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Regulating the doom loop

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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 by euro area banks under scenarios for regulatory reform. Simulations highlight a tension in regulatory design between concentration and credit risk. An area-wide low-risk asset—created by pooling and tranching cross-border portfolios of government debt securities—would resolve this tension by expanding the portfolio opportunity set. Banks could therefore reinvest into an asset that has both low concentration and low credit risk.

Keywords: Bank regulation, sovereign risk, systemic risk

JEL codes: G01, G11, G21, G28

"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 exposures of banks to sovereign risk. At present, euro area banks have no regulatory incentive to manage their sovereign 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 the regulatory treatment of banks' sovereign exposures. 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 how banks and sovereign debt markets would respond (Visco, 2016).

This paper does not take a stance on the broader desirability of reforming the regulatory treatment of sovereign exposures. Nor does it assess all of the trade-offs associated with regulatory reform—thorough overviews are already provided by Lenarčič, Mevis & Siklós (2016), Schneider & Steffen (2017) and van Riet (2018). Instead, this paper provides a complementary input to policy discussions by simulating reallocations of euro area banks' sovereign bond holdings under new regulatory regimes. In response to regulatory reform, banks retain their aggregate sovereign bond holdings but adjust portfolio composition to minimize capital requirements. The extent of adjustment depends on elasticities. Subject to this minimization objective, banks have degrees of freedom in portfolio selection. To quantify the range of possible portfolios, 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 a "base case" in which banks replicate the properties of their initial portfolio subject to their minimization objective.

The 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 in regulatory design between lowering concentration and lowering credit risk. Reforms focused on concentration, such as large exposure limits or concentration based capital charges, would 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. But high concentration in ostensibly low-risk sovereigns is undesirable as sovereign credit risk is imperfectly measured.

The tension between lowering concentration and lowering credit risk is a general insight that reflects the portfolio opportunity set of euro-denominated sovereign debt. At present, it is impossible to assemble a portfolio of euro area government debt securities 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 asset could be created by tranching portfolios of sovereign bonds (High-Level Task Force on Safe Assets, 2018; Leandro & Zettelmeyer, 2018). If banks were induced to hold such an asset, the endogenous risk arising from the doom loop could be eliminated and cross-border contagion risks avoided.

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. This doom loop was primarily domestic in the euro area sovereign debt crisis. Banks were home biased on the asset side of their balance sheets, rendering them vulnerable to domestic sovereign risk (Brunnermeier, Langfield, Pagano, Reis, van Nieuwerburgh & Vayanos, 2017) and related country risks (Bocola, 2016). Home bias in sovereign exposures 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 drivers of banks' sovereign debt exposures.

Much of the literature focuses on banks' risk-shifting incentives in their portfolio allocation decisions. Banks have incentives to load up on domestic sovereign debt holdings 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, banks shift the downside risk of their elevated sovereign risk exposure to others (Abad, 2018). When banks expect to be bailed out by governments, downside risk is shifted to taxpayers (Farhi & Tirole, 2018). Alternatively, if governments can credibly commit not to bail out banks, equity holders can shift downside risk to bank 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 is socially undesirable as it 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

[1] According to this view, risk-shifting is privately optimal for banks since their net worth would anyway become 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.

banks to finance government borrowing when external demand is weak (Ongena, Popov & van Horen, 2016). Together, banks' risk-shifting behavior and time-inconsistent national supervision have negative real effects even when sovereign default does not occur. By increasing sovereign bond holdings, banks have fewer resources available to fund their lending to the real economy (Broner, Erce, Martin & Ventura, 2014). Acharya, Eisert, Eufinger & Hirsch (2018), Altavilla, Pagano & Simonelli (2017) and Ferrando, Popov & Udell (2017) 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 regulator's solution is to rein in banks' risk-shifting behavior by requiring them 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 policy 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 effects 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 via cross-border interbank transactions.[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. 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 both domestic

[2] In Bolton & Jeanne (2011), cross-country contagion propagates via the scarcity of collateral in interbank markets. In their model, investment opportunities arise asymmetrically across banks, giving rise to an 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.

and foreign sovereign default. Consequently, sovereigns never default in equilibrium (as they are assumed to be solvent unless they bail out banks). However, when bank equity is low, the doom loop can occur at a national level if banks are exposed primarily to their domestic sovereign. An even more dangerous parameter region exists when bank equity is low and banks hold portfolios comprising domestic and foreign debt in equal proportions. In this case, all banks are vulnerable to domestic and foreign sovereign debt re-pricing, and 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 a regional doom loop between sovereigns anywhere and banks everywhere.

These theoretical models of international contagion are analogous to Wagner (2010) and Acemoglu, Ozdaglar & Tahbaz-Salehi (2015) in that they reveal a potential unintended consequence of regulatory reform to target concentration: when banks have little loss absorption capacity, increasing their exposure to foreign sovereign risk can exacerbate, rather than reduce, systemic risks. Despite the euro area sovereign debt crisis being characterized primarily by domestic doom loops, recent research has found empirical evidence of bank-sovereign contagion channels operating across borders (Popov & Van Horen, 2015; Kallestrup, Lando & Murgoci, 2016; Beltratti & Stulz, 2017; Breckenfelder & Schwaab, 2017; Kirschenmann, Korte & Steffen, 2017). These contagion channels would become stronger if regulation were to induce banks to reduce concentration in their sovereign exposures, as shown by Giuzio, Craig & Paterlini (2018).

The policy implication is that regulation should manage banks' sovereign risk exposure by lowering both concentration and credit risk. This is the central insight against which we benchmark ideas for how to reform the regulatory treatment of sovereign exposures. However, our numerical simulations indicate that there is a fundamental tension between lowering concentration and lowering credit risk in the absence of 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.

2 Regulation of banks' sovereign exposures

2.1 Current regulatory treatment of sovereign exposures

The principle underlying Basel standards for 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, under Basel standards, competent authorities may exercise their 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).

Banks' exposures to sovereigns are subject to a distinct regulatory treatment. Under Basel standards, jurisdictions may apply a preferential risk weight for sovereign exposures denominated and funded in domestic currency. Accordingly, the EU Capital Requirements Regulation (CRR) assigns a zero risk weight to such exposures under the standardized approach.[3] In addition, the CRR grants authorities the discretion to allow internal ratings-based (IRB) banks to use the standardized approach for their sovereign exposures.[4] 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 material exposures, including sovereign exposures, to the IRB framework.[5] In addition, owing to the zero risk weight, portfolios that benefit from the permanent partial

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

[4] 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.

[5] Under the IRB approach, sovereign exposures would typically be 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 would 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".

use provision are also exempt from large exposure limits, which constrain exposures to a single counterparty to be no greater than 25% of a bank's own funds.[6]

In combination, the zero risk weight and absence of a large exposure limit means that EU banks do not face any constraint with respect to their domestic currency sovereign exposures (as long as the leverage ratio requirement does not bind). Banks are therefore able to purchase more sovereign bonds without funding those additional assets with any equity. Hence, there is no regulatory incentive for banks to prudently manage their sovereign risk exposure.

From a systemic risk perspective, the European Systemic Risk Board (2015) has expressed a 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). These insights have prompted some policymakers to call for reforms to the regulatory treatment of banks' sovereign exposures (Nouy, 2012; Deutsche Bundesbank, 2014; Enria, Farkas & Overby, 2016).

2.2 Ideas for a new regulatory treatment of sovereign exposures

Proponents of regulatory reform have put forward various ideas for a new treatment of sovereign exposures. However, despite the abundance of ideas, policymakers have not reached consensus on whether any single option 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 banking 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 exposures.

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

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. Analytical 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, whether they are price-based or quantity-based; and second, whether they are targeted at concentration or credit risk. Table 1 depicts this 2×2 matrix, and provides examples of reform options that correspond to each of the four cells in that matrix. In particular:

- *Price-based tools 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 Panel A of Table 2.[7]

- *Price-based tools 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 Panel B of Table 2.[8]

- *Quantity-based tools to target credit risk*: Banks' sovereign exposures are subject to large exposure limits that are set as a function of sovereign credit ratings. This approach is not discussed by the Basel Committee on Banking Supervision (2017). Instead, this cell of the 2×2 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 of this policy option is reported in Panel C of Table 2.

[7] An alternative calibration of price-based tools to target credit risk is advanced by Matthes & Rocholl (2017). In their proposal, a fraction of sovereign exposures corresponding to the ECB capital key would receive a risk weight exemption, with risk weights applying only to exposures in excess of that fraction.

[8] A qualitatively similar approach is advocated by Véron (2017).

- *Quantity-based tools to target concentration*: Banks' sovereign exposures are subject to constant large exposure limits. This corresponds to discussions in the Basel Committee on Banking Supervision regarding the continued applicability of the existing exemption from the large exposures framework for sovereign exposures. If that exemption were to be removed, single-name sovereign exposures would be subject to a limit of 25% of a bank's Tier 1 capital.In the simulations, we also consider the possible impact of a continuum of less stringent calibrations of the large exposure limit, ranging from 25% to 500% of a bank's Tier 1 capital.

In the next section we describe the methodology by which we simulate banks' portfolio reallocations in response to the aforementioned policies. Then, after documenting the datasets at our disposal, section 5 presents the simulation results. In section 6, these results are compared to the case in which banks swap their current sovereign bond holdings for a newly created area-wide low-risk asset. Finally, section 7 infers conclusions for policymakers.

3 Simulation method

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 would maintain their current sovereign bond portfolios, and quantify the additional capital that banks would need to raise to maintain their capital ratios at the original level.[9] 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 costly (Diamond & Rajan, 2000).

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

We propose a more general characterization of banks' possible reactions to regulatory reform by allowing their sovereign bond portfolios to adjust according to a set of rules that guide their reinvestment decisions. To this end, our simulations make three baseline assumptions regarding banks' portfolio selection. 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. These non-pecuniary motivations for euro area banks to hold euro-denominated sovereign bonds would continue to exist under all regulatory reform options.

Second, we assume that banks prefer to maintain their current composition 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 current portfolio composition insofar as reinvestment achieves lower capital requirements.

Third, we assume that banks' portfolio composition is elastic with respect to regulation. This is where our approach differs from previous quantitative impact assessments. In our framework, banks change the composition of their sovereign bond portfolios in a manner that minimizes overall capital requirements. This is based on the insight that sovereign bonds are typically low-return investments, so that the portfolio composition decision is likely to be dominated by any non-zero capital requirement attached to them. The implication of this assumption is that the portfolio allocations resulting from our simulations are a globally unique solution to banks' constrained minimization problem. Consequently, in our simulations it is never possible for banks to further reduce their capital requirements following the envisaged regulatory reform.

These three baseline assumptions still leave many possible solutions for banks' portfolio selection under different regulatory reform scenarios. Most options for regulatory reform leave banks with degrees of freedom in how to globally minimize the capital requirements attached to their sovereign bond portfolio. To establish unique solutions, we focus on three illustrative reinvestment cases. These cases apply insofar as banks can minimize capital requirements by deviating from their initial (preferred) portfolio. In particular, for marginal changes in portfolio composition, banks adopt one of the following reinvestment rules:

- *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 regulatory regime.
- *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 that has the closest expected loss rate to their initial portfolio. Banks therefore replicate 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 regulatory regime, similar in spirit to Becker & Ivashina (2015) and Efing (2016).

These decision rules do not represent a forecast of banks' actual reinvestment behavior following regulatory reform. Instead, the polar cases of "prudence" and "imprudence" provide lower and upper bounds on the levels of concentration and riskiness of banks' resulting portfolios, based on 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 bond 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 reinvestment cases applied to the four regulatory reform options described in subsection 2.2. In all columns of the table, the hypothetical bank would maintain its aggregate sovereign bond holdings at 100 units. After reinvestment, these holdings would always be subject to a capital charge of zero, which represents the global minimum under all regulatory reform options. In the regulatory status quo, these two conclusions hold by construction, since the bank begins with a sovereign bond portfolio of 100 units, and the current regulatory treatment of sovereign exposures applies a capital charge of zero to any exposure constellation. In subsequent columns, the bank chooses a portfolio that is consistent with a capital charge of zero under the respective portfolio allocation rule. For each regulatory reform option, the credit risk of the resulting portfolio is weakly lowest in the prudent case and highest in the imprudent case, with the base case lying somewhere in between. In addition, the following insights emerge from the table:

- For *price-based tools to target credit risk*, the hypothetical bank divests all 75 units of its Italian holdings, since these would attract a risk weight of 4% owing to Italy's BBB rating (see Table 4). 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 (which had an S&P rating of A+ as of mid-2017 and a five-year expected loss rate of 8.17% in the adverse calibration of the simulation model of Brunnermeier et al. (2017)).

- For *price-based tools 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 and then 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 the expected loss rate closest to the portfolio's initial value of 5.61%, 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 *quantity-based tools to target credit risk*, the bank divests $75-(0.75\times 30) = 52.5$ 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 regulatory reform option; 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).

- For *quantity-based tools to target concentration*, the bank divests its single-name holdings in excess of 25% of Tier 1 capital, i.e. 0.25×30=7.5 units, implying an 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 for each single-name takes the bank from Germany 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 initial expected loss rate of 5.61%; in the imprudent case, the excess is reinvested into the highest-risk sovereigns from Greece to Estonia inclusive.

The combination of the four regulatory reform options and three cases for portfolio reallocation yields 12 distinct portfolios, which can be compared to the initial portfolio in terms of concentration and riskiness. To measure 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.[10] In particular, for a given bank's 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 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:

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

[10] 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.

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 5, which is the case 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 deviations from capital key shares would be zero. The maximum value of $KeyDeviation$ is given by a bank fully concentrated in Maltese sovereign debt: in this case, $KeyDeviation \approx 24.7$, given that $CK_{Malta} = 0.09\%$.[11]

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 sovereigns' stochastic default processes, implying 10 million draws in total. In a benchmark calibration, the model is calibrated to 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 qualitative insights are robust to different calibrations.

The output of the simulation 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

[11] Malta provides the limiting case because it has the lowest ECB capital key share in the euro area, as shown in Table 4. By construction, $KeyDeviation$ decreases as CK_i increases. For the country with the largest capital key share, i.e. $CK_{Germany} = 25.56\%$, $KeyDeviation \approx 18.5$ for a portfolio composed only of German debt securities.

probability and loss-given-default). In addition, the High-Level Task Force on Safe Assets (2018) uses the same simulation model to calculate value-at-risk, namely the minimum percentage reduction in value that would occur 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 we calculate:

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

where $ELRate$ is the expected loss rate of a bank's sovereign bond 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 would expect 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 bond portfolio. $UnexpectedLoss$ measures the the fraction of a bank's Tier 1 capital that it would lose in the 1% worst outcome over a five-year period.

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 bank, the degrees of freedom in portfolio selection following regulatory reform are such that all four reform scenarios are consistent with banks increasing their sovereign risk exposure in the imprudent case. Moreover, while home bias would decrease in all four reform scenarios, price-based tools to target credit risk are consistent with the hypothetical bank increasing its portfolio concentration (measured by HHI or $KeyDeviation$).

4 Data

To implement the simulation exercise, 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 information on 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) transparency exercise published in 2017. The EBA sample 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.[12] We obtain data on these banks' holdings of euro area government debt securities as of mid-2017.[13] Total holdings amounted to approximately €1.3tn in mid-2017.[14] According to ECB statistics, this represents 81% of all euro area banks' exposures to euro area central government debt securities.

Table 5 reports individual exposures of the 95 banks in our sample, and Table 6 provides summary statistics. Overall, euro area banks 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 government debt securities were marked down to zero, 57 banks would have negative capital.

Banks are profoundly home biased. The median bank has $HomeBias = 64\%$; 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 $KeyDeviation$. In addition,

[12] 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 EBA transparency exercise published in 2015.

[13] 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.

[14] 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. We choose not to include these exposures in our main analysis as many loans and advances represent exposures to local government and it is unclear whether regulatory reform would treat such exposures as equivalent to central government exposures.

bank portfolios exhibit significant heterogeneity in their risk properties. Nearly half of the banks in our sample should expect 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% (see Table 5). A similar degree of cross-sectional dispersion can be observed for value-at-risk. 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 reinvestment by banks under four scenarios for regulatory reform (as described in Table 1 and Table 2). The simulations envisage three portfolio reinvestment rules, which are illustrated for a hypothetical bank in Table 3. The benchmark comparison for the resulting portfolios is given in Table 6, which reports summary statistics for the variables characterizing bank holdings of government debt securities as of mid-2017.

5.1 Price-based tools to target credit risk

The first regulatory option is price-based tools to target 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).[15] Given credit ratings as of mid-2017, government debt issued by 14 euro area Member States would be subject to a risk weight of zero under this calibration. Debt issued by two Member States—i.e. Italy and Spain—would receive a risk weight of 4%, while Portugal, Cyprus and Greece would receive a risk weight of 7%.

The simulation results are shown in Table 7 for the limiting case of full reinvestment. According to these results, price-based tools to target credit risk would unambiguously reduce banks' exposure to sovereign credit risk. Even in the imprudent case, shown in Panel C of Table 7, $ELRate$ and VaR would decrease relative to mid-2017 exposures. For example, the median $ELRate$ stands at 3.5% after full reinvestment in the imprudent

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

case, down from 5.2% as of mid-2017; similarly large drops would occur at other points in the cross-sectional distribution. Nevertheless, there is wide dispersion in risk exposure according to the portfolio reinvestment rule that banks follow in response to regulatory reform. If banks were to instead follow a prudent reinvestment rule, the median $ELRate$ would drop to 0.7%. The implementation of price-based tools to target credit risk is therefore consistent with a wide set of possible outcomes in terms of the magnitude of bank exposure to sovereign risk.

The implications for portfolio concentration are less clear-cut. Price-based tools to target credit risk would reduce $HomeBias$, but only in countries subject to non-zero risk weights. This accounts for the substantial reduction in median $HomeBias$ from 64% as of mid-2017 to approximately 8-9% after full reinvestment. The decline in mean $HomeBias$, however, is less pronounced because a significant minority of banks are unaffected by price-based tools to target credit risk. At the 90th percentile, for example, $HomeBias$ declines from 100% as of mid-2017 to 87% in the base case and prudent case, with a somewhat lower number of 78% recorded in the imprudent case.

However, simulation results for HHI and $KeyDeviation$ suggest that bank portfolio concentration would increase throughout the cross-section of banks. This finding is consistent across all three portfolio reinvestment rules. The intuition is that price-based tools to target credit risk would dissuade banks from minimizing concentration in their portfolios. In the calibration envisaged by the Basel Committee on Banking Supervision (2017), eight euro area Member States would be subject to non-zero risk weights. For banks looking to minimize capital requirements, such a regulation would have the effect of decreasing the investible universe of government debt securities in the euro area from 19 to 11 Member States. As such, bank portfolios become more concentrated in this regulatory scenario.

From a prudential perspective, an increase in portfolio concentration could be problematic because sovereign credit risk is imperfectly measured. For example, at the beginning of 2009, Ireland had a sovereign credit rating of AAA from all three major agencies. As such, bank exposures to Ireland would have been subject to a risk weight of 0% until April 2011, when S&P was the last of the three major rating agencies to downgrade Ireland to BBB+, following downgrades by Moody's and Fitch at the end of the previous year. Irish debt would then have been subject to a risk weight of 4% until summer 2014, when

S&P and Fitch both upgraded Ireland's credit rating to A−. This episode exposes the vulnerability of price-based tools to target credit risk, particularly when the calibration of these tools relies on external credit ratings. To provide a more general quantification of volatility in sovereign credit ratings, Figure 1 plots the probability of a rating transitioning from A− or higher to below A− over five years. This transition probability varies substantially over recent financial history; at its peak, it reached 25% in 2012-13, reflecting a high chance of sovereign debt being downgraded from $A-$ or better under the price- and quantity-based approaches to credit risk. In light of this uncertainty regarding the measurement of idiosyncratic sovereign credit risk, reducing concentration is one appropriate objective of reforms aimed at regulating the doom loop.

Figure 2 plots the simulation results for the continuum of 0-100% reinvestment. In these figures, 0% corresponds to Table 6 and 100% reinvestment corresponds to Table 7. Between these polar extremes, measures of concentration and credit risk are a nonlinear function of the extent to which banks reinvest their initial sovereign bond portfolio into a new one that minimizes capital requirements. For example, $KeyDeviation$ initially falls, as banks divest from their own sovereign bonds in particular, but as the extent of reinvestment increases beyond approximately 50%, $KeyDeviation$ begins to rise back to its initial value as banks reinvest only into the subset of sovereign bonds which attract a 0% risk weight in this regulatory scenario. As such, when the extent of portfolio reinvestment is high, banks are correspondingly concentrated in highly rated sovereign bonds.

5.2 Price-based tools to target concentration

Rather than set risk weights according to credit risk, they could be calibrated as a function of portfolio 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.

Table 8 shows the simulation results for the limiting case of full reinvestment; Figure 3 depicts results for the continuum of 0-100% reinvestment. These results show that price-based tools to target concentration would unambiguously induce banks to lessen their portfolio concentration. Under all three reinvestment rules, mean $HomeBias$ would fall to 42% after full reinvestment, down from 55% as of mid-2017. This reduction in home bias is smaller than that observed under price-based tools to target credit risk because most banks have an exposure to their domestic sovereign that is less than 100% of their Tier 1 capital. Consequently, only 36 of the most heavily exposed banks would see a reduction in their home bias. Likewise, the simulation results for HHI and $KeyDeviation$ both indicate that banks would reduce concentration in their sovereign exposures in response to price-based tools to target concentration, but the magnitudes are again modest. Bank portfolios would therefore remain relatively concentrated. At the mean, $KeyDeviation$ would stand at 12 or 13 (depending on the reinvestment rule)—a long way from the low concentration benchmark of near-zero deviation.

The effect on sovereign risk exposures is ambiguous. Crucially, outcomes depend on the reinvestment rule that banks adopt. In the prudent case, which assumes that banks reinvest into safer securities, the median $ELRate$ would fall from 5.2% as of mid-2017 to 3.4%. Similarly large risk reductions would occur throughout the cross-section of banks. By contrast, in the imprudent case, which represents the upper bound on resulting risk exposures, the median $ELRate$ would increase to 6.0%. Heavily exposed banks would see a particularly large increase in their $ELRate$; that of the bank at the 90th percentile would go from 9.6% as of mid-2017 to 16.8% in the imprudent case, compared with 7.8% in the prudent case. Consequently, the bank at the 90th percentile would expect to lose half of its Tier 1 capital over five years in the imprudent case, up from 22.5% as of mid-2017, and compared with 13.6% in the prudent case. Similar insights can be drawn from changes in value-at-risk.

These simulation results highlight a trade-off. Following the implementation of price-based tools to target concentration, banks would unambiguously reduce their concentration, albeit to a modest extent. However, outcomes in terms of credit risk exposure are ambiguous. When banks reinvest imprudently, risk exposures could increase substantially, particularly in the right-tail of heavily exposed banks. From a prudential perspective, this raises concerns that price-based tools to target concentration could have unintended consequences in terms of sovereign credit risk exposures. In general equilibrium, banks' greater exposure to sovereign credit risk could generate additional risk endogenously via contagion effects (Bolton & Jeanne, 2011; Brunnermeier et al., 2017).

5.3 Quantity-based tools to target credit risk

The Basel Committee on Banking Supervision (2017) does not envisage quantity-based tools to target credit risk. However, this policy innovation 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, particularly during sovereign debt crises when expected returns on sovereign debt are high. Through the lens of our simulation model, this implies that bank portfolios would end up towards the left-hand side of Figure 2 or Figure 3. To counteract these concerns regarding low elasticity, quantity-based approaches place hard exposure limits on bank sovereign exposures. In the case of quantity-based tools to target credit risk, limits would be set as a stepwise function of external credit ratings. For example, sovereigns rated between AAA and AA− would be subject to a 100% limit (expressed as a percentage of Tier 1 capital), while sovereigns rated CCC+ or lower would be subject to a 25% limit. The intermediate limits are shown in Panel B of Table 2.

An important difference between price-based and quantity-based tools to target credit risk is that the latter allow banks to hold a 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 debt securities rated CCC+ or lower, but such an exposure would be 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 would divest entirely from these risky securities under the price-based approach to credit risk, but might choose to increase their holdings under the quantity-based approach, depending on the reinvestment rule that they adopt.

Consequently, the effects of quantity-based approaches on sovereign credit risk exposures are ambiguous. In the imprudent case, risk exposures would increase relative to mid-2017 levels, as shown in Panel C of Table 9 for the limiting case of full reinvestment and Figure 4 for the continuum of 0-100% reinvestment. For example, the median bank's $ELRate$ would increase to 6.1% after full reinvestment, up from 5.2% as of mid-2017, and slightly higher than under price-based tools to target concentration. The increase in risk exposure is more substantial for heavily exposed banks: at the 75th percentile, for example, the $ELRate$ increases from 6.9% as of mid-2017 to 13.2% in the imprudent case. From this perspective, quantity-based tools to target credit risk are less effective in inducing banks to reduce their credit risk exposures than price-based approaches.

A caveat to this conclusion is that the price-based approach is more sensitive to elasticities. If elasticities are low, the price-based approach could prove ineffective in inducing banks to adjust their sovereign exposures. This outcome is likelier during sovereign debt crises, when expected returns would increase but risk weights would remain constant. Visco (2016) argues that such an outcome is desirable as banks would be less constrained in their ability to act countercyclically in sovereign debt markets. Such considerations belong to a broader assessment of regulatory reform options, however, and are therefore beyond the scope of this paper, which is focused on prudential outcomes for banks.

The simulation results also reveal that quantity-based tools to target credit risk would reduce concentrations in bank sovereign bond portfolios under all portfolio reinvestment rules. In the base case, median $HomeBias$ would fall from 64% as of end-2017 to 32% after full reinvestment; median HHI would fall from 55 to 37; and median $KeyDeviation$ would fall from 15 to 12. Quantitatively, these reductions in portfolio concentration are somewhat larger than those achieved under price-based tools to target concentration, despite the fact that the latter is explicitly focused on reducing concentration. Ironically, then, quantity-based tools to target credit risk can be less effective than price-based tools in reducing credit risk exposures, including price-based tools that are calibrated to target concentration. On the other hand, they can be more effective at inducing lower concentration, despite not explicitly targeting that outcome.

5.4 Quantity-based tools to target concentration

The fourth option under consideration is the simplest: uniform quantitative restrictions would be placed on bank exposures to government debt securities. The results shown in Table 10 indicate that a 25% large exposure limit would be more effective than any other regulatory option in reducing portfolio concentration. Under all three portfolio reinvestment rules, median $HomeBias$ would fall from 64% as of mid-2017 to 8% following the implementation of large exposure limits. A significant minority of banks would no longer have any home bias. The values of HHI and $KeyDeviation$ would also be substantially lower than under any other regulatory option.

In terms of credit risk exposure, however, large exposure limits are consistent with the widest range of outcomes. In the base case, the median *ELRate* would stay almost constant. In the imprudent case, the median *ELRate* increases to 11.4%, which is substantially higher than under the other three policy options. This is because a large exposure limit does not prevent banks from reinvesting a fraction of their sovereign bond holdings into high-risk securities. A similar effect is at work under price-based tools to target concentration, although in that case fewer banks would be induced to reinvest their holdings of government debt securities (since non-zero risk weights would apply only to holdings in excess of 100% of Tier 1 capital). By contrast, more reinvestment occurs in the case of a 25% large exposure limit, which in the imprudent case is skewed towards the riskiest securities. As such, quantity-based tools to target concentration could exacerbate bank exposure to sovereign credit risk and generate new contagion risks.

Figure 5 depicts the simulation results for a continuum of quantitative restrictions, ranging the 25% limit reported in Table 10 to a much more liberal 500% limit. There is a nonlinear relationship between the large exposure limit and portfolio concentration and credit risk respectively. At relatively liberal calibrations of the large exposure limit—between 500% and 200%—*HomeBias* is only mildly affected, as the limit would be non-binding for most banks. As the limit gets tighter, more banks are affected, and *HomeBias* decreases more quickly. Likewise, the change in *ELRate* becomes greater as the large exposure limit approaches 25%. In the imprudent case, the median *ELRate* increases to 6.0% with a 100% large exposure limit, slightly higher than the initial condition of 5.2%, and to 11.4% with a 25% large exposure limit.

6 Area-wide low-risk assets

The simulation results highlight a tension between reducing concentration and reducing sovereign credit risk exposure. None of the four regulatory options considered in this paper would lead to unambiguous reductions in both concentration and credit risk exposures. In fact, some policies could lead to substantial increases in concentration or credit risk, which could introduce new contagion risks in general equilibrium. This tension reflects 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 would exhibit high concentration.

At the same time, a low-concentration portfolio would not be low-risk. Therefore, given the current portfolio opportunity set, it is impossible to assemble a portfolio of euro area government debt securities that has both low concentration and low credit risk.

To resolve this tension, existing government debt securities could be repackaged by a combination of pooling and tranching. Brunnermeier, Garicano, Lane, Pagano, Reis, Santos, Thesmar, Van Nieuwerburgh & Vayanos (2011) advocate a process by which a pooled portfolio of government debt securities is subsequently tranched into securities of different seniority; Monti (2010) advocates tranching government debt securities directly and then pooling the senior component.[16] Here, we assume that the pool-then-tranche approach of Brunnermeier et al. (2011) is adopted, because it is the only one that has been subject to a rigorous feasibility study (High-Level Task Force on Safe Assets, 2018). Nevertheless, our qualitative insights also apply to a tranche-then-pool approach if the latter could be designed to generate securities with similar risk properties (Leandro & Zettelmeyer, 2018).

A portfolio comprised of the senior component of a pooled-then-tranched security would have the following properties. First, in terms of concentration, $HomeBias \approx 0$, since underlying portfolio weights would target the ECB capital key. Such a portfolio weighting means that $HHI \approx 16$ and $KeyDeviation \approx 0$.[17] None of the regulatory reform measures considered in this paper would achieve similarly low levels of concentration. In terms of credit risk, Brunnermeier et al. (2017) calibrate a simulation model in which the senior component of a pooled-then-tranched security would have $ELRate = 0.42\%$ and $VaR = 18.37\%$. As with portfolio concentration, none of the regulatory reform measures considered in this paper can achieve equivalent outcomes.

[16] This tranche-then-pool design has some similarity to two other approaches to reforming sovereign debt markets that have been advanced in the literature. First, it is similar to Wendorff & Mahle (2015), who propose national tranching, but not the subsequent pooling of senior national bonds. Second, it is similar to Von Weizsacker & Delpla (2010), except that the latter also envisage joint guarantees for the pooled senior bond. Leandro & Zettelmeyer (2018) provide a detailed comparison of the various design options for pooling and tranching government debt securities.

[17] 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 would generate $KeyDeviation = 0.43$. A supply of pooled-then-tranched securities greater than the €1.5tn envisaged 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). Similar considerations apply to $HomeBias$.

Figure 6 plots the characteristics of sovereign bond portfolios as a function of the extent to which banks reinvest their mid-2017 holdings into the senior component of a pooled-then-tranched security. As the extent of reinvestment increases, bank portfolios unambiguously become less concentrated and less risky. This stands in contrast with outcomes under regulatory reform, where no option can achieve both lower concentration and lower credit risk in tandem. Pooling and tranching government debt securities can therefore overcome the trade-off between concentration and credit risk.

Naturally, banks would only reinvest into the senior component of a pooled-then-tranched security if they were adequately incentivized to do so. Regulation in particular could help to provide banks with strong incentives to adjust their sovereign bond portfolios accordingly. The High-Level Task Force on Safe Assets (2018) shows quantitatively that reforming the regulatory treatment of sovereign exposures would substantially enhance demand for the senior component of a pooled-then-tranched security. Banks could use that security to mitigate the impact on capital requirements associated with policy tools to target concentration and/or credit risk in sovereign exposures. Consequently, regulatory reform and the introduction of a pooled-then-tranched security would be jointly effective in breaking the doom loop. This policy conclusion supports 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. Four regulatory reform options are compared, namely price- and quantity-based tools to target concentration and credit risk. Simulations of portfolio adjustments by banks in response to regulatory reforms reveal a tension between between reducing concentration and reducing exposure to sovereign risk. None of the reforms unambiguously achieve both, as Table 11 indicates. In some cases, regulatory reform can have perverse effects. For example, quantity-based tools to target credit risk are consistent with banks increasing their sovereign risk exposure, contrary to the intended objective of that reform.

By pooling and tranching cross-border portfolios of government debt securities, it is possible to achieve prudentially superior outcomes. This is because debt repackaging can generate securities with properties unlike any security that currently exists in the euro area. To transition to this equilibrium, banks would need incentives to reinvest into new pooled-and-tranched securities. An adequate system of incentives could include some of the regulatory reform options envisaged in this paper, subject to an assessment of their broader implications for sovereign debt markets.

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

Target of policy tool:	Nature of policy tool: Price-based	Nature of policy tool: Quantity-based
Concentration risk	*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 additional 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 are targeted at concentration or credit risk.

Table 2: Illustrative calibrations of a new regulatory treatment of sovereign exposures

Panel A: Price-based tools to target credit risk

External credit rating	AAA to A−	BBB+ to BBB−	Below BBB− and unrated
Domestic-currency exposures	0%	4%	7%
Foreign-currency exposures	10%	50%	100%

Panel B: Price-based tools 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 C: Quantity-based tools to target credit risk

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

Note: This table provides illustrative calibrations for three sets of ideas for a new regulatory treatment of sovereign exposures. Panel A reports a possible calibration of standardized risk weights for sovereign exposures as a function of the external credit rating of those sovereign exposures, as outlined by the Basel Committee on Banking Supervision (2017). Panel B reports a possible calibration of risk weights for sovereign exposures as a function of a bank's concentration in a single name, again outlined by the Basel Committee on Banking Supervision (2017). Panel C 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 selection under regulatory reforms

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

Note: This table illustrates the application of portfolio selection rules for a stylized Italian bank funded by 30 units of Tier 1 capital and with holdings of 75 units of Italian, 20 units of German, and 5 units of French sovereign bonds. $Exp/T1$ 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 value that would occur 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 (mid-2017)

	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. "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 value that would occur over five years with 1% probability, as calculated by the High-Level Task Force on Safe Assets (2018).

Table 5: Individual bank sovereign exposures (mid-2017)

Panel A: Austrian banks

Name of bank	*Exp/T1*	*HomeBias*	*HHI*	*KeyDeviation*	*ELRate*	*VaR*
Erste Group Bank AG	84	45	36	15	3.3	58
Promontoria Sacher Holding N.V.	33	23	16	9	3.7	61
Raiffeisen Bank International AG	84	32	19	10	2.5	50
Raiffeisen-Holding NÖ-Wien	127	22	17	8	1.7	45
Raiffeisenbankengruppe OÖ Verbund	60	55	34	14	2.3	53
Sberbank Europe AG	28	0	25	12	7.7	79
Volksbanken Verbund	85	71	53	18	2.4	53
VTB Bank (Austria) AG	64	9	71	15	0.7	35

Panel B: Belgian banks

Name of bank	*Exp/T1*	*HomeBias*	*HHI*	*KeyDeviation*	*ELRate*	*VaR*
AXA Bank Belgium SA	235	10	20	11	2.4	49
Bank of New York Mellon	229	9	20	6	2.7	56
Belfius Banque SA	113	45	36	13	4.0	67
Dexia NV	325	0	55	14	7.2	77
Investar	142	64	45	17	3.6	65
KBC Group NV	185	44	26	12	3.4	63

Panel C: Cypriot banks

Name of bank	*Exp/T1*	*HomeBias*	*HHI*	*KeyDeviation*	*ELRate*	*VaR*
Bank of Cyprus Holdings	23	100	100	25	16.1	88
Co-operative Central Bank Ltd	81	100	100	25	16.1	88
Hellenic Bank Public Company Ltd	123	88	79	22	14.3	82

Panel D: Estonian banks

Name of bank	*Exp/T1*	*HomeBias*	*HHI*	*KeyDeviation*	*ELRate*	*VaR*
AS LHV Group	29	0	51	19	6.8	75

Panel E: Finnish banks

Name of bank	*Exp/T1*	*HomeBias*	*HHI*	*KeyDeviation*	*ELRate*	*VaR*
Kuntarahoitus Oyj	148	69	50	17	1.1	45
OP Financial group	33	5	48	12	0.7	35

Panel F: French banks

Name of bank	*Exp/T1*	*HomeBias*	*HHI*	*KeyDeviation*	*ELRate*	*VaR*
Banque Publique d'Investissement	43	100	100	20	1.9	60
BNP Paribas SA	104	9	17	5	3.3	60
Crédit Mutuel Group	58	52	40	11	2.6	58
Groupe BPCE	87	47	37	10	3.3	63
Groupe Crédit Agricole	89	50	40	10	2.8	60
La Banque Postale	317	74	64	15	2.0	58
Renault Crédit International	9	0	27	10	4.0	60
Société de Financement Local	566	0	66	16	6.4	76
Société Générale SA	51	29	24	7	2.1	52

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Panel G: German banks

Name of bank	$Exp/T1$	$HomeBias$	HHI	$KeyDeviation$	$ELRate$	VaR
Aareal Bank AG	271	39	36	8	2.5	48
Bayerische Landesbank	116	78	70	14	1.1	38
Commerzbank AG	83	3	32	8	5.2	65
DekaBank	135	90	85	17	0.9	35
Deutsche Bank AG	59	8	17	4	2.1	49
Deutsche Pfandbriefbank AG	227	0	21	6	5.2	68
Deutsche Zentral-Genossenschaftsbank	158	64	55	12	1.9	43
Erwerbsgesellschaft der S-Finanzgruppe	128	78	70	15	0.8	36
HASPA Finanzholding AG	79	82	76	15	1.5	38
HSH Beteiligungs Management GmbH	231	79	71	15	1.1	37
Landesbank Baden-Württemberg	80	67	59	13	1.6	41
Landesbank Hessen-Thüringen	109	76	69	14	0.8	37
Landwirtschaftliche Rentenbank	17	82	75	15	1.7	39
Norddeutsche Landesbank	186	63	54	12	1.3	39
NRW.Bank	98	18	21	4	2.5	51
State Street Europe Holdings Germany	67	0	37	11	2.2	58

Panel H: Greek banks

Name of bank	$Exp/T1$	$HomeBias$	HHI	$KeyDeviation$	$ELRate$	VaR
Alpha Bank AE	41	97	95	24	34.7	95
Eurobank Ergasias SA	53	100	100	24	35.2	95
National Bank of Greece SA	132	32	54	19	12.7	54
Piraeus Bank SA	121	18	67	21	7.8	45

Panel I: Irish banks

Name of bank	$Exp/T1$	$HomeBias$	HHI	$KeyDeviation$	$ELRate$	VaR
Allied Irish Banks, Plc	101	74	57	18	5.9	74
Bank of Ireland	97	65	45	16	5.4	72
Citibank Holdings Ireland Limited	8	0	20	11	2.0	49
DEPFA BANK Plc	254	0	50	11	1.7	43
Permanent TSB Group Holdings Plc	138	100	100	24	6.0	75

Panel J: Italian banks

Name of bank	$Exp/T1$	$HomeBias$	HHI	$KeyDeviation$	$ELRate$	VaR
Banca Carige SpA	96	100	100	21	7.2	80
Banca Monte dei Paschi di Siena	2046	99	98	20	7.2	80
Banca Popolare di Sondrio	386	79	71	17	6.9	79
Banco BPM S.p.A.	326	100	100	21	7.2	80
BPER Banca S.p.A.	131	92	87	19	6.8	78
Credito Emiliano Holding SpA	173	73	62	16	6.1	75
Iccrea Banca Spa	606	100	100	21	7.2	80
Intesa Sanpaolo SpA	150	51	41	11	5.9	72
Mediobanca	95	63	52	13	5.7	71
UniCredit SpA	215	45	36	10	5.4	69
Unione di Banche Italiane SCpA	178	100	100	21	7.2	80

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Panel K: Latvian banks

Name of bank	$Exp/T1$	$HomeBias$	HHI	$KeyDeviation$	$ELRate$	VaR
ABLV Bank	93	73	55	19	6.0	71

Panel L: Luxembourgish banks

Name of bank	$Exp/T1$	$HomeBias$	HHI	$KeyDeviation$	$ELRate$	VaR
Precision Capital S.A.	324	8	14	7	3.9	64
RBC Investor Services Bank S.A.	27	0	100	18	0.5	32

Panel M: Maltese banks

Name of bank	$Exp/T1$	$HomeBias$	HHI	$KeyDeviation$	$ELRate$	VaR
Bank of Valletta Plc	190	65	45	17	5.4	67
MeDirect Group Limited	73	4	55	12	1.8	53

Panel N: Dutch banks

Name of bank	$Exp/T1$	$HomeBias$	HHI	$KeyDeviation$	$ELRate$	VaR
ABN AMRO Group N.V.	133	23	17	7	1.5	45
Coöperatieve Rabobank U.A	54	78	65	18	0.9	37
de Volksholding B.V.	112	17	23	8	1.3	43
ING Groep N.V.	81	17	19	7	1.5	45
N.V. Bank Nederlandse Gemeenten	185	22	18	7	1.4	44

Panel O: Portuguese banks

Name of bank	$Exp/T1$	$HomeBias$	HHI	$KeyDeviation$	$ELRate$	VaR
Banco Comercial Português SA	105	98	97	24	11.7	85
Caixa Central de Crédito Agrícola	479	52	43	15	9.6	83
Caixa Geral de Depósitos SA	218	72	57	18	10.4	83
Novo Banco	142	60	45	16	9.6	81

Panel P: Slovenian banks

Name of bank	$Exp/T1$	$HomeBias$	HHI	$KeyDeviation$	$ELRate$	VaR
Abanka d.d.	183	85	72	21	7.5	77
Biser Topco S.a.r.l.	233	56	34	15	5.9	70
Nova Ljubljanska Banka	112	62	40	16	6.0	69

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Panel Q: Spanish banks

Name of bank	$Exp/T1$	$HomeBias$	HHI	$KeyDeviation$	$ELRate$	VaR
ABANCA Holding Financiero	165	84	75	19	7.1	80
Banco Bilbao Vizcaya Argentaria, SA	80	68	58	16	6.9	80
Banco de Crédito Social Cooperativo	154	79	70	18	7.7	81
Banco de Sabadell, SA	194	36	44	13	7.2	80
Banco Mare Nostrum	239	98	97	22	6.8	80
Banco Santander SA	93	69	57	16	7.5	80
Bankinter SA	166	95	91	21	6.8	80
BFA Tenedora de Acciones, S.A.U.	270	85	77	19	6.7	80
Criteria Caixa S.A.U.	133	94	91	21	6.7	79
Ibercaja Banco	304	94	89	21	6.9	80
Kutxabank	58	100	100	22	6.8	80
Liberbank	329	97	95	21	6.8	80
Unicaja Banco S.A.	362	96	93	21	6.8	80

Note: This table reports euro area banks' sovereign exposures as disclosed in 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 value that would occur over five years with 1% probability, as calculated by the High-Level Task Force on Safe Assets (2018).

Table 6: Summary statistics on bank sovereign exposures (mid-2017)

	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	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 value that would occur 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 7: Price-based tools to target credit risk—simulation results

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	33	0	0	8	56	78
HHI	64	29	23	40	64	98	100
$KeyDeviation$	17	7	8	12	17	24	24
$ELRate$	3.7	2.2	0.8	1.6	3.5	6.0	6.1
VaR	57	19	37	45	62	75	75
$ExpectedLoss$	7.7	13.9	0.9	1.4	4.1	9.3	18.3
$UnexpectedLoss$	111	169	22	40	69	125	228

Note: This table shows the simulation results for price-based tools to target credit risk in the limiting case of full reinvestment. In Panel A, banks reinvest into the lowest-risk sovereign bond that attracts the lowest capital charge; 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 that attracts the lowest capital charge. The summary statistics correspond to the case of 100% reinvestment shown in Figure 2. Variables are as defined in the note to Table 6.

Table 8: Price-based tools to target concentration—simulation results

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	161	150	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	9	12	16	20
ELRate	4.9	5.4	1.3	1.9	3.4	5.7	7.8
VaR	59	15	39	48	58	69	80
ExpectedLoss	7.1	10.2	1.1	1.6	5.4	9.3	13.6
UnexpectedLoss	93	91	22	42	73	117	157

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	9.4	14.1	1.1	2.0	5.6	12.0	19.8
UnexpectedLoss	112	150	22	42	75	133	206

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	161	150	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	8.0	6.8	1.5	2.4	6.0	12.3	16.8
VaR	65	17	41	51	67	81	86
ExpectedLoss	15.8	21.1	1.1	2.0	6.4	19.3	49.8
UnexpectedLoss	113	118	22	42	75	142	265

Note: This table shows the simulation results for price-based tools to target concentration in the limiting case of full reinvestment. In Panel A, banks reinvest into the lowest-risk sovereign bond that attracts the lowest capital charge; 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 that attracts the lowest capital charge. The summary statistics correspond to the case of 100% reinvestment shown in Figure 3. Variables are as defined in the note to Table 6.

Table 9: Quantity-based tools to target credit risk—simulation results

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	167	189	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
$ExpectedLoss$	6.2	9.6	1.1	1.6	5.4	7.8	11.2
$UnexpectedLoss$	90	112	22	42	68	111	145

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	169	205	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
$ExpectedLoss$	8.8	12.3	1.1	2.0	5.6	11.7	18.1
$UnexpectedLoss$	108	135	22	42	75	133	206

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	167	189	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
$ExpectedLoss$	15.4	17.5	1.1	2.0	6.4	24.7	42.9
$UnexpectedLoss$	116	134	22	42	75	143	257

Note: This table shows the simulation results for quantity-based tools to target credit risk in the limiting case of full reinvestment. In Panel A, banks reinvest into the lowest-risk sovereign bond that attracts the lowest capital charge; 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 that attracts the lowest capital charge. The summary statistics correspond to the case of 100% reinvestment shown in Figure 4. Variables are as defined in the note to Table 6.

Table 10: Quantity-based tools to target concentration—simulation results

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	152	109	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	5.3	6.5	1.0	1.5	3.3	5.8	11.1
UnexpectedLoss	81	70	22	37	56	100	189

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	152	109	41	80	123	194	324
HomeBias	13	17	0	0	8	18	29
HHI	21	16	8	11	17	24	36
KeyDeviation	10	3	7	8	9	11	14
ELRate	5.1	4.3	1.4	2.2	4.9	6.8	7.8
VaR	63	14	43	52	66	75	78
ExpectedLoss	7.8	7.5	1.1	1.7	5.6	11.6	18.6
UnexpectedLoss	98	75	22	43	74	128	224

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	152	109	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	16.0	9.3	2.0	8.4	16.9	22.5	30.3
UnexpectedLoss	111	79	27	54	90	151	240

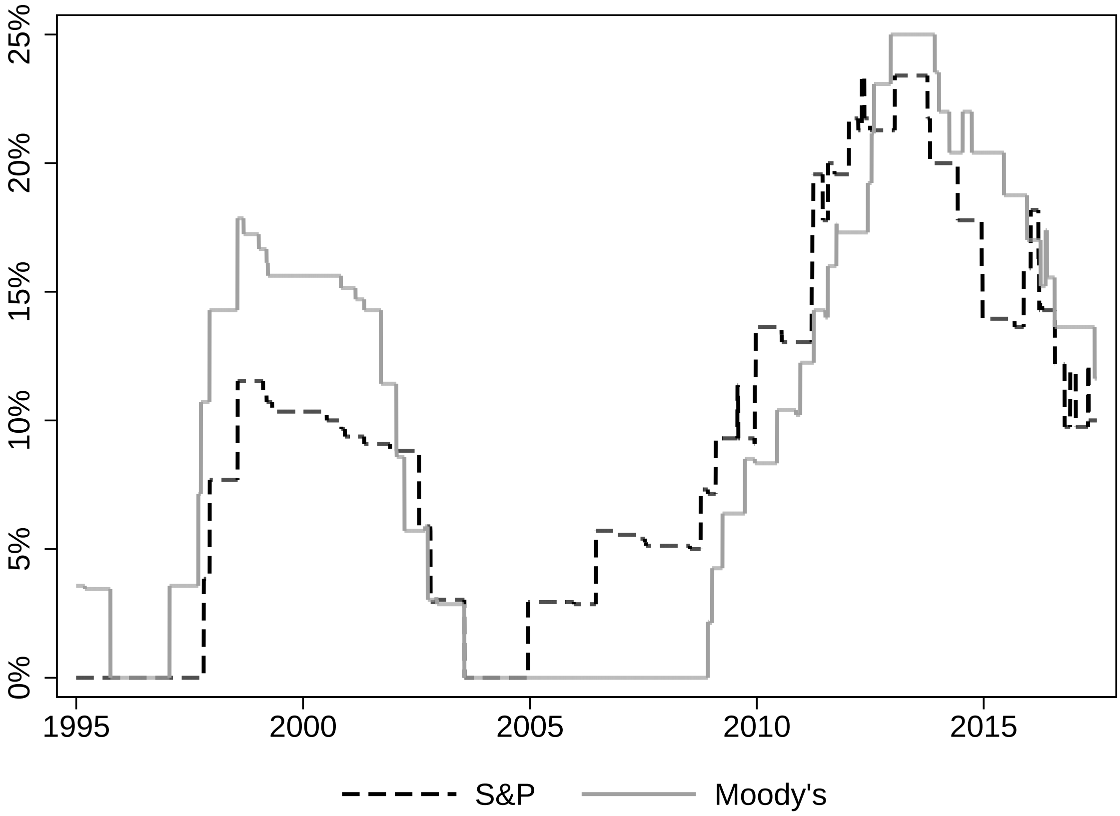
Note: This table shows the simulation results for quantity-based tools to target concentration in the limiting case of full reinvestment. In Panel A, banks reinvest into the lowest-risk sovereign bond that attracts the lowest capital charge; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond that attracts the lowest capital charge. The summary statistics correspond to the case of a 25% large exposure limit shown in Figure 5. Variables are as defined in the note to Table 6.

Table 11: Summary of simulation results

	Change in concentration relative to mid-2017	Change in credit risk relative to mid-2017
Price-based tools for credit risk	?	$\downarrow$
Price-based tools for concentration	$\downarrow$	?
Quantity-based tools for credit risk	$\downarrow$	?
Quantity-based tools for concentration	$\downarrow$	?
Area-wide low-risk asset	$\downarrow\downarrow$	$\downarrow\downarrow$

Note: This table summarizes the simulation results discussed in section 5 and section 6. Downward-facing arrows indicate a decrease in risk exposure; double arrows indicate a large change. Question marks denote an ambiguous directional effect that depends on banks' portfolio reinvestment strategies and the measurement of concentration or credit risk.

Figure 1: Probability of transitioning from A− or better to below A− over five years

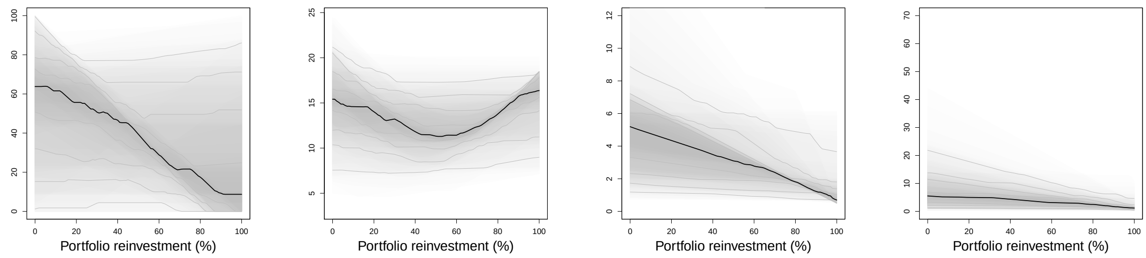


Note: This figure plots the probability of a sovereign rating transitioning from A− or higher to below A− over five years. To calculate transition probabilities, we collect historical data on sovereign ratings assigned to 102 countries globally by S&P and Moody's (Fitch ratings have a shorter time series and are therefore excluded). In each period, we count the number of countries assigned a rating of A− or higher five years previous. In this subset of countries, we count the instances in which the contemporaneous rating is lower than A−. We then divide the latter count by the former to obtain the fraction of countries initially rated A− or better that are downgraded to below A− over a five year period.

Figure 2: Price-based tools to target credit risk

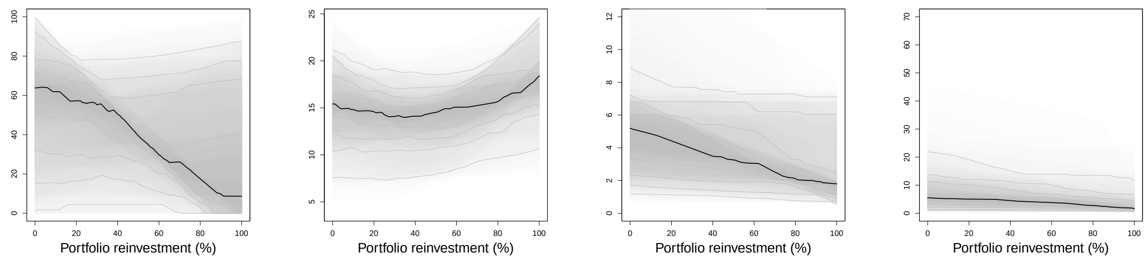
Panel A: Prudent case

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



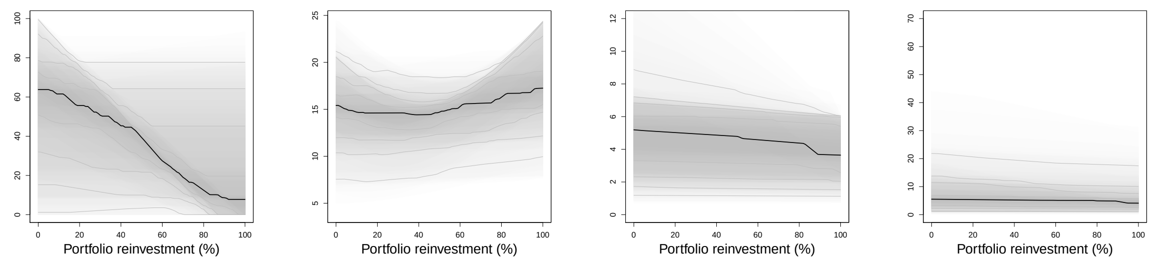
Panel B: Base case

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



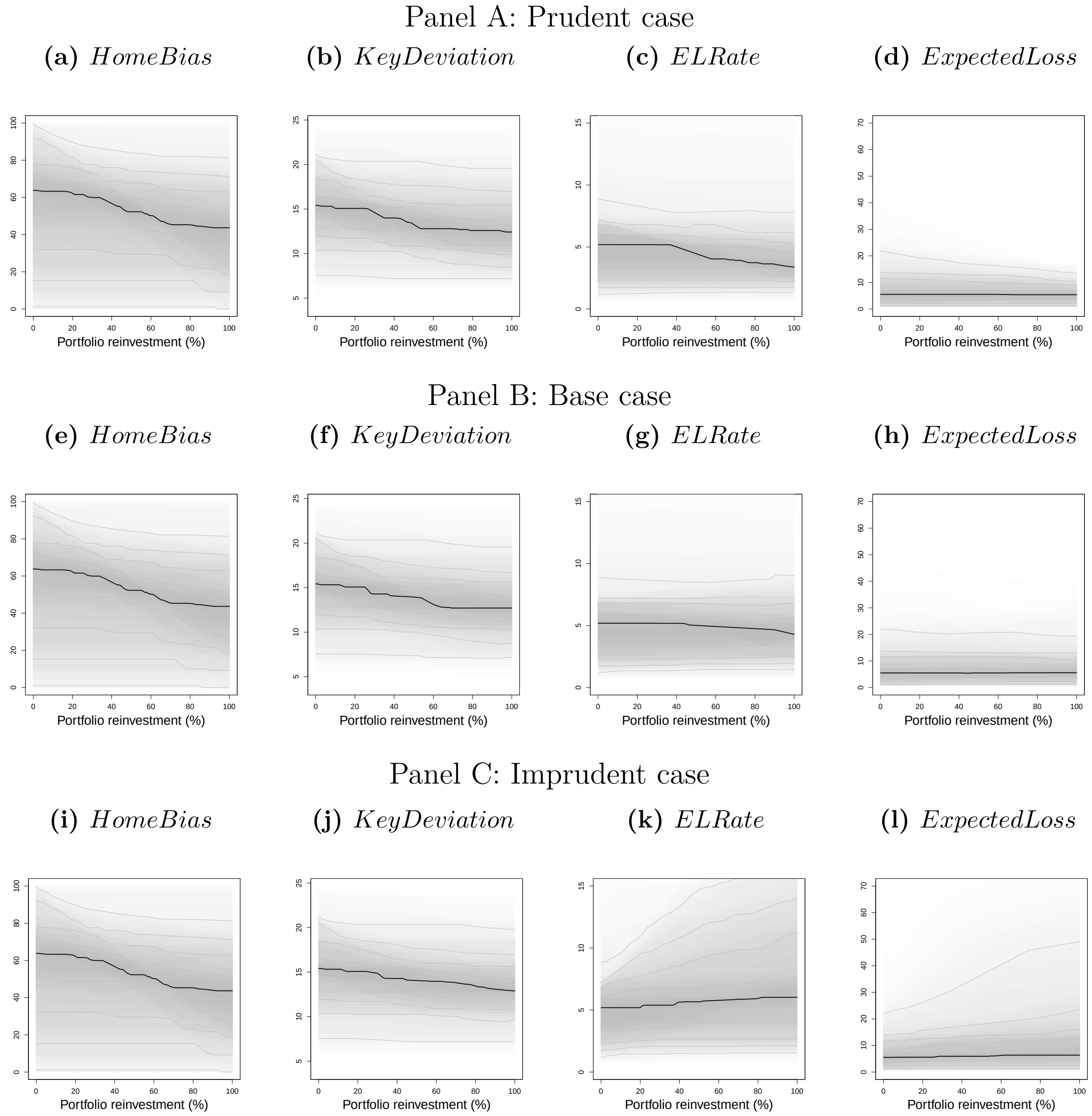
Panel C: Imprudent case

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



Note: This figure plots $HomeBias$, $KeyDeviation$, $ELRate$ and $ExpectedLoss$ as a function of the percentage of banks' sovereign bond portfolios that is reinvested. 0% reinvestment corresponds to Table 6 and 100% reinvestment corresponds to Table 7. In Panel A, banks reinvest into the lowest-risk sovereign bond that attracts the lowest capital charge; 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 that attracts the lowest capital charge. $HomeBias$ 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. $KeyDeviation$ 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)). $ExpectedLoss$ is calculated by multiplying $Exp/T1$ by $ELRate$.

Figure 3: Price-based tools to target concentration

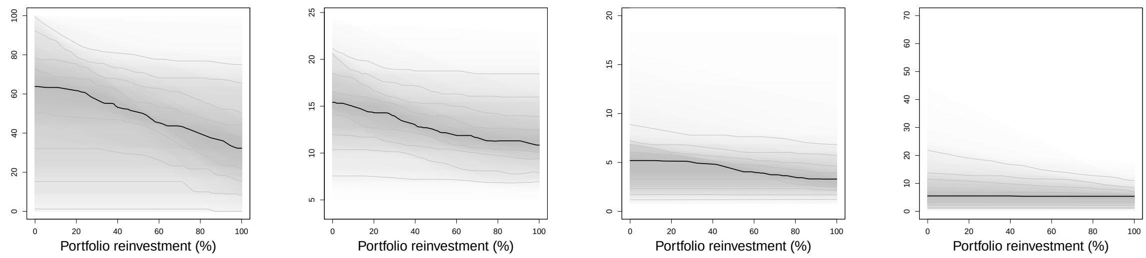


Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss* as a function of the percentage of banks' sovereign bond portfolios that is reinvested. 0% reinvestment corresponds to Table 6 and 100% reinvestment corresponds to Table 8. In Panel A, banks reinvest into the lowest-risk sovereign bond that attracts the lowest capital charge; 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 that attracts the lowest capital charge. *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. *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)). *ExpectedLoss* is calculated by multiplying $Exp/T1$ by *ELRate*.

Figure 4: Quantity-based tools to target credit risk

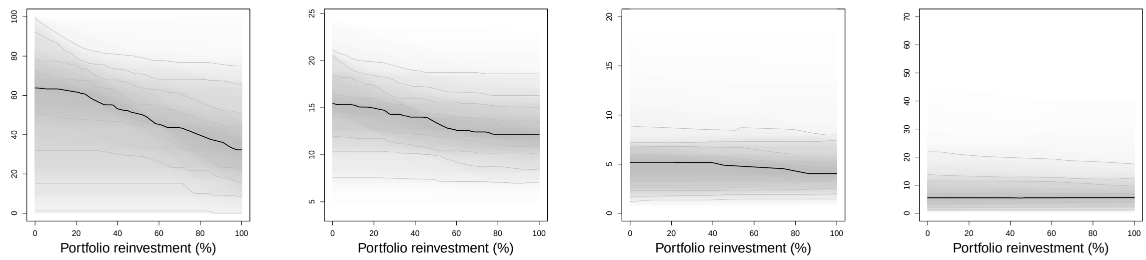
Panel A: Prudent case

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



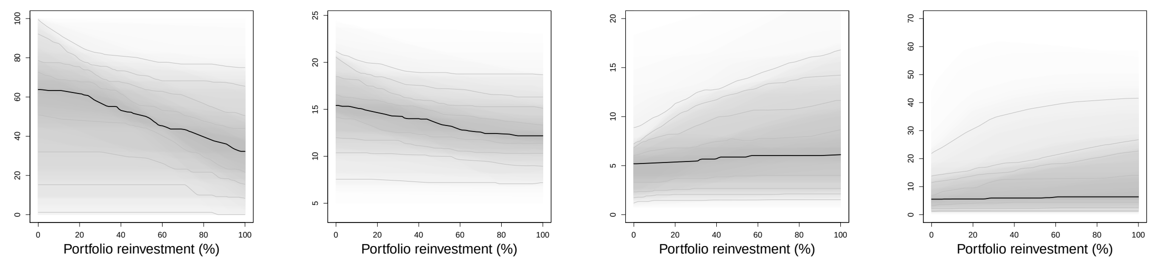
Panel B: Base case

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



Panel C: Imprudent case

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

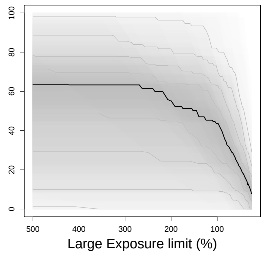


Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss* as a function of the large exposure limit (expressed as a percentage of Tier 1 capital). 0% reinvestment corresponds to Table 6 and 100% reinvestment corresponds to Table 9. In Panel A, banks reinvest into the lowest-risk sovereign bond that attracts the lowest capital charge; 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 that attracts the lowest capital charge. *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. *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)). *ExpectedLoss* is calculated by multiplying $Exp/T1$ by *ELRate*.

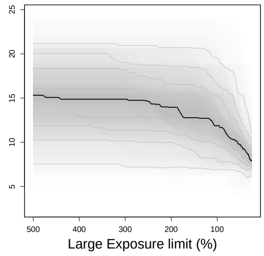
Figure 5: Quantity-based tools to target concentration

Panel A: Prudent case

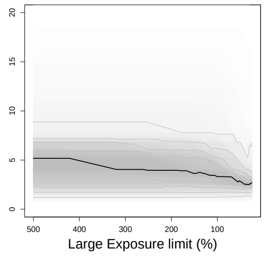
(a) *HomeBias*



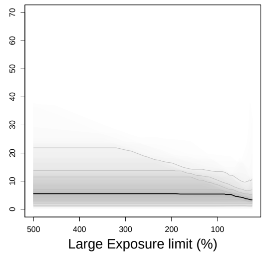
(b) *KeyDeviation*



(c) *ELRate*

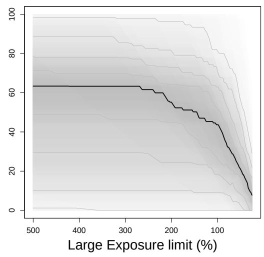


(d) *ExpectedLoss*

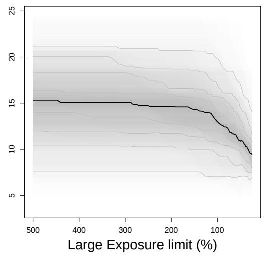


Panel B: Base case

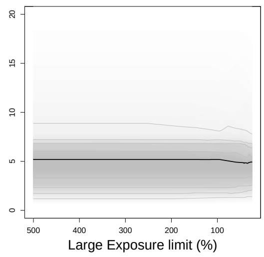
(e) *HomeBias*



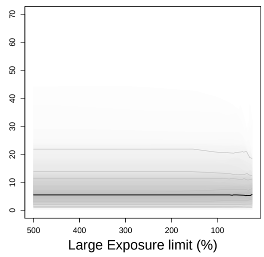
(f) *KeyDeviation*



(g) *ELRate*

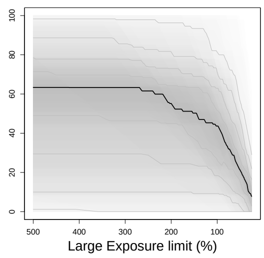


(h) *ExpectedLoss*

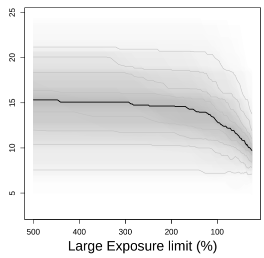


Panel C: Imprudent case

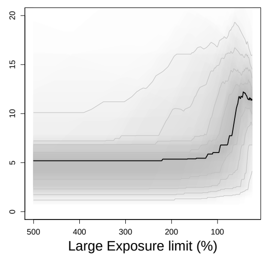
(i) *HomeBias*



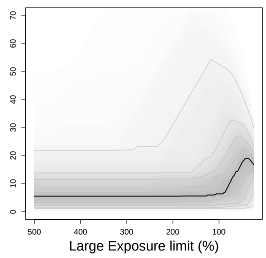
(j) *KeyDeviation*



(k) *ELRate*



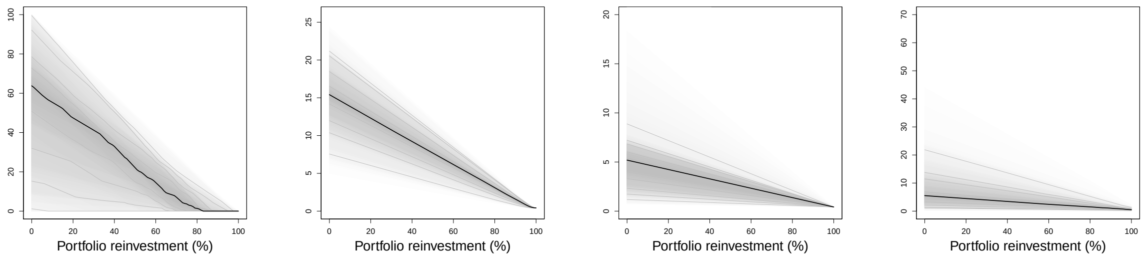
(l) *ExpectedLoss*



Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss* as a function of the percentage of banks' mid-2017 sovereign bond portfolios that is reinvested. A 25% limit corresponds to the summary statistics reported in Table 10. In Panel A, banks reinvest into the lowest-risk sovereign bond that attracts the lowest capital charge; 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 that attracts the lowest capital charge. *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. *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)). *ExpectedLoss* is calculated by multiplying $Exp/T1$ by *ELRate*.

Figure 6: Reinvestment into an area-wide low-risk asset

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



Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss* as a function of the percentage of banks' mid-2017 sovereign bond portfolios that is reinvested into the senior component of a pooled-then-tranched security (as envisaged by High-Level Task Force on Safe Assets (2018)). 0% reinvestment corresponds to Table 6; 100% reinvestment corresponds to $KeyDeviation = 0.43$ and $ELRate = 0.42\%$ for all banks (the values of *HomeBias* and *ExpectedLoss* vary slightly across banks depending on their location of residence and aggregate sovereign bond holdings, but cross-sectional variation is much lower than under all four of the regulatory reform options evaluated in section 5). *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. *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)). *ExpectedLoss* is calculated by multiplying $Exp/T1$ by *ELRate*.

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