{\beta}{2f}\right)\pi\tau\psi L_0 - \frac{\beta}{f}\pi\underline{S}(1-f) > E_0 \geq \frac{\beta}{2f(1-\alpha\pi)}\pi\tau\psi L_0 - \frac{\beta}{f}\pi\underline{S}(1-f)$.

- Contagion region: $\frac{\beta}{2f(1-\alpha\pi)}\pi\tau\psi L_0 - \frac{\beta}{f}\pi\underline{S}(1-f) > E_0$.

The argument goes as follows. Suppose that $\frac{\tau\psi L_0}{2} > \underline{S}(1-f)$. Then, when only one country recapitalizes, Case a is not possible because (16) and (17) imply that

$$\underline{S}(1-f) \geq \frac{\tau\psi L_0 - \alpha\pi\tau\psi L_0}{2(1-\alpha\pi)} = \frac{\tau\psi L_0}{2},$$

which is a contradiction. A similar argument implies that when both countries recapitalize, Cases a and b are not possible. Therefore, the boundaries of the regions when only one country recapitalizes and when both countries recapitalize are defined by Cases b and c, respectively.

Case 2 (high subordination): $\tau\psi L_0 > \underline{S}(1-f) > \frac{\tau\psi L_0}{2}$**.** There are four regions, as follows:

- No diabolic loop: $E_0 \geq (\alpha\pi + \frac{\beta}{f}\pi^2)\tau\psi L_0 - \frac{\beta}{f}\pi^2\underline{S}(1-f)$.
- Diversification region: $(\alpha\pi + \frac{\beta}{f}\pi^2)\tau\psi L_0 - \frac{\beta}{f}\pi^2\underline{S}(1-f) > E_0 \geq \alpha\pi\tau\psi L_0$.
- Uncorrelated diabolic loop: $\alpha\pi\tau\psi L_0 > E_0 \geq \max\{\frac{\beta}{2f(1-\alpha\pi)}\pi\tau\psi L_0 - \frac{\beta}{f}\pi\underline{S}(1-f), 0\}$.
- Contagion region: $\max\{\frac{\beta}{2f(1-\alpha\pi)}\pi\tau\psi L_0 - \frac{\beta}{f}\pi\underline{S}(1-f), 0\} > E_0$.

The argument goes as follows. Suppose that $\underline{S}(1-f) > \frac{\tau\psi L_0}{2}$. Then, when only one country recapitalizes, the maximum value of E_0 must belong to Case a. Indeed, if it belongs to Case b, then (19) implies that it must be equal to

$$E_0 = \left(\alpha + \frac{\beta}{2f}\right)\pi\tau\psi L_0 - \frac{\beta}{f}\pi\underline{S}(1-f).$$

Under that value, (21) holds if and only if

$$\underline{S}(1-f) < \frac{\tau\psi L_0 - \left(\alpha + \frac{\beta}{2f}\right)\pi\tau\psi L_0 + \frac{\beta}{f}\pi\underline{S}(1-f)}{2(1-\alpha\pi)}$$

which is equivalent to $\frac{\tau\psi L_0}{2} > \underline{S}(1-f)$ and hence implies a contradiction. Hence, the maximum value of E_0 is as in Case a, i.e., $E_0 = \alpha\pi\tau\psi L_0$. A similar argument implies that when both countries recapitalize, the maximum value of E_0 must belong to Case b. The latter argument uses both inequalities, i.e., $\tau\psi L_0 > \underline{S}(1-f) > \frac{\tau\psi L_0}{2}$.

Case 3 (very high subordination): $\underline{S}(1-f) > \tau\psi L_0$**.** There are three regions, as follows:

- No diabolic loop: $E_0 \geq \alpha\tau\psi L_0$.
- Uncorrelated diabolic loop region: $\alpha\pi\tau\psi L_0 > E_0 \geq \max\{\frac{\beta}{2f(1-\alpha\pi)}\pi\tau\psi L_0 - \frac{\beta}{f}\pi\underline{S}(1-f), 0\}$.
- Contagion region: $\max\{\frac{\beta}{2f(1-\alpha\pi)}\pi\tau\psi L_0 - \frac{\beta}{f}\pi\underline{S}(1-f), 0\} > E_0$.

The argument is similar to the preceding ones. Suppose that $\underline{S}(1-f) > \tau\psi L_0$. Then, when only one country recapitalizes, the maximum value of E_0 must belong to Case a. And when both countries recapitalize, the maximum value of E_0 must also belong to Case a.

We can fix $\gamma := \alpha + \beta$, and plot the regions in the $(E_0, \beta))$ space. Panels B and C in Figure 9 correspond to Cases 1 and 2 respectively. Case 3 represents the limiting case in which the diversification region and (for very high $\underline{S}(1-f)$) the contagion region disappear. The boundary between the no diabolic loop and the diversification regions, and the boundary between the diversification and the single diabolic loop regions, are straight lines. Assumption 1 ensures that these lines have negative slope.

Web appendix to:

ESBies: Safety in the tranches*

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Abstract

This web appendix accompanies the paper "ESBies: Safety in the tranches", in which we advocate the creation of a new union-wide safe asset without joint liability. The purpose of this web appendix is to present variations on the numerical simulations reported in Section 4 of that paper. These variations serve as robustness checks with respect to the paper's conclusions regarding securities' face values and risk characteristics.

*This draft: September 19, 2016; the latest draft is available at www.euro-nomics.com. This is web appendix to accompany the preliminary version of a paper prepared for the 64th Panel Meeting of *Economic Policy*, 14-15 October 2016. The views expressed herein are those of the authors and do not necessarily represent the views of the institutions to which they are affiliated.

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1 Overview of simulations

In the paper "ESBies: Safety in the tranches", published as working paper 21 of the European Systemic Risk Board,[1] we conduct numerical simulations to test the face values and risk characteristics of European Safe Bonds under benchmark and adverse scenarios.

The key result from these simulations is that ESBies with a subordination level of 30% have an expected loss rate slightly lower than German bunds. At the same time, they would approximately double the supply of safe assets relative to the *status quo*. The corresponding junior securities would be attractive investments, thanks to their embedded leverage and expected loss rates similar to those of vulnerable euro area sovereign bonds.

The purpose of this web appendix is to test the robustness of these results to different simulation design choices. In particular, we evaluate the following variations on the simulations conducted in the main paper:

Higher LGDs (Section 2): In this variation, we shift the distribution of loss-given-default rates to the right by 15%. Conditional on a nation-state's default, average losses imposed on bond holders are higher than under the benchmark and adverse scenarios envisaged in the main paper. We retain the relative ranking of average LGDs across nation-states.

Higher PDs (Section 3): We shift the distribution of default rates to the right by 15%. All nation-states are likelier to default than under the benchmark scenario envisaged in the main paper. Again, we retain nation-states' relative ranking.

More frequent severe recessions (Section 4): Severe recessions occur 10%, rather than 5%, of the time, while mild recessions occur 20%, rather than 25%, of the time. This scenario is much more pessimistic, since most defaults occur during severe recessions when default probabilities are elevated.

Very adverse (Section 5): The adverse scenario in the main paper is subject to more severe contagion assumptions. When Germany, France, Italy or Spain defaults, others are even more likely to default.

In this web appendix, results from each variant simulation are reported and discussed in the corresponding sections. Section 6 draws general conclusions.

[1] ESRB working papers are available here:
www.esrb.europa.eu/pub/working-papers/html/index.en.html

2 Higher loss-given-default rates

In this variant, the benchmark scenario in the main paper is repeated with loss-given-default rates that are 15% higher. The new LGDs in each of the three states of the world—i.e. severe recession, mild recession and macroeconomic expansion—are reported in Table 1.

In this scenario, five-year expected loss rates mechanically increase across the board, as we show in Table 2. Nevertheless, the three highest rated nation-states—namely Germany, the Netherlands and Luxembourg—remain comfortably below the 0.5% safety threshold, with five-year expected loss rates of 0.15%, 0.31% and 0.31% respectively. ESBies with a subordination level of 30% have a five-year expected loss rate of 0.18%, which remains similar to that of Germany's.

The supply of safe assets through ESBies is the same as in the benchmark scenario, with €4.22tn at 30% subordination. The *status quo*, by contrast, delivers €2.12tn of safe assets, which is €0.32tn less than in the benchmark scenario, since Austrian and Finnish debt is no longer safe. National tranching with a uniform subordination level of 30% delivers €1.70tn of safe assets—the same as in the benchmark scenario.

The expected loss rate of the junior tranche increases from 9.10% in the benchmark scenario to 10.24% in the "higher LGDs" variant. The junior tranche can still be sub-tranched to create an investment grade mezzanine tranche. With 30% subordination, this can be achieved by splitting the junior tranche in half: the 15% mezzanine tranche has an expected loss rate of 3.42%, which maps to an investment grade credit rating of A- (i.e. ranked 7 on a 1-22 rating scale); and the equity tranche has an expected loss rate of 17.07%, which is speculative grade.

3 Higher default rates

Here, default rates are 15% higher than in the benchmark scenario in the main paper. The new PDs are reported in Table 3.

Five-year expected loss rates increase across the board (Table 4), albeit by slightly less than in Section 2. ESBies with a 30% subordination level have an expected loss rate of 0.14%, which is slightly lower than that of untranched German bunds (0.15%).

Safe asset supply is the same as in Section 2: the *status quo* yields €2.12tn; *national tranching* with a uniform 30% subordination level yields €1.70tn; and ESBies with 30% subordination give €4.22tn.

Likewise, the risk characteristics of the junior tranche are similar compared with Section 2: the expected loss rate at 30% subordination is 10.35%. With 50/50 sub-tranching, the 15%-thick mezzanine tranche easily achieves investment grade, with an expected loss rate of 3.39%, while the corresponding equity tranche would have an expected loss rate of 17.31%.

4 More frequent severe recessions

We conduct a sensitivity analysis of the results with respect to the *ex ante* recession probabilities. In particular, we now assume that severe recessions occur 10%, rather than 5%, of the time, while mild recessions occur 20%, rather than 25%, of the time. This scenario is considerably more pessimistic, since defaults are more likely to occur during severe recessions.

In this scenario, *status quo* German bunds' expected loss rate increases from 0.13% (in the benchmark scenario) to 0.24%. With 30% subordination, ESBies' expected loss rate increases from 0.09% to 0.19%. They therefore remain slightly safer than German bunds.

The supply of safe assets from the *status quo*, *national tranching* and *pooling and tranching* remains the same as in Section 2 and Section 3, at €2.12tn, €1.70tn and €4.22tn respectively.

The junior tranche is slightly riskier than in Section 2 and Section 3, with an expected loss rate of 12.12%. Nevertheless, this junior tranche can be sub-tranched to create an investment grade 15%-thick mezzanine tranche (with an expected loss rate of 5.47%) and a high-yielding equity tranche (18.78%).

5 Very adverse scenario

Here, we perform a sensitivity analysis of the contagion assumptions that governs the adverse scenario in Subsection 4.3 of the main paper. In particular, we make four contagion assumptions, imposed sequentially in the following order:

1. Whenever there is a German default, others default with 75% probability. (In the main paper, this probability is set at 50%.)

2. Whenever there is a French default, other nation-states default with 75% probability, except the five highest rated nation-states, which default with 25% probability. (In the main paper, these probabilities are 40% and 10% respectively.)

3. Whenever there is an Italian default, the five highest rated nation-states default with 10% probability; the next three nation-states (France, Belgium and Estonia) default with 25% probability; and the other nation-states default with 75% probability—unless any of these nation-states had defaulted at step 1 or 2. (In the main paper, these probabilities are 5%, 10% and 40% respectively.)

4. Whenever there is a Spanish default, other nation-states' default probabilities are the same as under an Italian default—unless any of these nation-states had already defaulted.

These enhancements substantially increase the correlation of defaults across nation-states relative to those in the adverse scenario reported in Subsection 4.3 of the main paper. The first principal component of defaults now explains 57% of covariation in default rates, compared with 42% in the adverse scenario and 29% in the benchmark scenario, and the first three principal components account for 74% of the covariation compared to 64% in the adverse scenario and 57% in the benchmark scenario. Table 6 shows the conditional default probabilities, which have the feature that euro area nation-states are very sensitive to the default of Germany, France, Italy or Spain.

Five-year expected loss rates for *status quo* sovereign bonds are much higher than in the benchmark scenario. In fact, none is safe: *status quo* German bunds have an expected loss rate of 0.96%. They can only be made safe through tranching: with uniform *national tranching* at 30%, German, Dutch and Luxembourgish bonds' expected loss rates are below the 0.5% safety threshold.

With 30% subordination, ESBies are not safe: their expected loss rate stands at 0.98%. Nevertheless, loss rates decline quickly as the subordination level is increased, and at 40% ESBies are safe, with an expected loss rate of 0.39%. At this level, ESBies generate €3.62tn of safe assets, more than double that of *national tranching*.

6 Conclusion

ESBies continue to perform well in the more severe scenarios simulated in this web appendix. In all scenarios, the expected loss rate of ESBies with 30% subordination is similar to that of the *status quo* German bund. And in all scenarios, ESBies are able to generate approximately double the volume of safe assets generated through the *status quo*, *national tranching* or *pure pooling*. In most cases, this is achieved with our base-case of 30% subordination; only in the "very adverse" scenario is it necessary to increase ESBies' subordination to 40% in order to ensure their safety.

Table 1: Loss given default rates (in %) in the "higher LGDs" scenario (Section 2)

Country	Benchmark scenario				Higher LGDs scenario			
	lgd1	lgd2	lgd3	Average LGD	lgd1	lgd2	lgd3	Average LGD
Germany	40.0	32.0	20.0	36.1	46.0	36.8	23.0	41.7
Netherlands	40.0	32.0	20.0	37.0	46.0	36.8	23.0	42.5
Luxembourg	40.0	32.0	20.0	37.5	46.0	36.8	23.0	43.1
Austria	45.0	36.0	22.5	41.0	51.8	41.4	25.9	47.5
Finland	45.0	36.0	22.5	41.0	51.8	41.4	25.9	47.5
France	60.0	48.0	30.0	54.8	69.0	55.2	34.5	62.8
Belgium	62.5	50.0	31.3	56.3	71.9	57.5	35.9	64.7
Estonia	67.5	54.0	33.8	60.6	77.6	62.1	38.8	69.9
Slovakia	70.0	56.0	35.0	62.3	80.5	64.4	40.3	71.7
Ireland	75.0	60.0	37.5	67.4	86.3	69.0	43.1	77.3
Latvia	75.0	60.0	37.5	65.6	86.3	69.0	43.1	75.4
Lithuania	75.0	60.0	37.5	65.7	86.3	69.0	43.1	75.5
Malta	78.0	62.4	39.0	68.1	89.7	71.8	44.9	78.3
Slovenia	80.0	64.0	40.0	69.3	92.0	73.6	46.0	79.6
Spain	80.0	64.0	40.0	69.3	92.0	73.6	46.0	79.6
Italy	80.0	64.0	40.0	68.8	92.0	73.6	46.0	79.1
Portugal	85.0	68.0	42.5	68.8	97.8	78.2	48.9	79.1
Cyprus	87.5	70.0	43.8	64.3	100.0	80.0	50.0	73.9
Greece	95.0	76.0	47.5	61.7	100.0	80.0	50.0	70.2
Average	59.4	47.6	29.7	52.3	68.2	54.5	34.1	60.1

Note: This table reports the LGD inputs used in the numerical simulations described in Section 2, as compared with those used in the benchmark scenario in the main paper. The columns lgd1, lgd2 and lgd3 refer to the loss given default rates in state 1 (which is characterized by a severe recession), state 2 (mild recession) and state 3 (macroeconomic expansion) respectively. By construction, $lgd1 = 1.25 \times lgd2 = 2 \times lgd3$ in both scenarios. The "average LGD" column reports the average LGD across the three states; this average is 15% higher in the "higher LGDs" scenario than in the benchmark scenario.

Table 2: Five-year expected loss rates (in %) in the "higher LGDs" scenario (Section 2)

Subordination	0%	10%		20%		30%		40%		50%	
Tranche		**S**	**J**	**S**	**J**	**S**	**J**	**S**	**J**	**S**	**J**
Germany	0.15	0.13	0.36	0.10	0.36	0.07	0.36	0.02	0.35	0.00	0.31
Netherlands	0.31	0.26	0.73	0.20	0.73	0.13	0.73	0.05	0.70	0.00	0.62
Luxembourg	0.31	0.26	0.72	0.20	0.72	0.13	0.72	0.05	0.70	0.00	0.62
Austria	0.58	0.51	1.22	0.42	1.22	0.30	1.22	0.15	1.22	0.02	1.13
Finland	0.58	0.51	1.22	0.42	1.22	0.30	1.22	0.15	1.22	0.02	1.13
France	1.25	1.17	1.99	1.06	1.99	0.93	1.99	0.76	1.99	0.52	1.98
Belgium	1.63	1.53	2.52	1.41	2.52	1.25	2.52	1.04	2.51	0.76	2.50
Estonia	2.11	2.00	3.02	1.88	3.02	1.71	3.02	1.50	3.02	1.21	3.00
Slovakia	2.36	2.26	3.29	2.13	3.29	1.96	3.29	1.74	3.29	1.44	3.28
Ireland	2.73	2.64	3.53	2.53	3.53	2.39	3.53	2.20	3.53	1.94	3.52
Latvia	3.93	3.79	5.21	3.61	5.21	3.39	5.21	3.08	5.21	2.69	5.18
Lithuania	3.92	3.78	5.19	3.60	5.19	3.37	5.19	3.07	5.19	2.68	5.16
Malta	4.51	4.37	5.76	4.20	5.76	3.97	5.76	3.67	5.76	3.28	5.73
Slovenia	5.63	5.47	7.07	5.27	7.07	5.01	7.07	4.67	7.07	4.21	7.05
Spain	5.63	5.47	7.07	5.27	7.07	5.02	7.07	4.67	7.07	4.21	7.05
Italy	6.47	6.28	8.18	6.05	8.18	5.74	8.18	5.33	8.18	4.79	8.16
Portugal	10.31	10.01	13.03	9.63	13.03	9.15	13.03	8.50	13.03	7.63	12.99
Cyprus	15.60	14.99	21.11	14.22	21.11	13.23	21.11	11.92	21.11	10.08	21.11
Greece	38.88	37.05	55.39	34.76	55.39	31.81	55.39	27.88	55.39	22.38	55.39
Pooled	**3.20**										
ESBies		**1.22**	**21.06**	**0.51**	**13.98**	**0.18**	**10.24**	**0.06**	**7.92**	**0.00**	**6.40**

Note: Table shows the five-year expected loss rates (in %) in the "higher LGDs" scenario described in Section 2. The first row refers to the subordination level, which defines the size of the junior tranche. The second row refers to the tranche type; "S" (in black) denotes the senior tranche and "J" (in gray) the junior tranche. The cell referring to 0% subordination is blank, since there is no tranching in this case: all bonds are *pari passu*. The remaining rows refer to the bonds of nation-states and, in the final row, the pooled security, which represents a GDP-weighted securitization of the 19 euro area nation-states' sovereign bonds.

Table 3: Default rates (in %) in the “higher PDs” scenario (Section 3)

Country	Benchmark scenario				Higher PDs scenario			
	pd1	pd2	pd3	Average PD	pd1	pd2	pd3	Average PD
Germany	5.0	0.5	0.0	0.4	5.8	0.6	0.0	0.4
Netherlands	10.0	1.0	0.0	0.7	11.5	1.2	0.0	0.8
Luxembourg	10.0	1.0	0.0	0.7	11.5	1.2	0.0	0.8
Austria	15.0	2.0	0.0	1.2	17.3	2.3	0.0	1.4
Finland	15.0	2.0	0.0	1.2	17.3	2.3	0.0	1.4
France	25.0	3.0	0.1	2.0	28.8	3.5	0.1	2.3
Belgium	30.0	4.0	0.1	2.5	34.5	4.6	0.1	2.9
Estonia	35.0	5.0	0.1	3.0	40.3	5.8	0.1	3.5
Slovakia	35.0	6.0	0.1	3.3	40.3	6.9	0.1	3.8
Ireland	40.0	6.0	0.1	3.5	46.0	6.9	0.1	4.1
Latvia	50.0	10.0	0.3	5.2	57.5	11.5	0.3	6.0
Lithuania	50.0	10.0	0.3	5.2	57.5	11.5	0.3	6.0
Malta	55.0	11.0	0.4	5.8	63.3	12.7	0.5	6.6
Slovenia	60.0	15.0	0.4	7.1	69.0	17.3	0.5	8.1
Spain	60.0	15.0	0.4	7.1	69.0	17.3	0.5	8.1
Italy	65.0	18.0	0.5	8.2	74.8	20.7	0.6	9.4
Portugal	70.0	30.0	2.5	13.0	80.5	34.5	2.9	15.0
Cyprus	75.0	40.0	10.0	21.1	86.3	46.0	11.5	24.3
Greece	95.0	75.0	45.0	55.4	100.0	86.3	51.8	63.3
Average	31.3	8.1	1.1	4.4	35.8	9.3	1.3	5.0

Note: This table reports the PD inputs used in the numerical simulations described in Section 3, as compared with those used in the benchmark scenario in the main paper. The columns pd1, pd2 and pd3 refer to the default rates in state 1 (which is characterized by a severe recession), state 2 (mild recession) and state 3 (macroeconomic expansion) respectively. The “average PD” column reports the average PD across the three states; this average is 15% higher in the “higher PDs” scenario than in the benchmark scenario.

Table 4: Five-year expected loss rates (in %) in the "higher PDs" scenario (Section 3)

Subordination	**0%**	**10%**		**20%**		**30%**		**40%**		**50%**	
Tranche		**S**	**J**	**S**	**J**	**S**	**J**	**S**	**J**	**S**	**J**
Germany	0.15	0.13	0.42	0.09	0.42	0.04	0.42	0.00	0.39	0.00	0.31
Netherlands	0.31	0.25	0.83	0.18	0.83	0.08	0.83	0.00	0.77	0.00	0.62
Luxembourg	0.31	0.25	0.83	0.18	0.83	0.08	0.83	0.00	0.77	0.00	0.62
Austria	0.58	0.48	1.41	0.37	1.41	0.22	1.41	0.07	1.35	0.00	1.15
Finland	0.58	0.49	1.41	0.37	1.41	0.22	1.41	0.07	1.35	0.00	1.16
France	1.25	1.13	2.29	0.99	2.29	0.80	2.29	0.56	2.28	0.26	2.24
Belgium	1.63	1.49	2.90	1.31	2.90	1.09	2.90	0.80	2.88	0.39	2.87
Estonia	2.11	1.95	3.47	1.76	3.47	1.52	3.47	1.20	3.46	0.77	3.45
Slovakia	2.36	2.20	3.79	2.00	3.79	1.75	3.79	1.42	3.78	0.96	3.76
Ireland	2.73	2.59	4.07	2.40	4.07	2.16	4.07	1.85	4.06	1.42	4.04
Latvia	3.93	3.70	5.99	3.42	5.99	3.05	5.99	2.57	5.97	1.94	5.93
Lithuania	3.92	3.69	5.96	3.40	5.96	3.04	5.96	2.56	5.95	1.93	5.90
Malta	4.51	4.27	6.62	3.98	6.62	3.60	6.62	3.10	6.61	2.46	6.55
Slovenia	5.63	5.35	8.13	5.00	8.13	4.56	8.13	3.96	8.13	3.19	8.07
Spain	5.63	5.35	8.13	5.01	8.13	4.56	8.13	3.96	8.13	3.19	8.07
Italy	6.47	6.15	9.41	5.74	9.41	5.21	9.41	4.51	9.41	3.61	9.33
Portugal	10.31	9.79	14.99	9.15	14.99	8.31	14.99	7.20	14.99	5.93	14.69
Cyprus	15.62	14.66	24.29	13.46	24.29	11.91	24.29	9.85	24.29	7.94	23.30
Greece	38.90	36.19	63.30	32.80	63.30	28.44	63.30	22.63	63.30	16.27	61.53
Pooled	**3.20**										
ESBies		**1.13**	**21.81**	**0.46**	**14.18**	**0.14**	**10.35**	**0.02**	**7.97**	**0.00**	**6.40**

Note: Table shows the five-year expected loss rates (in %) in the "higher PDs" scenario described in Section 3. The first row refers to the subordination level, which defines the size of the junior tranche. The second row refers to the tranche type; "S" (in black) denotes the senior tranche and "J" (in gray) the junior tranche. The cell referring to 0% subordination is blank, since there is no tranching in this case: all bonds are *pari passu*. The remaining rows refer to the bonds of nation-states and, in the final row, the pooled security, which represents a GDP-weighted securitization of the 19 euro area nation-states' sovereign bonds.

Table 5: Five-year expected loss rates (in %) in the "more recessions" scenario (Section 4)

Subordination	**0%**	**10%**		**20%**		**30%**		**40%**		**50%**	
Tranche		**S**	**J**	**S**	**J**	**S**	**J**	**S**	**J**	**S**	**J**
Germany	0.24	0.19	0.61	0.14	0.61	0.08	0.61	0.00	0.59	0.00	0.47
Netherlands	0.47	0.39	1.22	0.28	1.22	0.15	1.22	0.00	1.18	0.00	0.94
Luxembourg	0.47	0.39	1.22	0.28	1.22	0.15	1.22	0.00	1.18	0.00	0.94
Austria	0.83	0.71	1.94	0.56	1.94	0.36	1.94	0.13	1.89	0.00	1.67
Finland	0.83	0.71	1.94	0.56	1.94	0.36	1.94	0.13	1.90	0.00	1.67
France	1.83	1.68	3.20	1.49	3.20	1.25	3.20	0.93	3.19	0.50	3.16
Belgium	2.34	2.16	3.95	1.94	3.95	1.65	3.95	1.27	3.93	0.75	3.92
Estonia	2.98	2.80	4.67	2.56	4.67	2.26	4.67	1.86	4.66	1.32	4.65
Slovakia	3.22	3.03	4.89	2.80	4.89	2.50	4.89	2.11	4.88	1.56	4.87
Ireland	3.83	3.65	5.40	3.43	5.40	3.15	5.40	2.78	5.40	2.27	5.38
Latvia	5.15	4.90	7.40	4.59	7.40	4.18	7.40	3.66	7.39	2.95	7.35
Lithuania	5.14	4.89	7.39	4.58	7.39	4.18	7.39	3.65	7.38	2.94	7.34
Malta	5.91	5.65	8.18	5.34	8.18	4.93	8.18	4.39	8.18	3.69	8.12
Slovenia	7.00	6.72	9.54	6.37	9.54	5.92	9.54	5.31	9.54	4.52	9.48
Spain	7.02	6.73	9.56	6.38	9.56	5.93	9.56	5.32	9.56	4.53	9.50
Italy	7.86	7.53	10.77	7.13	10.77	6.61	10.77	5.92	10.77	5.01	10.71
Portugal	11.12	10.66	15.23	10.09	15.23	9.35	15.23	8.37	15.23	7.26	14.97
Cyprus	15.66	14.84	23.05	13.81	23.05	12.49	23.05	10.73	23.05	9.12	22.19
Greece	35.99	33.71	56.49	30.86	56.49	27.20	56.49	22.32	56.49	17.02	54.96
Pooled	**3.77**										
ESBies		**1.69**	**22.55**	**0.72**	**15.98**	**0.19**	**12.12**	**0.02**	**9.40**	**0.00**	**7.54**

Note: Table shows the five-year expected loss rates (in %) in the "more recessions" scenario described in Section 4. The first row refers to the subordination level, which defines the size of the junior tranche. The second row refers to the tranche type; "S" (in black) denotes the senior tranche and "J" (in gray) the junior tranche. The cell referring to 0% subordination is blank, since there is no tranching in this case: all bonds are *pari passu*. The remaining rows refer to the bonds of nation-states and, in the final row, the pooled security, which represents a GDP-weighted securitization of the 19 euro area nation-states' sovereign bonds.

Table 6: Conditional default probabilities (in %) (Section 5)

	Adverse scenario *conditional on a default by:*				Very adverse scenario *conditional on a default by:*			
	Germany	France	Spain	Italy	Germany	France	Spain	Italy
Germany	100	18	12	11	100	27	21	21
Netherlands	26	19	14	14	36	32	26	26
Luxembourg	25	20	14	14	36	32	26	26
Austria	28	22	16	16	38	34	28	27
Finland	28	22	16	16	38	33	28	27
France	46	100	28	27	61	100	47	47
Belgium	44	45	31	30	63	60	51	50
Estonia	46	47	32	32	63	61	52	52
Slovakia	70	69	62	61	93	92	90	89
Ireland	70	70	63	62	93	92	90	89
Latvia	72	72	65	64	93	93	90	90
Lithuania	72	72	65	64	93	93	90	90
Malta	73	73	66	65	93	93	90	90
Slovenia	75	74	68	67	94	93	91	91
Spain	81	77	100	67	94	93	100	89
Italy	84	79	72	100	95	94	91	100
Portugal	80	79	74	73	95	94	93	92
Cyprus	82	82	77	77	96	95	94	93
Greece	93	93	91	91	98	98	97	97

Note: Table shows the default probabilities of euro area nation-states (given in the rows of the table) conditional on the default of Germany, France, Spain or Italy (given in the columns). These conditional default probabilities are shown for the adverse scenario (described in Subsection 4.3 of the main paper) and the "very adverse" scenario (Section 5). Owing to the more aggressive contagion assumptions in the "very adverse" scenario, default probabilities conditional on the default of Germany, France, Spain or Italy increase monotonically relative to the adverse scenario. If Italy defaults, for example, Spain then has a probability of default of 89% in the "very adverse" scenario, up from 67% in the adverse scenario and 31% in the benchmark scenario. This underscores the severity of the "very adverse" scenario.

Table 7: Five-year expected loss rates (in %) in the "very adverse" scenario (Section 5)

Subordination	0%	10%		20%		30%		40%		50%	
Tranche		S	J	S	J	S	J	S	J	S	J
Germany	0.96	0.76	2.76	0.51	2.76	0.20	2.73	0.00	2.40	0.00	1.92
Netherlands	1.30	1.03	3.64	0.71	3.64	0.30	3.61	0.00	3.24	0.00	2.59
Luxembourg	1.30	1.03	3.64	0.71	3.64	0.30	3.61	0.00	3.24	0.00	2.59
Austria	1.63	1.36	4.08	1.02	4.08	0.59	4.06	0.16	3.83	0.00	3.26
Finland	1.63	1.36	4.08	1.02	4.08	0.59	4.06	0.16	3.83	0.00	3.26
France	3.20	2.87	6.18	2.46	6.18	1.93	6.18	1.26	6.12	0.47	5.94
Belgium	4.12	3.73	7.63	3.25	7.63	2.62	7.63	1.83	7.57	0.73	7.52
Estonia	4.67	4.30	8.00	3.83	8.00	3.24	8.00	2.48	7.96	1.43	7.91
Slovakia	7.92	7.32	13.38	6.56	13.38	5.59	13.38	4.34	13.30	2.66	13.19
Ireland	8.53	7.98	13.43	7.30	13.43	6.43	13.43	5.28	13.39	3.78	13.27
Latvia	9.10	8.51	14.42	7.78	14.42	6.83	14.42	5.59	14.37	3.98	14.23
Lithuania	9.10	8.51	14.41	7.77	14.41	6.82	14.41	5.59	14.36	3.97	14.22
Malta	9.64	9.08	14.71	8.38	14.71	7.47	14.71	6.28	14.69	4.75	14.53
Slovenia	10.43	9.86	15.54	9.15	15.54	8.24	15.54	7.02	15.54	5.48	15.38
Spain	8.30	7.87	12.22	7.32	12.22	6.62	12.22	5.69	12.22	4.50	12.11
Italy	8.47	8.03	12.48	7.47	12.48	6.76	12.48	5.80	12.48	4.58	12.37
Portugal	13.75	13.06	19.98	12.19	19.98	11.08	19.98	9.59	19.98	7.85	19.65
Cyprus	17.79	16.76	27.08	15.47	27.08	13.81	27.08	11.60	27.08	9.42	26.17
Greece	35.92	33.49	57.77	30.46	57.77	26.56	57.77	21.35	57.77	15.62	56.22
Pooled	**4.87**										
ESBies		**3.15**	**20.38**	**1.97**	**16.48**	**0.98**	**13.95**	**0.39**	**11.60**	**0.11**	**9.64**

Note: Table shows the five-year expected loss rates (in %) in the "very adverse" scenario described in Section 5. The first row refers to the subordination level, which defines the size of the junior tranche. The second row refers to the tranche type; "S" (in black) denotes the senior tranche and "J" (in gray) the junior tranche. The cell referring to 0% subordination is blank, since there is no tranching in this case: all bonds are *pari passu*. The remaining rows refer to the bonds of nation-states and, in the final row, the pooled security, which represents a GDP-weighted securitization of the 19 euro area nation-states' sovereign bonds.