Regulating the doom loop*

Spyros Alogoskoufis† Sam Langfield‡

Abstract

Euro area governments have committed to break the doom loop between bank risk and sovereign risk. But policymakers have not reached consensus on whether and how to reform the regulatory treatment of banks' sovereign exposures. To inform policy discussions, this paper simulates portfolio reallocations under regulatory reform scenarios. Simulations highlight a tension in between concentration and credit risk. Resolving this tension requires regulatory reform to be complemented by an expansion in the portfolio opportunity set to include an area-wide low-risk asset that embeds both low concentration and low credit risk.

Keywords: Bank regulation, sovereign risk, systemic risk

JEL codes: G01, G11, G21, G28

*This draft: December 7, 2018. First draft: May 4, 2018. The Online Appendix to this paper is available at www.samlangfield.com/research. We thank the editor (Elena Carletti) and two anonymous referees for helpful comments and suggestions. We also thank Jorge Abad, Inês Drumond (discussant), Robert Düll, Peter Dunne, Tina Engler, Jeroen Hessel, Laura Izquierdo Rios, Marco Pagano, Valerio Vacca, Marco van Hengel, Ad van Riet and Jeromin Zettelmeyer, as well as participants at the European Banking Authority annual research workshop (2018) and a seminar at the European Central Bank. The views expressed herein are those of the authors and do not necessarily represent the views of the institutions to which they are affiliated.

†European Central Bank. Email: spyridon.alogoskoufis@ecb.int.
‡European Central Bank. Email: sam.langfield@ecb.int.

"It is imperative to break the vicious circle between banks and sovereigns."

Euro area summit statement, 29 June 2012

1 Introduction

Sovereigns are exposed to bank risk, and banks are exposed to sovereign risk. During the euro area sovereign debt crisis, this two-way risk exposure generated what heads of state and government referred to as a "vicious circle" following a euro area summit in 2012. This vicious circle is also known as the "doom loop" (Farhi & Tirole, 2018) or "diabolic loop" (Brunnermeier, Garicano, Lane, Pagano, Reis, Santos, Thesmar, Van Nieuwerburgh & Vayanos, 2016) owing to its devilish implications for systemic risk.

To weaken the doom loop, the financial architecture has been substantially improved since that summit. Higher capital and bail-in requirements for banks have led to substantial increases in loss absorption capacity. The Bank Recovery and Resolution Directive provides a common framework with which to restructure failing banks, and the Single Resolution Mechanism is empowered to execute restructurings, financed by a Single Resolution Fund. The European Stability Mechanism can grant loans to euro area Member States that are illiquid or otherwise in need of assistance. All of these reforms serve to mitigate the exposures of sovereigns to bank risk.

However, recent reforms do not directly address the direct exposures of banks to sovereign risk. At present, euro area banks have no regulatory incentive to manage these exposures prudently. Reports published by the European Systemic Risk Board (2015), the German Council of Economic Experts (2015) and the Basel Committee on Banking Supervision (2017) consider ideas for reforming regulation. But policymakers have not reached consensus on which type of reform dominates, or even whether reform is generally desirable, in part owing to uncertainty regarding the response of banks and sovereign debt markets (Visco, 2016).

To inform policy discussions, this paper simulates portfolio reallocations by euro area banks under four regulatory reform scenarios. In our simulations, banks respond to regulatory reform by reallocating their sovereign portfolio to minimize capital requirements while keeping total portfolio value fixed. Subject to this constraint, banks have degrees of freedom in portfolio allocation. To quantify the range of portfolios that satisfy the constraint, we characterize two limiting cases: in a "prudent case", banks reinvest into the lowest-risk sovereign bonds; in an "imprudent case", banks reinvest into the highest-risk (i.e. highest-yielding) sovereign bonds. We also define an intermediate "base case" in which banks replicate the properties of their initial portfolio.

Simulation results shed light on two questions. First, would reforms induce banks to reduce concentration in their sovereign exposures? Second, would reforms reduce banks' exposures to sovereign credit risk? Results highlight a fundamental tension between reducing concentration and reducing credit risk. Reforms focused on concentration, such as capital charges for concentration or large exposure limits, indeed reduce home bias, but are consistent with banks increasing their overall exposure to sovereign credit risk. This is because a less concentrated portfolio can have higher credit risk. By contrast, regulatory reforms aimed at inducing banks to reduce risk exposures, such as credit risk based capital charges, can exacerbate portfolio concentrations. High concentration—even in ostensibly low-risk sovereigns—can be problematic as sovereign credit risk is time-varying. Either outcome could give rise to new sources of contagion.

The tension between concentration and credit risk is a general insight that reflects the portfolio opportunity set of euro-denominated sovereign bonds. At present, it is impossible to assemble a portfolio of euro area sovereign bonds that has both low concentration and low credit risk. The existence of a euro-denominated asset that embeds both of these properties would make financial markets more complete by expanding the set of investible securities. Such an area-wide low-risk asset could be created by tranching portfolios of sovereign bonds (High-Level Task Force on Safe Assets, 2018; Leandro & Zettelmeyer, 2018). With such an asset, banks could simultaneously reduce concentration and credit risk without reducing the value of their sovereign portfolios.

On its own, however, the existence of an area-wide low-risk asset may be insufficient to induce substantial portfolio reallocation. For this reason, an area-wide low-risk asset complements, rather than substitutes, regulatory reform. In a final implementation of the simulation model, we show that banks reliably reinvest into an area-wide low-risk asset only when regulatory reform includes positive capital charges for all sovereign bonds and/or very restrictive large exposure limits. This characterizes the set of policies necessary to finally break the doom loop.

Literature on the doom loop

A burgeoning research agenda has studied the causes and consequences of the doom loop between bank risk and sovereign risk. In the euro area sovereign debt crisis, this doom loop was primarily domestic. Banks were home biased in their asset allocation, rendering them vulnerable to domestic sovereign risk (Brunnermeier, Langfield, Pagano, Reis, van Nieuwerburgh & Vayanos, 2017) and related country risks (Bocola, 2016). Home bias increased even further over the course of the sovereign debt crisis (Brutti & Sauré, 2016). In light of these stylized facts, theoretical contributions to the literature have shed light on the reasons for banks' home bias.

Much of the literature focuses on risk-shifting incentives in asset allocation decisions. Due to limited liability, banks have incentives to load up on domestic sovereign debt as default risk increases, since equity holders earn positive payoffs in expectation (Acharya & Steffen, 2015). Proceeds from these payoffs can be reinvested in high-value projects, which materialize in good states of the world in which sovereign default does not occur (Gennaioli, Martin & Rossi, 2014). At the same time, downside risk is shifted to others. When banks expect to be bailed out by governments, taxpayers bear the downside risk (Farhi & Tirole, 2018). Alternatively, if governments can credibly commit not to bail out banks, equity holders shift downside risk to creditors (Acharya, Drechsler & Schnabl, 2014).[1] Battistini, Pagano & Simonelli (2014) document such risk-shifting behavior by banks in vulnerable euro area countries, which increased their holdings of domestic sovereign debt following increases in sovereign risk.

Banks' risk-shifting behavior implies credit misallocation ex ante and the materialization of a doom loop ex post. Time-consistent supervisors should therefore prevent banks from risk-shifting. This is the rationale for outsourcing responsibility for supervision to a credible supranational entity (Farhi & Tirole, 2018). Without a commitment device, however, national supervisors can be tempted to encourage banks to finance government borrowing when external demand is weak (Ongena, Popov & van Horen, 2018). Together, banks' risk-shifting behavior and time-inconsistent national supervision have negative real

[1] According to this view, risk-shifting is privately optimal for banks since their net worth would anyway be negative in the event of a sovereign default, particularly if their initial condition is one of weak capitalization (Crosignani, 2017). This is consistent with Bocola (2016), wherein increases in expectations of a sovereign default exacerbates the riskiness of non-financial firms, thereby affecting bank risk even if banks do not hold any sovereign bonds.

effects even when sovereign default does not occur. By increasing sovereign bond holdings, banks have fewer resources available to fund real economy lending (Broner, Erce, Martin & Ventura, 2014). Altavilla, Pagano & Simonelli (2017), Ferrando, Popov & Udell (2017), Acharya, Eisert, Eufinger & Hirsch (2018) and Becker & Ivashina (2018) identify this effect in vulnerable euro area countries, where banks increased their domestic sovereign bond holdings but cut back on their lending to non-financial firms.

In Farhi & Tirole (2018), the time-consistent supervisor's solution is to control risk-shifting by requiring banks to hold foreign sovereign debt, which in their model is assumed to be safe, rather than risky domestic debt. However, if both foreign and domestic sovereign debt is risky, this conclusion no longer holds. In fact, in a financially integrated monetary union such as the euro area, exposure to both foreign and domestic sovereign risk can be counterproductive in the presence of contagion effects. Bolton & Jeanne (2011) show this in a two-country model in which contagion can operate from sovereign risk to bank risk. Exposure to foreign sovereign risk brings diversification benefits, but it can also give rise to greater systemic risk, as sovereign distress can propagate internationally.[2]

Likewise, Brunnermeier et al. (2016) model international spillovers arising from losses in the banking system due to government default. In their model, banks (as well as governments) can default outright, and the doom loop between them can occur either nationally or internationally, depending on bank equity levels and whether banks hold only domestic sovereign debt or a portfolio comprising domestic and foreign debt in equal proportions. Brunnermeier et al. (2017) extend this model to study the equilibrium effects of a continuum of possible bank portfolios, ranging from full home bias to full diversification. Consistent with Cooper & Nikolov (2018) in a closed economy setting, Brunnermeier et al. (2017) find that the doom loop cannot occur when bank equity is sufficiently high, since banks are fully insulated from sovereign default, whether foreign or domestic. Consequently, sovereigns never default in equilibrium (as they are assumed to be solvent unless they bail out banks). However, when bank equity is low, a national doom loop can occur if banks are exposed primarily to their domestic sovereign. An even more

[2] In Bolton & Jeanne (2011), cross-country contagion occurs due to collateral scarcity in interbank markets. In their model, investment opportunities arise asymmetrically across banks, giving rise to an international interbank market in which banks with surplus endowment (i.e. few investment opportunities) lend to banks with abundant investment opportunities. Interbank lending must be collateralized by government bonds. When a government defaults (or is expected to default), its bonds can no longer be used as collateral. This restricts the size of interbank markets, depressing aggregate investment.

dangerous parameter region exists when bank equity is low and banks hold well-diversified portfolios comprising both domestic and foreign sovereign debt. In this case, all banks are vulnerable to domestic and foreign sovereign debt re-pricing: sovereign distress in any country can endogenously cause bank and sovereign defaults in every country. Hence, such portfolios can be counterproductive, as they can generate an international doom loop between sovereigns anywhere and banks everywhere.

These theoretical models of the doom loop reveal a dark side of diversification: contagion.[3] When banks have little loss absorption capacity, greater exposure to foreign sovereign risk can exacerbate, rather than reduce, endogenous risks arising from the doom loop. Despite the euro area sovereign debt crisis being characterized primarily by domestic doom loops, there is considerable empirical evidence of bank-sovereign contagion channels operating across borders (Popov & Van Horen, 2015; Kallestrup, Lando & Murgoci, 2016; Beltratti & Stulz, 2017; Kirschenmann, Korte & Steffen, 2018; Breckenfelder & Schwaab, 2018). These international contagion channels would strengthen if regulation were to induce banks to lower the concentration in their sovereign portfolios.

The policy implication is that regulation should lower both concentration and credit risk in banks' sovereign portfolios. This is the central insight against which we benchmark ideas for how to reform the regulatory treatment of sovereign exposures. Numerical simulations reveal a fundamental tension between reducing concentration and reducing credit risk in the absence of an area-wide low-risk asset. By expanding the portfolio opportunity set, such an asset can resolve this tension. It follows that regulatory reform should be calibrated to induce reinvestment into an area-wide low-risk asset. Before describing these simulations in detail, the next section characterizes the current regulation of banks' sovereign exposures, and proposes a framework for classifying reform ideas.

[3] Analogous models of contagion within networks of diversified intermediaries include Wagner (2010), Ibragimov, Jaffee & Walden (2011), Elliott, Golub & Jackson (2014) and Acemoglu, Ozdaglar & Tahbaz-Salehi (2015).

2 Regulation of banks' sovereign exposures

2.1 Current regulation

A principle underlying the prudential regulation of banks is that capital requirements should be sensitive to risk. For sovereigns, the standardized approach set out by the Basel Committee on Banking Supervision prescribes risk weights that are a stepwise function of credit ratings, ranging from 0% for sovereign debt rated AA− or higher to 150% for debt rated B− or lower. However, Basel standards grant competent authorities the discretion to set a lower risk weight for exposures denominated and funded in domestic currency. In addition, Basel II introduced the possibility for banks to adopt an internal ratings-based approach, rather than the standardized approach, to determine risk weights, including with respect to sovereign exposures (Basel Committee on Banking Supervision, 2006).

The Capital Requirements Regulation (CRR) of the European Union assigns a zero risk weight to such exposures under the standardized approach.[4] In addition, the CRR grants authorities the discretion to allow internal ratings-based (IRB) banks to use the standardized approach for their sovereign exposures.[5] According to the Basel Committee on Banking Supervision (2014), this latter provision is "materially non-compliant" with Basel standards, which require IRB banks to move all significant exposures, including to sovereigns, to the IRB framework.[6] In addition, owing to the zero risk weight, portfolios that benefit from the permanent partial use provision are exempt from large exposure limits, which constrain exposures to a single counterparty to 25% of a bank's own funds.[7]

In combination, the zero risk weight and absence of a large exposure limit means that CRR-regulated banks do not face any constraint with respect to their domestic currency

[4] See article 114, paragraph 4 of the CRR (575/2013).

[5] Article 150 of the CRR states: "Where institutions have received the prior permission of the competent authorities, institutions permitted to use the IRB Approach in the calculation of risk-weighted exposure amounts and expected loss amounts for one or more exposure classes may apply the Standardised Approach" for certain exposures, including (per paragraph 1d) exposures to central governments (that are assigned a zero risk weight under article 114). Under these provisions, competent authorities have discretion to revoke permission for this permanent partial use of the standardized approach.

[6] Under the IRB approach, sovereign exposures are typically subject to small positive risk weights, depending on the estimated default and loss given default rates. However, given the size of banks' sovereign exposures, the application of even very small risk weights can result in meaningfully higher capital requirements. On this basis, the Basel Committee on Banking Supervision (2014) concludes that "the permanent exclusion of sovereign exposures from the IRB approach generally results in a material overstatement of [banks'] CET1 ratios".

[7] See article 400 (paragraph 1a) of the CRR.

sovereign exposures (as long as the leverage ratio requirement does not bind). Banks are therefore able to purchase sovereign bonds without funding those additional assets with any equity. Hence, there is no regulatory incentive for banks to prudently manage their direct exposure to sovereign risk.

From a systemic risk perspective, the European Systemic Risk Board (2015) has expressed concern that the current regulatory framework may have led to excessive investment by financial institutions in government debt. Empirical research supports the view that the regulatory framework can indeed lead to an over-exposure of banks to sovereign risk (Acharya & Steffen, 2015; Bonner, 2016), prompting some policymakers to call for regulatory reform (Nouy, 2012; Deutsche Bundesbank, 2014; Enria, Farkas & Overby, 2016).

2.2 Scenarios for regulatory reform

Proponents of regulatory reform have put forward various ideas for how to treat sovereign exposures. However, despite the abundance of ideas, policymakers have not reached consensus on which one dominates. This section describes the ideas that have attained prominence in policy discussions and proposes a framework for classifying those ideas.

The European Systemic Risk Board (2015) provides an extensive examination of policy options for regulatory reform. The report covers the full gamut of possible reforms to bank regulation, including Pillar 1 capital requirements for sovereign exposures, large exposure limits, macroprudential requirements, enhanced Pillar 2 and Pillar 3 requirements, and requirements with respect to liquidity risk. In this paper, we focus on the first two of these options, namely Pillar 1 capital requirements and large exposure limits, owing to their direct implications for banks' sovereign portfolio allocation.

Following the ESRB's contribution, international policy discussions migrated to Basel. In January 2015, the Basel Committee on Banking Supervision initiated a review of the regulatory treatment of sovereign exposures. Insights from that review were published in December 2017 in a discussion paper, which lays out ideas for how regulation could, in principle, be reformed, without advocating that such ideas should actually be implemented (Basel Committee on Banking Supervision, 2017). Those reform ideas provide the basis for the numerical simulations conducted in this paper.

Pillar 1 reform ideas can be classified along two dimensions. First, they can be either price-based or quantity-based: the former implies that certain sovereign exposures attract a positive risk weight and thereby contribute to banks' capital requirements, while the latter implies that certain sovereign exposures may not exceed a given threshold relative to total capital. The second dimension concerns whether reforms target concentration or credit risk. Reforms aimed at concentration are bank-specific as they are calibrated according to portfolio concentration in a given single-name sovereign. Reforms aimed at credit risk are country-specific as they are calibrated according to the measured credit risk properties of each single-name sovereign. Taken together, these two dimensions give rise to the 2×2 matrix shown in Table 1, comprising four reform categories.[8] In particular:

- *Price-based reform to target concentration*: Risk weights are set as a function of a bank's concentration in a single sovereign. This corresponds to what the Basel Committee on Banking Supervision (2017) refers to as "marginal risk weight add ons", an illustrative calibration of which is reported in Table 2, Panel A.[9]

- *Price-based reform to target credit risk*: Risk weights are set as a function of credit ratings under the standardized approach to calculating capital requirements. This corresponds to what the Basel Committee on Banking Supervision (2017) refers to as "standardized risk weights", an illustrative calibration of which is reported in Table 2, Panel B.

- *Quantity-based reform to target concentration*: Banks' sovereign exposures are subject to uniform large exposure limits. This idea corresponds to discussions in the Basel Committee on Banking Supervision regarding the exemption of sovereign exposures from the large exposures framework. If that exemption were removed, single-name sovereign exposures would be subject to a limit of 25% of a bank's Tier 1 capital, as shown in Table 2, Panel C. In the simulations, we also consider the possible impact of a continuum of calibrations of the large exposure limit, ranging from 500% to 1% of a bank's Tier 1 capital.

[8] In principle, these categories could also be combined to produce hybrid reforms, but it is useful conceptually to approach them as mutually exclusive.

[9] A qualitatively similar approach is proposed by Véron (2017).

- *Quantity-based reform to target credit risk*: Banks' sovereign exposures are subject to large exposure limits set as a function of sovereign credit ratings. This approach is not discussed by the Basel Committee on Banking Supervision (2017). Instead, this element of the policy matrix corresponds to the main pillar of a proposal put forward by German Council of Economic Experts (2015) and elaborated by Andritzky, Gadatsch, Körner, Schäfer & Schnabel (2016). Their proposed calibration is reported in Table 2, Panel D.

In the next section we describe our model for simulating banks' portfolio reallocations in response to the aforementioned reforms. Then, after documenting the datasets at our disposal, Section 5 presents the simulation results for the four reform scenarios. In Section 6, these results are compared to the case in which banks reinvest into an area-wide low-risk asset. Finally, Section 7 infers conclusions for policymakers.

3 Model

Despite the abundance of ideas for reforming the regulatory treatment of banks' sovereign exposures, there has been little analysis of the impact of such reform on banks' sovereign exposures. The European Systemic Risk Board (2015) and Schneider & Steffen (2017) provide insightful quantitative assessments of the impact on banks' capital requirements under various regulatory reform scenarios. However, these contributions assume that banks maintain their current sovereign portfolios, and quantify the additional capital that banks would need to raise to maintain their capital ratios at the original level.[10] As such, they assume that the elasticity of banks' sovereign bond holdings with respect to their associated capital requirements is zero. Hence, while such quantitative analyses are informative, they characterize only a special case of banks' reaction functions, and one that is perhaps unlikely to materialize in practice, given that banks behave as though capital is a relatively expensive source of marginal funding (Diamond & Rajan, 2000). We describe our more general approach in the remainder of this section.

[10] Alternatively, banks could choose not to raise additional capital, and instead see their capital ratio fall. This is viable until the new capital ratio hits the binding regulatory minimum. However, evidence suggests that banks tend to have internal targets for capital ratios that exceed regulatory minima (Adrian & Shin, 2010; Brinkhoff, Langfield & Weeken, 2018).

3.1 Simulation design

We propose a more general characterization of banks' possible reactions to regulatory reform by allowing portfolio allocation. To this end, our simulations make three baseline assumptions. First, in line with the European Systemic Risk Board (2015) and Schneider & Steffen (2017), we assume that aggregate holdings of euro area sovereign bonds are inelastic with respect to their regulatory treatment. This assumption is motivated by the insight that banks use euro area sovereign bonds as liquid stores of value and as collateral in euro-denominated transactions. In addition, regulation requires banks to hold liquid assets, such as sovereign bonds, to comply with liquidity requirements and to insure against systemic illiquidity events.[11] These non-pecuniary motivations for euro area banks to hold euro-denominated sovereign bonds would continue to exist under all scenarios for regulatory reform.

Second, we assume that banks prefer to maintain their current allocation of sovereign bonds. This again follows the approach of previous quantitative impact assessments, and is motivated by the insight that banks have a revealed preference for their current holdings. Banks only deviate from their pre-existing portfolio allocation insofar as reinvestment achieves lower capital requirements under each of the four reform scenarios.

Third, we assume that banks' portfolio allocation is elastic with respect to regulation. This is where our approach differs from previous quantitative impact assessments. In our framework, banks choose their sovereign portfolio allocation to minimize overall capital requirements. This is based on the insight that sovereign bonds are typically low-return investments, so that portfolio allocation is likely to be sensitive to regulatory requirements. The implication of this assumption is that the portfolio allocations in our simulations represent a globally unique solution to the constrained minimization problem facing banks. Consequently, in our simulations it is never possible for banks to further reduce their capital requirements.

These three baseline assumptions allow for multiple solutions to banks' portfolio allocation decisions under different regulatory reform scenarios. To establish unique solutions, we focus on three illustrative reallocation cases. For marginal changes in portfolio allo-

[11] Ferrara, Langfield, Liu & Ota (2018) document that banks generally hold substantially higher liquid asset buffers than required by regulation, suggesting a high level of structural demand for sovereign bonds.

cation, banks adopt one of the following reallocation rules, which apply insofar as banks can lower capital requirements by deviating from their initial (preferred) portfolio:

- *Prudent case:* Banks reinvest into the lowest-risk sovereign bond that attracts the lowest capital charge. This provides a limiting case of the most conservative portfolio allocation under a given reform scenario.

- *Base case:* Banks first reinvest into their existing holdings of sovereign bonds that attract the lowest capital charge. Then, banks reinvest into the sovereign bond with credit risk properties that most closely matches their initial portfolio. Banks therefore replicate the characteristics of their initial portfolio allocation under the new regulatory constraints.

- *Imprudent case:* Banks reinvest into the highest-risk sovereign bond that attracts the lowest capital charge. This provides a limiting case of the highest credit risk exposure that banks could reasonably be expected to take on under a given reform scenario, similar in spirit to Becker & Ivashina (2015).

These decision rules do not represent a forecast of banks' actual portfolio reallocation following regulatory reform. Instead, the limiting cases of "prudence" and "imprudence" provide lower and upper bounds on the levels of concentration and credit risk in banks' resulting portfolios, following the central assumption that banks adjust the composition of their portfolio to globally minimize the corresponding capital requirements.

Table 3 provides a pedagogic application of these portfolio rules to a hypothetical Italian bank with 30 units of Tier 1 capital and an initial sovereign portfolio of 100 units, comprised of 75 units of Italian, 20 units of German, and 5 units of French debt securities. The table shows portfolio allocations under each of the three reallocation cases applied to the four regulatory reform scenarios described in Section 2.2. In all columns, the hypothetical bank maintains its aggregate sovereign bond holdings at 100 units and these holdings are subject to a globally minimal capital charge. In the regulatory status quo, these two conclusions hold by construction, since the hypothetical bank begins with a sovereign portfolio of 100 units, and current regulation applies no restrictions to sovereign portfolios. In subsequent columns, the bank chooses a portfolio that attracts a globally minimal capital charge under the respective portfolio reallocation rule. In each regulatory reform scenario, the credit risk of the resulting portfolio is weakly lowest in the prudent case and highest in the imprudent case, with the base case representing an interior solution. The following insights emerge from the table:

- For *price-based reform to target concentration*, the bank divests its single-name holdings in excess of 100% of Tier 1 capital, i.e. $75 - 30 = 45$ of its Italian bond holdings. In the prudent case, this 45 unit excess is reinvested into the lowest-risk sovereigns, i.e. Germany up to the 30 unit limit followed by the Netherlands up to the 30 unit limit, with the residual 5 units invested in Luxembourg; in the base case, the excess is invested in German and French bonds up to the 30 unit limit, with the residual 10 units invested in the country with a credit risk that most closely matches the initial portfolio, which happens to be Slovakia; in the imprudent case, the excess is reinvested into the highest-risk sovereigns, i.e. Greece up to the 30 unit limit, with the residual 15 units reinvested in Cyprus.

- For *price-based reform to target credit risk*, the hypothetical bank divests all 75 units of its Italian holdings, since these attract a risk weight of 4% owing to Italy's BBB rating as of mid-2017. In the prudent case, this 75 unit excess is reinvested into German bonds (which are the lowest-risk securities); in the base case, the excess is divided between German and French bonds in proportion to the bank's initial holdings of these securities; and in the imprudent case, the excess is reinvested into the highest-risk sovereign bond that nevertheless has a 0% risk weight, which happens to be Slovenia.

- For *quantity-based reform to target concentration*, the bank divests its single-name holdings in excess of 25% of Tier 1 capital, i.e. $0.25 \times 30 = 7.5$ units. This implies a total excess of 80 units across its Italian and German holdings. In the prudent case, this 80 unit excess is reinvested into the lowest-risk sovereigns, which given the 7.5 unit limit takes the bank from the Netherlands to Latvia inclusive; in the base case, the bank increases its holdings of French bonds by 2.5 units, and then invests the 7.5 unit maximum in countries in order of their proximity to the credit risk of the initial portfolio; in the imprudent case, the excess is reinvested into the highest-risk sovereigns from Greece to Estonia inclusive.

- For *quantity-based reform to target credit risk*, the bank divests $75-(0.75\times30) = 52.5$ of its Italian bond holdings. In the prudent case, this 52.5 unit excess is reinvested into the lowest-risk sovereigns, as in the previous reform scenario; in the base case, the excess is divided proportionally between German and French bonds, with the residual 17.5 units reinvested into Slovakia; in the imprudent case, the excess is reinvested into the highest-risk sovereigns, i.e. Greece, Cyprus and Portugal (in that order).

3.2 Portfolio measurement

The combination of the four regulatory reform scenarios and three cases for portfolio reallocation yields 12 distinct portfolios, which can be compared to the initial portfolio in terms of concentration and credit risk. To measure portfolio concentration, we calculate three metrics. First, we measure home bias as the excess of a bank's holdings of debt securities issued by its domestic sovereign relative to that sovereign's share in the European Central Bank (ECB) capital key.[12] In particular, for a given bank portfolio we calculate:

$$HomeBias = Max[0, 100 \times \frac{(h_{i=d}/\sum_{i=1}^{19} h_i) - CK_{i=d}}{1 - CK_{i=d}}],$$

where $h_{i=d}$ is the bank's holdings of debt issued by its domestic sovereign d, $\sum_{i=1}^{19} h_i$ is the bank's holdings of debt issued by each sovereign i summed across all 19 euro area sovereigns, and $CK_{i=d}$ is the ECB capital key share of domestic country d (as reported in Table 4). Note that the measure is bounded at zero, so that when a bank is underweight its own sovereign, i.e. $h_{i=d}/\sum_{i=1}^{19} h_i < CK_{i=d}$, $HomeBias = 0$.

Second, we measure portfolio concentration by the standard Herfindahl Hirschman index (HHI), calculated as the sum of the squared shares of bank holdings:

$$HHI = \frac{\sum_{i=1}^{19}(h_i/\sum_{i=1}^{19} h_i)^2}{100},$$

where the division by 100 means that the index is bounded by 0 and 100. A value of 100 represents full concentration. In practice, the minimum value of HHI is approximately

[12] The ECB capital key provides a good benchmark for low portfolio concentration as it reflects Member States' relative economic size and population, rather than confounding variables such as debt issuance decisions.

5, which holds when a bank's sovereign exposures are uniformly distributed across euro area Member States. The benchmark for low concentration is given by $HHI \approx 16$, which obtains for a portfolio of sovereign exposures weighted by the ECB capital key.

Third, we measure deviation from the ECB capital key by $KeyDeviation$, which is calculated as the square root of the sum of squared deviations from the ECB capital key, namely:

$$KeyDeviation = \sqrt{\frac{\sum_{i=1}^{19}((h_i / \sum_{i=1}^{19} h_i) - CK_i)^2}{19}}.$$

For a portfolio weighted exactly by the ECB capital key, $KeyDeviation = 0$, since all individual deviations from capital key shares are zero. The maximum value of $KeyDeviation$ is given by a bank fully concentrated in sovereign debt issued by the country with the lowest ECB capital key share in the euro area, which happens to be Malta. In this case, $KeyDeviation \approx 24.7$, given that $CK_{Malta} = 0.09\%$. For the country with the largest capital key share, i.e. $CK_{Germany} = 25.56\%$, $KeyDeviation \approx 18.5$ for a portfolio comprised only of German debt securities.

Next, we calculate measures of portfolio risk. For this, we rely on Brunnermeier et al. (2017), who simulate a two-level stochastic model of sovereign default. In the first level, they simulate 2,000 five-year periods, in each of which the aggregate economic state can be expansionary, in which case default risk is generally low; mildly recessionary, in which case default risk is somewhat higher; or severely recessionary, in which case default risk is much higher. In the second level of the model, Brunnermeier et al. (2017) take 5,000 draws of the stochastic default process, implying 10 million draws in total. In a benchmark calibration, the model is designed to generate default rates inferred from end-2015 CDS spreads. An alternative adverse calibration builds in additional cross-country dependence, whereby defaults are even more likely if other sovereigns also default. For conservatism, we take the outputs of the adverse model calibration, but our insights are robust to different calibrations.

The model can be used to calculate a variety of risk metrics. Brunnermeier et al. (2017) focus on five-year expected loss rates, namely the losses than an investor expects to incur over a five-year period (calculated as the product of the default probability and loss-given-default). In addition, the High-Level Task Force on Safe Assets (2018) uses the same model to calculate value-at-risk, namely the minimum percentage reduction in portfolio value that occurs over five years with 1% probability. We report both of these risk measures and compare them to loss absorption capacity at the bank-level. In particular, for a given bank portfolio we calculate:

$$ExpectedLoss = \frac{ELRate \times Exp}{T1},$$

where $ELRate$ is the expected loss rate of a bank's sovereign portfolio, Exp is the total value of that portfolio, and $T1$ is the bank's Tier 1 capital. $ExpectedLoss$ therefore measures the fraction of a bank's Tier 1 capital that it expects to lose on its sovereign bond holdings over a five-year period (under the adverse calibration of the simulation model). For value-at-risk, we calculate for each bank portfolio:

$$UnexpectedLoss = \frac{VaR \times Exp}{T1},$$

where VaR is the 1% value-at-risk of a bank's sovereign portfolio. $UnexpectedLoss$ measures the fraction of a bank's Tier 1 capital that it loses over a five-year period in the 1st percentile of worst outcomes.

Computing these measures of portfolio concentration and credit risk for our hypothetical Italian bank—as shown in Table 3—provides early intuition of the simulations results that we obtain in Section 5 using data on banks' actual sovereign exposures. In the case of this hypothetical bank, the degrees of freedom in portfolio allocation following regulatory reform are such that all reform scenarios are consistent with increased sovereign risk exposure in the imprudent case. Moreover, while home bias unambiguously decreases in all reform scenarios, price-based reform to target credit risk is consistent with the hypothetical bank increasing its portfolio concentration (as measured by HHI and $KeyDeviation$).

4 Data

To implement the simulation model, we assemble two datasets on sovereign risk and bank exposures. To measure sovereign risk, we collect information on five-year expected loss rates (from Brunnermeier et al. (2017)) and value-at-risk (calculated by the High-Level Task Force on Safe Assets (2018)). We complement this with sovereign credit ratings assigned by the three major rating agencies as of mid-2017. These country-level variables are reported in Table 4.

To measure bank exposures, we collect information from the European Banking Authority (EBA). For our main simulations, we use data from the EBA transparency exercise published in 2017; in Online Appendix B, we repeat our simulations using older exposures data published at the end of 2011. The 2017 exercise covers 132 banks, of which 107 are resident in the euro area. After discarding banks for which the EBA does not provide sufficiently granular information on holdings, we are left with a final sample of 95 banks.[13] We obtain data on these banks' holdings of euro area government debt securities as of mid-2017, when total holdings amounted to approximately €1.3tn.[14] According to ECB statistics, this represents 81% of all euro area banks' exposures to euro area central government debt securities.

Table 5 provides summary statistics of banks' exposures. More granular data for the 95 individual banks in our sample are reported in Online Appendix A. These statistics indicate that euro area banks generally hold substantial quantities of government debt securities issued by euro area Member States: as of mid-2017, the median bank has an exposure worth 123% of its Tier 1 capital. Mean exposure is 171% of Tier 1 capital. If the value of all central government debt securities were marked down to zero, 57 banks would have negative capital. Bank value therefore exhibits significant heterogeneity in its sensitivity to sovereign risk. Nearly half of the banks in our sample should expect

[13] For several sample banks, the EBA transparency exercise published in 2017 does not provide a country breakdown of sovereign exposures. In these cases, we use the breakdown from an earlier exercise published in 2015.

[14] More precisely, we download the series "1720806", which provides a country breakdown for the carrying amount of banks' holdings of government debt securities. This series includes holdings of both central and sub-central debt securities, although in practice sub-central governments tend to be funded by loans and advances rather than debt securities. The EBA transparency exercise also contains information on banks' loans and advances to governments. Across our 95 sample banks, these loans and advances amount to €0.9tn. Including these loans and advances in the simulation model would obviously increase aggregate portfolio reallocation, but would not alter our qualitative conclusions regarding concentration and credit risk at the bank-level.

to lose less than 5% of their Tier 1 capital over five years, whereas more than one-third should expect to lose more than 10%. A similar degree of cross-sectional dispersion can be observed for $UnexpectedLoss$.

Banks are profoundly home biased. Median $HomeBias$ is 64%; only 10 banks in our sample of 95 do not exhibit any home bias. Consequently, portfolios tend to be heavily concentrated, as measured by HHI and $KeyDeviation$. Starting from these initial conditions, we now turn to numerical simulations to shed light on how bank portfolios could adjust in response to regulatory reform.

5 Simulation results

We simulate portfolio reallocation by banks under the four scenarios for regulatory reform outlined in Table 1 and Table 2. The simulations envisage three portfolio reallocation rules, which are illustrated for a hypothetical bank in Table 3. The benchmark comparison for the resulting portfolios is given in Table 5, which reports summary statistics for bank holdings of central government debt securities as of mid-2017.[15] Simulation results are shown in Tables 6, 7, 8 and 9 and the corresponding Figures 1, 2, 3 and 4.

5.1 Price-based reform to target concentration

The Basel Committee on Banking Supervision (2017) envisages a risk weight of 0% for exposures up to 100% of Tier 1 capital. For excess exposures, the marginal risk weight increases as a stepwise function of exposures (analogous to progressive marginal tax rates on income). The precise calibration of this stepwise function is reported in Table 2. Simulation results for the limiting case of full reallocation are shown in Table 6. Figure 1 plots the simulation results for the continuum of 0-100% reallocation, where 0% corresponds to Table 5 and 100% reallocation corresponds to Table 6. Between these polar extremes, measures of concentration and credit risk are a nonlinear function of the extent to which banks reallocate their sovereign portfolio.

These results show that price-based reform to target concentration unambiguously induces the average bank to lessen its portfolio concentration. Under all three reallocation

[15] Corresponding statistics for bank holdings as of end-2011 are reported in Online Appendix B.

rules, mean $HomeBias$ falls to 42% after full reallocation, down from 55% as of mid-2017. Likewise, the results for HHI and $KeyDeviation$ both indicate that banks unambiguously reduce their portfolio concentration on average, but the magnitudes are again modest. The reason is that these average reductions in portfolio concentration are driven entirely by only 36 banks with a single-name sovereign exposure that exceeds 100% of their Tier 1 capital. The remaining 59 banks do not engage in any portfolio reallocation under this regulatory reform scenario. Most bank portfolios therefore remain relatively concentrated. Mean $KeyDeviation$ stands at 13—a long way from the low concentration benchmark of near-zero deviation.

The effect on credit risk exposure is ambiguous. Crucially, outcomes depend on the reallocation rule that banks adopt. In the prudent case, which assumes that banks reallocate into safer securities, the mean $ELRate$ falls modestly from 5.5% as of mid-2017 to 4.8%. By contrast, in the imprudent case, which represents the upper bound on resulting risk exposures, the mean $ELRate$ increases substantially to 8.2%. Banks with very risky sovereign portfolios see a particularly large increase in their $ELRate$; that of the bank at the 90th percentile goes from 9.6% as of mid-2017 to 16.8% in the imprudent case, compared with 7.7% in the prudent case. Consequently, the bank at the 90th percentile expects to lose more than half of its Tier 1 capital over five years in the imprudent case, more than double the initial condition in mid-2017, and considerably higher than the 13.6% that it expects to lose in the prudent case. Similar insights can be drawn from changes in value-at-risk.

These simulation results therefore highlight a trade-off. Average portfolio concentration reduces modestly, driven by a minority of 36 banks affected by this regulatory reform. By contrast, outcomes in terms of credit risk exposure are ambiguous. When banks reallocate imprudently, risk exposures could increase substantially, particularly in the right-tail of banks with very risky portfolios. This raises concerns that price-based reform to target concentration could have unintended consequences for the doom loop. In general equilibrium, banks' greater exposure to the credit risk of foreign sovereigns could generate additional risk endogenously via contagion effects (Bolton & Jeanne, 2011; Brunnermeier et al., 2017).

5.2 Price-based reform to target credit risk

Rather than concentration, risk weights can be calibrated as a function of credit risk. The Basel Committee on Banking Supervision (2017) outlines a possible calibration of standardized risk weights, with domestic-currency sovereign exposures assigned a risk weight of 0% if government debt is rated between AAA to A−, 4% if debt is rated between BBB+ and BBB−, and 7% if debt is rated BBB− or below (as in Table 2, Panel B).[16] Given credit ratings as of mid-2017, debt issued by 14 euro area Member States is subject to a risk weight of zero under this calibration (see Table 4). Debt issued by two Member States—i.e. Italy and Spain—receives a risk weight of 4%, while exposures to Portugal, Cyprus and Greece receive a risk weight of 7%.

Simulation results are shown in Table 7 for the limiting case of full reallocation and Figure 2 for the continuum of 0-100% reallocation. Price-based reform to target credit risk reduces approximately half of the sample banks' exposure to sovereign credit risk in the prudent case (Panel A) as well as the base case (Panel B), with the other half unaffected by regulation since they hold only 0%-weighted sovereigns. By contrast, results are mixed in the imprudent case, shown in Panel C: in terms of $ELRate$ and $ExpectedLoss$, the portfolios of affected banks see a modest improvement, with median values falling by 0.7% points and 0.6% points respectively. However, improvements are concentrated in affected banks with relatively low $Exp/T1$. For some banks, $ELRate$ actually increases in the imprudent case. Consequently, mean $ExpectedLoss$ increases slightly from 9.8% to 9.9%. The upshot is that price-based reform to target credit risk cannot be relied upon to stimulate a reduction in credit risk exposure for all banks, or even for the average bank when risk is measured in terms of $ExpectedLoss$.

The explanation for this surprising finding lies in the fact that the ordinal ranking of countries by credit ratings as of mid-2017 does not correspond to their ranking by $ELRate$ or VaR. For example, Italy's S&P rating as of mid-2017 was BBB−, implying a 4% risk weight, but its $ELRate$ is lower than that of Slovenia, which had a A+ rating and therefore a 0% risk weight under price-based reform to target credit risk. This insight highlights how regulations predicated on credit ratings are subject to measurement error in ratings. Marginal changes in credit rating agencies' opinions around critical ratings thresholds

[16] For the purposes of the simulation model, we assume that euro area banks' euro-denominated sovereign exposures are always classified as domestic currency exposures.

can have large implications for portfolio allocation. Moreover, discontinuities embedded in ratings-based regulation can generate perverse incentives for banks to concentrate their portfolio allocation in securities just above critical thresholds, even when securities just below these thresholds are similar or even slightly less risky. Evidence from securitization markets suggests that this concern is empirically relevant: Efing (2018) finds that banks subject to binding capital requirements concentrate their portfolio allocation in asset-backed securities with the highest ratio of yield spread to required capital.

The implications for portfolio concentration are even more ambiguous. Price-based reform to target credit risk reduces $HomeBias$, but only for banks located in countries subject to positive risk weights. This accounts for the substantial reduction in median $HomeBias$ from 64% as of mid-2017 to approximately 9% after full reallocation in the prudent and base cases. However, the decline in mean $HomeBias$ is less pronounced because approximately half of the sample banks are unaffected by price-based reform to target credit risk, and therefore remain considerably home biased.

By contrast, simulation results for HHI and $KeyDeviation$ suggest that portfolio concentration increases throughout the cross-section of banks affected by regulatory reform. This finding is consistent across all three portfolio reallocation rules. The intuition is that price-based reform to target credit risk actively dissuades banks from minimizing concentration when portfolio reallocation is extensive. In the calibration envisaged by the Basel Committee on Banking Supervision (2017), five euro area Member States are subject to non-zero risk weights as of mid-2017. Such a regulation has the effect of decreasing the investible universe of euro area government debt securities for banks looking to minimize capital requirements. As such, after full reallocation, bank portfolios become more concentrated when measured in terms of HHI and $KeyDeviation$, but not in terms of $HomeBias$. However, for intermediate levels of portfolio reallocation, depicted in Figure 2, $KeyDeviation$ can be lower than as of mid-2017. At low levels of portfolio reallocation, the marginal reduction in $HomeBias$ dominates the reduction in $KeyDeviation$. When reallocation increases beyond approximately 50%, this relation changes, since the marginal reduction in $HomeBias$ diminishes and banks reinvest only into the subset of sovereign bonds that attract a 0% risk weight. Consequently, $KeyDeviation$ reverts to its initial value as reallocation approaches 100%, since affected banks become more concentrated in highly rated sovereign bonds.

5.3 Quantity-based reform to target concentration

This reform type is perhaps the simplest: uniform quantitative restrictions are placed on bank holdings of government debt. Consequently, virtually all banks are affected under this regulatory reform scenario. The results shown in Table 8 indicate that a 25% large exposure limit is more effective than any other regulation in reducing portfolio concentration. Under all three portfolio reallocation rules, mean $HomeBias$ falls from 64% as of mid-2017 to 13%. A significant minority of banks no longer have any home bias. The values of HHI and $KeyDeviation$ are also substantially lower than under any other regulatory reform scenario, although $KeyDeviation$ remains above the zero-deviation benchmark for all banks.

In terms of credit risk exposure, however, large exposure limits are consistent with the widest range of outcomes. In the base case, mean $ELRate$ drops slightly, from 5.5% to 5.2%. In the imprudent case, the mean $ELRate$ increases to 11.1%, which is substantially higher than under the other reform scenarios. This is because a large exposure limit places no restriction on banks reallocating a finite fraction of their sovereign bond holdings into high-risk securities. A similar effect operates under price-based reform to target concentration, although in that scenario only a minority of banks are induced to reallocate their portfolios (since non-zero risk weights apply only to holdings in excess of 100% of Tier 1 capital). By contrast, much more reallocation occurs with a 25% large exposure limit. As such, quantity-based reform to target concentration could exacerbate bank exposure to sovereign credit risk and potentially give rise to new contagion risks (Bolton & Jeanne, 2011; Brunnermeier et al., 2017).

Figure 3 depicts the simulation results for a continuum of quantitative restrictions, ranging from an aggressive 1% limit, through the standard 25% limit reported in Table 8, to a liberal 500% limit. There is a nonlinear relationship between the calibration of the large exposure limit and portfolio concentration and credit risk respectively. At relatively liberal calibrations of the large exposure limit—from 500% to approximately 200%—$HomeBias$ and $KeyDeviation$ are barely affected, as the limit is non-binding for most banks. As the limit gets tighter, more banks are affected. $HomeBias$ and $KeyDeviation$ decrease more quickly, and the change in $ELRate$ becomes greater as the large exposure limit tightens. In the imprudent case, the mean $ELRate$ increases to 8.2% with a 100%

large exposure limit, above the initial condition of 5.5%, and reaches a peak of 11.3% with a 32% limit, which is close to the 25% limit mooted by the Basel Committee on Banking Supervision (2017). However, as the large exposure limit gets very small, $ELRate$ drops again in the imprudent case, since banks increasingly lose degrees of freedom in portfolio allocation. With an extreme large exposure limit of 1%, almost all banks are forced to hold an equally-weighted portfolio of euro area sovereigns, the average $ELRate$ of which equals 6.8%. In the other two cases, banks' $ELRate$ converges to 6.8% from below as the large exposure limit approaches 1%.[17]

5.4 Quantity-based reform to target credit risk

The Basel Committee on Banking Supervision (2017) does not envisage quantity-based reform to target credit risk. Instead, this reform is proposed by German Council of Economic Experts (2015) and Andritzky et al. (2016) on the grounds that price-based approaches might provide only weak incentives for banks to reduce their exposure to sovereign credit risk. Through the lens of our simulation model, this reasoning implies that equilibrium bank portfolios lie towards the left-hand side of Figure 1 or Figure 2. To counteract these concerns regarding low elasticity, quantity-based approaches place hard exposure limits on bank sovereign exposures. In the case of quantity-based reform to target credit risk, limits are set as a stepwise function of external credit ratings. The German Council of Economic Experts (2015) proposes that sovereigns rated between AAA and AA− be subject to a 100% limit (expressed as a percentage of Tier 1 capital), with sovereigns rated CCC+ or lower subject to a 25% limit. The limits for intermediate credit ratings are shown in Panel B of Table 2.

An important difference between price-based and quantity-based reforms to target credit risk is that the latter allow banks to hold a finite fraction of risky sovereign debt at a risk weight of zero. For example, banks can freely hold up to 25% of the value of their Tier 1 capital in securities rated CCC+ or lower, whereas such an exposure is subject to a risk weight of 7% under the price-based approach to credit risk, regardless of its size. As such, in our numerical simulations, banks divest entirely from these risky securities

[17] Moreover, with a 1% large exposure limit, most banks either need to reduce their aggregate portfolio value or increase Tier 1 capital, regardless of the reallocation rule that they adopt. We abstract from these additional margins of adjustment in order to focus attention on portfolio allocation.

under the price-based approach to credit risk, but maintain and even increase holdings under the quantity-based approach, depending on the reallocation rule that they adopt.

Consequently, the effects of quantity-based reform to target credit risk are ambiguous. In the imprudent case, credit risk exposures increase relative to mid-2017, as shown in Figure 9, Panel C. For example, the mean $ELRate$ increases from 5.5% as of mid-2017 to 8.4%, which is slightly higher than in the case of price-based reform to target concentration. The increase in risk exposure is more substantial for banks with already risky portfolios: at the 90th percentile, for example, the $ELRate$ increases from 9.6% as of mid-2017 to 16.9% in the imprudent case. Similar conclusions can be drawn from Figure 4, which plots the results for a continuum of possible risk-sensitive large exposure limits.

Overall, simulation results indicate that quantity-based reform to target credit risk is less effective in inducing banks to reduce their credit risk exposures than the corresponding price-based approach. A caveat to this conclusion is that price-based approaches are more sensitive to elasticities. If elasticities are low, price-based approaches could prove ineffective in inducing banks to adjust their sovereign exposures. This outcome is likelier during sovereign debt crises, when expected returns increase but risk weights remain constant.

The simulation results also reveal that quantity-based reform to target credit risk reduces concentrations in bank sovereign portfolios under all portfolio reallocation rules. Mean $HomeBias$ falls from 55% as of end-2017 to 37%; mean HHI falls from 57 to 39-41; and mean $KeyDeviation$ falls from 14 to 12-13. Quantitatively, these reductions in portfolio concentration are somewhat larger than those achieved under price-based reform to target concentration, although they are smaller than under the quantity-based counterpart. Ironically, then, quantity-based reform to target credit risk can be counterproductive in reducing credit risk exposures, but effective at inducing lower concentration, despite not explicitly targeting that outcome. The general insight here is that the intention of regulatory reform can be divorced from equilibrium outcomes when banks retain degrees of freedom in portfolio allocation.

6 Area-wide low-risk assets

On their own, none of the four regulatory reform scenarios considered in this paper lead to unambiguous reductions in both portfolio concentration and credit risk. In fact, some scenarios could lead to substantial increases in concentration or credit risk, potentially giving rise to new contagion risks. These conclusions reflect the constellation of available sovereign debt securities in the euro area. Some sovereign debt is low-risk, but a portfolio comprised only of such debt exhibits high concentration. At the same time, a low-concentration portfolio is not low-risk.

To illustrate this intuition, Figure 5, Panel A plots the characteristics of banks' sovereign portfolios when they are reallocated into a low-concentration portfolio weighted by the ECB capital key. By construction, $HomeBias$ and $KeyDeviation$ improve as banks reallocate into this portfolio, becoming negligible in the limiting case of full reinvestment. However, credit risk does not exhibit a similarly large decline, since a sovereign portfolio weighted by the ECB capital key entails moderate credit risk, with $ELRate = 4.4\%$. Whether bank exposure to sovereign credit risk increases or decreases depends on their initial condition as of mid-2017: for 45 banks, $ELRate$ increases, while it decreases for 50 banks. In this setting, the net effect on the doom loop is ambiguous. On one hand, banks are no longer profoundly home biased, thereby mitigating the national doom loop. On the other hand, banks are more exposed to the credit risk of foreign sovereigns, in some cases substantially. As in Bolton & Jeanne (2011) and Brunnermeier et al. (2017), this latter effect could give rise to new cross-border contagion effects and an international doom loop.

Given the current portfolio opportunity set, it is impossible to assemble a portfolio of euro area government debt securities with both low concentration and low credit risk. Resolving this tension requires an expansion in the portfolio opportunity set to include a security with both low concentration and low credit risk. We refer to such a security as an "area-wide low-risk asset". In the absence of fiscal co-insurance, such a security can be created contractually by pooling and tranching existing government debt securities. In the pool-then-tranche approach of Brunnermeier, Garicano, Lane, Pagano, Reis, Santos, Thesmar, Van Nieuwerburgh & Vayanos (2011), an entity issues securities with claims of different seniority on a portfolio of euro area government debt securities weighted according to the ECB capital key. The most senior claim represents an area-wide low-risk asset. Under certain regulatory conditions, issuance of such an asset is feasible (High-Level Task Force on Safe Assets, 2018). Therefore, we take the senior component of a pooled-then-tranched security as the exemplary area-wide low-risk asset, but our findings are generalizable to other designs that generate securities with similar properties.[18]

An area-wide low-risk asset has the following properties. First, in terms of concentration, it is similar to the low-concentration portfolio weighted by the ECB capital key envisaged previously, with $HomeBias \approx 0$ and $KeyDeviation \approx 0$.[19] Owing to the relative lumpiness of ECB capital key weights, $HHI \approx 16$. Second, in terms of credit risk, an area-wide low-risk asset differs substantially to a low-concentration portfolio without credit protection. Brunnermeier et al. (2017) calibrate a simulation model in which the senior component of a pooled-then-tranched security has $ELRate = 0.42\%$ and $VaR = 18.37\%$. By comparison, the lowest-risk government debt, issued by Germany, has $ELRate_{Germany} = 0.50\%$ and $VaR_{Germany} = 32\%$, while the highest-risk government debt, issued by Greece, has $ELRate_{Greece} = 35.19\%$ and $VaR_{Greece} = 95\%$ (see Table 4).

Figure 5, Panel B plots the characteristics of sovereign portfolios as a function of the extent to which banks reinvest their mid-2017 holdings into an area-wide low-risk asset. As the extent of reallocation increases, portfolios unambiguously become less concentrated and less risky. In the limit, with full reallocation, portfolios reflect the properties of the area-wide low-risk asset described previously. This stands in contrast with outcomes when banks reinvest into a low-concentration portfolio without credit protection, which has moderate credit risk, and contrasts with all four regulatory reform scenarios, which cannot achieve both low concentration and low credit risk.

Regulation may be required to incentivize banks to reinvest into an area-wide low-risk asset. In a next step, we repeat our simulation of the four regulatory reform scenarios

[18] Leandro & Zettelmeyer (2018) provide a detailed comparison of various options for designing an area-wide low-risk asset. In one approach, the ordering of pooling and tranching is reversed, so that national securities are tranched before the senior component is pooled (Monti, 2010). This approach is comparable to Von Weizsäcker & Delpla (2010), except that the latter also envisage fiscal co-insurance for the pooled senior bond.

[19] In practice, $KeyDeviation$ would be greater than zero insofar as the portfolio underling the pooled-then-tranched security has weights that deviate from the ECB capital key. To account for sovereigns with little outstanding debt, the High-Level Task Force on Safe Assets (2018) envisages indicative portfolio weights that generate $KeyDeviation = 0.43$. A supply of pooled-then-tranched securities greater than the €1.5tn suggested by the High-Level Task Force on Safe Assets (2018) could be achieved by deviating more substantially from the ECB capital key, for example with $KeyDeviation \approx 2$, as shown by Leandro & Zettelmeyer (2018).

with the innovation that an area-wide low-risk asset exists alongside national bonds in the investible universe. Results are reported in Online Appendix C. Intriguingly, most outcomes under the two price-based approaches are similar to those in the main simulations. Neither reform scenario embeds strong incentives for banks to reallocate their portfolios in favor of an area-wide low-risk asset, since other portfolio allocations can be equally effective at minimizing capital requirements. Consequently, banks reinvest into an area-wide low-risk asset only in the prudent case; in the other cases, banks generally prefer a different portfolio allocation. Under the two quantity-based approaches, banks reliably reallocate their portfolios in favor of an area-wide low-risk asset only when large exposure limits are very restrictive. An area-wide low-risk asset allows banks to maintain the aggregate value of their sovereign portfolio while respecting binding large exposure limits and avoiding the need for additional capital.

To induce all banks to reinvest into an area-wide low-risk asset with price-based regulatory reform, an additional ingredient is required. This is introduced in Online Appendix D, where the calibration of the two price-based reforms are modified to include a positive risk-weight floor for all single-name sovereign exposures. In this way, a sovereign portfolio comprised of an area-wide low-risk asset always represents the unique solution to banks' optimization problem, regardless of the reallocation rule that they adopt. The calibration of this positive risk-weight floor for all single-name sovereign exposures depends on the empirical elasticities of banks' sovereign portfolio allocation with respect to regulatory requirements.

There are two central insights arising from this section. First, the tension between concentration and credit risk in portfolio allocation can only be resolved by expanding the portfolio opportunity set to include an area-wide low-risk asset. Second, regulatory reform can complement the introduction of an area-wide low-risk asset by providing banks with correct incentives. Price-based reforms should include a positive risk weight floor for all single-name sovereign exposures, while quantity-based reforms need to be set sufficiently restrictively to induce adequate portfolio reallocation and to prevent reallocation from favoring riskier national bonds. Overall, these policy conclusions support the approach taken by Bénassy-Quéré, Brunnermeier, Enderlein, Farhi, Fratzscher, Fuest, Gourinchas, Martin, Pisani-Ferry, Rey, Schnabel, Véron, Weder di Mauro & Zettelmeyer (2018), who advocate regulatory reform alongside the introduction of an area-wide low-risk asset.

7 Conclusion

This paper provides a quantitative assessment of options for regulating the doom loop between sovereign risk and bank risk. Four scenarios for regulatory reform are compared, namely price- and quantity-based reforms that target concentration or credit risk. Simulations of portfolio reallocation reveal a tension between between reducing concentration and reducing credit risk. None of the reforms unambiguously achieve both, as Table 10 indicates. In fact, portfolio reallocation in response to regulatory reform could even strengthen the doom loop and lead to its international propagation, as in the models of Bolton & Jeanne (2011) and Brunnermeier et al. (2017).

The tension between concentration and credit risk is a general insight that reflects the portfolio opportunity set of sovereign bonds. Resolving this tension requires an expansion in the portfolio opportunity set to include a security that embeds both low concentration and low credit risk. Such an asset—defined as *area-wide* and *low-risk*—can be created by pooling and tranching cross-border portfolios of government debt securities, as explained by Leandro & Zettelmeyer (2018).

To regulate the doom loop, our simulation results provide support for two complementary policy actions advocated by Bénassy-Quéré et al. (2018). First, facilitate the creation of an area-wide low-risk asset. Currently, regulatory frictions impede its market-led development (High-Level Task Force on Safe Assets, 2018; European Commission, 2018). Second, change the regulatory treatment of banks' sovereign exposures to induce portfolio reallocation into the area-wide low-risk asset. Existing reform ideas—notably from the Basel Committee on Banking Supervision (2017) and German Council of Economic Experts (2015)—do not reliably meet this condition, and could even strengthen the doom loop. Instead, reform that includes either a positive risk weight floor on all single-name sovereign exposures or very restrictive large exposure limits would complement an area-wide low-risk asset by incentivizing banks to reinvest into it. Together, these two policies characterize the set of actions necessary to finally break the doom loop.

References

Acemoglu, D., Ozdaglar, A., & Tahbaz-Salehi, A. (2015). Systemic risk and stability in financial networks. *American Economic Review*, *105*(2), 564–608.

Acharya, V. V., Drechsler, I., & Schnabl, P. (2014). A pyrrhic victory? Bank bailouts and sovereign credit risk. *Journal of Finance*, *69*(6), 2689–2739.

Acharya, V. V., Eisert, T., Eufinger, C., & Hirsch, C. (2018). Real effects of the sovereign debt crisis in Europe: Evidence from syndicated loans. *Review of Financial Studies*, *31*(8), 2855–2896.

Acharya, V. V. & Steffen, S. (2015). The "greatest" carry trade ever? Understanding eurozone bank risks. *Journal of Financial Economics*, *115*(2), 215–236.

Adrian, T. & Shin, H. S. (2010). Liquidity and leverage. *Journal of Financial Intermediation*, *19*(3), 418–437.

Altavilla, C., Pagano, M., & Simonelli, S. (2017). Bank exposures and sovereign stress transmission. *Review of Finance*, *21*(6), 2103–2139.

Andritzky, J., Gadatsch, N., Körner, T., Schäfer, A., & Schnabel, I. (2016). Removing priviliges for banks' sovereign exposures—A proposal. *European Economy*, *2016.1*.

Basel Committee on Banking Supervision (2006). Basel II: International convergence of capital measurement and capital standards.

Basel Committee on Banking Supervision (2014). Assessment of Basel III regulations—European Union.

Basel Committee on Banking Supervision (2017). The regulatory treatment of sovereign exposures—Discussion paper.

Battistini, N., Pagano, M., & Simonelli, S. (2014). Systemic risk, sovereign yields and bank exposures in the euro crisis. *Economic Policy*, *29*(78), 203–251.

Becker, B. & Ivashina, V. (2015). Reaching for yield in the bond market. *Journal of Finance*, *70*(5), 1863–1902.

Becker, B. & Ivashina, V. (2018). Financial repression in the European sovereign debt crisis. *Review of Finance*, *22*(1), 83–115.

Beltratti, A. & Stulz, R. M. (2017). How important was contagion through banks during the European sovereign crisis? Working Paper 03-015, Fisher College of Business.

Bénassy-Quéré, A., Brunnermeier, M. K., Enderlein, H., Farhi, E., Fratzscher, M., Fuest, C., Gourinchas, P.-O., Martin, P., Pisani-Ferry, J., Rey, H., Schnabel, I., Véron, N., Weder di Mauro, B., & Zettelmeyer, J. (2018). Reconciling risk sharing with market discipline: A constructive approach to euro area reform. Policy Insight 91, CEPR.

Bocola, L. (2016). The pass-through of sovereign risk. *Journal of Political Economy*, *124*(4), 879–926.

Bolton, P. & Jeanne, O. (2011). Sovereign default risk and bank fragility in financially integrated economies. *IMF Economic Review*, *59*(2), 162–194.

Bonner, C. (2016). Preferential regulatory treatment and banks' demand for government bonds. *Journal of Money, Credit and Banking*, *48*(6), 1195–1221.

Breckenfelder, J. H. & Schwaab, B. (2018). Bank to sovereign risk spillovers across borders: Evidence from the ECB's comprehensive assessment. *Journal of Empirical Finance*, forthcoming.

Brinkhoff, J., Langfield, S., & Weeken, O. (2018). From the horse's mouth: Surveying responses to stress by banks and insurers. Occasional Paper 15, European Systemic Risk Board.

Broner, F., Erce, A., Martin, A., & Ventura, J. (2014). Sovereign debt markets in turbulent times: Creditor discrimination and crowding-out effects. *Journal of Monetary Economics*, *61*(C), 114–142.

Brunnermeier, M. K., Garicano, L., Lane, P., Pagano, M., Reis, R., Santos, T., Thesmar, D., Van Nieuwerburgh, S., & Vayanos, D. (2011). European Safe Bonds (ESBies). The Euronomics Group.

Brunnermeier, M. K., Garicano, L., Lane, P., Pagano, M., Reis, R., Santos, T., Thesmar, D., Van Nieuwerburgh, S., & Vayanos, D. (2016). The sovereign-bank diabolic loop and ESBies. *American Economic Review Papers and Proceedings*, *106*(5), 508–512.

Brunnermeier, M. K., Langfield, S., Pagano, M., Reis, R., van Nieuwerburgh, S., & Vayanos, D. (2017). ESBies: Safety in the tranches. *Economic Policy*, *32*(90), 175–219.

Brutti, F. & Sauré, P. (2016). Repatriation of debt in the euro crisis. *Journal of the European Economic Association*, *14*(1), 145–174.

Cooper, R. & Nikolov, K. (2018). Government debt and banking fragility: The spreading of strategic uncertainty. *International Economic Review*, forthcoming.

Crosignani, M. (2017). Why are banks not recapitalized during crises? Working Paper 57, European Systemic Risk Board.

Deutsche Bundesbank (2014). Annual Report.

Diamond, D. & Rajan, R. (2000). A theory of bank capital. *Journal of Finance*, *55*(6), 2431–2465.

Efing, M. (2018). Arbitraging the Basel securitization framework: Evidence from German ABS investment. Mimeo.

Elliott, M., Golub, B., & Jackson, M. O. (2014). Financial networks and contagion. *American Economic Review*, *104*(10), 3115–53.

Enria, A., Farkas, A., & Overby, L. J. (2016). Sovereign risk: Black swans and white elephants. *European Economy*, *2016.1*.

European Commission (2018). Proposal for a regulation on sovereign bond-backed securities.

European Systemic Risk Board (2015). Report on the regulatory treatment of sovereign exposures.

Farhi, E. & Tirole, J. (2018). Deadly embrace: Sovereign and financial balance sheets doom loops. *Review of Economic Studies*, *85*(3), 1781–1823.

Ferrando, A., Popov, A. A., & Udell, G. F. (2017). Sovereign stress and SMEs' access to finance: Evidence from the ECB's SAFE survey. *Journal of Banking & Finance*, *81*(C), 65–80.

Ferrara, G., Langfield, S., Liu, Z., & Ota, T. (2018). Systemic illiquidity in the interbank network. *Quantitative Finance*, forthcoming.

Gennaioli, N., Martin, A., & Rossi, S. (2014). Sovereign default, domestic banks, and financial institutions. *Journal of Finance*, *69*(2), 819–866.

German Council of Economic Experts (2015). Annual Report.

High-Level Task Force on Safe Assets (2018). Sovereign bond-backed securities: A feasibility study. European Systemic Risk Board.

Ibragimov, R., Jaffee, D., & Walden, J. (2011). Diversification disasters. *Journal of Financial Economics*, *99*(2), 333–348.

Kallestrup, R., Lando, D., & Murgoci, A. (2016). Financial sector linkages and the dynamics of bank and sovereign credit spreads. *Journal of Empirical Finance*, *38*(A), 374–393.

Kirschenmann, K., Korte, J., & Steffen, S. (2018). The zero risk fallacy—Banks' sovereign exposure and sovereign risk spillovers. Mimeo.

Leandro, A. & Zettelmeyer, J. (2018). The search for a euro area safe asset. Working Paper 18-3, Peterson Institute for International Economics.

Monti, M. (2010). A new strategy for the single market. Report to the President of the European Commission.

Nouy, D. (2012). Is sovereign risk properly addressed by financial regulation? *Financial Stability Review*, Banque de France.

Ongena, S., Popov, A. A., & van Horen, N. (2018). The invisible hand of the government: "Moral suasion" during the European sovereign debt crisis. *American Economic Journal: Macroeconomics*, forthcoming.

Popov, A. A. & Van Horen, N. (2015). Exporting sovereign stress: Evidence from syndicated bank lending during the euro area sovereign debt crisis. *Review of Finance*, *19*(5), 1825–1866.

Schneider, Y. M. & Steffen, S. (2017). Feasibility check: Transition to a new regime for bank sovereign exposure? Study provided at the request of the Economic and Monetary Affairs Committee, European Parliament.

Véron, N. (2017). Sovereign concentration charges: A new regime for banks' sovereign exposures. Study provided at the request of the Economic and Monetary Affairs Committee, European Parliament.

Visco, I. (2016). Banks' sovereign exposures and the feedback loop between banks and their sovereigns. Speech, Banca d'Italia.

Von Weizsäcker, J. & Delpla, J. (2010). The Blue Bond proposal. Policy Brief 3, Bruegel.

Wagner, W. (2010). Diversification at financial institutions and systemic crises. *Journal of Financial Intermediation*, *19*(3), 373–386.

Table 1: Classification of reform ideas for the regulatory treatment of sovereign exposures

Target of reform:	Nature of reform: Price-based	Nature of reform: Quantity-based
Concentration	*Marginal risk weight add-ons:* Risk weights increase with a bank's concentration in a single sovereign. E.g.: a bank's sovereign exposures are subject to a zero risk weight up to X% of Tier 1 capital, with exposures >X% subject to positive risk weights.	*Large exposure limits:* A bank is prevented from holding large exposures. E.g.: a bank cannot hold more than X% of Tier 1 capital in a single sovereign; when a bank hits the limit, it can only increase exposure by raising capital.
Credit risk	*Standardized risk weights:* Risk weights are a function of the measured credit risk of a given sovereign. E.g.: exposures to risky sovereigns are subject to positive risk weights, while exposures to safe sovereigns have no risk weight.	*Risky exposure limits:* A bank is prevented from holding risky exposures beyond a certain level. E.g.: a bank cannot hold more than X% of Tier 1 capital in exposure to a risky sovereign, while exposures to safe sovereigns are unlimited.

Note: This table classifies ideas for reform of the regulatory treatment of banks' sovereign exposures along two dimensions: first, whether they are price-based or quantity-based; and second, whether they target concentration or credit risk.

Table 2: Scenarios for reforming the regulatory treatment of sovereign exposures

Panel A: Price-based reform to target concentration

Exposure as % of Tier 1 capital	<100%	100-150%	150-200%	200-250%	250-300%	>300%
Marginal risk weight add-on	0%	5%	6%	9%	15%	30%

Panel B: Price-based reform to target credit risk

External credit rating	AAA to A−	BBB+ to BBB−	BBB− to D
Domestic-currency exposures	0%	4%	7%

Panel C: Quantity-based reform to target concentration

Sovereign credit rating	AAA to D
Exposure limit as % of Tier 1 capital	25%

Panel D: Quantity-based reform to target credit risk

Sovereign credit rating	AAA to AA−	A+ to A−	BBB+ to BBB−	BB+ to B−	CCC+ to D
Exposure limit as % of Tier 1 capital	100%	90%	75%	50%	25%

Note: This table provides illustrative calibrations for four scenarios for the regulatory treatment of sovereign exposures. Panel A reports a possible calibration of risk weights for sovereign exposures as a function of a bank's concentration in a single name, as outlined by the Basel Committee on Banking Supervision (2017). Panel B reports a possible calibration of standardized risk weights for sovereign exposures as a function of the external credit rating of those sovereign exposures, again outlined by the Basel Committee on Banking Supervision (2017). Panel C reports the uniform application of a large exposure limit, set as 25% of Tier 1 capital, which corresponds with the current limit for non-sovereign single-name exposures. Panel D reports a possible calibration of large exposure limits as a function of the sovereign credit ratings, as proposed by the German Council of Economic Experts (2015) and elaborated by Andritzky et al. (2016).

Table 3: Illustrative portfolio reallocation under four regulatory reform scenarios

		Price-based for concentration			Price-based for credit risk			Quantity-based for concentration			Quantity-based for credit risk		
	Status quo	Prudent	Base	Imprudent	Prudent	Base	Imprudent	Prudent	Base	Imprudent	Prudent	Base	Imprudent
Germany	20	30	30	20	95	80	20	7.5	7.5	7.5	30	30	20
Netherlands		30						7.5			30		
Luxembourg		5						7.5			12.5		
Austria								7.5	2.5				
Finland								7.5	7.5				
France	5	5	30	5	5	20	5	7.5	7.5	5	5	30	5
Belgium								7.5	7.5				
Estonia								7.5	7.5	5			
Slovakia			10					7.5	7.5	7.5		17.5	
Ireland								7.5	7.5	7.5			
Lithuania								7.5	7.5	7.5			
Spain								7.5	7.5	7.5			
Latvia								2.5	7.5	7.5			
Italy	75	30	30	30				7.5	7.5	7.5	22.5	22.5	22.5
Malta									7.5	7.5			
Slovenia							75		7.5	7.5			
Portugal										7.5			22.5
Cyprus				15						7.5			15
Greece				30						7.5			15
Exp/T1	333	333	333	333	333	333	333	333	333	333	333	333	333
HomeBias	70	15	15	15	0	0	0	0	0	0	6	6	6
HHI	61	28	28	25	91	68	61	7	7	7	25	26	19
KeyDeviation	14	8	6	9	17	14	18	7	7	8	8	6	8
ELRate	5.6	2.7	3.5	15.3	0.6	0.8	6.3	3.5	4.8	9.1	2.2	3.3	12.2
VaR	69	48	59	75	33	38	69	59	67	75	44	58	74
ExpectedLoss	18.7	8.8	11.5	51.1	1.9	2.6	21.1	11.6	16.1	30.4	7.2	11.1	40.6
UnexpectedLoss	231	159	195	250	111	125	231	195	224	249	147	193	246

Note: This table illustrates portfolio reallocation for a stylized Italian bank funded by 30 units of Tier 1 capital and with initial ("status quo") holdings of 75 units of Italian, 20 units of German, and 5 units of French sovereign bonds. The table reports 12 sovereign portfolio reallocations, namely four regulatory reform scenarios crossed with three cases—"prudent", "base" and "imprudent"—that determine the portfolio allocation rule that banks adopt. $Exp/T1$ refers to a bank's holdings of debt securities issued by euro area Member States as a percentage of its Tier 1 capital. $HomeBias$ is defined as $Max[0, 100 \times \frac{(h_{i=d}/\sum_{i=1}^{19} h_i)-CK_{i=d}}{1-CK_{i=d}}]$, where $h_{i=d}$ is the bank's holdings of debt issued by its domestic sovereign d, $\sum_{i=1}^{19} h_i$ is the bank's sovereign exposures summed across all 19 euro area countries, and $CK_{i=d}$ is the ECB capital key share of domestic country d (as reported in Table 4). HHI refers to the Herfindahl Hirschman index of concentration, defined as $\frac{\sum_{i=1}^{19}(h_i/\sum_{i=1}^{19} h_i)^2}{100}$. $KeyDeviation$ measures the extent to which a bank's portfolio deviates from ECB capital key weights, and is calculated as $\sqrt{\frac{\sum_{i=1}^{19}((h_i/\sum_{i=1}^{19} h_i)-CK_i)^2}{19}}$. $ELRate$ refers to a bank's five-year expected loss rate (expressed as a percentage) on its sovereign portfolio (based on the adverse model calibration in Brunnermeier et al. (2017)), and VaR refers to the minimum percentage reduction in portfolio value that occurs over five years with 1% probability, as calculated by the High-Level Task Force on Safe Assets (2018). $ExpectedLoss$ and $UnexpectedLoss$ are calculated by multiplying $Exp/T1$ by $ELRate$ and VaR respectively. In the table, countries are ordered in ascending order of their expected loss rate (as reported in Table 4).

Table 4: Sovereign credit risk in euro area Member States

	ECB capital key (%)	C.Bonds (% of GDP)	G.Debt (% of GDP)	S&P	Moody's	Fitch	*ELRate* (%)	*VaR* (%)
Germany	25.57	36.1	64.8	AAA	Aaa	AAA	0.50	32
Netherlands	5.69	45.7	57.6	AAA	Aaa	AAA	0.69	32
Luxembourg	0.29	15.0	23.0	AAA	Aaa	AAA	0.69	32
Austria	2.79	63.6	79.8	AA+	Aa1	AA+	0.96	45
Finland	1.78	45.5	60.8	AA+	Aa1	AA+	0.96	45
France	20.14	74.8	97.9	AA	Aa2	AA	1.94	60
Belgium	3.52	83.7	104.5	AA	Aa3	AA−	2.64	62.5
Estonia	0.27	0.3	8.6	AA−	A1	A+	3.10	67.5
Slovakia	1.10	44.6	52.3	A+	A2	A+	5.58	70
Ireland	1.65	46.3	71.8	A+	A3	A	6.05	75
Lithuania	0.59	33.1	40.6	A−	A3	A−	6.80	75
Spain	12.56	79.1	98.2	BBB+	Baa2	BBB+	6.80	80
Latvia	0.40	28.7	38.7	A−	A3	A−	6.81	75
Italy	17.49	112.4	133.5	BBB−	Baa2	BBB	7.22	80
Malta	0.09	49.4	53.0	A−	A3	A	7.32	78
Slovenia	0.49	67.7	77.4	A+	Baa3	A−	8.17	80
Portugal	2.48	78.3	129.5	BB+	Ba1	BB+	11.80	85
Cyprus	0.21	35.8	103.0	BB+	B1	BB−	16.07	87.5
Greece	2.89	36.6	175.0	B−	Caa2	CCC	35.19	95

Note: This table reports indicators of sovereign credit risk for euro area Member States as of mid-2017. "ECB capital key" refers to the relative contributions of euro area national central banks to the ECB's capital (valid from July 2013 to December 2018). "C.Bonds" refers to central government debt securities ("bonds") as a percentage of national GDP as of mid-2017; "G.Debt" refers to general government debt as a percentage of national GDP as of mid-2017 (both sourced from Eurostat). The columns labeled "S&P", "Moody's" and "Fitch" report the credit ratings issued by those agencies as of mid-2017. *ELRate* refers to five-year expected loss rates (in percentages) in the adverse calibration of a simulation model estimated by Brunnermeier et al. (2017). *VaR* refers to the minimum percentage reduction in portfolio value that occurs over five years with 1% probability, as calculated by the High-Level Task Force on Safe Assets (2018).

Table 5: Summary statistics on bank sovereign exposures

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	55	35	0	22	64	85	100
HHI	57	27	20	36	55	77	100
$KeyDeviation$	14	6	7	10	15	19	21
$ELRate$	5.5	5.5	1.1	2.0	5.2	6.9	9.6
VaR	63	17	38	49	65	80	81
$ExpectedLoss$	9.8	16.8	1.1	1.6	5.5	12.7	22.5
$UnexpectedLoss$	117	181	22	42	72	130	244

Note: This table reports summary statistics on banks' exposures to government debt securities as of mid-2017 according to the EBA transparency exercise (2017). $Exp/T1$ refers to a bank's sovereign exposure as a percentage of its Tier 1 capital. $HomeBias$ is defined as $Max[0, 100 \times \frac{(h_{i=d}/\sum_{i=1}^{19} h_i) - CK_{i=d}}{1 - CK_{i=d}}]$, where $h_{i=d}$ is the bank's holdings of debt issued by its domestic sovereign d, $\sum_{i=1}^{19} h_i$ is the bank's sovereign exposures summed across all 19 euro area countries, and $CK_{i=d}$ is the ECB capital key share of domestic country d (as reported in Table 4). HHI refers to the Herfindahl Hirschman index of concentration, defined as $\frac{\sum_{i=1}^{19}(h_i/\sum_{i=1}^{19} h_i)^2}{100}$. $KeyDeviation$ measures the extent to which a bank's portfolio deviates from ECB capital key weights, and is calculated as $\sqrt{\frac{\sum_{i=1}^{19}((h_i/\sum_{i=1}^{19} h_i) - CK_i)^2}{19}}$. $ELRate$ refers to a bank's five-year expected loss rate (expressed as a percentage) on its sovereign portfolio (based on the adverse model calibration in Brunnermeier et al. (2017)), and VaR refers to the minimum percentage reduction in portfolio value that occurs over five years with 1% probability, as calculated by the High-Level Task Force on Safe Assets (2018). $ExpectedLoss$ and $UnexpectedLoss$ are calculated by multiplying $Exp/T1$ by $ELRate$ and VaR respectively.

Table 6: Price-based reform to target concentration

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	42	31	0	15	44	67	82
HHI	44	24	18	24	40	58	76
$KeyDeviation$	13	5	7	9	12	16	20
$ELRate$	4.8	5.4	1.2	1.9	3.3	5.7	7.7
VaR	58	15	38	45	58	69	80
$ExpectedLoss$	7.5	14.5	1.1	1.6	5.4	9.3	13.6
$UnexpectedLoss$	98	142	22	42	72	115	155

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	42	31	0	15	44	67	82
HHI	45	24	18	26	40	58	76
$KeyDeviation$	13	5	7	10	13	16	20
$ELRate$	5.5	5.4	1.4	2.2	4.3	7.2	9.1
VaR	63	16	41	50	64	79	82
$ExpectedLoss$	9.7	15.9	1.1	2.0	5.6	12.0	19.8
$UnexpectedLoss$	112	154	22	42	75	133	206

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	42	31	0	15	44	67	82
HHI	44	24	18	24	39	58	76
$KeyDeviation$	13	5	7	10	13	16	20
$ELRate$	8.2	7.0	1.5	2.4	6.0	13.8	16.8
VaR	66	17	41	51	66	81	87
$ExpectedLoss$	17.0	23.8	1.1	2.0	6.4	19.4	54.5
$UnexpectedLoss$	120	160	22	42	75	145	265

Note: This table shows the simulation results for price-based reform to target concentration in the limiting case of full reallocation. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond. The summary statistics correspond to the case of 100% reallocation shown in Figure 1. Variables are defined in the note to Table 5.

Table 7: Price-based reform to target credit risk

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	29	35	0	0	9	64	87
HHI	68	29	23	40	71	99	100
$KeyDeviation$	15	4	9	12	16	18	18
$ELRate$	1.4	1.6	0.5	0.5	0.7	1.5	4.1
VaR	42	12	32	32	35	49	60
$ExpectedLoss$	2.0	2.5	0.4	0.7	1.2	2.0	4.7
$UnexpectedLoss$	67	74	17	29	47	86	123

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	33	38	0	0	9	74	87
HHI	73	27	33	50	81	100	100
$KeyDeviation$	18	5	11	15	18	22	25
$ELRate$	2.7	2.5	0.6	0.7	1.8	5.5	7.3
VaR	53	16	32	35	52	69	77
$ExpectedLoss$	4.6	6.9	0.5	0.9	1.6	5.6	12.1
$UnexpectedLoss$	89	98	22	39	57	105	181

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	26	32	0	0	5	63	78
HHI	64	29	21	41	64	97	100
$KeyDeviation$	18	6	9	13	17	24	25
$ELRate$	4.8	2.8	1.2	2.0	4.5	8.0	8.2
VaR	63	16	38	48	65	79	80
$ExpectedLoss$	9.9	18.7	1.1	1.6	4.9	11.9	24.7
$UnexpectedLoss$	116	181	22	42	70	130	243

Note: This table shows the simulation results for price-based reform to target credit risk in the limiting case of full reallocation. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond. The summary statistics correspond to the case of 100% reallocation shown in Figure 2. Variables are defined in the note to Table 5.

Table 8: Quantity-based reform to target concentration

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	171	224	41	80	123	194	324
HomeBias	13	17	0	0	8	18	29
HHI	21	16	8	11	17	23	35
KeyDeviation	9	3	6	7	8	10	11
ELRate	3.4	3.1	1.3	2.0	2.7	3.5	6.8
VaR	52	9	40	46	51	55	61
ExpectedLoss	6.6	15.2	1.0	1.5	3.3	5.8	11.1
UnexpectedLoss	94	148	22	37	56	100	189

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	171	224	41	80	123	194	324
HomeBias	13	17	0	0	8	20	31
HHI	22	16	8	12	18	25	39
KeyDeviation	9	4	5	7	9	11	14
ELRate	5.2	4.2	1.7	2.7	4.4	6.8	8.0
VaR	63	12	48	55	63	72	78
ExpectedLoss	9.3	15.5	1.2	2.7	5.7	11.4	18.5
UnexpectedLoss	110	149	25	48	71	130	224

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	171	224	41	80	123	194	324
HomeBias	13	17	0	0	8	18	29
HHI	20	16	8	11	17	23	35
KeyDeviation	10	3	7	8	10	11	14
ELRate	11.1	4.9	4.0	8.0	11.4	14.3	16.1
VaR	71	12	52	66	74	80	85
ExpectedLoss	17.3	15.8	2.0	8.4	16.9	22.5	30.3
UnexpectedLoss	123	151	27	54	90	151	240

Note: This table shows the simulation results for quantity-based reform to target concentration in the limiting case of full reallocation. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond. The summary statistics correspond to the case of a 25% large exposure limit shown in Figure 3. Variables are defined in the note to Table 5.

Table 9: Quantity-based reform to target credit risk

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	37	29	0	9	32	63	76
HHI	41	22	17	24	36	54	70
$KeyDeviation$	12	5	7	8	11	15	18
$ELRate$	4.3	5.0	1.2	1.9	3.3	5.2	6.8
VaR	56	13	38	45	56	64	72
$ExpectedLoss$	6.5	11.7	1.1	1.6	5.4	7.8	11.2
$UnexpectedLoss$	93	135	22	42	68	111	145

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	37	29	0	9	32	63	76
HHI	41	22	17	24	37	54	70
$KeyDeviation$	13	4	7	9	12	15	19
$ELRate$	5.2	5.2	1.4	2.2	4.0	7.0	8.0
VaR	62	15	41	50	62	77	80
$ExpectedLoss$	8.9	13.5	1.1	2.0	5.6	11.7	18.1
$UnexpectedLoss$	110	148	22	42	75	133	206

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	37	29	0	9	32	63	76
HHI	39	23	17	20	34	54	70
$KeyDeviation$	13	4	7	10	12	15	19
$ELRate$	8.4	7.1	1.5	2.4	6.1	13.2	16.9
VaR	66	17	41	51	65	82	86
$ExpectedLoss$	15.6	18.6	1.1	2.0	6.4	24.7	42.9
$UnexpectedLoss$	118	153	22	42	75	143	257

Note: This table shows the simulation results for quantity-based reform to target credit risk in the limiting case of full reallocation. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond. The summary statistics correspond to the case of 100% reallocation shown in Figure 4. Variables are defined in the note to Table 5.

Table 10: Summary of simulation results

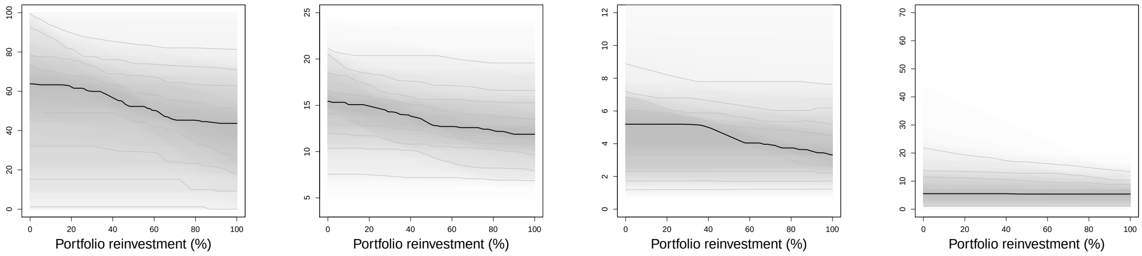
	Change in concentration	Change in credit risk
Price-based reform to target concentration (Figure 1)	↓	?
Price-based reform to target credit risk (Figure 2)	?	?
Quantity-based reform to target concentration (Figure 3)	↓	?
Quantity-based reform to target credit risk (Figure 4)	↓	?
Area-wide low-risk asset (Figure 5, Panel B)	↓↓	↓↓

Note: This table summarizes simulation results for the change in concentration and credit risk in banks' holdings of government debt securities induced by regulatory reform. Downward-facing arrows indicate a decrease in concentration or credit risk exposure for all bank portfolios relative to their initial conditions. Double arrows indicate a quantitatively large change. Question marks denote an ambiguous directional effect that depends on the portfolio reallocation rule that banks adopt and/or the measurement of concentration or credit risk.

Figure 1: Price-based reform to target concentration

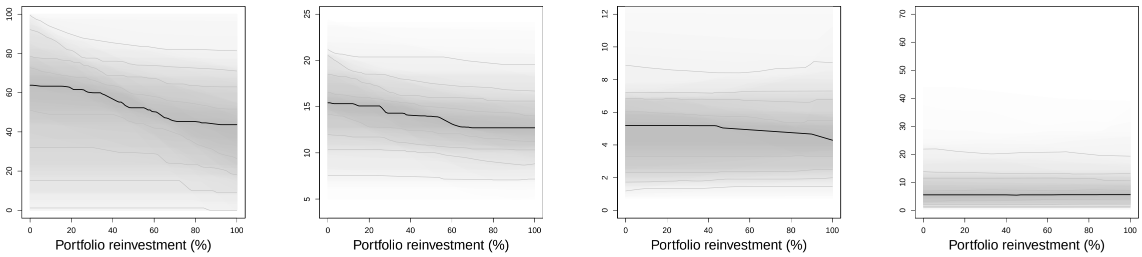
Panel A: Prudent case

(a) *HomeBias* **(b)** *KeyDeviation* **(c)** *ELRate* **(d)** *ExpectedLoss*



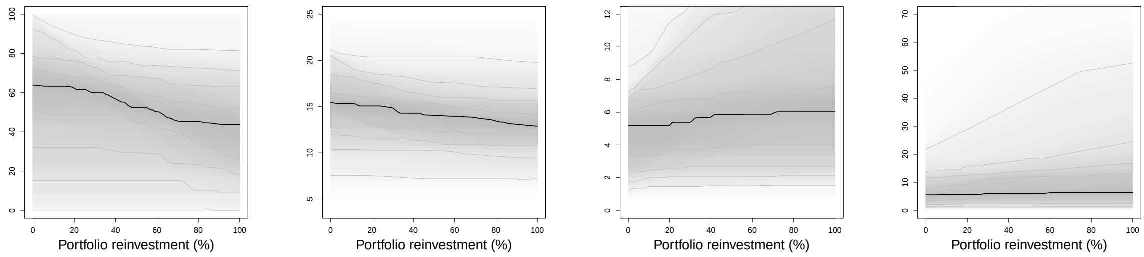
Panel B: Base case

(e) *HomeBias* **(f)** *KeyDeviation* **(g)** *ELRate* **(h)** *ExpectedLoss*



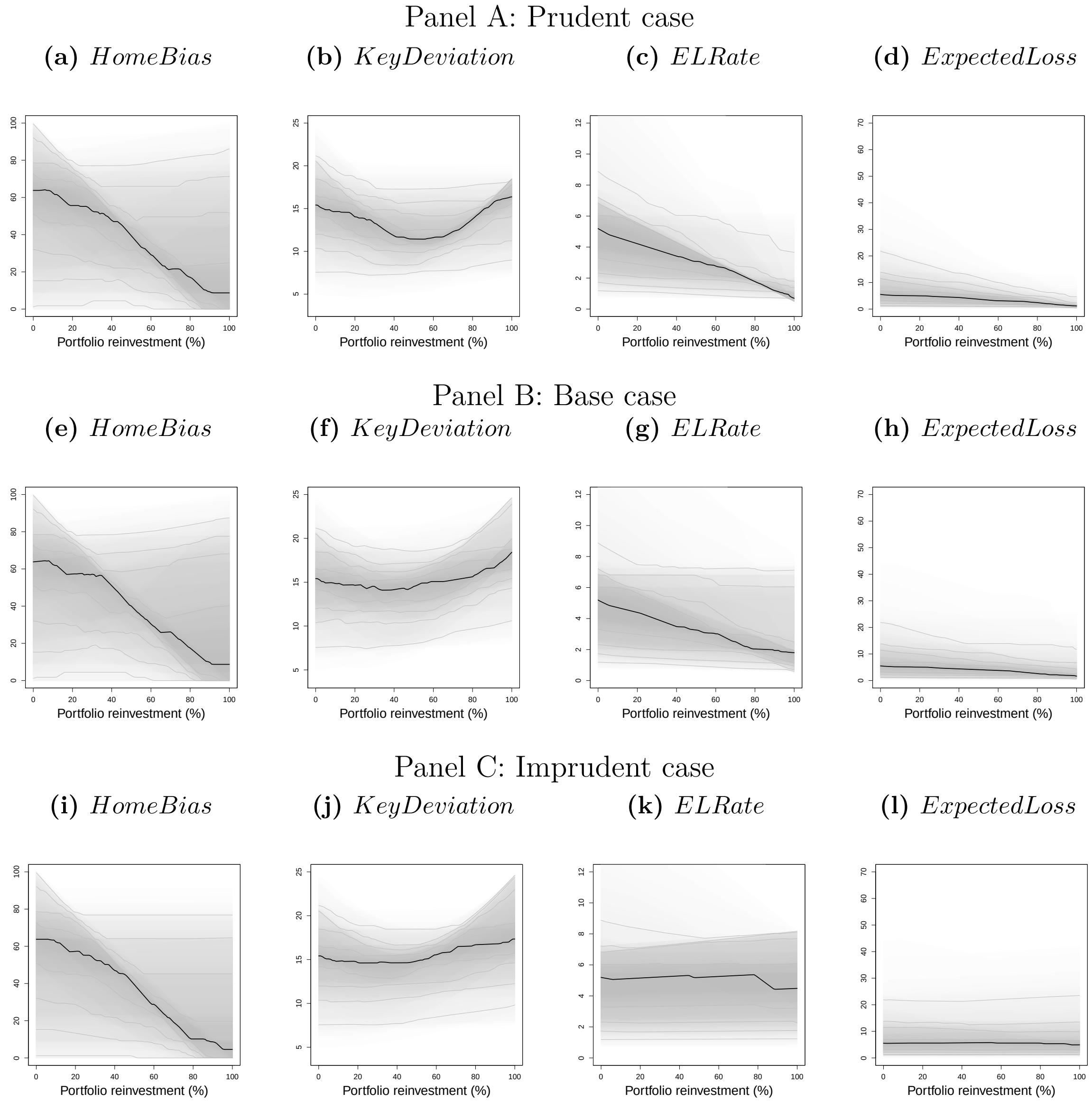
Panel C: Imprudent case

(i) *HomeBias* **(j)** *KeyDeviation* **(k)** *ELRate* **(l)** *ExpectedLoss*



Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table 5, as a function of the percentage of banks' sovereign portfolios that is reallocated. 0% reinvestment corresponds to Table 5 and 100% reallocation corresponds to Table 6. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond.

Figure 2: Price-based reform to target credit risk

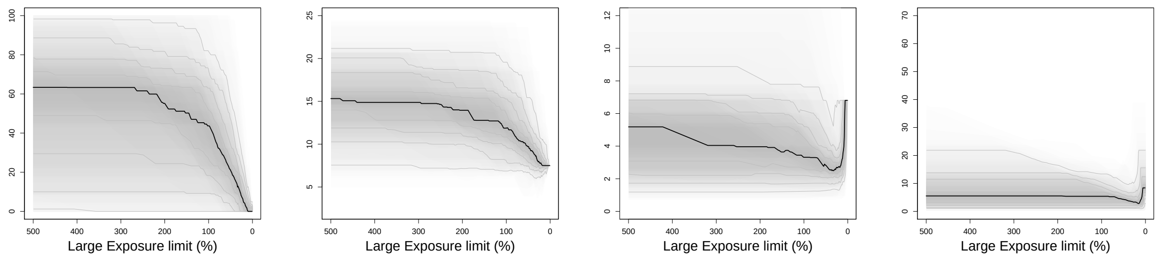


Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table 5, as a function of the percentage of banks' sovereign portfolios that is reallocated. 0% reallocation corresponds to Table 5 and 100% reallocation corresponds to Table 7. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond.

Figure 3: Quantity-based reform to target concentration

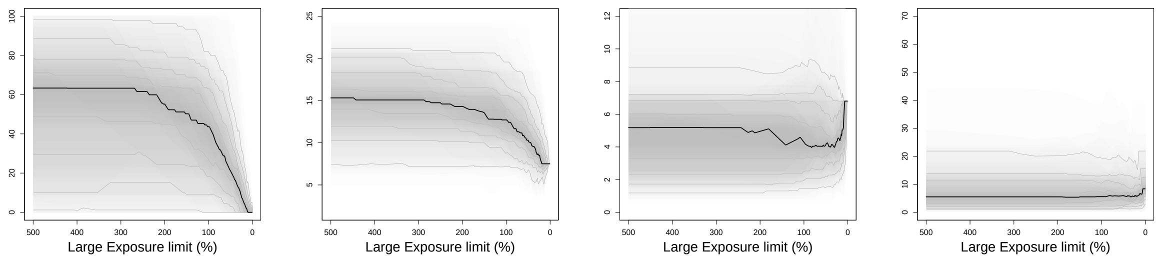
Panel A: Prudent case

(a) *HomeBias* (b) *KeyDeviation* (c) *ELRate* (d) *ExpectedLoss*



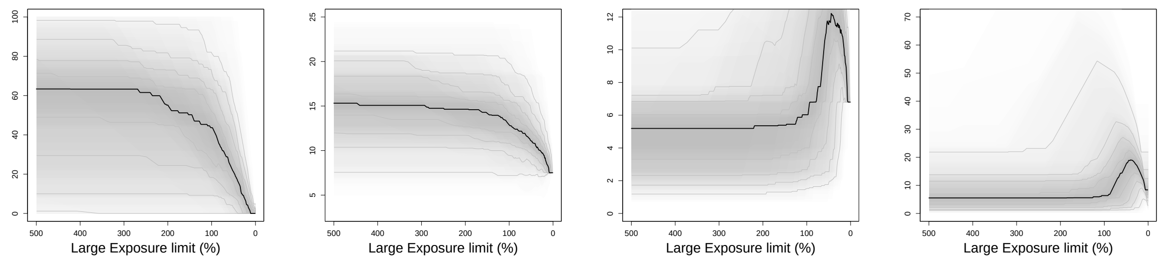
Panel B: Base case

(e) *HomeBias* (f) *KeyDeviation* (g) *ELRate* (h) *ExpectedLoss*



Panel C: Imprudent case

(i) *HomeBias* (j) *KeyDeviation* (k) *ELRate* (l) *ExpectedLoss*

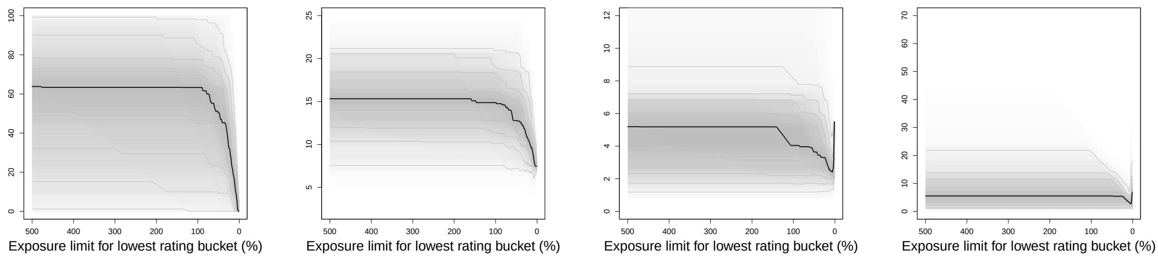


Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table 5, as a function of the large exposure limit (expressed as a percentage of Tier 1 capital), where a 25% limit corresponds to Table 2, Panel C. Results for the 25% limit reflect the summary statistics reported in Table 8. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond.

Figure 4: Quantity-based reform to target credit risk

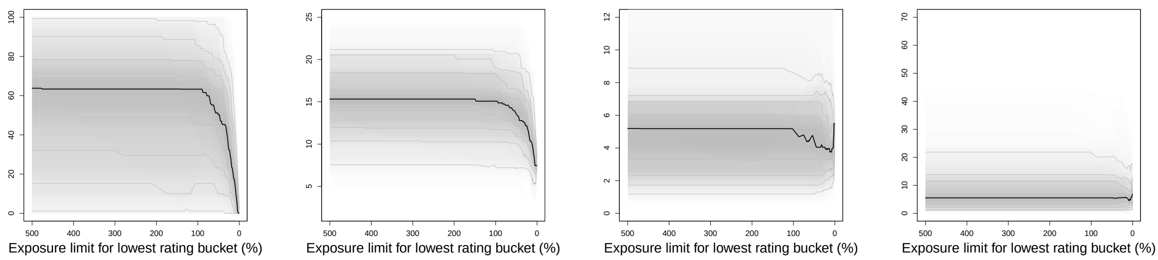
Panel A: Prudent case

(a) *HomeBias* **(b)** *KeyDeviation* **(c)** *ELRate* **(d)** *ExpectedLoss*



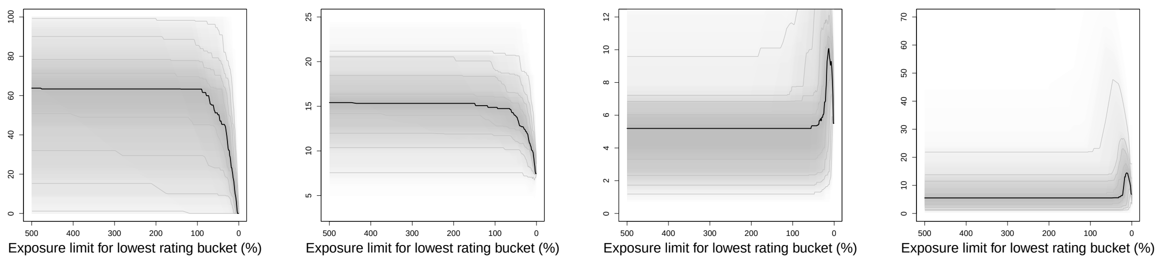
Panel B: Base case

(e) *HomeBias* **(f)** *KeyDeviation* **(g)** *ELRate* **(h)** *ExpectedLoss*



Panel C: Imprudent case

(i) *HomeBias* **(j)** *KeyDeviation* **(k)** *ELRate* **(l)** *ExpectedLoss*

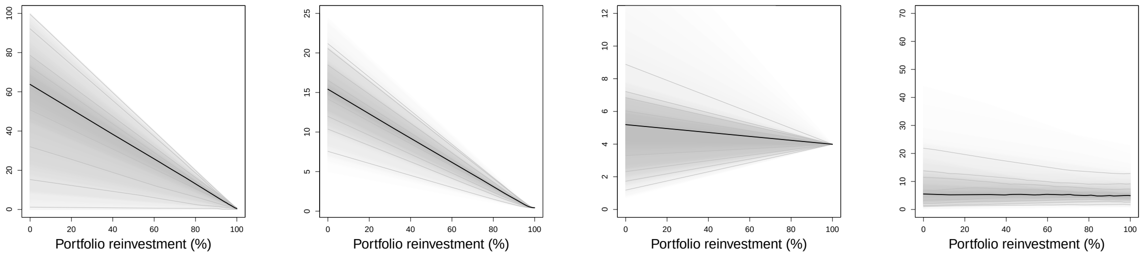


Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table 5, as a function of the large exposure limit (expressed as a percentage of Tier 1 capital) for the lowest sovereign credit rating bucket (CCC+ to D), where a 25% limit corresponds to the vector of limits shown in Table 2, Panel D. Results for the 25% limit reflect the summary statistics reported in Table 8. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond.

Figure 5: Reinvestment into an area-wide asset

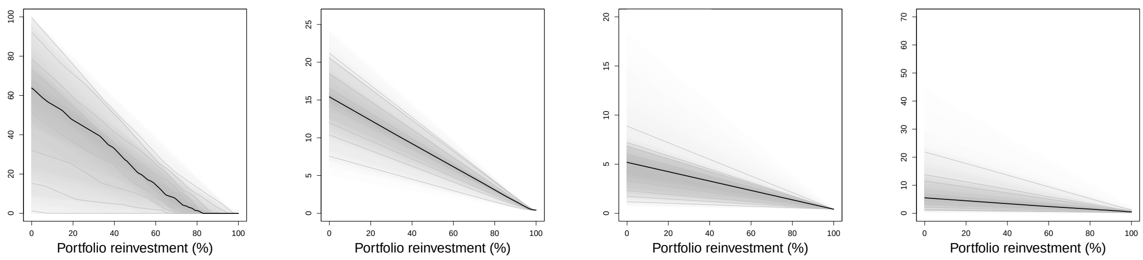
Panel A: Portfolio weighted by the ECB capital key (no credit protection)

(a) *HomeBias* (b) *KeyDeviation* (c) *ELRate* (d) *ExpectedLoss*



Panel B: Area-wide low-risk asset (with credit protection)

(e) *HomeBias* (f) *KeyDeviation* (g) *ELRate* (h) *ExpectedLoss*



Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table 5, as a function of the percentage of banks' mid-2017 sovereign portfolios that is reallocated into a sovereign portfolio with weights given by the ECB capital key. Panel A reports results for a portfolio with no credit protection; Panel B shows results for a portfolio with credit protection (e.g. from tranching). In both panels, 0% reallocation corresponds to Table 5. 100% reallocation corresponds to negligible *HomeBias* and *KeyDeviation* for all banks. By contrast, the simulation results for *ELRate* and *ExpectedLoss* vary across the two panels. For example, $ELRate = 4.4\%$ for all banks after 100% of portfolio reallocation in Panel A (with no credit protection), compared with $ELRate = 0.42\%$ in Panel B (with credit protection, e.g. from tranching).