# Regulating the doom loop*

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**Abstract**

Euro area governments have committed to break the doom loop between banks and sovereigns. But policymakers disagree on how to treat sovereign exposures in bank regulation. Our contribution is to model endogenous sovereign portfolio reallocation by banks in response to regulatory reform. Simulations highlight a tension between concentration and credit risk in portfolio reallocation. Resolving this tension requires regulatory reform to be complemented by an expansion in the portfolio opportunity set to include an area-wide low-risk asset. By reinvesting into such an asset, banks would reduce both their concentration and credit risk exposure.

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JEL codes: G01, G11, G21, G28

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*"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. At a summit during the euro area sovereign debt crisis, governments referred to this two-way risk exposure as a "vicious circle". The phenomenon is also known as a "doom loop" (Farhi & Tirole, 2018) and "diabolic loop" (Brunnermeier, Garicano, Lane, Pagano, Reis, Santos, Thesmar, Van Nieuwerburgh & Vayanos, 2016) owing to its devilish implications for systemic stability. While the doom loop has since been weakened by policy reforms that mitigate the exposures of sovereigns to bank risk,[1] there is still no regulatory incentive for banks to manage their sovereign exposures prudently. Ideas abound on how to change regulation (European Systemic Risk Board, 2015), but there is no consensus on which idea dominates, or even whether reform is desirable, owing to uncertainty regarding how banks would respond (Visco, 2016).

Our contribution to these policy discussions is to model endogenous portfolio reallocation by banks under regulatory reform. In our simulations, banks respond to regulatory reform by reallocating their sovereign portfolio to minimize capital requirements. Subject to this constraint, banks have degrees of freedom in portfolio allocation. To quantify the range of portfolios that satisfy the constraint, we define 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 bonds. We also define an intermediate "base case" in which banks replicate the credit risk properties of their initial portfolio.

The model sheds light on two questions. First, would banks reduce portfolio concentration in response to regulatory reform? Second, would banks reduce their exposure to sovereign credit risk? Simulations show that the answer is never "yes" to both questions under reform ideas put forward by the Basel Committee on Banking Supervision (2017) and German Council of Economic Experts (2015). Reforms that target concen-

[1] In particular, 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.

tration indeed reduce home bias, but are consistent with banks increasing their sovereign credit risk exposure, which could strengthen the doom loop and lead to its international propagation. By contrast, reforms aimed at reducing credit risk exposure can exacerbate portfolio concentration. High concentration—even in ostensibly low-risk sovereigns—can be problematic as sovereign credit risk is time-varying, as Figure 1 indicates. Concentrated exposure to foreign sovereign credit risk can generate cross-border contagion.

Any regulatory design must confront the tension between concentration and credit risk. With the current portfolio opportunity set of euro area sovereign bonds, it is impossible to assemble a sovereign portfolio that has both low concentration and low credit risk. A new asset that embeds both properties would therefore make financial markets more complete. However, expanding the portfolio opportunity set to include an area-wide low-risk asset may be insufficient to induce substantial reallocation. In a final application of our simulation model, we show that banks unambiguously reinvest into an area-wide low-risk asset only when regulatory reform includes positive capital charges or restrictive large exposure limits for all single-name sovereign bonds. The policy conclusion is that regulatory reform must be designed in tandem with an area-wide low-risk asset: they are fundamentally complementary.

## Literature on the doom loop

A burgeoning research agenda has studied the causes and consequences of the doom loop between banks and sovereigns. In the euro area sovereign debt crisis of 2011-12, this doom loop was primarily domestic. Banks were home biased in their asset allocation, rendering them vulnerable to domestic sovereign risk (Brunnermeier, Langfield, Pagano, Reis, van Nieuwerburgh & Vayanos, 2017) and related country risks (Bocola, 2016). Home bias increased even further over the course of the sovereign debt crisis (Brutti & Sauré, 2016).

In light of these stylized facts, theoretical contributions focus on risk-shifting incentives in banks' asset allocation decisions. Due to limited liability, banks have incentives to load up on domestic sovereign bonds 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 when sovereign default does not occur (Gennaioli, Martin & Rossi, 2014). At the same time,

downside risk is shifted to others. When banks expect to be bailed out, taxpayers bear the downside risk (Farhi & Tirole, 2018). Alternatively, if governments can credibly commit not to bail out banks, equity holders shift downside risk to creditors (Acharya, Drechsler & Schnabl, 2014).[2] Battistini, Pagano & Simonelli (2014) document such risk-shifting behavior by banks in vulnerable euro area countries, which increased their holdings of domestic sovereign bonds following increases in sovereign risk.

Risk-shifting 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 supervisory responsibilities to a credible supranational entity (Farhi & Tirole, 2018). Without a commitment device, however, national supervisors can be tempted to encourage banks to finance government borrowing when external demand is weak (Ongena, Popov & van Horen, 2019). 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 real economy lending (Broner, Erce, Martin & Ventura, 2014). This effect has been identified in vulnerable euro area countries, where banks increased their domestic sovereign bond holdings but cut back on lending to non-financial firms (Altavilla, Pagano & Simonelli, 2017; Ferrando, Popov & Udell, 2017; Acharya, Eisert, Eufinger & Hirsch, 2018; Becker & Ivashina, 2018).

In Farhi & Tirole (2018), the time-consistent supervisor's solution is to control risk-shifting by requiring banks to hold foreign sovereign bonds, which in their model are assumed to be safe, rather than risky domestic bonds. However, if both foreign and domestic sovereign bonds are risky, this conclusion no longer holds. In a financially integrated monetary union such as the euro area, exposure to foreign sovereign risk can be counterproductive in the presence of contagion effects. Bolton & Jeanne (2011) show this in a two-country model in which contagion can operate from sovereign risk to bank risk. Exposure to foreign sovereign risk brings diversification benefits, but can also give rise to greater systemic risk, as sovereign distress propagates internationally.[3]

[2] According to this view, risk-shifting is optimal for banks since their net worth would be negative in the event of a sovereign default, particularly if they are weakly capitalized (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.

[3] In Bolton & Jeanne (2011), cross-country contagion occurs due to collateral scarcity in interbank markets. Investment opportunities arise asymmetrically across banks, giving rise to an international

Relatedly, Brunnermeier et al. (2016) model international spillovers arising from losses in the banking system due to government default. In their model, the doom loop between banks and governments can occur nationally or internationally, depending on bank equity levels and whether banks hold only domestic sovereign bonds or an equally weighted portfolio of domestic and foreign bonds. Brunnermeier et al. (2017) extend the model to a continuum of possible bank portfolios. Consistent with Cooper & Nikolov (2018) in a closed economy setting, they find that the doom loop cannot occur when bank equity is sufficiently high, since banks are fully insulated from 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, a national doom loop can occur if banks are primarily exposed to their domestic sovereign. An even more dangerous parameter region exists when bank equity is low and banks hold diversified portfolios, since all banks are vulnerable to either domestic or foreign sovereign bond re-pricing. Hence, an international doom loop can occur between sovereigns anywhere and banks everywhere.

These models of the doom loop reveal a dark side of diversification: contagion.[4] When banks have little equity, greater exposure to foreign sovereign risk can exacerbate endogenous risks arising from the doom loop. Despite the euro area sovereign debt crisis being characterized primarily by domestic doom loops, there is considerable empirical evidence of cross-border contagion (Popov & Van Horen, 2015; Kallestrup, Lando & Murgoci, 2016; Beltratti & Stulz, 2017; Breckenfelder & Schwaab, 2018; Kirschenmann, Korte & Steffen, 2018). Consequently, regulation should aim to lower credit risk as well as concentration in banks' sovereign portfolios. However, our simulations reveal a fundamental tension between concentration and credit risk in sovereign portfolios. An area-wide low-risk asset can resolve this tension by expanding the portfolio opportunity set. It follows that regulatory reform should be calibrated to induce reinvestment into an area-wide low-risk asset. Before describing these simulations in detail, the next section describes the current regulation of banks' sovereign exposures and classifies reform ideas.

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interbank market in which banks with surplus endowment lend to banks with abundant investment opportunities. Interbank lending must be collateralized by government bonds. When a government is expected to default, its bonds can no longer be used as collateral. This restricts the size of interbank markets, depressing aggregate investment.

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

# 2 Regulation of banks' sovereign exposures

## 2.1 Current regulation

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

Jurisdictions differ in their implementation of Basel accords. In the European Union, the Capital Requirements Regulation (CRR) assigns a zero risk weight to sovereign exposures under the standardized approach.[5] In addition, the CRR grants authorities the discretion to allow internal ratings-based (IRB) banks to use the standardized approach for their sovereign exposures.[6] According to the Basel Committee on Banking Supervision (2014), this latter provision is "materially non-compliant" with Basel accords, which require IRB banks to move all significant exposures to the IRB framework.[7] Moreover, owing to the zero risk weight, portfolios that benefit from the permanent partial use provision are exempt from large exposure limits, which ordinarily constrain exposures to a single counterparty to 25% of a bank's own funds.[8]

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

[6] 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.

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

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

In combination, the zero risk weight and large exposure limit exemption mean that CRR-regulated banks do not face any constraint on their domestic currency sovereign exposures (as long as the leverage ratio requirement does not bind). Banks are therefore able to purchase sovereign bonds without funding them with any equity. Hence, there is no regulatory incentive for banks to prudently manage their direct exposure to sovereign risk. Empirical research supports the view that regulation can incentivize excessive exposure to sovereign risk (Acharya & Steffen, 2015; Bonner, 2016), prompting some policymakers to call for regulatory reform (Nouy, 2012; Deutsche Bundesbank, 2014; Enria, Farkas & Overby, 2016). We turn to these reform ideas next.

## 2.2 Options for regulatory reform

Proponents of reform have put forward various ideas for how to treat sovereign exposures in the first pillar of bank regulation (European Systemic Risk Board, 2015). These ideas can be classified along two dimensions. First, reform can be price- or quantity-based: the former implies that certain sovereign exposures attract a positive risk weight and thereby contribute to banks' capital requirements, while the latter implies that certain sovereign exposures may not exceed a given threshold relative to total capital. The second dimension concerns whether reforms target concentration or credit risk. Reforms aimed at concentration are bank-specific as they are calibrated according to portfolio concentration in a single-name sovereign. Reforms aimed at credit risk are country-specific as they are calibrated according to the credit risk of each single-name sovereign.

Taken together, these two dimensions give rise to a $2 \times 2$ matrix of reform options, summarized in Table 1.[9] For each element of the matrix, we calibrate our simulation model using specific designs envisaged by the Basel Committee on Banking Supervision (2017) and German Council of Economic Experts (2015). In particular:

- *Price-based reform to target concentration* (Table 2, Panel A): 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".[10]

[9] In principle, options could be combined to produce hybrid reforms, but it is useful conceptually to approach them as mutually exclusive.

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

- *Price-based reform to target credit risk* (Table 2, Panel B): 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".[11]

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

- *Quantity-based reform to target credit risk* (Table 2, Panel D): Banks' sovereign exposures are subject to large exposure limits set as a function of sovereign credit ratings. This approach is not discussed by the Basel Committee on Banking Supervision (2017), but is instead proposed by the German Council of Economic Experts (2015) and elaborated by Andritzky, Gadatsch, Körner, Schäfer & Schnabel (2016).

In the next section we describe our model of endogenous portfolio reallocation by banks in response to the aforementioned reforms. Then, after documenting the datasets at our disposal, Section 5 presents simulation results (with additional results reported in the Appendix). In Section 6, an area-wide low-risk asset is introduced to the portfolio opportunity set. Section 7 infers policy conclusions.

[11] An alternative calibration of price-based reform 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.

# 3 Model of endogenous portfolio reallocation

Despite the abundance of ideas for regulatory reform, there has been little analysis of the impact on banks' sovereign exposures. The European Systemic Risk Board (2015) and Schneider & Steffen (2017) provide insightful quantitative assessments of the impact of regulatory reforms on capital requirements. However, these contributions assume that banks maintain their current sovereign portfolios—the elasticity of banks' sovereign bond holdings with respect to their associated capital requirements is taken to be zero. Hence, such analyses characterize only a special case of banks' reaction functions, and one that is unlikely to materialize in practice given that banks behave as though capital is a relatively expensive source of marginal funding (Diamond & Rajan, 2000). To provide a more general characterization of banks' reaction functions, we model endogenous portfolio reallocation in response to regulatory reform.

## 3.1 Simulation design

Unlike previous work, we allow sovereign portfolio allocation to be sensitive to its regulatory treatment. In our model, banks deviate from their extant portfolio allocation insofar as reinvestment achieves lower capital requirements. Corner solutions are characterized by banks choosing a sovereign portfolio allocation that globally minimizes capital requirements. We also quantify the full range of intermediate elasticities in which banks partially reallocate their sovereign portfolios. These conditions generally allow for multiple solutions to banks' portfolio allocation under different regulatory reforms. To establish unique solutions, we focus on three illustrative reallocation cases, which apply insofar as portfolio reallocation can lower banks' capital requirements:

- *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 reform.
- *Base case:* Banks re-weight their existing holdings of sovereign bonds insofar as this can lower the capital charge. Otherwise, banks reinvest into another sovereign bond that attracts the lowest capital charge. When more than one such security is

available, banks choose the bond with credit risk properties that most closely match their initial portfolio.

- *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 would assume under a given regulatory reform, similar in spirit to Becker & Ivashina (2015).

While portfolio allocation is endogenous in our model, total holdings of 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 addition, regulation requires banks to hold liquid assets, such as sovereign bonds, to comply with liquidity requirements and insure against systemic illiquidity events.[12] These non-pecuniary motivations for euro area banks to hold sovereign bonds exist under all regulatory reforms.

In Appendix A, we illustrate our simulation model by applying it to a hypothetical Italian bank (under the assumption of 100% reinvestment). This illustrative application highlights the basic mechanics at work in the model. In each regulatory reform and reallocation case, the hypothetical bank maintains a constant level of sovereign bond holdings and chooses a portfolio allocation that minimizes capital requirements. Consequently, in our model it is never possible for the bank to achieve even lower capital requirements.

## 3.2 Portfolio measurement

The combination of four regulatory reforms and three cases for portfolio reallocation yields 12 post-reform portfolios per bank. We summarize these portfolios in terms of their concentration and credit risk, which jointly characterize the propensity of the doom loop to operate through bank balance sheets. High concentration strengthens the bank-sovereign nexus, potentially giving rise to a national doom loop. When credit risk is material, a doom loop equilibrium can occur nationally or even internationally.

We calculate three distinct measures of portfolio concentration. Since the bank-sovereign nexus has historically been characterized primarily by national doom loops,

[12] Ferrara, Langfield, Liu & Ota (2019) document that banks generally hold substantially higher liquid asset buffers than required by regulation, suggesting a high level of structural demand for sovereign bonds.

we begin by defining $HomeBias$ as the excess of a bank's holdings of bonds issued by its domestic sovereign relative to that sovereign's share in the European Central Bank (ECB) capital key.[13] In particular, for each bank portfolio we calculate:

$$HomeBias = Max[0, 100 \times \frac{(h_{i=d}/\sum_{i=1}^{19} h_i) - CK_{i=d}}{1 - CK_{i=d}}], \tag{3.1}$$

where $h_{i=d}$ is the bank's holdings of bonds issued by its domestic sovereign $d$, $\sum_{i=1}^{19} h_i$ is the bank's holdings of bonds 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 3). Note that the measure is bounded at zero, so that when a bank is underweight its own sovereign, i.e. $h_{i=d}/\sum_{i=1}^{19} h_i < CK_{i=d}$, $HomeBias = 0$.

$HomeBias$ does not provide a sufficient statistic of portfolio concentration, however, since banks can also be concentrated in foreign sovereigns. To account for this, we define two additional measures of portfolio concentration. The first is the Herfindahl Hirschman index ($HHI$), calculated as the sum of the squared shares of bank holdings:

$$HHI = \frac{\sum_{i=1}^{19}(h_i/\sum_{i=1}^{19} h_i)^2}{100}, \tag{3.2}$$

where the division by 100 means that the index is bounded by 0 and 100. In practice, the minimum value of $HHI$ is approximately 5, when a bank's sovereign exposures are uniformly distributed across euro area Member States. However, since countries are of different sizes, a uniformly weighted portfolio is skewed towards smaller countries. To account for this, the final measure of portfolio concentration is calculated as the square root of the sum of squared deviations from the ECB capital key:

$$KeyDeviation = \sqrt{\frac{\sum_{i=1}^{19}((h_i/\sum_{i=1}^{19} h_i) - CK_i)^2}{19}}. \tag{3.3}$$

For a portfolio weighted exactly by the ECB capital key, $KeyDeviation = 0$. The maximum value of $KeyDeviation$ is given by a bank fully concentrated in sovereign bonds issued by the country with the lowest ECB capital key share in the euro area, which happens to be Malta. In this case, $KeyDeviation \approx 24.7$, given that $CK_{Malta} = 0.09\%$. For

[13] The ECB capital key provides a good benchmark for low portfolio concentration as it reflects Member States' relative economic size and population.

the country with the largest capital key share, i.e. $CK_{Germany} = 25.56\%$, $KeyDeviation \approx 18.5$ for a portfolio comprised only of German sovereign bonds.

Next, we calculate measures of credit 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, so default risk is generally low; mildly recessionary, so default risk is somewhat higher; or severely recessionary, so default risk is much higher. In the second level of the model, they take 5,000 draws of the stochastic default process, implying 10 million draws in total. When calibrated,[14] the model can be used to calculate a variety of risk metrics. Brunnermeier et al. (2017) focus on five-year expected loss rates, namely the losses than an investor expects to incur over a five-year period (calculated as the product of the default probability and loss-given-default). In addition, the High-Level Task Force on Safe Assets (2018) uses the same model to calculate value-at-risk, namely the minimum percentage reduction in portfolio value that occurs over five years with 1% probability. We report both of these risk measures and also normalize them by loss absorption capacity at the bank level. In particular, for each bank portfolio we calculate:

$$ExpectedLoss = \frac{ELRate \times Exp}{T1}, \tag{3.4}$$

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

$$UnexpectedLoss = \frac{VaR \times Exp}{T1}, \tag{3.5}$$

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

[14] In a benchmark calibration, the model is designed to generate default rates inferred from end-2015 CDS spreads. An alternative, more adverse, calibration builds in additional cross-country dependence, whereby defaults are even more likely if other sovereigns also default. For conservatism, we take the outputs of the adverse model calibration, but our insights are robust to different calibrations.

# 4 Data on sovereign risk and bank exposures

To apply the simulation model, we assemble two datasets on sovereign risk and bank exposures. For sovereign risk, we collect information on five-year expected loss rates (from Brunnermeier et al. (2017)), value-at-risk (calculated by the High-Level Task Force on Safe Assets (2018)), and credit ratings assigned by the three major rating agencies. These country-level variables are reported in Table 3. To measure bank exposures, we collect information from the European Banking Authority (EBA) published in 2017.[15] The data cover 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.[16] We obtain data on these banks' holdings of euro area sovereign bonds as of mid-2017, when total holdings amounted to approximately €1.3tn.[17] According to ECB statistics, this represents 81% of all euro area banks' exposures to euro area sovereign bonds.

Table 4 provides summary statistics of banks' exposures as of mid-2017; more granular data for the 95 individual banks in our sample are reported in Appendix B. These statistics indicate that euro area banks generally hold substantial quantities of sovereign bonds: 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 sovereign bonds were marked down to zero, 57 banks would have negative capital. Moreover, banks are profoundly home biased. Median $HomeBias$ is 64%; only 10 banks in our sample of 95 do not exhibit any home bias. Consequently, portfolios tend to be heavily concentrated, as measured by $HHI$ and $KeyDeviation$. Starting from these initial conditions, we now turn to simulations to shed light on endogenous portfolio reallocation by banks in response to regulatory reform.

[15] In the Appendix, we apply our simulation model to older data vintages from 2010 and 2011.

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

[17] 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. For simplicity, we refer to all government debt securities as "sovereign bonds". The EBA transparency exercise also contains information on banks' loans and advances to governments, which amount to €0.9tn in our sample. Including these loans and advances in the simulation model would obviously increase aggregate portfolio reallocation, but would not alter our qualitative conclusions regarding concentration and credit risk.

# 5 Simulation results

We simulate portfolio reallocation by banks under the four regulatory reforms outlined in Table 1 and Table 2. The benchmark comparison for the resulting portfolios is given in Table 4, which reports summary statistics for bank holdings of sovereign bonds in mid-2017. Simulation results using these data are shown in Tables 5, 6, 7 and 8 and the corresponding Figures 2, 3, 4 and 5. Appendix C and Appendix D report results for older exposure data from end-2010 and end-2011 respectively.

## 5.1 Price-based reform to target concentration

The Basel Committee on Banking Supervision (2017) envisages a risk weight of 0% for exposures up to 100% of Tier 1 capital. For excess exposures, the marginal risk weight increases as a stepwise function of exposures (analogously to progressive marginal tax rates on income). The precise calibration of this stepwise function is reported in Table 2. Simulation results for the corner solution of full reallocation are shown in Table 5. Figure 2 plots the results for the continuum of 0-100% reallocation, where 0% corresponds to Table 4 and 100% reallocation corresponds to Table 5. Between these polar extremes, measures of concentration and credit risk are a nonlinear function of the extent to which banks reallocate their sovereign portfolio.

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

The effect on credit risk exposure is ambiguous. Crucially, outcomes depend on the reallocation rule that banks adopt. In the prudent case, which assumes that banks real-

locate into the safest securities, mean *ELRate* falls modestly from 5.5% as of mid-2017 to 4.8%. By contrast, in the imprudent case, which represents the upper bound on resulting risk exposures, mean *ELRate* increases substantially to 8.2%. Banks with very risky sovereign portfolios see a particularly large increase in their *ELRate*; that of the bank at the 90th percentile goes from 9.6% as of mid-2017 to 16.8% in the imprudent case, compared with 7.7% in the prudent case. The bank at the 90th percentile expects to lose more than half of its Tier 1 capital over five years in the imprudent case—more than double the initial condition in mid-2017, and considerably higher than the 13.6% that it expects to lose in the prudent case. Similar insights hold for changes in value-at-risk.

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

## 5.2 Price-based reform to target credit risk

Rather than concentration, risk weights can be calibrated as a function of credit risk. The Basel Committee on Banking Supervision (2017) outlines a calibration in which domestic-currency sovereign bonds are assigned a risk weight of 0% when rated between AAA to A−, 4% when rated between BBB+ and BBB−, and 7% when rated BBB− or below (as in Table 2, Panel B).[18] Given credit ratings as of mid-2017, bonds issued by 14 euro area Member States are subject to a risk weight of zero under this calibration (see Table 3). Bonds issued by two Member States—i.e. Italy and Spain—receive a risk weight of 4%, while those issued by Portugal, Cyprus and Greece receive a risk weight of 7%.

Simulation results are shown in Table 6 for the corner solution of full reallocation and Figure 3 for the continuum of 0-100% reallocation. Price-based reform to target credit risk

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

would reduce approximately half of the sample banks' exposure to sovereign credit risk in the prudent case (Panel A) as well as the base case (Panel B), with other banks unaffected by regulatory reform since they hold only 0%-weighted sovereigns. Results are mixed in the imprudent case, shown in Panel C: in terms of $ELRate$, the portfolios of affected banks see a modest improvement, with average values falling by 0.7 percentage points. However, improvements are concentrated in affected banks with relatively low $Exp/T1$. For some banks, $ELRate$ actually increases in the imprudent case. Consequently, mean $ExpectedLoss$ increases slightly from 9.8% to 9.9%. Moreover, average values of $VaR$ and $UnexpectedLoss$ remain essentially unchanged relative to mid-2017. The upshot is that price-based reform to target credit risk cannot be relied upon to stimulate a reduction in credit risk exposure for all banks, or even for the average bank when risk is measured in terms of $ExpectedLoss$, $VaR$ and $UnexpectedLoss$.

The explanation for this surprising finding lies in the fact that the ordinal ranking of countries by credit ratings as of mid-2017 does not correspond to their ranking by $ELRate$ or $VaR$. For example, Italy's S&P rating as of mid-2017 was BBB−, implying a 4% risk weight, but its $ELRate$ is lower than that of Slovenia, which had a A+ rating and therefore a 0% risk weight under price-based reform to target credit risk. This insight highlights how regulations predicated on credit ratings are subject to measurement error in ratings. Marginal changes in credit rating agencies' opinions around critical ratings thresholds can have large implications for portfolio allocation. Moreover, discontinuities embedded in ratings-based regulation can generate perverse incentives for banks to concentrate portfolio allocation in securities just above critical thresholds, even when securities just below these thresholds are similarly or even slightly less risky. Evidence from securitization markets suggests that this concern is empirically relevant: Efing (2018) finds that banks subject to binding capital requirements concentrate portfolio allocation in asset-backed securities with the highest ratio of yield spread to required capital.

The implications for portfolio concentration depend on measurement. On one hand, price-based reform to target credit risk would reduce $HomeBias$ for banks located in countries subject to positive risk weights. On the other hand, $HHI$ and $KeyDeviation$ increase throughout the cross-section of banks affected by regulatory reform. This finding is consistent across all three portfolio reallocation rules. The intuition is that price-based reform to target credit risk actively dissuades banks from minimizing concentration when

portfolio reallocation is extensive. In the calibration envisaged by the Basel Committee on Banking Supervision (2017), five euro area Member States are subject to non-zero risk weights as of mid-2017. Such a regulation has the effect of shrinking the portfolio opportunity set of euro area sovereign bonds. As such, after full reallocation, the portfolios of affected banks become more concentrated when measured in terms of $HHI$ and $KeyDeviation$, although not in terms of $HomeBias$.

## 5.3 Quantity-based reform to target concentration

Next, we consider uniform quantitative restrictions on bank holdings of sovereign bonds. If restrictions were set at 25% of Tier 1 capital, virtually all banks would be affected. Consequently, a 25% limit is more effective than any other regulation in reducing portfolio concentration. As Table 7 shows, mean $HomeBias$ would fall from 64% as of mid-2017 to 13% under all three portfolio reallocation rules. A significant minority of banks no longer have any home bias. The values of $HHI$ and $KeyDeviation$ are also substantially lower than under any other regulatory reform, although $KeyDeviation$ remains above the zero-deviation benchmark for all banks.

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

Figure 4 depicts the simulation results for a continuum of quantitative restrictions, ranging from an aggressive 1% limit, through the standard 25% limit reported in Table 7, to a liberal 500% limit. The calibration of the large exposure limit affects portfolio concentration and credit risk nonlinearly. At relatively liberal calibrations of the large

exposure limit (above approximately 200%), *HomeBias* and *KeyDeviation* are barely affected, as the limit is non-binding for most banks. As the limit gets tighter, more banks are affected. *HomeBias* and *KeyDeviation* decrease more quickly, and the change in *ELRate* becomes greater as the large exposure limit tightens. In the imprudent case, mean *ELRate* increases to 8.2% with a 100% large exposure limit, above the initial condition of 5.5%. It reaches a peak of 11.3% with a 32% limit, which is close to the 25% limit mooted by the Basel Committee on Banking Supervision (2017). However, as the large exposure limit tightens further, *ELRate* drops again in the imprudent case, since banks increasingly lose degrees of freedom in portfolio allocation. With an extreme large exposure limit of 1%, almost all banks are forced to hold an equally-weighted portfolio of euro area sovereigns, the mean *ELRate* of which equals 6.8%.[19] In the other two cases, banks' *ELRate* converge to 6.8% from below as the large exposure limit approaches 1%.

## 5.4 Quantity-based reform to target credit risk

The Basel Committee on Banking Supervision (2017) does not envisage quantity-based reform to target credit risk. Instead, this reform is proposed by German Council of Economic Experts (2015) and Andritzky et al. (2016) on the grounds that price-based approaches provide only weak incentives for banks to reduce their exposure to sovereign credit risk. Through the lens of our simulation model, this reasoning implies that equilibrium bank portfolios would lie towards the left-hand side of Figure 2 or Figure 3. To counteract concerns regarding low elasticity, quantity-based approaches place hard exposure limits on bank sovereign exposures. In the case of quantity-based reform to target credit risk, limits are set as a stepwise function of external credit ratings. The German Council of Economic Experts (2015) proposes that sovereigns rated between AAA and AA− be subject to a 100% limit (expressed as a percentage of Tier 1 capital), with sovereigns rated CCC+ or lower subject to a 25% limit. Limits for intermediate credit ratings are shown in Table 2, Panel B.

An important difference between price- and quantity-based reforms to target credit risk is that the latter allow banks to hold a finite fraction of risky sovereign bonds at a

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

risk weight of zero. For example, under the calibration given above, banks can freely hold up to 25% of the value of their Tier 1 capital in securities rated CCC+ or lower, whereas such an exposure 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 simulations, banks divest entirely from these risky securities under the price-based approach to credit risk, but maintain and even increase such holdings under the quantity-based approach, depending on the reallocation rule that they adopt.

Consequently, the effects of quantity-based reform to target credit risk are ambiguous. In the imprudent case, credit risk exposures increase relative to mid-2017, as shown in Figure 8, Panel C. For example, the mean $ELRate$ increases from 5.5% as of mid-2017 to 8.4%, which is slightly higher than under price-based reform to target concentration. The increase in risk exposure is more substantial for banks with already risky portfolios: at the 90th percentile, for example, the $ELRate$ increases from 9.6% as of mid-2017 to 16.9% in the imprudent case. Similar conclusions can be drawn from Figure 5, which plots the results for a continuum of risk-sensitive large exposure limits. Overall, quantity-based reform to target credit risk is therefore less effective in inducing banks to reduce their credit risk exposures than the corresponding price-based approach. A caveat to this conclusion is that price-based approaches are more sensitive to elasticities. If elasticities are low, price-based approaches could prove ineffective in inducing banks to adjust their sovereign exposures. This outcome is likelier during sovereign debt crises, when expected returns increase but risk weights remain constant.

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

# 6 Area-wide assets in the portfolio opportunity set

None of the four regulatory reforms considered in this paper lead to unambiguous reductions in both portfolio concentration and credit risk. In fact, reforms are consistent with substantial increases in concentration or credit risk, potentially giving rise to new contagion risks. These insights apply more generally to any regulatory design as they reflect the constellation of available sovereign bonds in the euro area. Some sovereign bonds have low measured credit risk, but a portfolio comprised only of such securities exhibits high concentration. At the same time, a low-concentration portfolio has medium-high credit risk.

To illustrate this point, Figure 6, Panel A plots the characteristics of banks' sovereign portfolios when they are reallocated into a low-concentration portfolio weighted by the ECB capital key. By construction, $HomeBias$ and $KeyDeviation$ improve as banks reallocate into this portfolio, becoming negligible in the corner case of full reinvestment. However, credit risk does not exhibit a similarly large decline, since a sovereign portfolio weighted by the ECB capital key entails medium-high credit risk, with $ELRate = 4.4\%$. Whether bank exposure to sovereign credit risk increases or decreases depends on initial conditions as of mid-2017: for 45 banks, $ELRate$ increases, while it decreases for 50 banks. In this setting, the net effect on the doom loop is ambiguous. On one hand, banks are no longer profoundly home biased, thereby mitigating national doom loops. On the other hand, banks are more exposed to the credit risk of foreign sovereigns, in some cases substantially. As in Bolton & Jeanne (2011) and Brunnermeier et al. (2017), this latter effect could give rise to cross-border contagion and an international doom loop.

With the current portfolio opportunity set, it is impossible to assemble a portfolio of euro area sovereign bonds with both low concentration and low credit risk. This can only be achieved by expanding the portfolio opportunity set to include a security that entails both properties. We refer to such a security as an "area-wide low-risk asset". In the absence of fiscal co-insurance, this asset can be created contractually by pooling and tranching existing sovereign bonds. For example, in the pool-then-tranche approach of Brunnermeier, Garicano, Lane, Pagano, Reis, Santos, Thesmar, Van Nieuwerburgh & Vayanos (2011), a pooled portfolio of euro area sovereign bonds weighted by the ECB capital key is tranched to generate senior and non-senior securities. The senior security

represents the area-wide low-risk asset. With an appropriate design and under certain regulatory conditions, issuance of such an asset in significant volumes is feasible (High-Level Task Force on Safe Assets, 2018). Therefore, we take the senior component of a pooled-then-tranched security as the exemplary area-wide low-risk asset, but our findings are generalizable to other designs that generate securities with similar properties.[20]

An area-wide low-risk asset has the following properties. First, in terms of concentration, it is similar to a portfolio weighted by the ECB capital key, with $HomeBias \approx 0$ and $KeyDeviation \approx 0$.[21] Owing to the relative lumpiness of ECB capital key weights, $HHI \approx 16$. Second, in terms of credit risk, an area-wide low-risk asset differs substantially from a low-concentration portfolio without credit protection. Brunnermeier et al. (2017) calibrate a simulation model in which the senior component of a pooled-then-tranched security has $ELRate = 0.42\%$ and $VaR = 18.37\%$. By comparison, the lowest-risk sovereign bonds, issued by Germany, have $ELRate = 0.50\%$ and $VaR = 32\%$, while the highest-risk bonds, issued by Greece, have $ELRate = 35.19\%$ and $VaR = 95\%$ (see Table 3).

Figure 6, Panel B plots the characteristics of sovereign portfolios as a function of the extent to which banks reinvest their mid-2017 holdings into the area-wide low-risk asset defined above. As the extent of reallocation increases, portfolios unambiguously become less concentrated and less risky. In the limit, with full reallocation, all portfolios reflect the properties of the area-wide low-risk asset. This stands in contrast with outcomes under regulatory reforms, none of which can achieve both low concentration and low credit risk with the current portfolio opportunity set.

Banks would reinvest into an area-wide low-risk asset insofar as they have incentives to do so. Regulation can play an important role in providing such incentives. In a next step, we repeat our simulation of the four regulatory reforms with the innovation that

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

[21] 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 few outstanding bonds, the High-Level Task Force on Safe Assets (2018) envisages indicative portfolio weights that generate $KeyDeviation = 0.43$. A supply of pooled-then-tranched securities greater than the €1.5tn suggested by the High-Level Task Force on Safe Assets (2018) could be achieved by deviating more substantially from the ECB capital key, for example with $KeyDeviation \approx 2$, as shown by Leandro & Zettelmeyer (2018).

an area-wide low-risk asset exists alongside national bonds in the portfolio opportunity set. Results are reported in Appendix E. Intriguingly, most outcomes under the two price-based approaches are similar to those in Section 5. Neither reform embeds strong incentives for banks to reallocate their portfolios in favor of an area-wide low-risk asset, since other portfolio allocations can be equally effective at minimizing capital requirements. Consequently, banks reinvest into an area-wide low-risk asset only in the prudent case; in the other cases, banks generally prefer a different portfolio allocation. Under the two quantity-based approaches, banks unambiguously reallocate their portfolios in favor of an area-wide low-risk asset only when large exposure limits are set very restrictively. Under these conditions, an area-wide low-risk asset allows banks to maintain the total value of their sovereign portfolio while avoiding the need for additional capital and respecting binding large exposure limits.

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

Two central insights emerge from this section. First, the tension between concentration and credit risk in portfolio allocation can only be resolved by expanding the portfolio opportunity set to include an area-wide low-risk asset. Second, regulatory reform can complement the introduction of an area-wide low-risk asset by providing banks with correct incentives. This requires price-based reforms to be modified to include a minimum positive risk weight for all single-name sovereign exposures. Alternatively, very restrictive quantity-based reform can induce adequate portfolio reallocation and prevent banks from favoring riskier national bonds.

# 7 Conclusion

We model endogenous sovereign portfolio reallocation in response to regulatory reform. Four reforms are compared, namely price- and quantity-based reforms to target concentration or credit risk. Simulations reveal a tension between between reducing concentration and reducing credit risk. No reform unambiguously achieves both, as summarized in Table 9. Portfolio reallocation in response to regulatory reform could therefore strengthen the doom loop and lead to its international propagation, as in the models of Bolton & Jeanne (2011) and Brunnermeier et al. (2017).

The tension between concentration and credit risk is a general insight that reflects the sovereign portfolio opportunity set. Resolving this tension requires an expansion in the opportunity set to include a security that embeds both low concentration and low credit risk. Such an asset—defined as *area-wide* and *low-risk*—can be created by pooling and tranching portfolios of sovereign bonds (Leandro & Zettelmeyer, 2018). Simulations show that well-designed regulatory reform can complement the introduction of this asset by incentivizing banks to reinvest into it.

In summary, our findings support two complementary policy actions advocated by Bénassy-Quéré, Brunnermeier, Enderlein, Farhi, Fratzscher, Fuest, Gourinchas, Martin, Pisani-Ferry, Rey, Schnabel, Véron, Weder di Mauro & Zettelmeyer (2018). First, facilitate the creation of an area-wide low-risk asset. This requires policymakers to remove the regulatory frictions that currently impede its market-led development (High-Level Task Force on Safe Assets, 2018; European Commission, 2018). Second, reform regulation to induce portfolio reallocation into an area-wide low-risk asset. Reforms mooted by the Basel Committee on Banking Supervision (2017) and German Council of Economic Experts (2015) do not meet this condition and could even backfire by strengthening the doom loop. Instead, reforms that include positive capital charges or restrictive large exposure limits for all single-name sovereign bonds would complement an area-wide low-risk asset by incentivizing banks to reinvest into it. Together, these two policies are necessary to break the doom loop between banks and sovereigns.

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

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

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

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

Panel A: Price-based reform to target concentration

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

Panel B: Price-based reform to target credit risk

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

Panel C: Quantity-based reform to target concentration

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

Panel D: Quantity-based reform to target credit risk

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

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

**Table 3:** Sovereign credit risk in euro area Member States

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

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

**Table 4:** Summary statistics on bank sovereign exposures

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

Note: This table reports summary statistics on banks' exposures to sovereign bonds 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 bonds issued by its domestic sovereign $d$, $\sum_{i=1}^{19} h_i$ is the bank's sovereign bond holdings 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 3). $HHI$ refers to the Herfindahl Hirschman index of concentration, defined as $\frac{\sum_{i=1}^{19}(h_i/\sum_{i=1}^{19} h_i)^2}{100}$. $KeyDeviation$ measures the extent to which a bank's portfolio deviates from ECB capital key weights, and is calculated as $\sqrt{\frac{\sum_{i=1}^{19}((h_i/\sum_{i=1}^{19} h_i)-CK_i)^2}{19}}$. $ELRate$ refers to a bank's five-year expected loss rate (expressed as a percentage) on its sovereign portfolio (based on the adverse model calibration in Brunnermeier et al. (2017)), and $VaR$ refers to the minimum percentage reduction in portfolio value that occurs over five years with 1% probability, as calculated by the High-Level Task Force on Safe Assets (2018). $ExpectedLoss$ and $UnexpectedLoss$ are calculated by multiplying $Exp/T1$ by $ELRate$ and $VaR$ respectively.

**Table 5:** Price-based reform to target concentration

Panel A: Prudent case

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

Panel B: Base case

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

Panel C: Imprudent case

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

Note: This table shows the simulation results for price-based reform to target concentration in the corner solution of full reallocation. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond. The summary statistics correspond to the case of 100% reallocation shown in Figure 2. Variables are defined in the note to Table 4.

**Table 6:** Price-based reform to target credit risk

Panel A: Prudent case

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

Panel B: Base case

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

Panel C: Imprudent case

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

Note: This table shows the simulation results for price-based reform to target credit risk in the corner solution of full reallocation. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond. The summary statistics correspond to the case of 100% reallocation shown in Figure 3. Variables are defined in the note to Table 4.

**Table 7:** Quantity-based reform to target concentration

Panel A: Prudent case

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

Panel B: Base case

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

Panel C: Imprudent case

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

Note: This table shows the simulation results for quantity-based reform to target concentration under the calibration given in Table 2, Panel C. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond. The summary statistics correspond to the case of a 25% large exposure limit shown in Figure 4. Variables are defined in the note to Table 4.

**Table 8:** Quantity-based reform to target credit risk

Panel A: Prudent case

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

Panel B: Base case

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

Panel C: Imprudent case

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

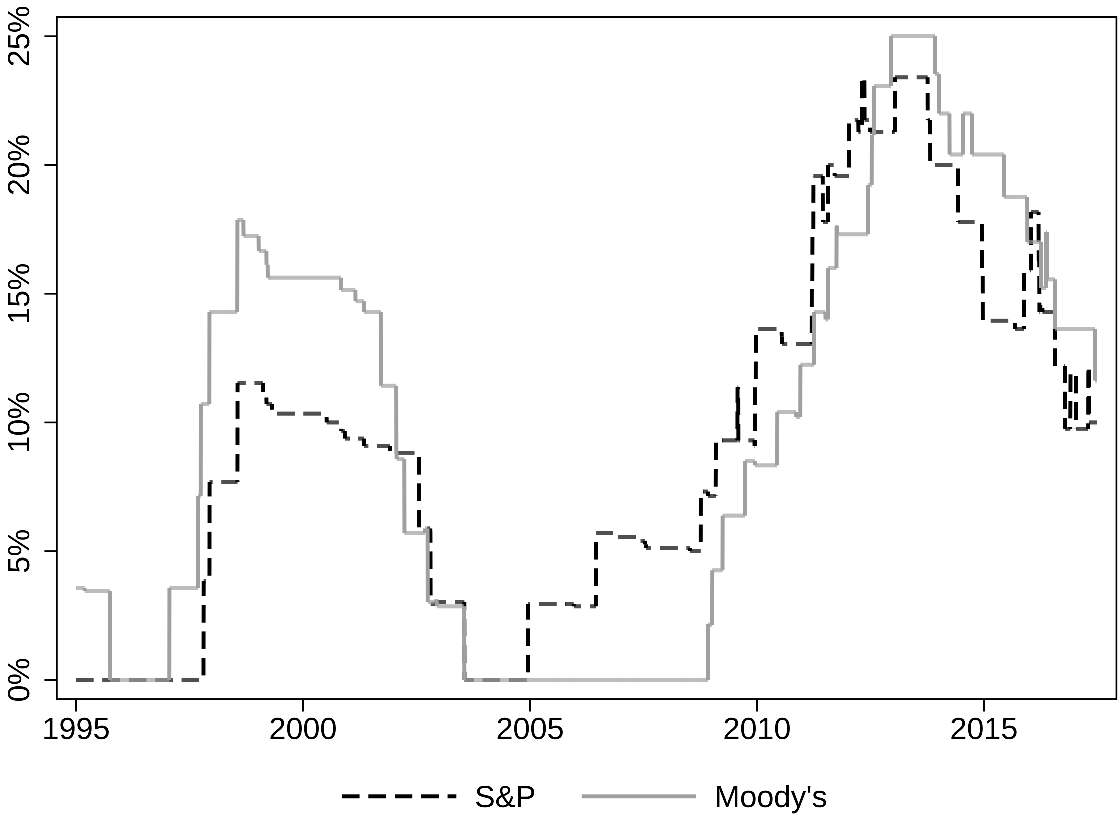
Note: This table shows the simulation results for quantity-based reform to target credit risk under the calibration given in Table 2, Panel D. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond. The summary statistics correspond to the case of a 25% large exposure limit for the lowest rating bucket shown in Figure 5. Variables are defined in the note to Table 4.

**Table 9:** Summary of simulation results

| | Change in concentration | Change in credit risk |
|---|---|---|
| Price-based reform to target concentration (Figure 2) | ↓ | ? |
| Price-based reform to target credit risk (Figure 3) | ? | ? |
| Quantity-based reform to target concentration (Figure 4) | ↓ | ? |
| Quantity-based reform to target credit risk (Figure 5) | ↓ | ? |
| Area-wide asset without credit protection (Figure 6, Panel A) | ↓↓ | ? |
| Area-wide low-risk asset (Figure 6, Panel B) | ↓↓ | ↓↓ |

Note: This table summarizes simulation results for the change in concentration and credit risk in banks' holdings of sovereign bonds induced by regulatory reform. Downward-facing arrows indicate a decrease in concentration or credit risk exposure for all bank portfolios relative to their initial conditions. Double arrows indicate a quantitatively large change. Question marks denote an ambiguous directional effect.

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

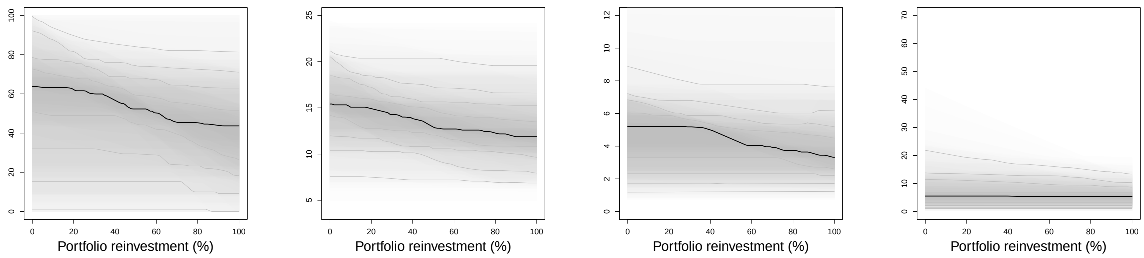



Note: This figure plots the probability of a sovereign rating transitioning from A− or higher to below A− over five years. To calculate transition probabilities, we collect historical data on sovereign ratings assigned to 102 countries globally by S&P and Moody's (Fitch ratings have a shorter time series 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 reform to target concentration

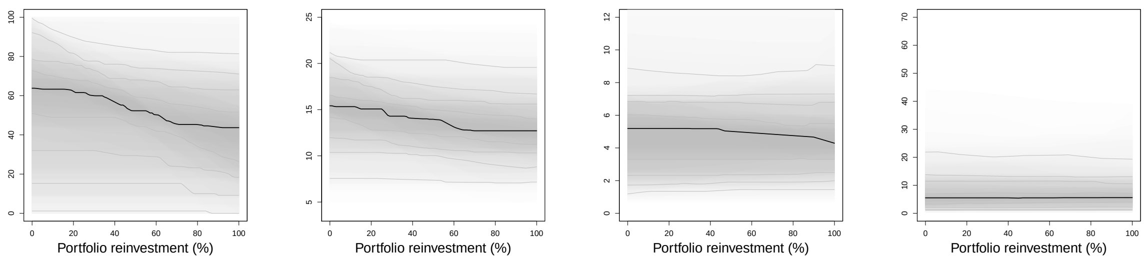
Panel A: Prudent case

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



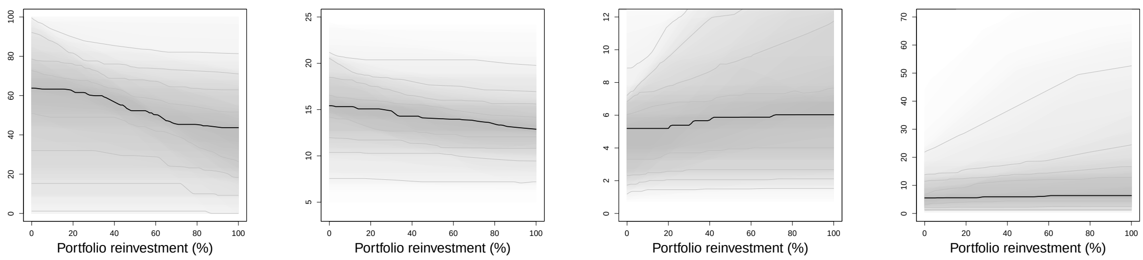

Panel B: Base case

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



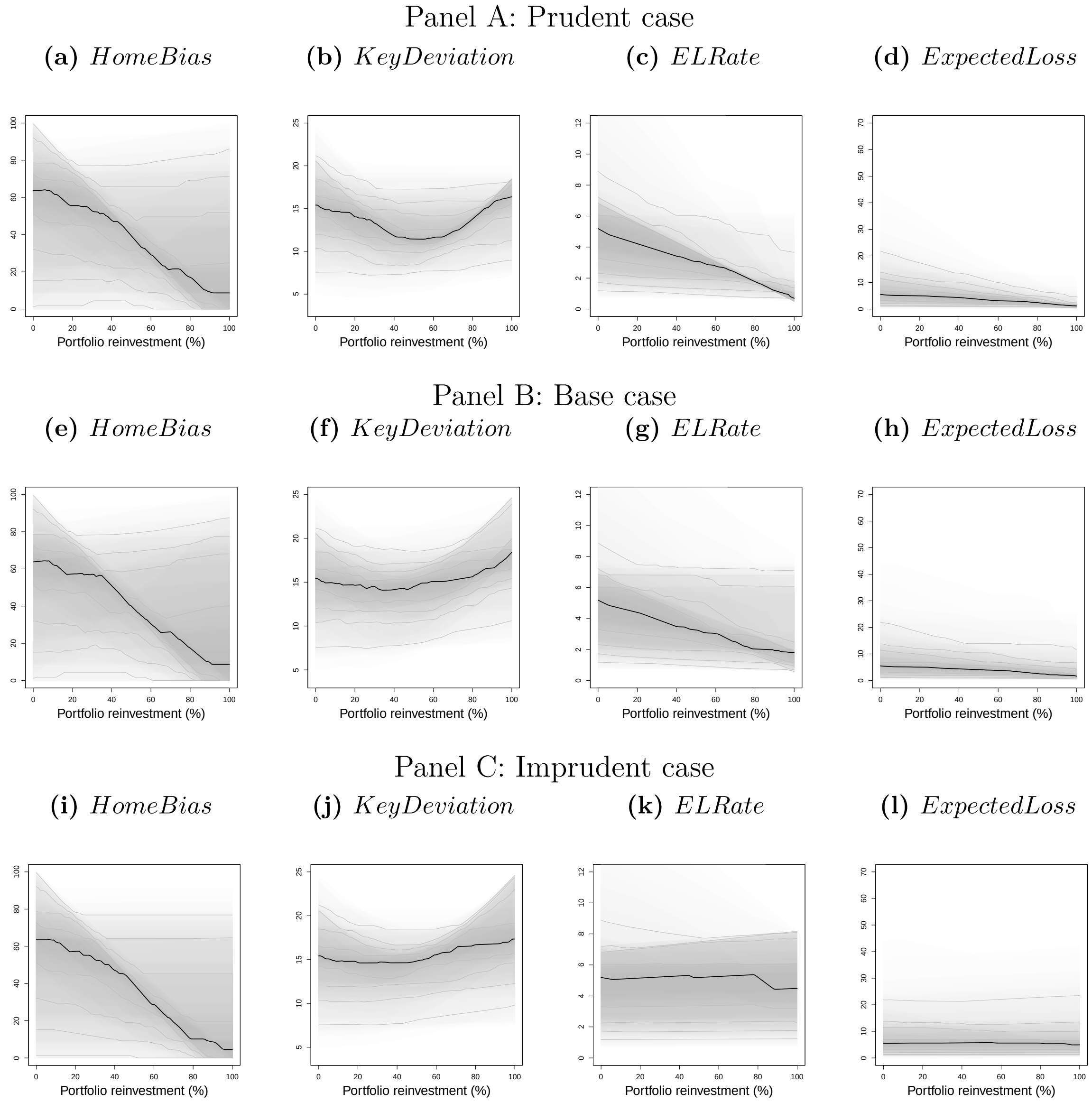

Panel C: Imprudent case

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




Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table 4, as a function of the percentage of banks' sovereign portfolios that is reallocated. 0% reinvestment corresponds to Table 4 and 100% reallocation corresponds to Table 5. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond.

**Figure 3:** Price-based reform to target credit risk

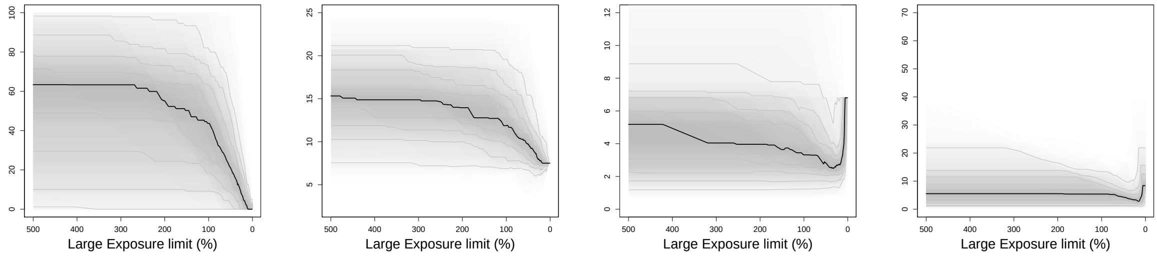



Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table 4, as a function of the percentage of banks' sovereign portfolios that is reallocated. 0% reallocation corresponds to Table 4 and 100% reallocation corresponds to Table 6. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond.

**Figure 4:** Quantity-based reform to target concentration

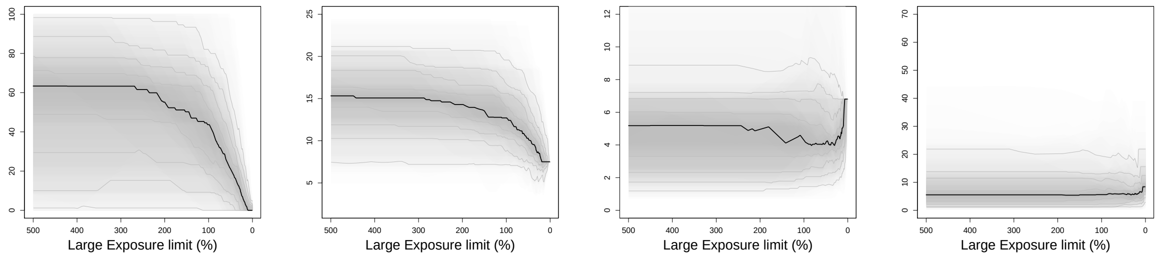
Panel A: Prudent case

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



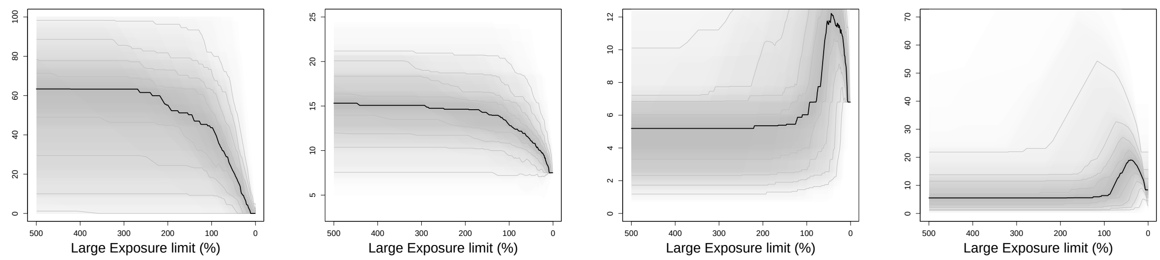

Panel B: Base case

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



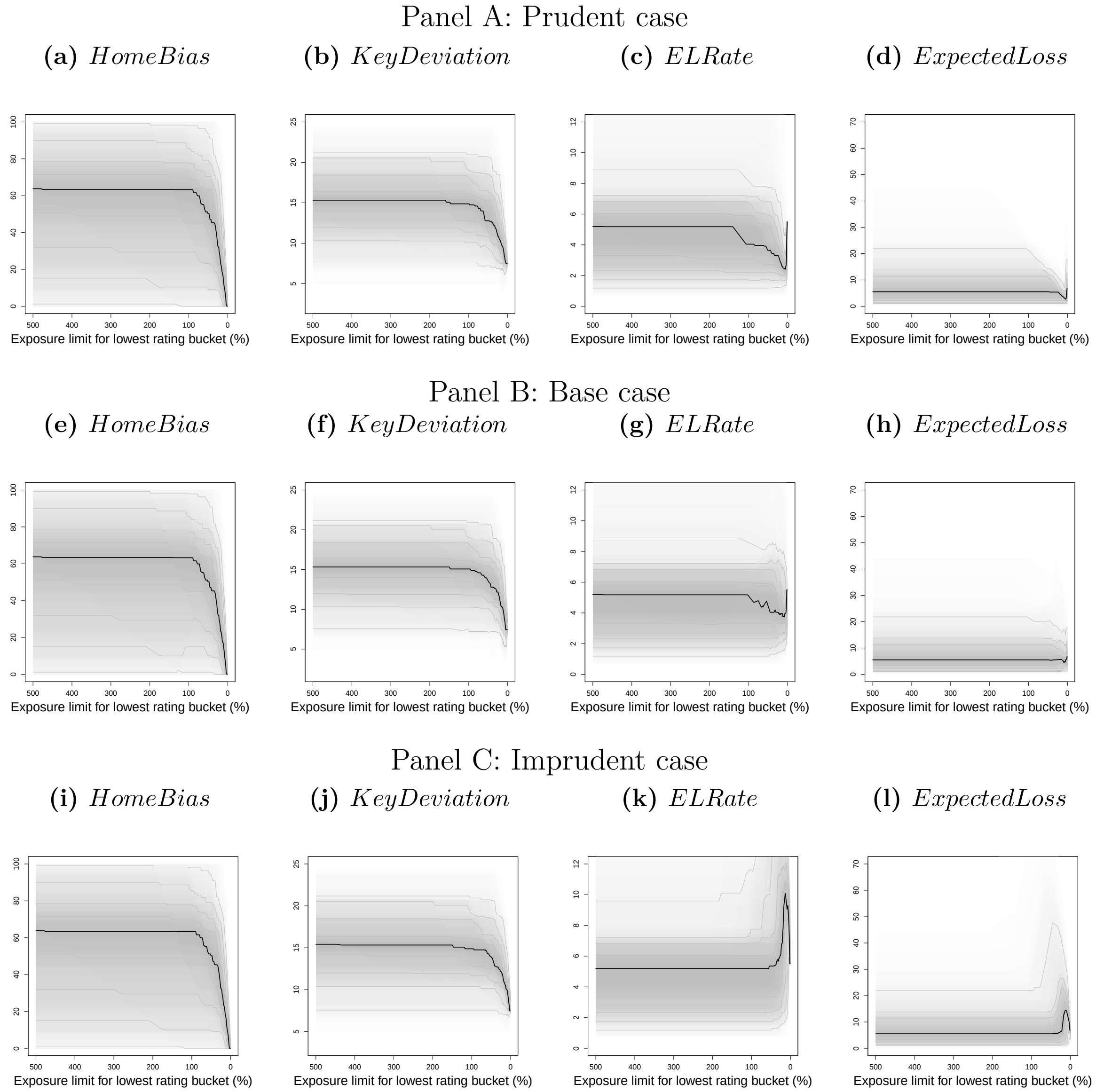

Panel C: Imprudent case

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




Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table 4, as a function of the large exposure limit (expressed as a percentage of Tier 1 capital), where a 25% limit corresponds to the summary statistics reported in Table 7. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond.

**Figure 5:** Quantity-based reform to target credit risk

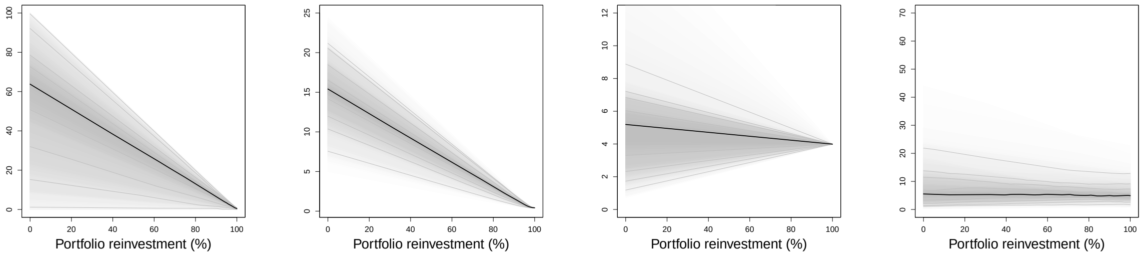



Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table 4, as a function of the large exposure limit (expressed as a percentage of Tier 1 capital) for the lowest sovereign credit rating bucket (CCC+ to D), where a 25% limit corresponds to the summary statistics reported in Table 8. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond.

**Figure 6:** Reinvestment into an area-wide asset

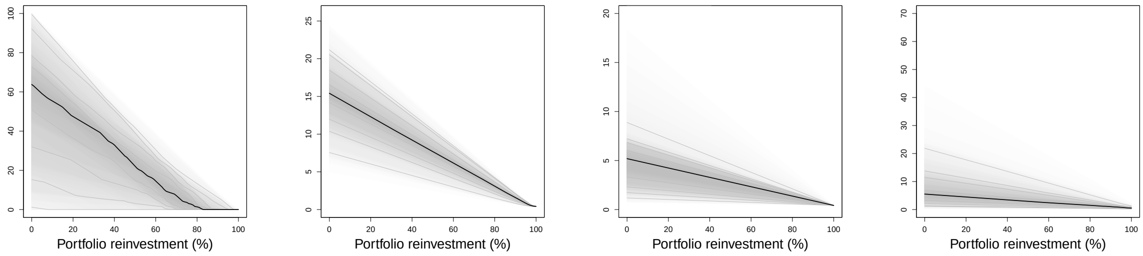
Panel A: Area-wide asset without credit protection

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




Panel B: Area-wide low-risk asset

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




Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table 4, as a function of the percentage of banks' mid-2017 sovereign portfolios that is reallocated into a sovereign portfolio with weights given by the ECB capital key. Panel A reports results for a portfolio with no credit protection; Panel B shows results for a portfolio with credit protection (e.g. from tranching). In both panels, 0% reallocation corresponds to Table 4. 100% reallocation corresponds to negligible *HomeBias* and *KeyDeviation* for all banks. By contrast, the simulation results for *ELRate* and *ExpectedLoss* vary across the two panels. In Panel A (with no credit protection), $ELRate = 4.4\%$ for all banks after 100% of portfolio reallocation, compared with $ELRate = 0.42\%$ in Panel B (with credit protection).