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Regulating the doom loop

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.

Keywords: Bank regulation, sovereign risk, systemic risk
JEL codes: G01, G11, G21, G28

Non-technical summary

During crises, bank risk and sovereign risk interact to create additional risk endogenously. Although euro area governments have recognized the imperative of breaking this "doom loop", bank regulation still treats sovereign debt as risk-free, and there is no consensus on whether and how to reform it.

To inform policy discussions, we model portfolio reallocation by euro area banks following regulatory reforms discussed by the Basel Committee on Banking Supervision (2017). Banks reallocate their sovereign portfolio to minimize capital requirements. Subject to this, banks have degrees of freedom in portfolio allocation. To quantify the range of portfolios, we define the limiting cases of "prudence", in which banks reinvest into the lowest-risk sovereign bond(s), and "imprudence", in which banks reinvest into the highest-risk bond(s). We also define an intermediate "base case" in which banks replicate the credit risk properties of their initial portfolio.

We find that regulatory reforms targeting portfolio concentration indeed reduce banks' home bias, but are consistent with increased sovereign credit risk exposure. Conversely, reforms aimed at reducing credit risk exposure can exacerbate concentration. None of the envisaged reforms unambiguously reduce both concentration and credit risk. Consequently, reforms could strengthen the doom loop through cross-border contagion.

These findings reflect the incompleteness of euro area sovereign debt markets. A portfolio with both low concentration and low credit risk can only be assembled if the investible universe is expanded to include a security that entails both properties. In a final step, we apply our model to a world in which national sovereign debt exists alongside an asset that is both *area-wide* and *low-risk*. Strikingly, none of the envisaged reforms would provide strong regulatory incentives for banks to reinvest into such an asset, since they allow multiple solutions to the constrained optimization problem. To strengthen regulatory incentives, one option would be to set a positive risk-weight floor on all single-name sovereign holdings. In this setting, holding an area-wide low-risk asset uniquely minimizes capital requirements.

The policy conclusion is that reforming the regulatory treatment of sovereign exposures can complement the introduction of an area-wide low-risk asset. These two initiatives are jointly necessary to break the bank-sovereign doom loop.

"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 concentration 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

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[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.

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

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[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.

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]

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.

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[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 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.

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 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.

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 expo-

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[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).

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

sures.[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]

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 2×2 matrix of reform options, summarized

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[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 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]

- *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.

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[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).

[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, 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

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[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.

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

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 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]

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[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.

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.

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

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[15]In Appendices C and D, 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.

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.

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. Appendices C and 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

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[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.

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 reallocate 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 below BBB− (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 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

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[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.

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 risk weight of zero. For example, under the calibration given above, banks can freely hold up to 25% of

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[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.

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 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

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[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).

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

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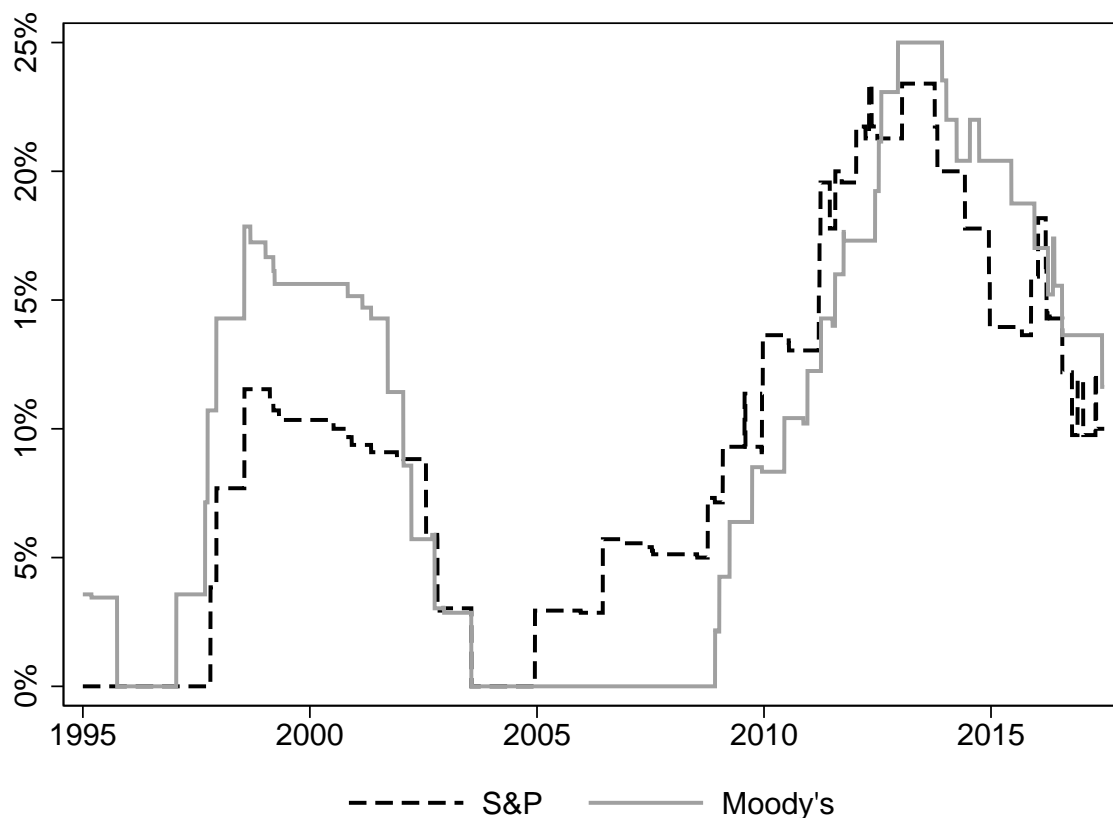
Note: This figure plots the probability of a sovereign rating transitioning from A− or higher to below A− over five years. To calculate transition probabilities, we collect historical data on sovereign ratings assigned to 102 countries globally by S&P and Moody's (Fitch ratings have a shorter time series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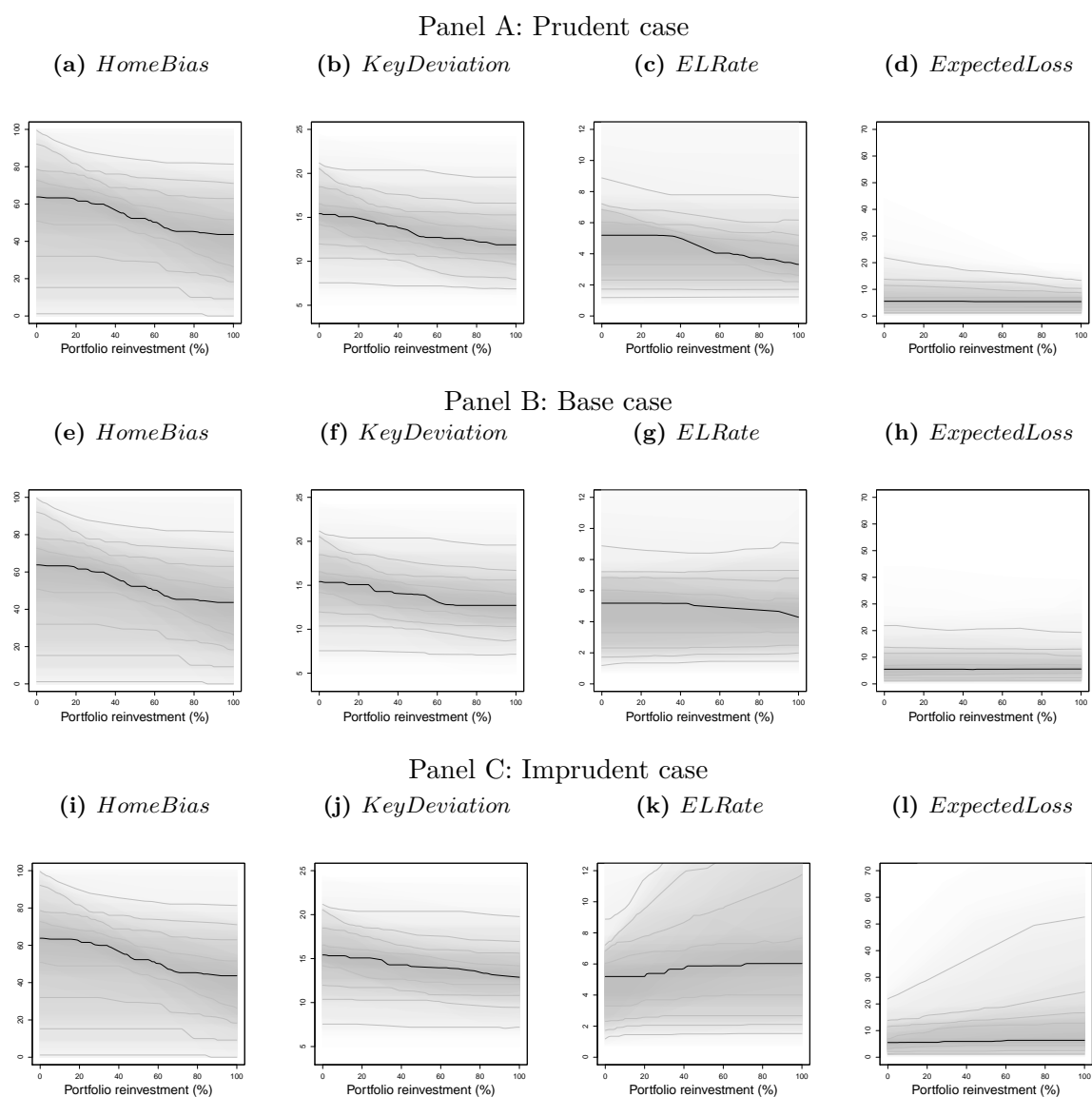
Panel A: Prudent case

(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
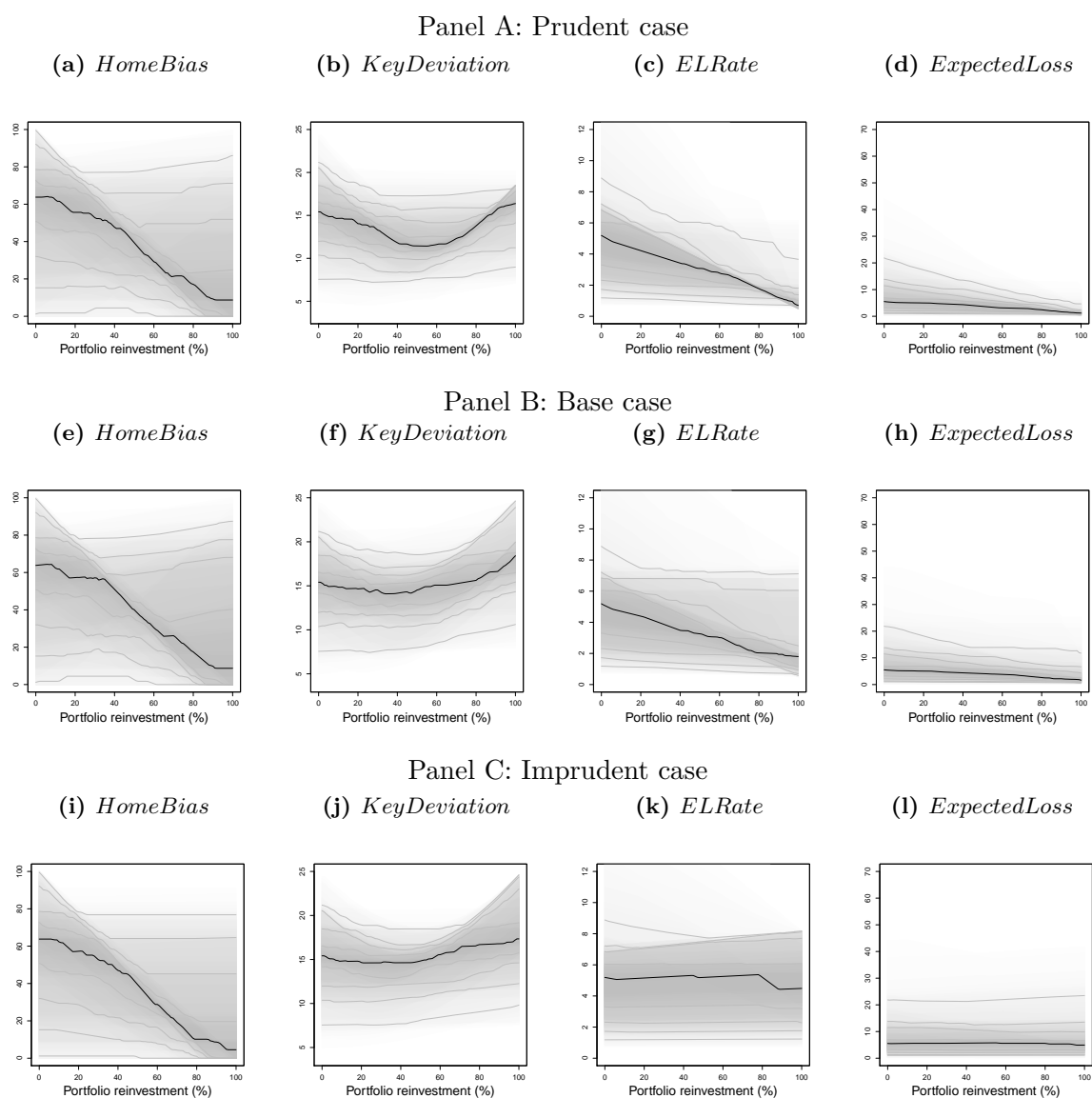
Panel A: Prudent case

(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% 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
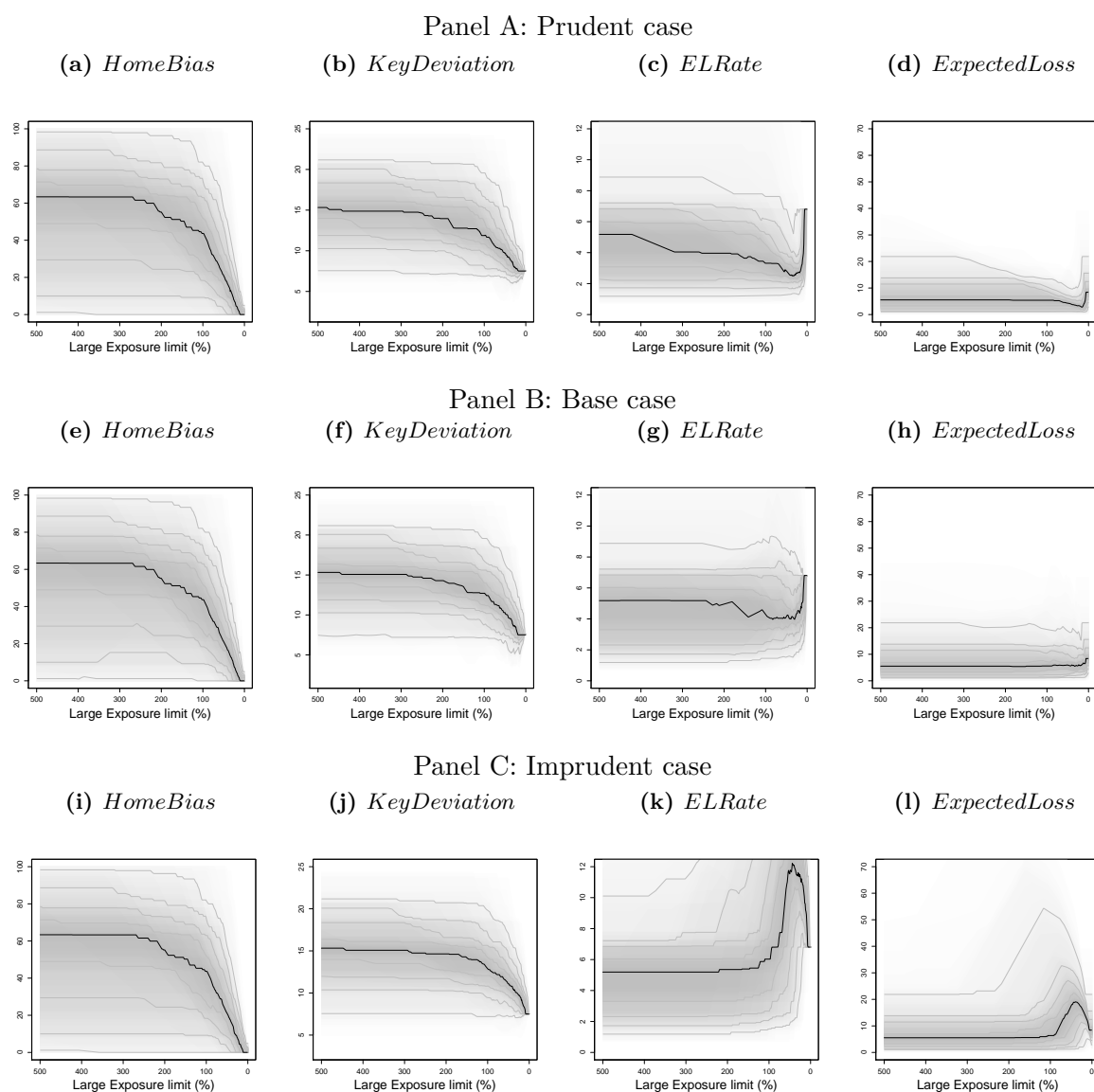
Panel A: Prudent case

(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
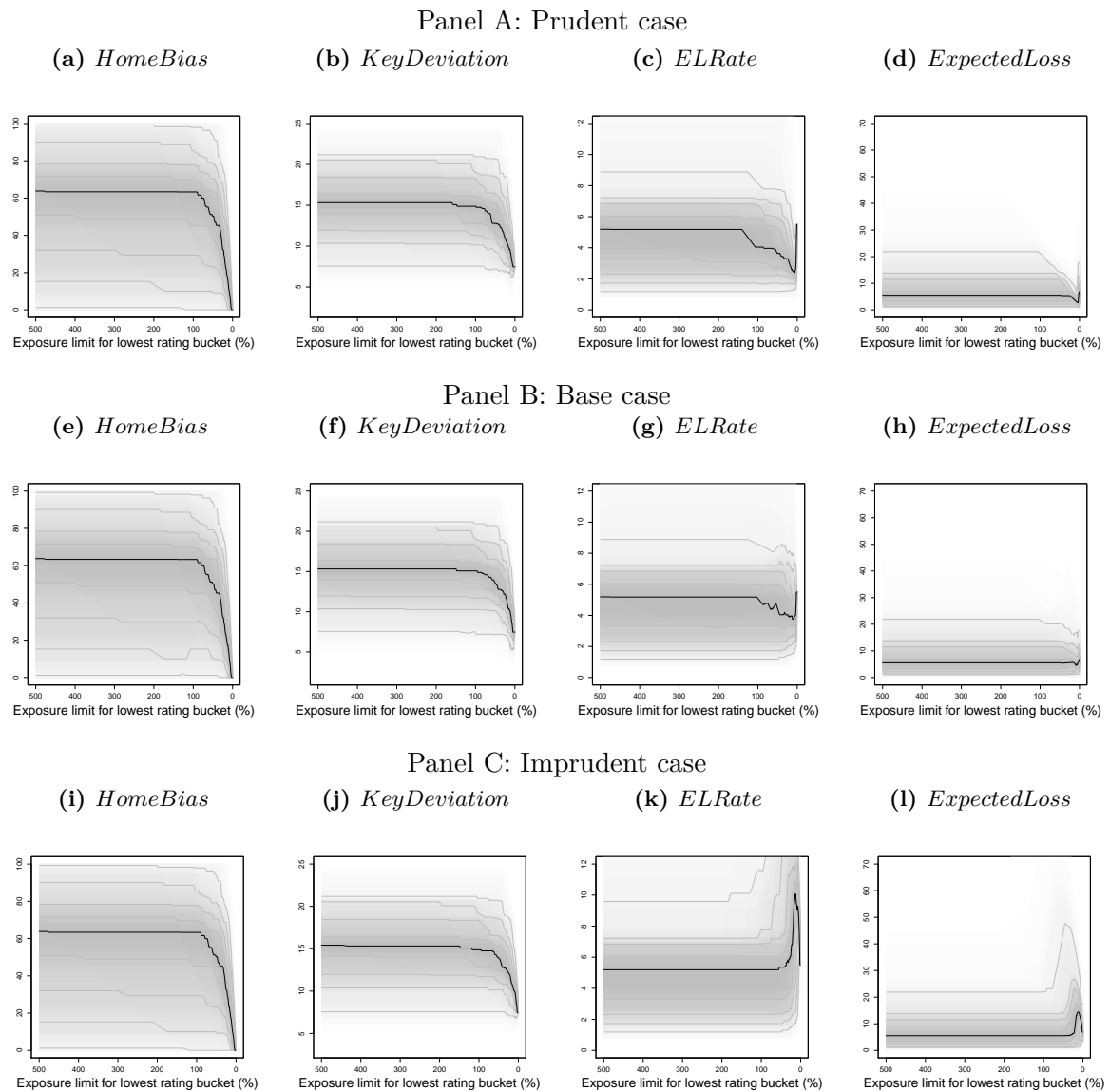
Panel A: Prudent case

(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) 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*
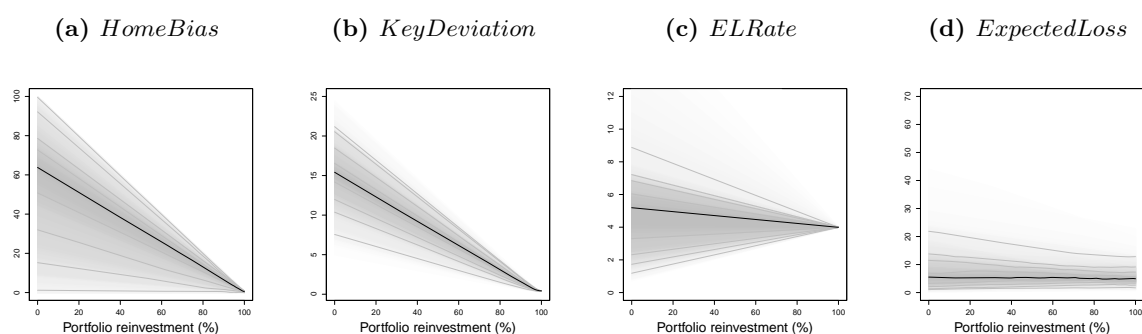
Panel B: Area-wide low-risk asset
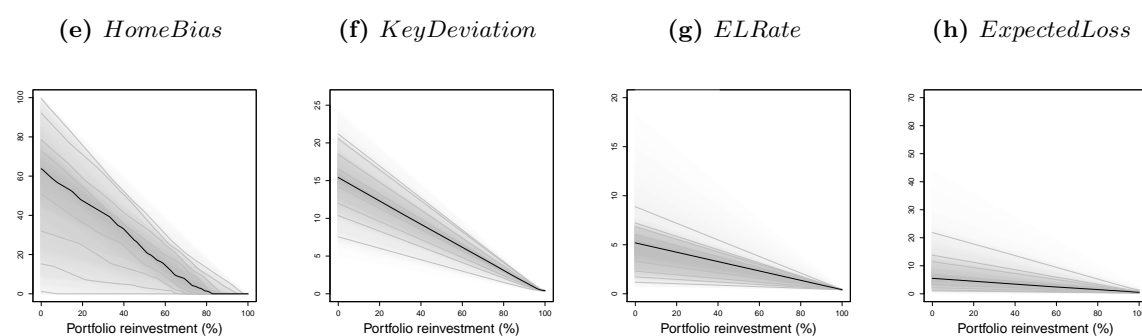
(e) *HomeBias*   **(f)** *KeyDeviation*   **(g)** *ELRate*   **(h)** *ExpectedLoss*

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).

Appendix

This appendix contains the following sections:

- Appendix A reports an illustrative application of the portfolio reallocation model to a hypothetical bank.

- Appendix B reports bank-level statistics for sovereign exposures as of mid-2017.

- Appendix C reproduces tables and figures from the main paper using bank exposure data from end-2010.

- Appendix D reproduces tables and figures from the main paper using bank exposure data from end-2011.

- Appendix E reproduces tables and figures from the main paper using bank exposure data from mid-2017 and under the assumption that an area-wide low-risk asset exists as part of the portfolio opportunity set.

- Appendix F reproduces tables and figures from the main paper using bank exposure data from mid-2017 and under two assumptions: (i) an area-wide low-risk asset exists as part of the portfolio opportunity set and (ii) price-based regulatory reforms also include a minimum positive risk weight for all single-name sovereign exposures.

Appendix A: Illustrative application of the simulation model

Table A.1 provides an illustrative application of our model of endogenous portfolio reallocation to a hypothetical Italian bank endowed with a sovereign portfolio of 100 units, comprising 75 units of Italian, 20 units of German, and 5 units of French bonds. These assets are funded with 30 units of equity (Tier 1 capital) and 70 units of debt. The table shows portfolio allocations under the three reallocation cases applied to the four regulatory reforms. In all columns, the bank maintains its aggregate sovereign bond holdings at 100 units, and cannot reallocate those holdings to further reduce capital requirements. In the regulatory status quo, these two conclusions hold by construction, since the hypothetical bank begins with a sovereign portfolio of 100 units to which current regulation applies no capital charge. In subsequent columns, the bank chooses a portfolio under the respective reallocation rule that attracts a globally minimal capital charge according to a given regulatory reform. In particular, the bank reallocates its portfolio as follows:

- Under *price-based reform to target concentration*, the bank divests its single-name holdings in excess of 100% of Tier 1 capital, i.e. $75 - 30 = 45$ of Italian bond holdings. In the prudent case, this 45 unit excess is reinvested into the lowest-risk sovereigns, i.e. Germany up to the 30 unit limit followed by the Netherlands, 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 an *ELRate* that most closely matches the initial portfolio, namely 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.

- Under *price-based reform to target credit risk*, the hypothetical bank divests all 75 units of its Italian holdings, since these attract a risk weight of 4%. 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 entirely into the highest-risk sovereign bond with a 0% risk weight, which happens to be Slovenia.

- Under *quantity-based reform to target concentration*, the bank divests its single-name holdings in excess of 25% of Tier 1 capital, i.e. all holdings in excess of $0.25 \times 30 = 7.5$ units. This implies an excess of $75 - 7.5 = 67.5$ for its Italian holdings and $20 - 7.5 = 12.5$ for its

German holdings, for a total excess of 80 units. In the prudent case, this 80 unit excess is reinvested into the lowest-risk sovereigns up to the 7.5 unit limit, which takes the bank from the Netherlands to Latvia inclusive; in the base case, the bank increases its holdings of French bonds by 2.5 units, and then invests the 7.5 unit maximum in countries in order of their proximity to the credit risk of the initial portfolio; in the imprudent case, the excess is reinvested into the highest-risk sovereigns from Greece to Estonia inclusive.

- Under *quantity-based reform to target credit risk*, the bank divests its single-name holdings in excess of a fraction of Tier 1 capital given by a sovereign's credit ratings. For the hypothetical bank, this constraint applies only to its Italian holdings, which have a $BBB-$ rating and therefore a 75% large exposure limit. The bank therefore divests $75 - (0.75 \times 30) = 52.5$ of its Italian holdings. In the prudent case, this 52.5 unit excess is reinvested into the lowest-risk sovereigns, as in the previous reform scenario; in the base case, the excess is divided proportionally between German and French bonds, with the residual 17.5 units reinvested into Slovakia; in the imprudent case, the excess is reinvested into the highest-risk sovereigns up to the respective large exposure limit, i.e. Greece, Cyprus and Portugal (in that order).

Computing measures of portfolio concentration and credit risk provides early intuition of the results that we obtain using data on banks' actual sovereign exposures. For each of the four reform scenarios, the credit risk of the resulting portfolio is weakly lowest in the prudent case and highest in the imprudent case, with the base case representing an interior solution. In the case of this hypothetical bank, the degrees of freedom in portfolio reallocation following regulatory reform are such that all reform scenarios are consistent with increased sovereign credit risk exposure in the imprudent case relative to the status quo. Moreover, while home bias unambiguously decreases in all reform scenarios, price-based reform to target credit risk is consistent with the hypothetical bank increasing its portfolio concentration (as measured by HHI and $KeyDeviation$).

Table A.1: Illustrative portfolio reallocation under four regulatory reform scenarios

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

Note: This table illustrates portfolio reallocation for a stylized Italian bank funded by 30 units of Tier 1 capital and with initial ("status quo") holdings of 75 units of Italian, 20 units of German, and 5 units of French sovereign bonds. The table reports 12 sovereign portfolio reallocations, namely four regulatory reform scenarios crossed with three cases—"prudent", "base" and "imprudent"—that determine the portfolio allocation rule that banks adopt. $Exp/T1$ refers to a bank's holdings of bonds 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 bonds 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. 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 and VaR refers to the minimum percentage reduction in portfolio value that occurs over five years with 1% probability. $ExpectedLoss$ 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.

Appendix B: Individual bank sovereign exposures (mid-2017)

Table B.1 reports bank-level statistics on sovereign exposures as of mid-2017. The sample includes 95 banks located in 17 different countries. 57 of these banks have a sovereign exposure that exceeds their Tier 1 capital. Moreover, home bias is widespread: only 10 banks do not exhibit any home bias. The resulting portfolio concentration is reflected in generally high values of HHI and $KeyDeviation$. In terms of credit risk, banks exhibit significant heterogeneity. Due to home bias, the most heavily exposed bank is located in the riskiest country, namely Greece.

Table B.1: 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

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

Table B.1 (continued from previous page)

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

Table B.1 continues on next page...

Table B.1 (continued from previous page)

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 bonds 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 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 and VaR refers to the minimum percentage reduction in value that would occur over five years with 1% probability.

Appendix C: Robustness to exposure data from end-2010

We report simulation results using exposure data from end-2010, when the EBA publicly disclosed euro area banks' sovereign exposures for the first time. This older vintage covers 75 banks located in 15 countries. Summary statistics for these older exposures data are shown in Table C.1. Compared with mid-2017, bank exposures are 45 percentage points higher on average, with $Exp/T1 = 216\%$. Moreover, portfolios generally exhibit higher levels of concentration and credit risk. From the perspective of the doom loop, end-2010 exposure data therefore represent a more severe initial condition.

Subsequent tables and figures reproduce the standard set of simulation results for each of the four regulatory reform scenarios. Despite the aggravated initial condition as of end-2010, the prudent case generates outcomes in terms of concentration and credit risk that are comparable to those obtained using mid-2017 data. By contrast, the base case and in particular the imprudent case demonstrate higher levels of concentration and credit risk. Consequently, greater severity in initial conditions widens the range of outcomes associated with the prudent and imprudent cases, exacerbating uncertainty regarding banks' portfolio reallocation decisions. In turn, this implies more ambiguity regarding equilibrium outcomes for the doom loop.

Table C.1: Summary statistics on bank sovereign exposures (end-2010)

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	216	206	79	107	159	240	392
HomeBias	76	27	30	60	88	98	100
HHI	72	27	28	45	81	97	100
KeyDeviation	18	5	9	14	20	22	23
ELRate	8.4	9.0	1.7	3.7	6.8	7.2	26.3
VaR	69	18	40	55	79	80	90
ExpectedLoss	19.4	44.2	2.7	5.3	8.9	14.3	33.1
UnexpectedLoss	139	126	55	84	112	168	238

Note: This table reports summary statistics on banks' sovereign bond holdings as of end-2010 according to the EBA. $Exp/T1$ 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 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 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 and VaR refers to the minimum percentage reduction in value that would occur over five years with 1% probability. $ExpectedLoss$ and $UnexpectedLoss$ are calculated by multiplying $Exp/T1$ by $ELRate$ and VaR respectively.

Table C.2: Price-based reform to target concentration (end-2010)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	216	206	79	107	159	240	392
$HomeBias$	49	31	7	25	45	73	99
HHI	48	26	20	26	42	64	98
$KeyDeviation$	13	5	7	10	12	17	22
$ELRate$	6.2	5.8	1.8	3.3	4.8	6.8	12.3
VaR	62	14	44	50	61	75	80
$ExpectedLoss$	11.3	11.5	2.7	5.3	7.7	9.8	36.0
$UnexpectedLoss$	122	110	55	83	100	129	175

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	216	206	79	107	159	240	392
$HomeBias$	49	31	7	25	45	73	99
HHI	49	26	21	28	44	64	98
$KeyDeviation$	14	5	7	9	14	18	22
$ELRate$	7.9	6	3.5	4.6	6.6	8.2	15.2
VaR	71	12	53	62	73	80	83
$ExpectedLoss$	17.1	19.8	3.7	6.7	9.5	20.3	37.5
$UnexpectedLoss$	149	139	55	85	112	161	267

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	216	206	79	107	159	240	392
$HomeBias$	49	31	7	25	45	73	99
HHI	48	26	20	27	41	64	98
$KeyDeviation$	15	5	8	11	15	18	22
$ELRate$	12.2	6.8	3.9	6.8	11.4	16.9	19.8
VaR	75	12	56	67	80	84	87
$ExpectedLoss$	27.9	25.7	3.7	7.7	18.6	43.3	57.6
$UnexpectedLoss$	163	158	55	85	119	192	281

Note: Using exposures data from end-2010, this table shows the simulation results for price-based reform to target concentration in the limiting case of full reinvestment. 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% reinvestment shown in Figure C.1. Variables are defined in the note to Table C.1.

Table C.3: Price-based reform to target credit risk (end-2010)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	216	206	79	107	159	240	392
HomeBias	29	38	0	0	0	62	94
HHI	81	25	40	64	95	100	100
KeyDeviation	17	3	12	16	18	18	18
ELRate	1.1	1.4	0.5	0.5	0.6	1.0	2.3
VaR	38	11	32	32	33	38	55
ExpectedLoss	2.2	2.7	0.4	0.7	1.2	2.3	5.0
UnexpectedLoss	79	69	27	42	59	93	149

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	216	206	79	107	159	240	392
HomeBias	32	40	0	0	0	75	94
HHI	85	22	43	81	97	100	100
KeyDeviation	20	4	13	17	20	24	25
ELRate	3.2	2.7	0.5	0.7	1.9	6.1	6.8
VaR	55	18	32	33	59	75	75
ExpectedLoss	5.0	4.5	1.0	1.5	2.8	7.8	10.8
UnexpectedLoss	103	70	44	59	89	131	174

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	216	206	79	107	159	240	392
HomeBias	26	34	0	0	0	58	86
HHI	77	27	31	48	89	99	100
KeyDeviation	20	5	11	16	23	25	25
ELRate	5.8	2.8	1.3	2.8	7.8	8.2	8.2
VaR	67	16	40	54	78	80	80
ExpectedLoss	10.8	10.5	2.4	4.4	9.1	13.0	18.6
UnexpectedLoss	134	111	55	80	110	157	219

Note: Using exposures data from end-2010, this table shows the simulation results for price-based reform to target credit risk in the limiting case of full reinvestment. 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% reinvestment shown in Figure C.2. Variables are defined in the note to Table C.1.

Table C.4: Quantity-based reform to target concentration (end-2010)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	216	206	79	107	159	240	392
$HomeBias$	12	18	0	0	7	16	23
HHI	17	16	6	10	15	20	27
$KeyDeviation$	9	3	7	7	8	10	11
$ELRate$	3.7	2.0	1.9	2.2	3.0	4.7	6.8
VaR	52	8	45	47	50	55	65
$ExpectedLoss$	9.5	14.7	2.0	2.8	4.4	9.3	18.0
$UnexpectedLoss$	121	140	37	52	77	127	242

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	216	206	79	107	159	240	392
$HomeBias$	12	18	0	0	7	16	23
HHI	18	16	6	10	15	21	27
$KeyDeviation$	9	3	6	7	8	11	12
$ELRate$	7.8	3.4	4.3	6.1	7.3	8.8	12.7
VaR	69	9	57	64	69	77	80
$ExpectedLoss$	16.2	14.4	4.1	7.8	14.5	19.8	29.0
$UnexpectedLoss$	147	135	57	78	116	164	253

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	216	206	79	107	159	240	392
$HomeBias$	12	18	0	0	7	16	23
HHI	17	16	6	10	14	20	27
$KeyDeviation$	10	3	8	8	10	12	14
$ELRate$	12.3	3.9	6.8	9.4	12.0	14.9	17.5
VaR	78	8	66	72	80	85	87
$ExpectedLoss$	22.6	12.8	12.5	17.4	20.8	26.1	31.7
$UnexpectedLoss$	161	135	63	89	125	186	283

Note: Using exposures data from end-2010, this table shows the simulation results for quantity-based reform to target concentration. 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 C.3. Variables are defined in the note to Table C.1.

Table C.5: Quantity-based reform to target credit risk (end-2010)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	216	206	79	107	159	240	392
$HomeBias$	39	27	3	21	35	54	87
HHI	41	22	20	26	37	49	79
$KeyDeviation$	12	4	7	9	11	14	19
$ELRate$	4.8	3.3	1.8	2.8	4.1	6.0	7.4
VaR	57	12	42	48	56	64	75
$ExpectedLoss$	8.8	8.2	2.7	5.1	6.4	9.3	18.8
$UnexpectedLoss$	114	110	55	68	89	114	175

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	216	206	79	107	159	240	392
$HomeBias$	39	27	3	21	36	54	87
HHI	41	22	18	25	37	50	79
$KeyDeviation$	13	5	6	9	13	16	20
$ELRate$	7.1	4.4	3.1	4.1	6.5	8.0	14.0
VaR	68	12	52	58	68	80	83
$ExpectedLoss$	14.5	14.1	3.7	6.2	9.6	20.1	28.0
$UnexpectedLoss$	143	131	55	84	104	154	264

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	216	206	79	107	159	240	392
$HomeBias$	40	27	3	21	36	54	87
HHI	37	23	16	21	30	48	79
$KeyDeviation$	13	4	7	10	13	16	19
$ELRate$	11.8	5.5	3.9	7.9	12.2	16.2	18.0
VaR	75	12	56	67	81	85	86
$ExpectedLoss$	24.4	17.7	3.7	8.6	23.6	34.3	42.6
$UnexpectedLoss$	160	147	55	86	122	186	275

Note: Using exposures data from end-2010, this table shows the simulation results for quantity-based reform to target credit risk. 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 C.4. Variables are defined in the note to Table C.1.

Figure C.1: Price-based reform to target concentration (end-2010)
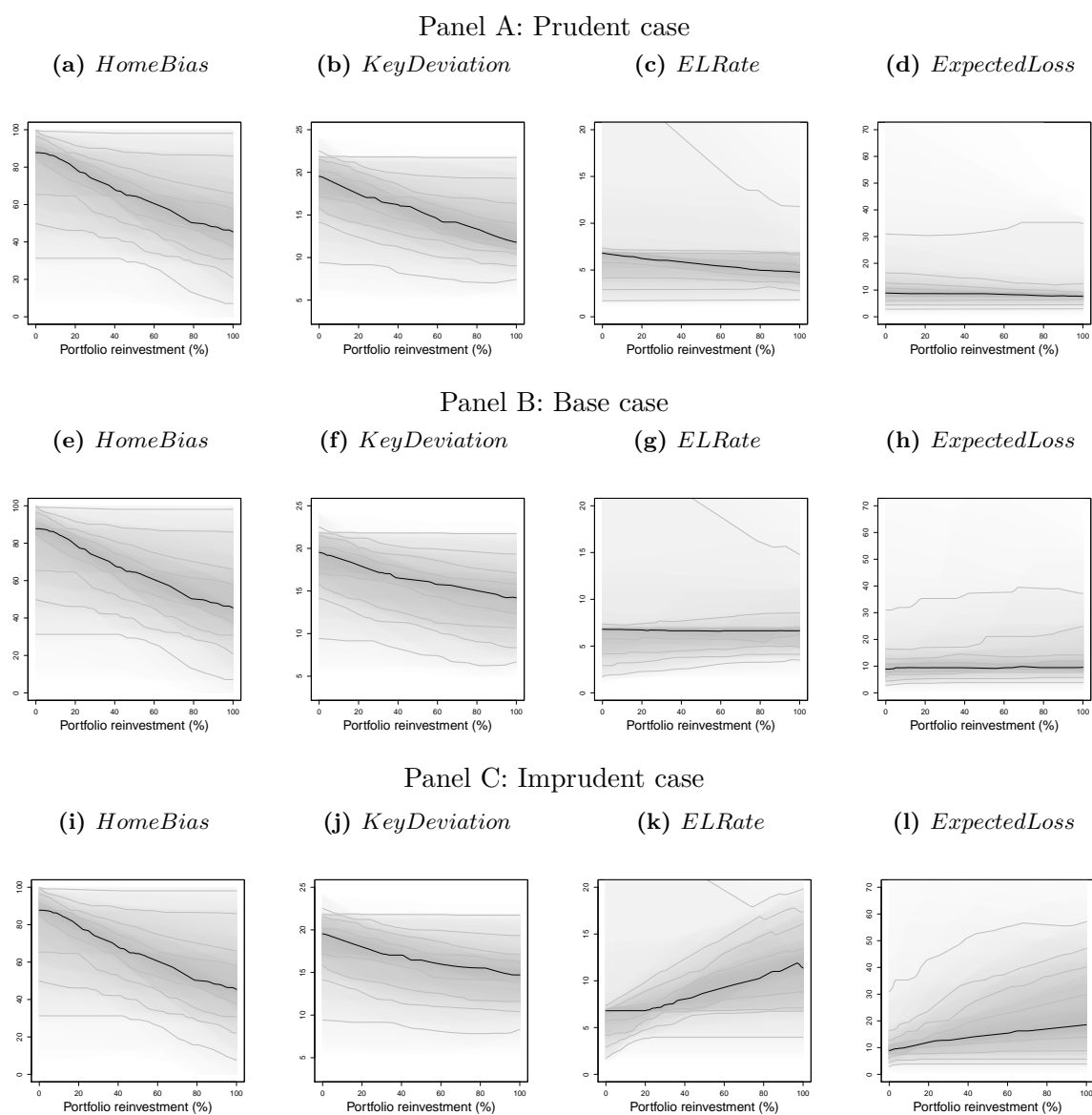
Panel A: Prudent case

(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: Using exposures data from end-2010, this figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table C.1, as a function of the percentage of banks' sovereign bond portfolios that is reinvested. 0% reinvestment corresponds to Table C.1 and 100% reinvestment corresponds to Table C.2. 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 C.2: Price-based reform to target credit risk (end-2010)
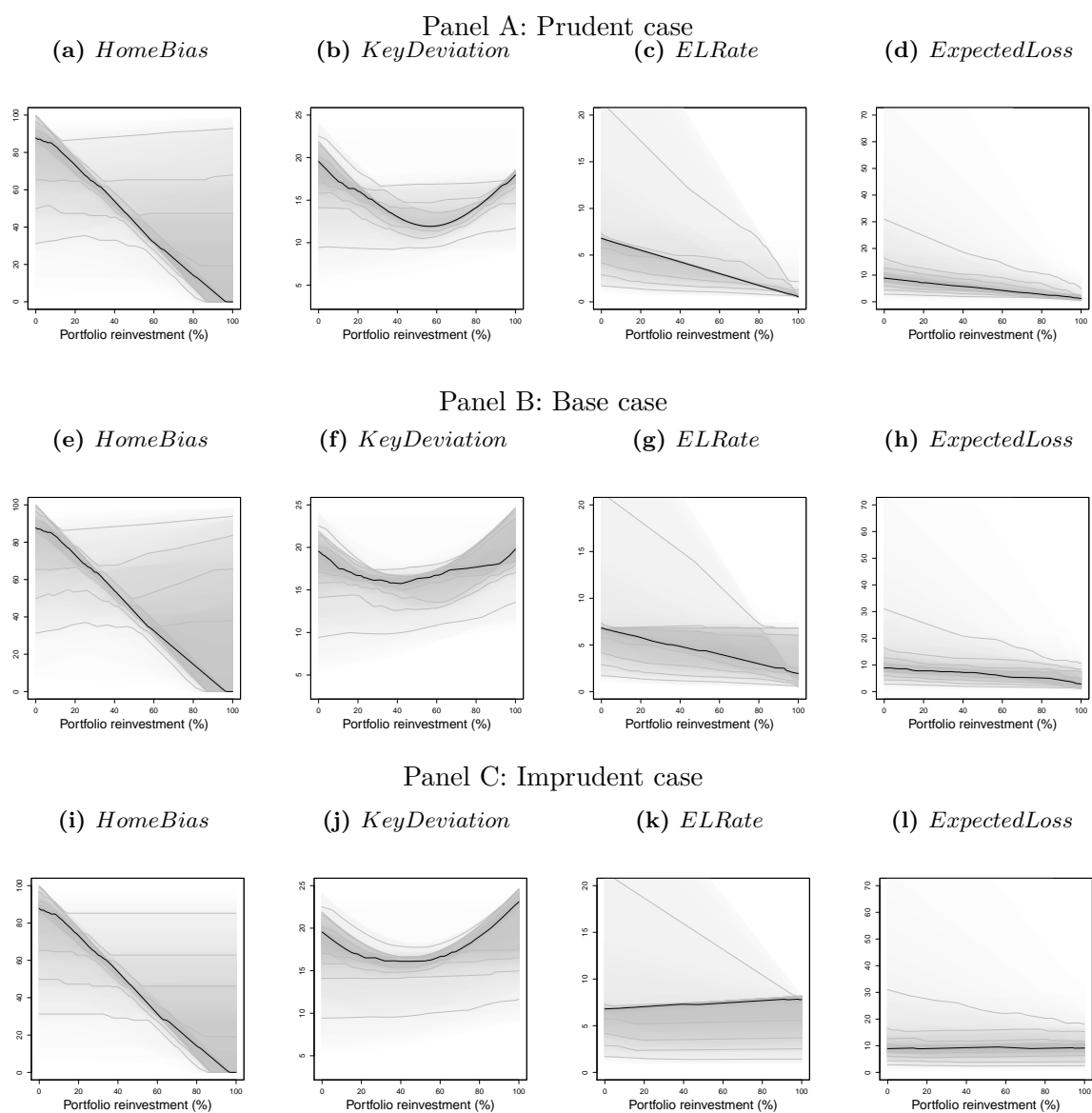
Panel A: Prudent case

(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: Using exposures data from end-2010, this figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table C.1, as a function of the percentage of banks' sovereign bond portfolios that is reinvested. 0% reinvestment corresponds to Table C.1 and 100% reinvestment corresponds to Table C.3. 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 C.3: Quantity-based reform to target concentration (end-2010)

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: Using exposures data from end-2010, this figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table C.1, 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 C.4. 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 C.4: Quantity-based reform to target credit risk (end-2010)

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

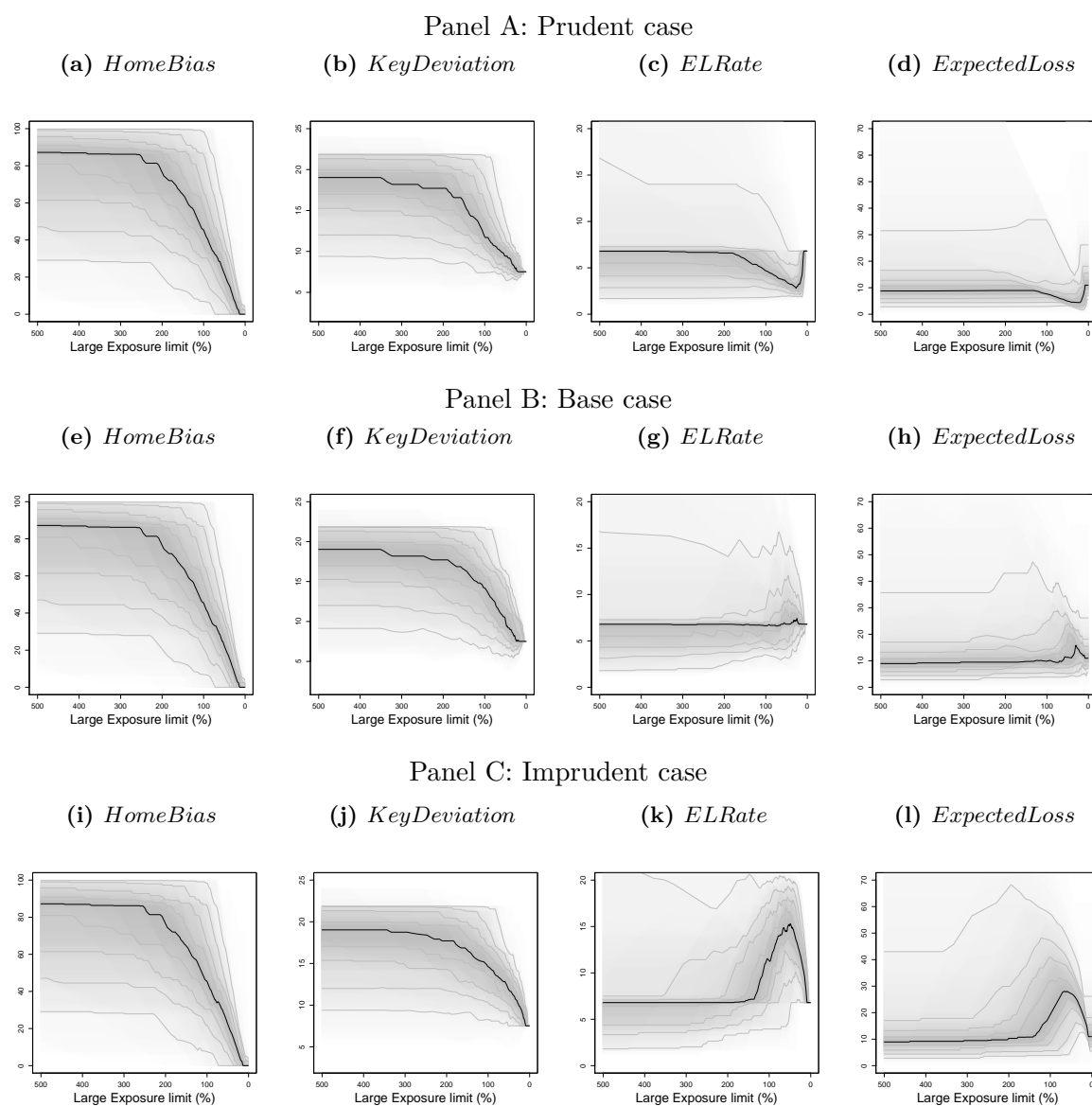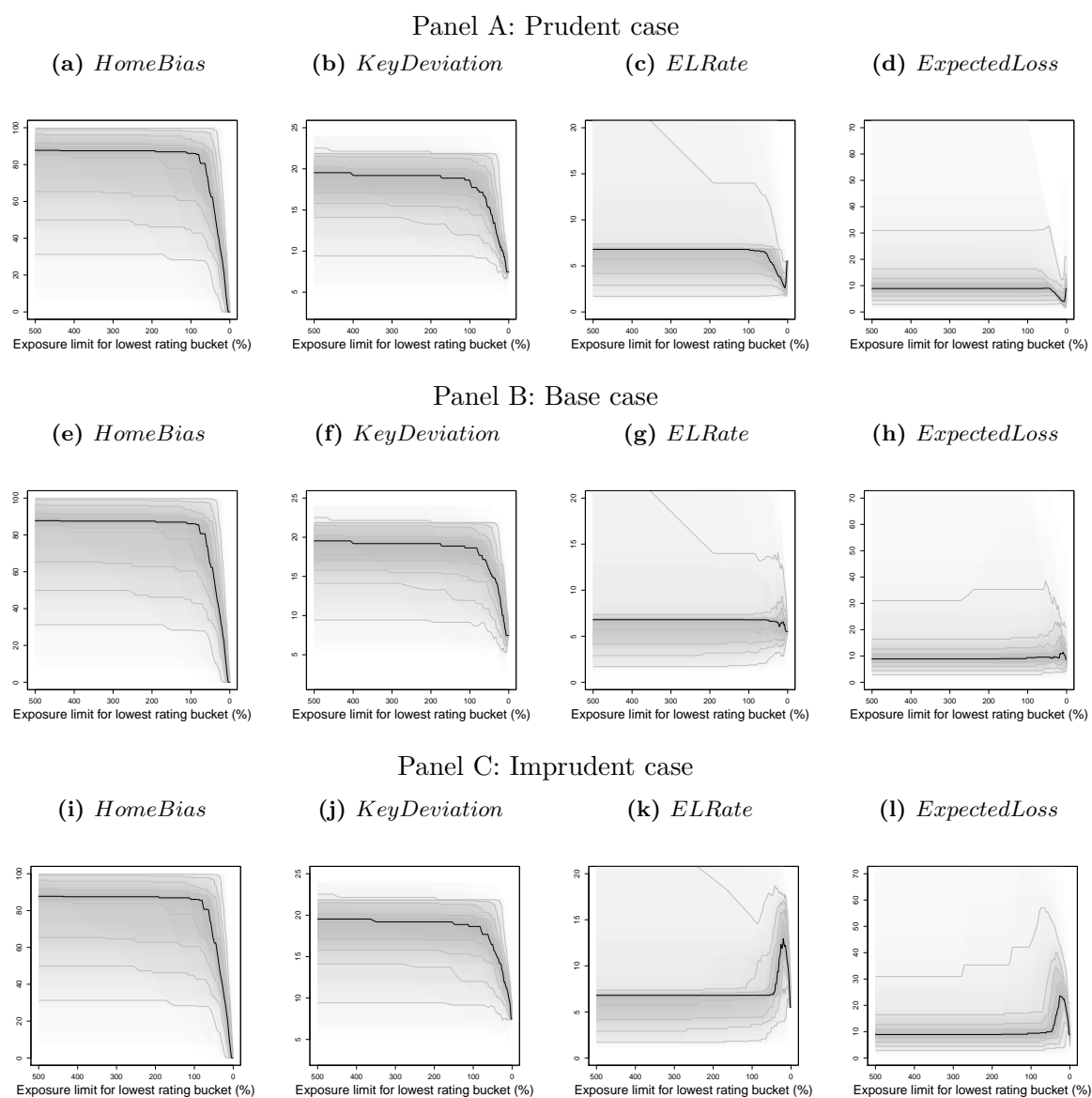**(i)** *HomeBias* **(j)** *KeyDeviation* **(k)** *ELRate* **(l)** *ExpectedLoss*

Note: Using exposures data from end-2010, this figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table C.1, 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 C.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.

Appendix D: Robustness to exposure data from end-2011

We report simulation results using exposure data from end-2011, when the EBA ran an ad hoc recapitalization exercise designed to restore confidence in the European banking sector. This data vintage covers a smaller sample, with 46 banks located in 14 countries. Summary statistics are shown in Table D.1. Compared with end-2010 data, banks generally have larger sovereign exposures relative to capital, but maintain a portfolio allocation with lower concentration and credit risk. This is primarily due to sample selection: in the end-2011 sample, the median bank in terms of $ELRate$ resides in Germany, whereas the median bank in the end-2010 sample is from Spain. Consequently, post-reform portfolios appear somewhat more benign in terms of concentration and credit risk using end-2011 data, although outcomes remain heterogeneous across banks. Compared with mid-2017 data, however, outcomes are more severe, particularly in the imprudent case. This reflects reductions in banks' sovereign exposures between 2011 and 2017.

Table D.1: Summary statistics on bank sovereign exposures (end-2011)

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	238	228	59	119	175	286	502
HomeBias	69	26	29	51	73	93	98
HHI	63	25	34	39	66	89	96
KeyDeviation	16	5	8	14	16	20	23
ELRate	5.6	5.6	1.0	2.0	4.4	7.0	11.5
VaR	61	18	36	43	61	79	84
ExpectedLoss	13.3	29.2	1.8	3.5	6.7	13.0	21.7
UnexpectedLoss	132	115	37	67	102	146	211

Note: This table reports summary statistics on banks' sovereign bond holdings as of end-2011 according to the EBA. $Exp/T1$ 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 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 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 and VaR refers to the minimum percentage reduction in value that would occur over five years with 1% probability. $ExpectedLoss$ and $UnexpectedLoss$ are calculated by multiplying $Exp/T1$ by $ELRate$ and VaR respectively.

Table D.2: Price-based reform to target concentration (end-2011)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	238	228	59	119	175	286	502
$HomeBias$	43	30	0	21	42	59	88
HHI	41	23	17	24	36	49	80
$KeyDeviation$	13	5	8	10	11	15	19
$ELRate$	4.6	3.8	1.1	2.0	3.9	5.7	9.0
VaR	57	15	37	44	57	69	79
$ExpectedLoss$	9.5	11.7	1.8	3.5	6.7	8.8	17.5
$UnexpectedLoss$	125	123	37	67	99	136	193

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	238	228	59	119	175	286	502
$HomeBias$	43	29	0	21	42	59	88
HHI	42	22	17	26	37	50	80
$KeyDeviation$	13	5	7	8	12	15	20
$ELRate$	5.9	3.9	2.0	3.5	5.0	7.0	10.4
VaR	65	13	45	60	63	79	81
$ExpectedLoss$	15.0	20.5	1.8	4.7	9.0	16.7	22.2
$UnexpectedLoss$	156	161	37	67	115	177	350

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	238	228	59	119	175	286	502
$HomeBias$	43	29	0	21	42	59	88
HHI	41	23	17	23	36	49	80
$KeyDeviation$	14	5	8	10	13	17	20
$ELRate$	10.4	5.9	2.0	5.0	11.2	15.6	17.1
VaR	70	14	48	61	72	83	85
$ExpectedLoss$	28.3	27.9	1.8	4.7	19.4	46.2	71.1
$UnexpectedLoss$	171	174	37	67	126	201	378

Note: Using exposures data from end-2011, this table shows the simulation results for price-based reform to target concentration in the limiting case of full reinvestment. 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% reinvestment shown in Figure D.1. Variables are defined in the note to Table D.1.

Table D.3: Price-based reform to target credit risk (end-2011)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	238	228	59	119	175	286	502
HomeBias	48	39	0	0	55	91	97
HHI	74	24	38	50	87	95	99
KeyDeviation	16	3	11	15	17	18	18
ELRate	1.6	1.9	0.5	0.6	0.8	1.5	5.4
VaR	42	14	32	33	34	47	67
ExpectedLoss	3.1	4.8	0.6	1.0	1.7	2.9	5.6
UnexpectedLoss	93	83	31	41	67	118	196

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	238	228	59	119	175	286	502
HomeBias	51	40	0	0	61	91	97
HHI	78	22	39	62	88	97	100
KeyDeviation	18	4	14	16	18	22	24
ELRate	2.6	2.4	0.5	0.6	1.4	5.0	6.8
VaR	51	17	32	33	49	67	75
ExpectedLoss	4.4	5.2	1.1	1.4	2.4	5.2	11.7
UnexpectedLoss	106	84	33	62	77	131	196

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
Exp/T1	238	228	59	119	175	286	502
HomeBias	44	36	0	0	51	74	93
HHI	67	25	35	42	72	92	99
KeyDeviation	18	5	11	15	17	23	25
ELRate	4.4	2.8	1	1.7	3.4	7.8	8.2
VaR	60	17	36	43	61	78	80
ExpectedLoss	8.8	8.9	1.8	3.1	5.9	11.7	17.5
UnexpectedLoss	129	107	37	67	99	146	211

Note: Using exposures data from end-2011, this table shows the simulation results for price-based reform to target credit risk in the limiting case of full reinvestment. 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% reinvestment shown in Figure D.2. Variables are defined in the note to Table D.1.

Table D.4: Quantity-based reform to target concentration (end-2011)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	238	228	59	119	175	286	502
$HomeBias$	12	16	0	0	7	16	41
HHI	16	10	5	8	14	19	36
$KeyDeviation$	8	2	6	7	8	9	13
$ELRate$	3.6	1.8	2.0	2.3	3.1	4.3	6.8
VaR	53	7	45	47	52	58	66
$ExpectedLoss$	10.8	16.5	1.7	2.8	4.5	11.8	34.1
$UnexpectedLoss$	137	156	33	54	82	159	332

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	238	228	59	119	175	286	502
$HomeBias$	12	16	0	0	7	16	41
HHI	17	11	5	9	14	20	36
$KeyDeviation$	8	3	5	7	8	8	14
$ELRate$	6.3	2.7	3.0	4.1	6.7	8.5	9.8
VaR	65	8	54	61	66	68	75
$ExpectedLoss$	16.0	16.3	2.0	4.9	15.1	21.2	34.1
$UnexpectedLoss$	155	152	37	69	116	178	332

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	238	228	59	119	175	286	502
$HomeBias$	12	16	0	0	7	16	41
HHI	16	10	5	9	13	20	34
$KeyDeviation$	10	3	8	8	9	12	14
$ELRate$	11.2	4.0	6.8	8.6	11.0	13.0	16.9
VaR	74	9	63	66	74	82	85
$ExpectedLoss$	22.7	14.5	8.7	15.2	21.9	27.9	34.1
$UnexpectedLoss$	171	150	43	81	141	214	332

Note: Using exposures data from end-2011, this table shows the simulation results for quantity-based reform to target concentration. 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 D.3. Variables are defined in the note to Table D.1.

Table D.5: Quantity-based reform to target credit risk (end-2011)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	238	228	59	119	175	286	502
$HomeBias$	36	26	0	17	35	53	73
HHI	37	18	17	23	35	47	59
$KeyDeviation$	12	4	8	9	10	13	17
$ELRate$	3.8	2.5	1.1	2.0	3.6	4.8	6.1
VaR	54	11	37	44	55	61	69
$ExpectedLoss$	7.9	9.5	1.8	3.5	5.9	7.6	12.4
$UnexpectedLoss$	119	123	37	67	95	132	193

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	238	228	59	119	175	286	502
$HomeBias$	36	25	0	21	35	53	73
HHI	37	18	17	24	34	47	59
$KeyDeviation$	11	5	6	8	11	15	18
$ELRate$	5.5	3.5	2.0	3.4	4.8	6.7	9.3
VaR	64	12	45	57	61	74	80
$ExpectedLoss$	13.0	14.9	1.8	4.7	8.2	16.7	25.2
$UnexpectedLoss$	150	150	37	67	109	177	295

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	238	228	59	119	175	286	502
$HomeBias$	36	25	0	21	35	53	73
HHI	34	19	15	20	29	41	58
$KeyDeviation$	12	4	7	9	12	15	17
$ELRate$	10.0	5.6	2.0	5.2	10.0	15.3	17.4
VaR	70	14	48	61	70	83	86
$ExpectedLoss$	24.0	19.7	1.8	4.7	25.4	34.4	51.7
$UnexpectedLoss$	168	163	37	67	129	194	363

Note: Using exposures data from end-2011, this table shows the simulation results for quantity-based reform to target credit risk. 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 D.4. Variables are defined in the note to Table D.1.

Figure D.1: Price-based reform to target concentration (end-2011)
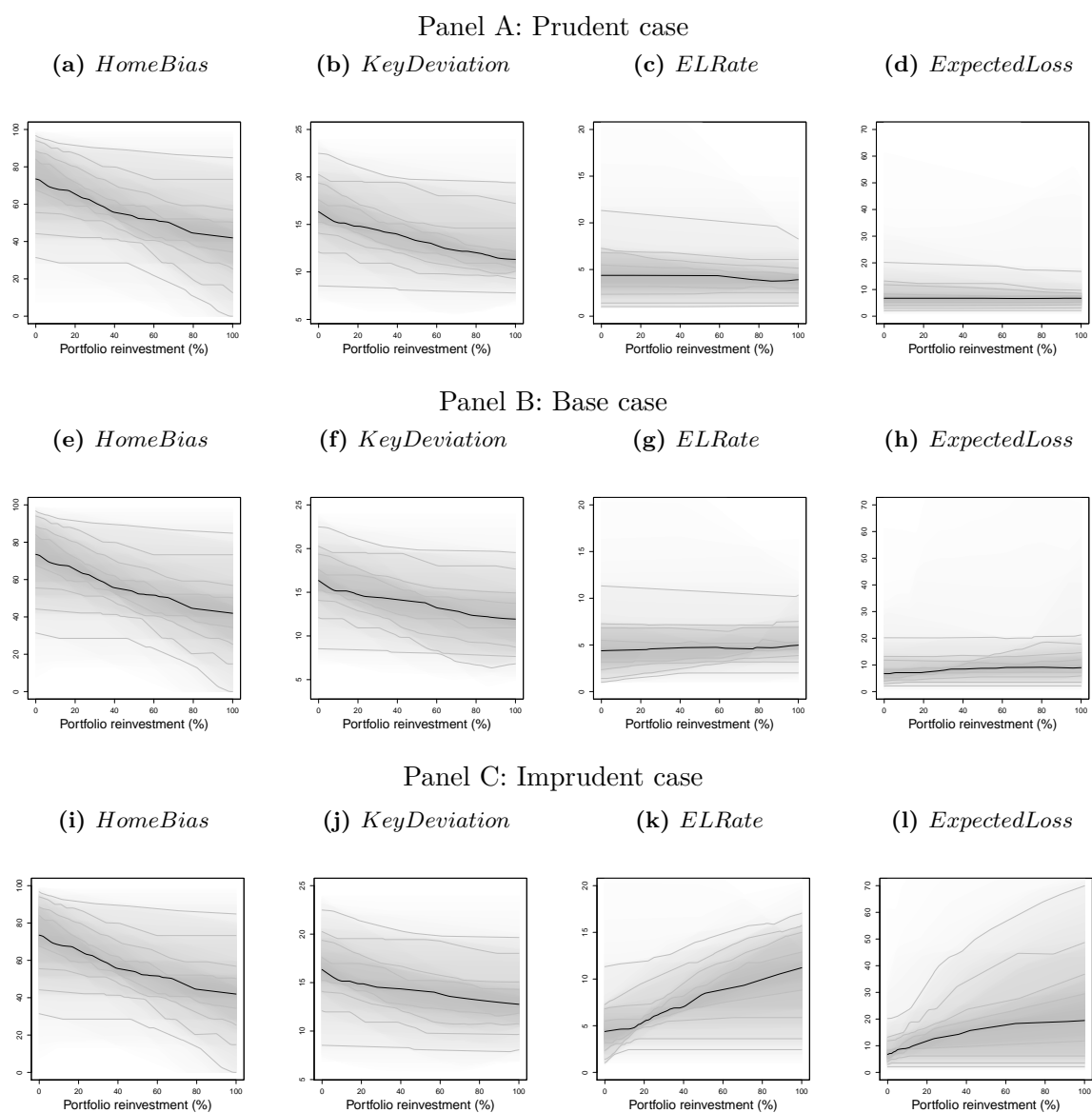
Panel A: Prudent case

(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: Using exposures data from end-2011, this figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table D.1, as a function of the percentage of banks' sovereign bond portfolios that is reinvested. 0% reinvestment corresponds to Table D.1 and 100% reinvestment corresponds to Table D.2. 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 D.2: Price-based reform to target credit risk (end-2011)
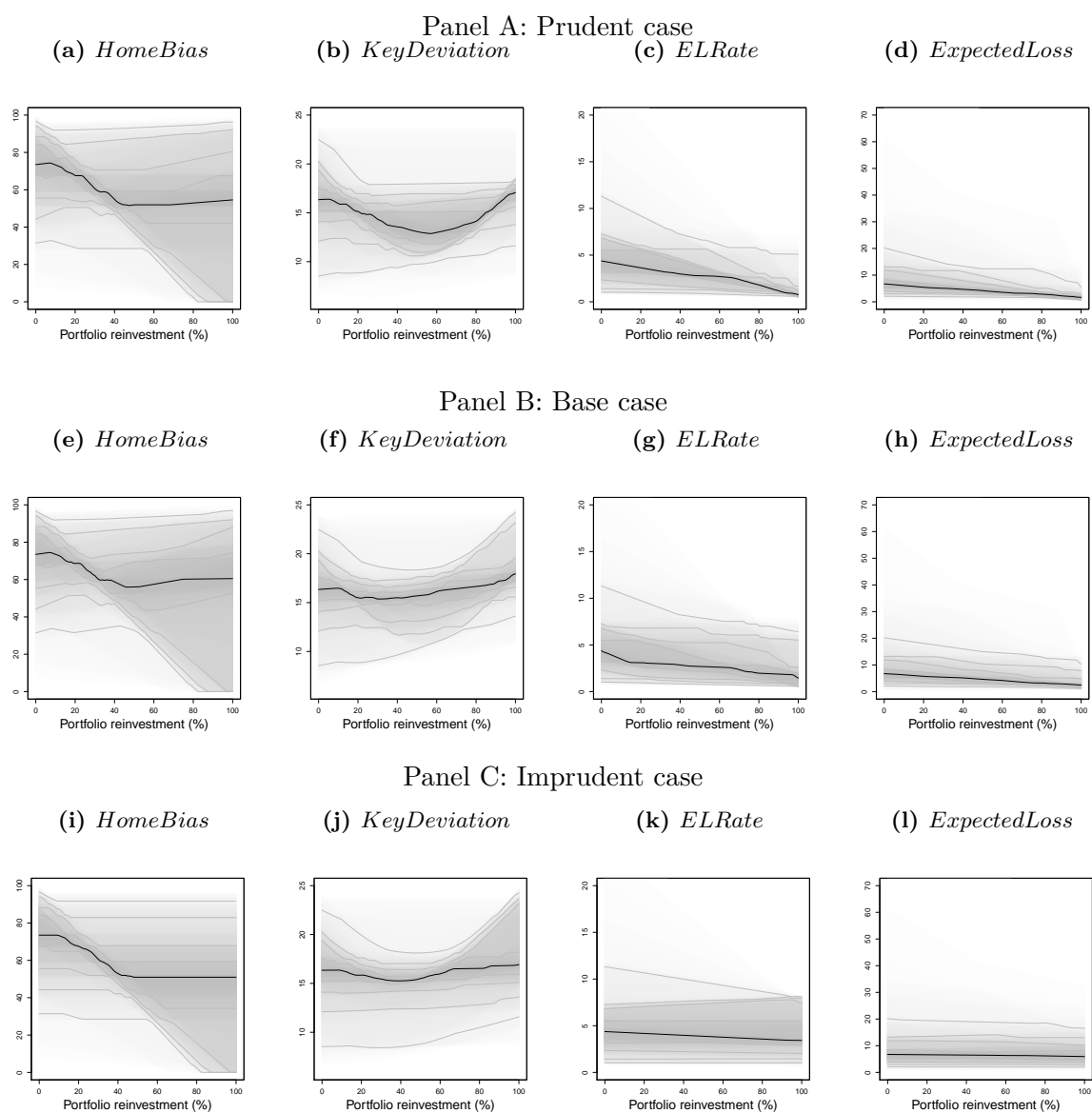
Panel A: Prudent case

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

Panel B: Base case

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

Panel C: Imprudent case

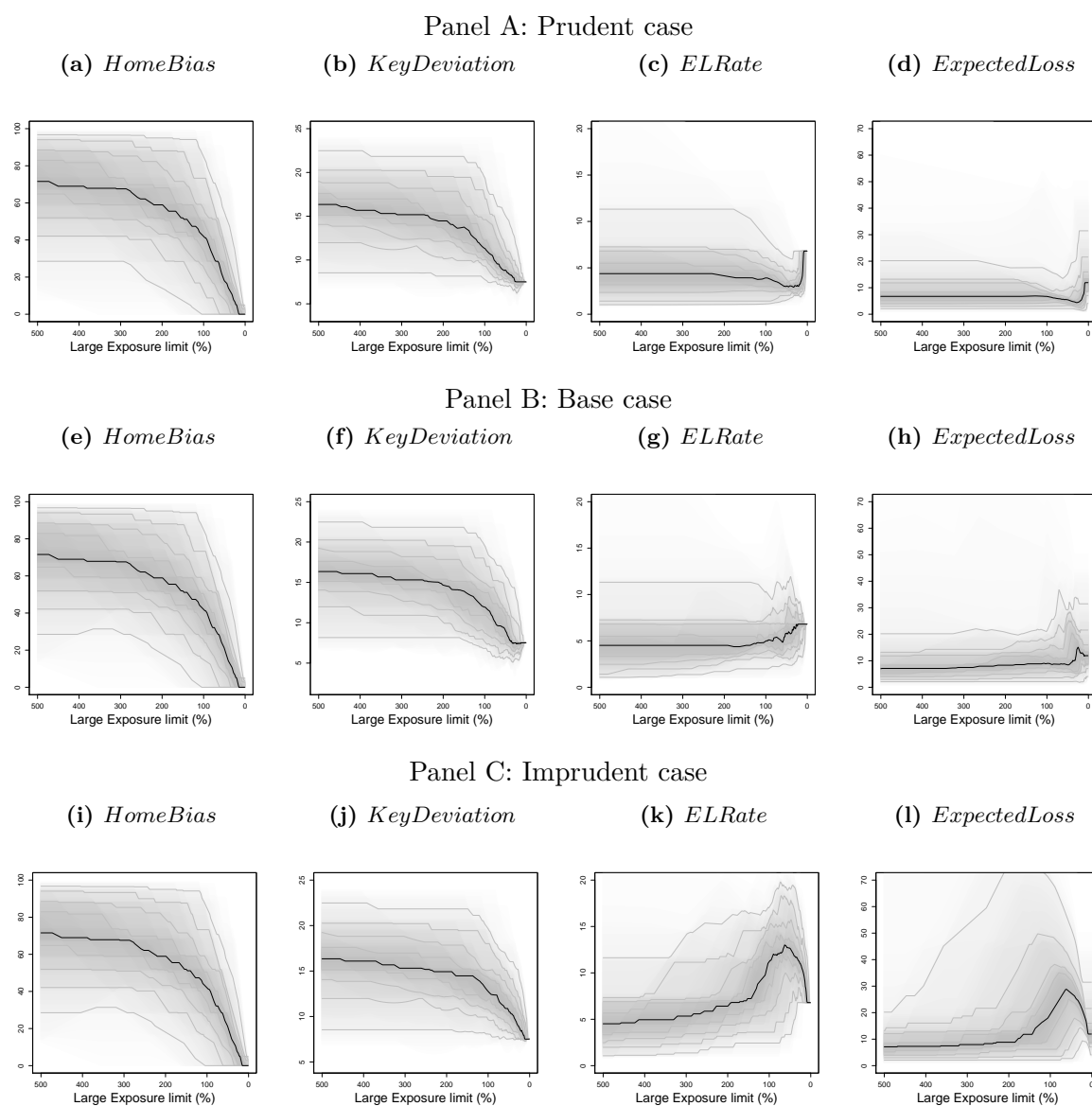**(i)** *HomeBias*   **(j)** *KeyDeviation*   **(k)** *ELRate*   **(l)** *ExpectedLoss*

Note: Using exposures data from end-2011, this figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table D.1, as a function of the percentage of banks' sovereign bond portfolios that is reinvested. 0% reinvestment corresponds to Table D.1 and 100% reinvestment corresponds to Table D.3. 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 D.3: Quantity-based reform to target concentration (end-2011)

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

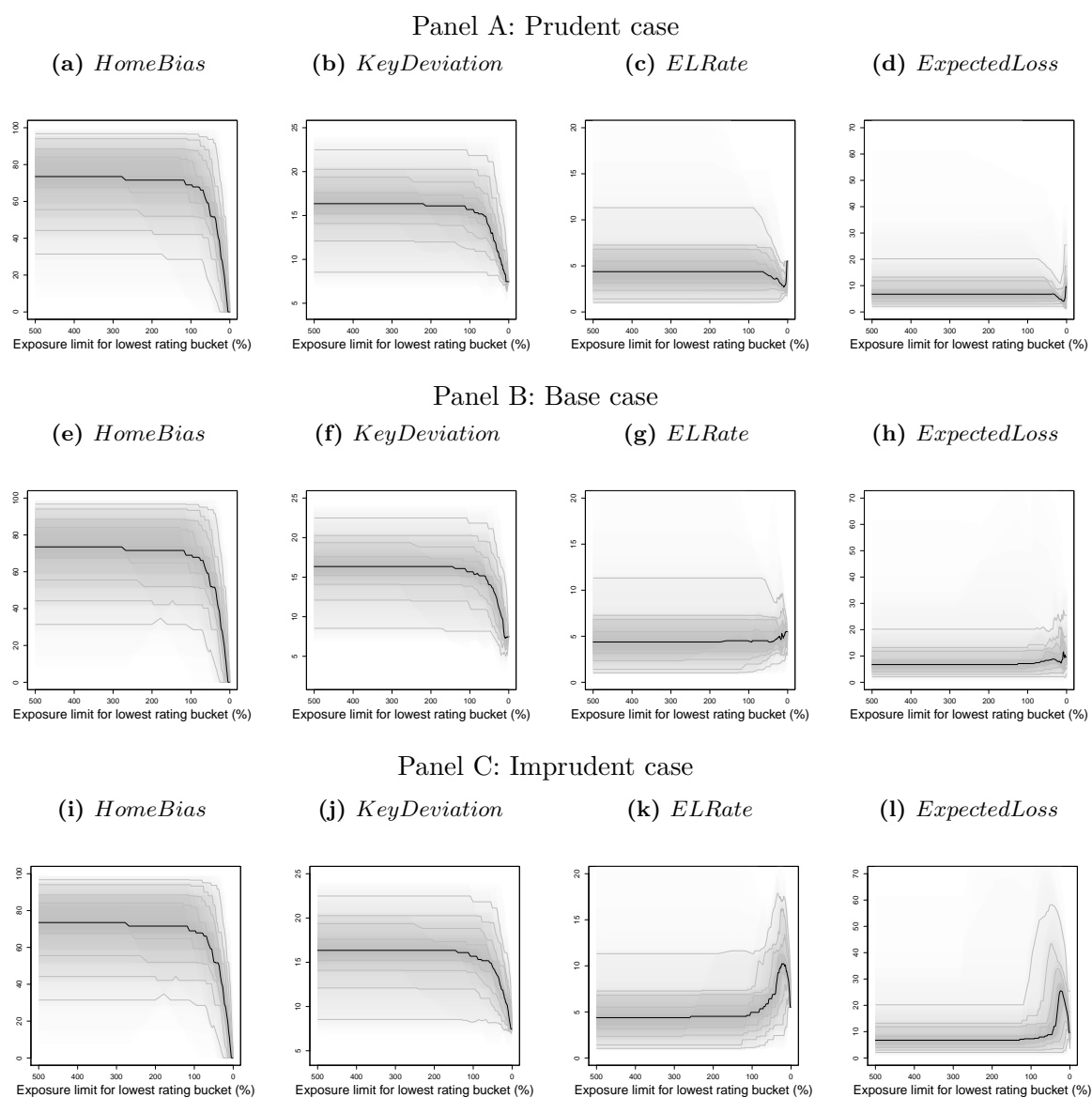**(i)** *HomeBias*　　　**(j)** *KeyDeviation*　　　**(k)** *ELRate*　　　**(l)** *ExpectedLoss*

Note: Using exposures data from end-2011, this figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table D.1, 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 D.4. 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 D.4: Quantity-based reform to target credit risk (end-2011)

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: Using exposures data from end-2011, this figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table D.1, 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 D.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.

Appendix E: Endogenizing an area-wide low-risk asset

We repeat the simulation exercise using mid-2017 data with one innovation: an area-wide low-risk asset exists alongside national sovereign bonds in the portfolio opportunity set.

As explained in the main paper, most outcomes under the two price-based approaches—shown in Tables E.1 and E.2 and the corresponding Figures E.1 and E.2—are similar to those that obtain in the absence of an area-wide low-risk asset. Neither of the two price-based reforms embeds strong incentives for banks to reinvest into 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—reported in Tables E.3 and E.4 and Figures E.3 and E.4—banks reliably reallocate their portfolios in favor of an area-wide low-risk asset only when large exposure limits are very restrictive. This is because an area-wide low-risk asset allows banks to maintain the aggregate value of their sovereign portfolio while respecting binding large exposure limits and avoiding the need for additional capital. However, when large exposure limits are not restrictive, banks have no regulatory incentive to reallocate their portfolios, regardless of the existence of an area-wide low-risk asset.

Table E.1: Price-based reform to target concentration (with an area-wide low-risk asset)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	44	30	3	18	45	68	82
HHI	44	24	19	23	40	57	76
$KeyDeviation$	12	5	6	7	12	16	20
$ELRate$	4.7	5.4	1.1	1.8	3.3	5.7	7.7
VaR	56	16	37	43	56	67	80
$ExpectedLoss$	6.1	5.0	1.1	1.6	5.4	9.1	13.6
$UnexpectedLoss$	83	61	22	42	71	112	146

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	63	79	82
$ExpectedLoss$	9.6	15.2	1.1	2.0	5.6	12.0	19.8
$UnexpectedLoss$	111	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
$HomeBias$	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	65	81	87
$ExpectedLoss$	16.9	23.3	1.1	2.0	6.4	19.4	54.5
$UnexpectedLoss$	119	155	22	42	75	145	265

Note: This table shows the simulation results for price-based reform to target concentration in the limiting case of full reinvestment. 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% reinvestment shown in Figure E.1. Variables are defined in the note to Table A.1.

Table E.2: Price-based reform to target credit risk (with an area-wide low-risk asset)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	27	32	0	0	9	56	78
HHI	35	23	17	17	22	51	71
$KeyDeviation$	8	7	0	1	9	15	17
$ELRate$	1.4	1.6	0.4	0.5	0.7	1.5	4.1
VaR	36	16	18	19	33	46	60
$ExpectedLoss$	1.9	2.5	0.3	0.6	1.1	1.9	4.7
$UnexpectedLoss$	53	49	14	24	39	66	100

Panel B: Base case

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

Panel C: Imprudent case

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

Note: This table shows the simulation results for price-based reform to target credit risk in the limiting case of full reinvestment. 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% reinvestment shown in Figure E.2. Variables are defined in the note to Table A.1.

Table E.3: Quantity-based reform to target concentration (with an area-wide low-risk asset)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	14	18	0	0	9	20	31
HHI	20	15	8	12	17	23	30
$KeyDeviation$	8	3	5	6	7	9	11
$ELRate$	3.2	3.1	1.3	1.9	2.5	3.3	5.3
VaR	48	10	35	42	47	52	57
$ExpectedLoss$	5.0	6.5	0.9	1.4	3.2	5.3	9.6
$UnexpectedLoss$	79	84	20	36	52	94	175

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
$ELRate$	5.1	4.2	1.7	2.6	4.3	6.1	8.0
VaR	62	12	47	55	61	72	78
$ExpectedLoss$	8.0	7.7	1.2	2.7	5.5	11.4	18.5
$UnexpectedLoss$	101	88	25	48	71	129	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	6	8	10	11	14
$ELRate$	11.0	5.0	3.9	8.0	11.4	14.3	16.1
VaR	71	13	52	64	74	80	85
$ExpectedLoss$	16.1	9.5	2.0	8.4	16.9	22.5	30.3
$UnexpectedLoss$	114	92	27	54	90	151	240

Note: This table shows the simulation results for quantity-based reform to target concentration. 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 E.3. Variables are defined in the note to Table A.1.

Table E.4: Quantity-based reform to target credit risk (with an area-wide low-risk asset)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	2	3	0	0	1	3	4
HHI	16	2	13	14	16	17	17
$KeyDeviation$	2	2	1	1	1	2	3
$ELRate$	1.0	0.6	0.6	0.6	0.8	1.2	1.7
VaR	26	7	20	21	24	27	33
$ExpectedLoss$	1.3	1.0	0.4	0.9	1.2	1.6	2.0
$UnexpectedLoss$	38	42	11	20	29	48	65

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	1	3	0	0	0	2	4
HHI	10	4	6	7	9	11	13
$KeyDeviation$	4	3	1	2	4	6	8
$ELRate$	3.1	1.5	1.4	2.0	3.0	4.0	4.6
VaR	44	13	27	34	42	54	60
$ExpectedLoss$	3.7	1.4	1.9	3.7	3.8	4.1	4.7
$UnexpectedLoss$	58	43	22	44	52	65	89

Panel C: Imprudent case

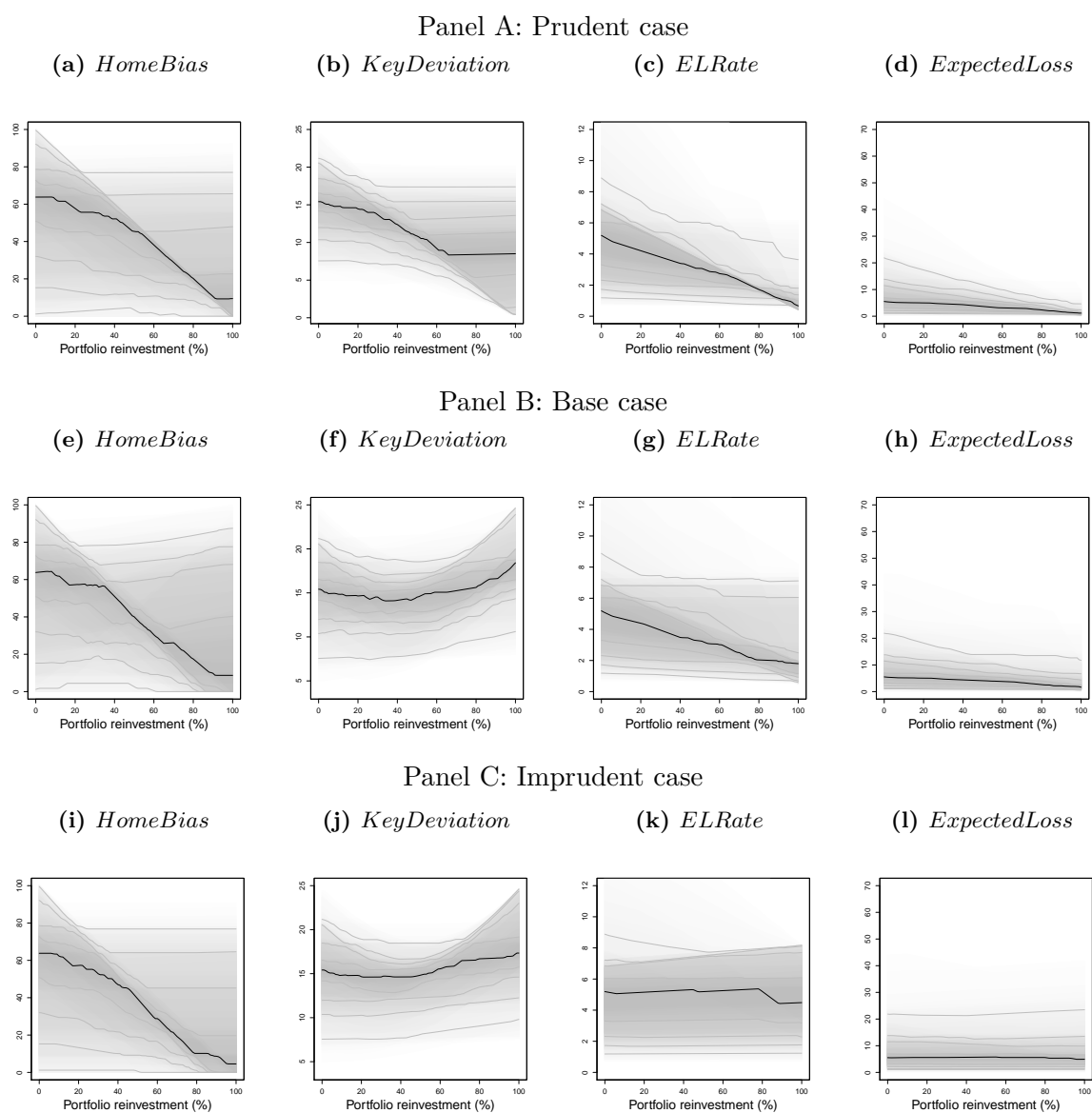|	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	1	2	0	0	0	1	3
HHI	9	3	6	7	9	11	13
$KeyDeviation$	4	3	1	2	4	6	9
$ELRate$	3.7	2.2	1.4	2.0	3.1	4.5	6.7
VaR	45	15	27	34	42	55	68
$ExpectedLoss$	3.9	1.2	3.3	3.7	3.9	4.1	4.7
$UnexpectedLoss$	59	43	32	44	52	65	89

Note: This table shows the simulation results for quantity-based reform to target credit risk. 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 E.4. Variables are defined in the note to Table A.1.

Figure E.1: Price-based reform to target concentration (with an area-wide low-risk asset)
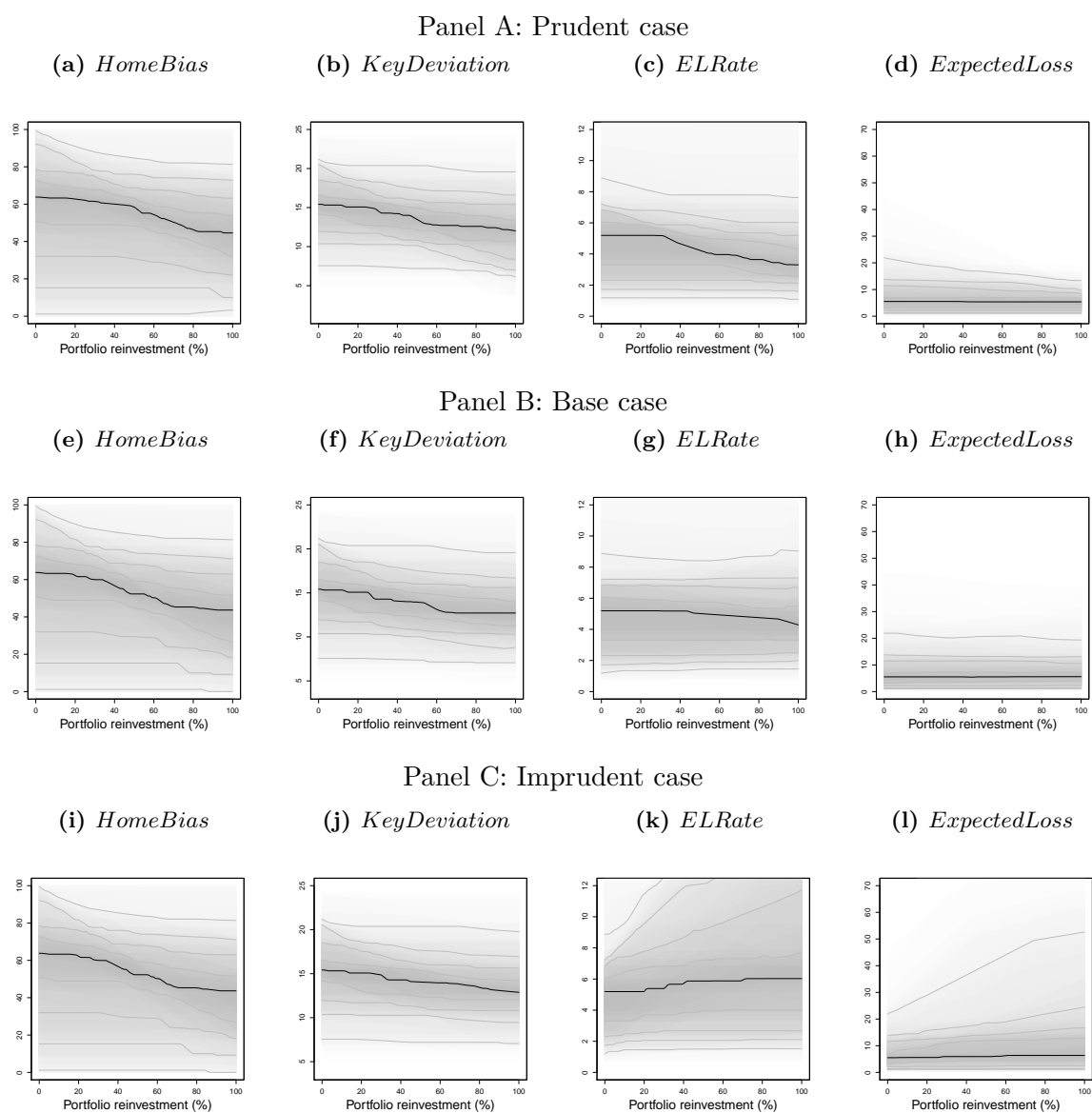
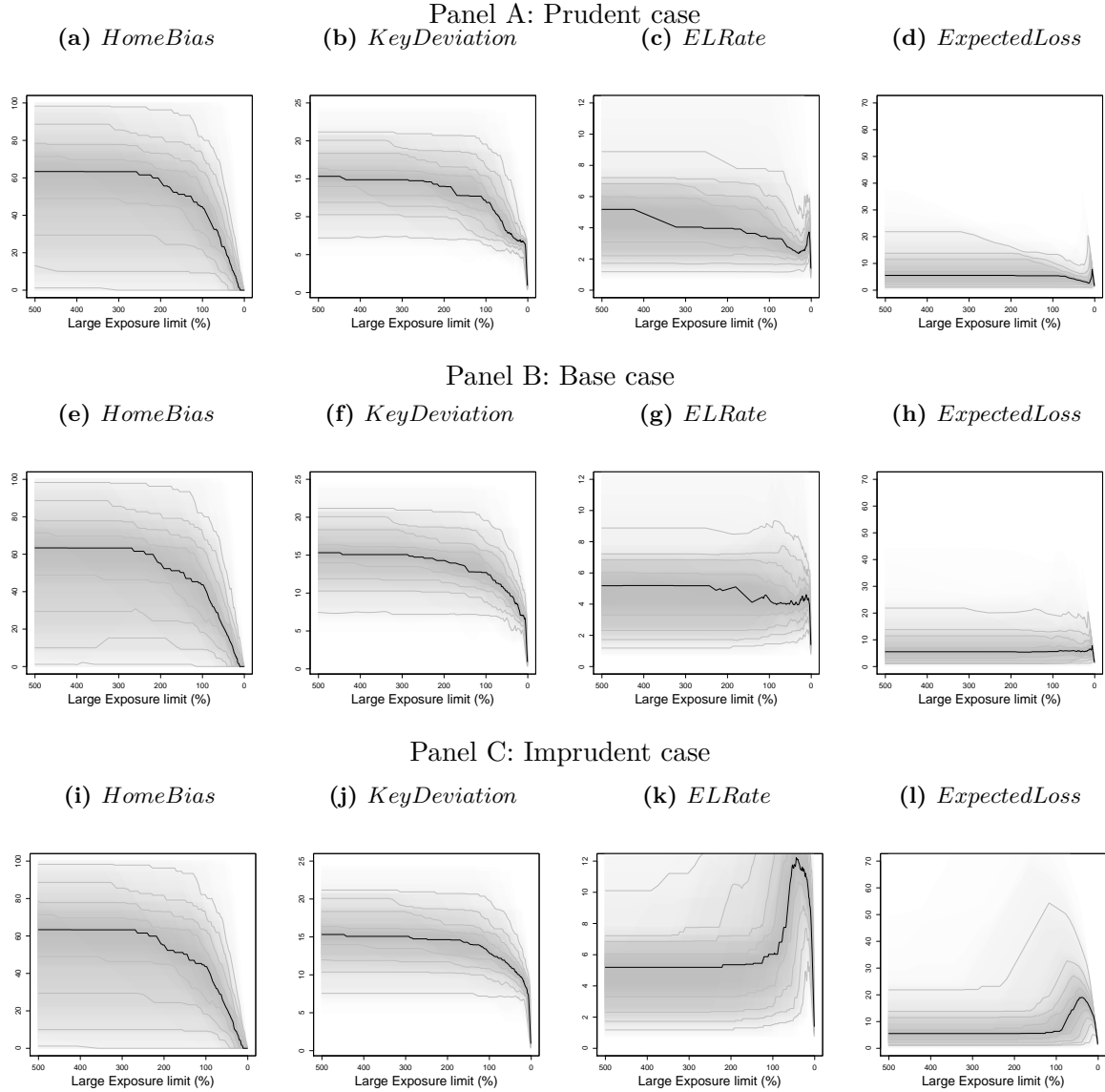Panel A: Prudent case

(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 bond portfolios that is reinvested. 0% reinvestment corresponds to Table 4 and 100% reinvestment corresponds to Table E.1. 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.

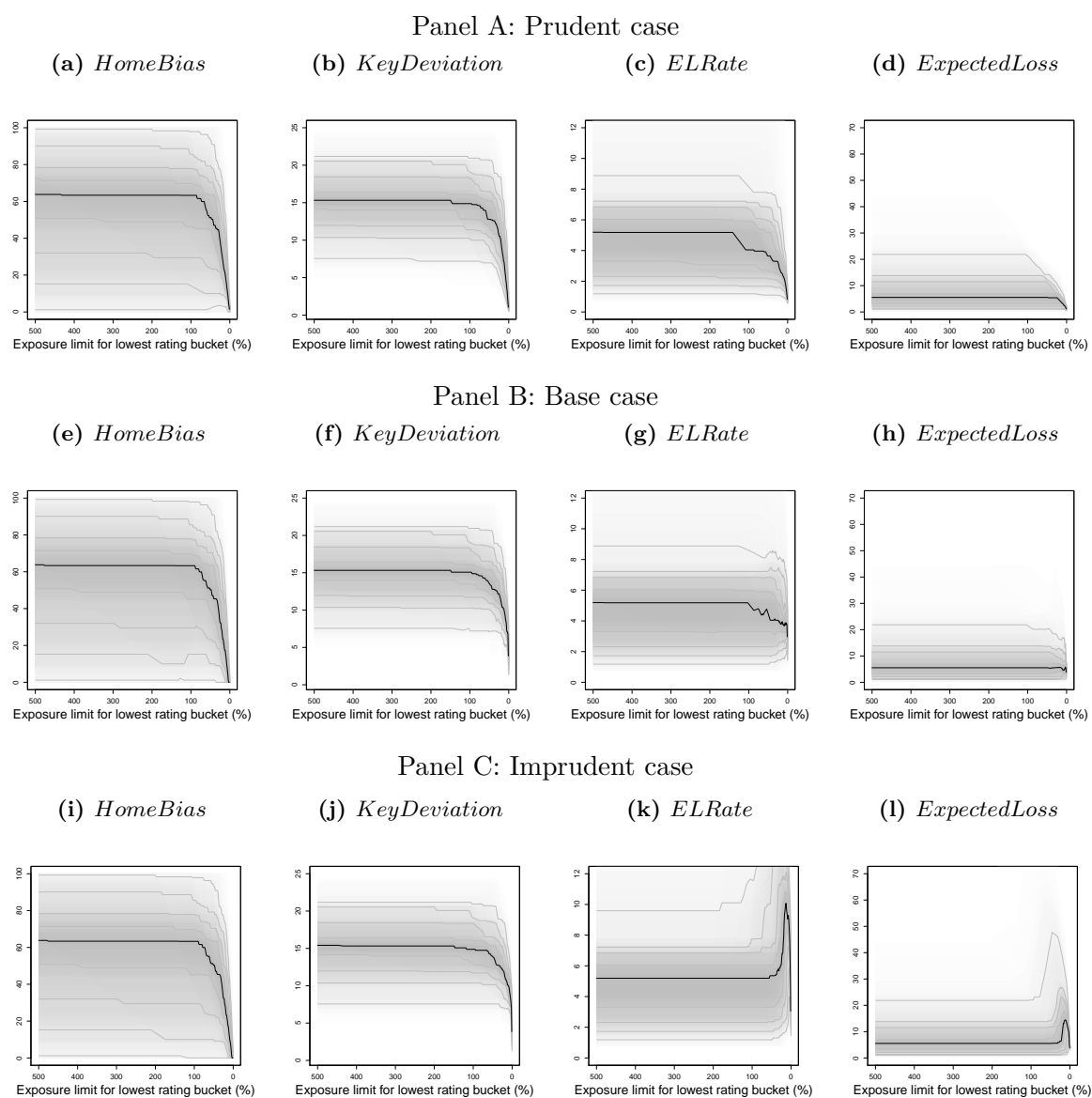**Figure E.2:** Price-based reform to target credit risk (with an area-wide low-risk asset)

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 bond portfolios that is reinvested. 0% reinvestment corresponds to Table 4 and 100% reinvestment corresponds to Table E.2. 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 E.3: Quantity-based reform to target concentration (with an area-wide low-risk asset)

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 E.3. 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 E.4: Quantity-based reform to target credit risk (with an area-wide low-risk asset)

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) for the lowest sovereign credit rating bucket (CCC+ to D), where a 25% limit corresponds to the summary statistics reported in Table E.4. 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.

Appendix F: Area-wide low-risk asset with a risk weight floor

We repeat the simulation exercise for price-based reforms using mid-2017 data with two innovations: (i) an area-wide low-risk asset exists alongside national sovereign bonds in the portfolio opportunity set and (ii) a minimum positive risk-weight is imposed on all single-name sovereign exposures. Under these conditions, the results reported in Tables F.1 and F.2 and Figures F.1 and F.2 indicate that the prudent, base and imprudent cases generate identical outcomes, with banks reallocating their portfolios in favor of the area-wide low-risk asset. With 100% reallocation, sovereign portfolios consist exclusively of the area-wide low-risk asset, which is characterized by low concentration and low credit risk. The explanation for this finding is that a sovereign portfolio comprised of an area-wide low-risk asset always represents the unique solution to banks' constrained optimization problem, regardless of the reallocation rule that they adopt.

Table F.1: Price-based reform to target concentration (with an area-wide low-risk asset and positive risk weight floor)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	0	0	0	0	0	1	1
HHI	17	0	17	17	17	17	17
$KeyDeviation$	0	0	0	0	0	0	0
$ELRate$	0.4	0.0	0.4	0.4	0.4	0.4	0.4
VaR	18	0	18	18	18	18	18
$ExpectedLoss$	0.7	0.9	0.2	0.3	0.5	0.8	1.4
$UnexpectedLoss$	31	41	8	15	23	36	60

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	0	0	0	0	0	1	1
HHI	17	0	17	17	17	17	17
$KeyDeviation$	0	0	0	0	0	0	0
$ELRate$	0.4	0.0	0.4	0.4	0.4	0.4	0.4
VaR	18	0	18	18	18	18	18
$ExpectedLoss$	0.7	0.9	0.2	0.3	0.5	0.8	1.4
$UnexpectedLoss$	31	41	8	15	23	36	60

Panel C: Imprudent case

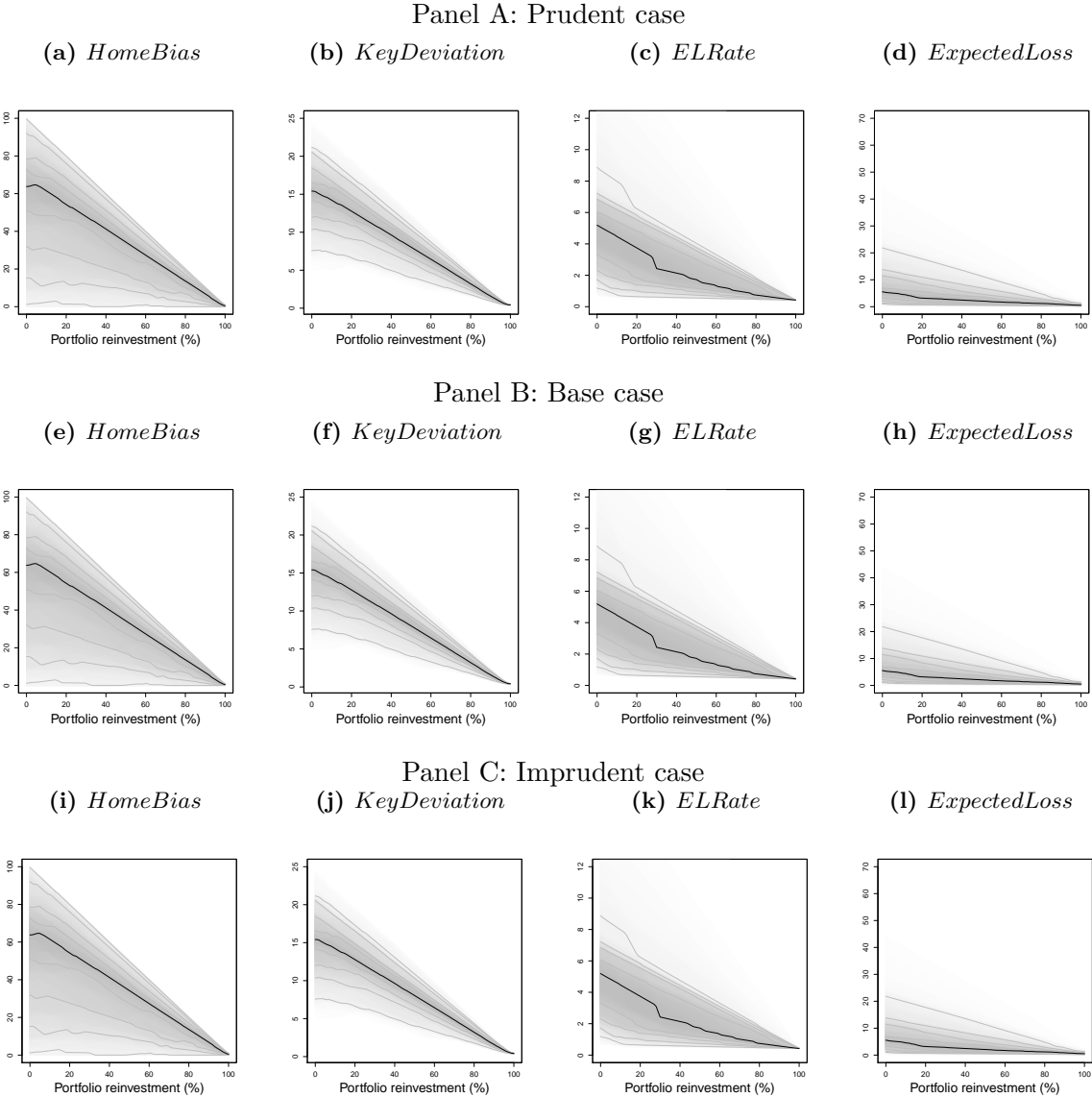|	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	0	0	0	0	0	1	1
HHI	17	0	17	17	17	17	17
$KeyDeviation$	0	0	0	0	0	0	0
$ELRate$	0.4	0.0	0.4	0.4	0.4	0.4	0.4
VaR	18	0	18	18	18	18	18
$ExpectedLoss$	0.7	0.9	0.2	0.3	0.5	0.8	1.4
$UnexpectedLoss$	31	41	8	15	23	36	60

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

Table F.2: Price-based reform to target credit risk (with an area-wide low-risk asset and positive risk weight floor)

Panel A: Prudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	0	0	0	0	0	1	1
HHI	17	0	17	17	17	17	17
$KeyDeviation$	0	0	0	0	0	0	0
$ELRate$	0.4	0.0	0.4	0.4	0.4	0.4	0.4
VaR	18	0	18	18	18	18	18
$UnexpectedLoss$	31	41	8	15	23	36	60

Panel B: Base case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	0	0	0	0	0	1	1
HHI	17	0	17	17	17	17	17
$KeyDeviation$	0	0	0	0	0	0	0
$ELRate$	0.4	0.0	0.4	0.4	0.4	0.4	0.4
VaR	18	0	18	18	18	18	18
$UnexpectedLoss$	31	41	8	15	23	36	60

Panel C: Imprudent case

	Mean	StDev	p10	p25	p50	p75	p90
$Exp/T1$	171	224	41	80	123	194	324
$HomeBias$	0	0	0	0	0	1	1
HHI	17	0	17	17	17	17	17
$KeyDeviation$	0	0	0	0	0	0	0
$ELRate$	0.4	0.0	0.4	0.4	0.4	0.4	0.4
VaR	18	0	18	18	18	18	18
$UnexpectedLoss$	31	41	8	15	23	36	60

Note: This table shows the simulation results for price-based reform to target credit risk in the limiting case of full reallocation. In Panel A, banks reinvest into the lowest-risk sovereign bond; in Panel B, banks reinvest into a portfolio that is similar to their existing portfolio; in Panel C, banks reinvest into the highest-risk sovereign bond. The summary statistics correspond to the case of 100% reallocation shown in Figure F.2. Variables are defined in the note to Table A.1.

Figure F.1: Price-based reform to target concentration (with an area-wide low-risk asset and positive risk weight floor)

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*
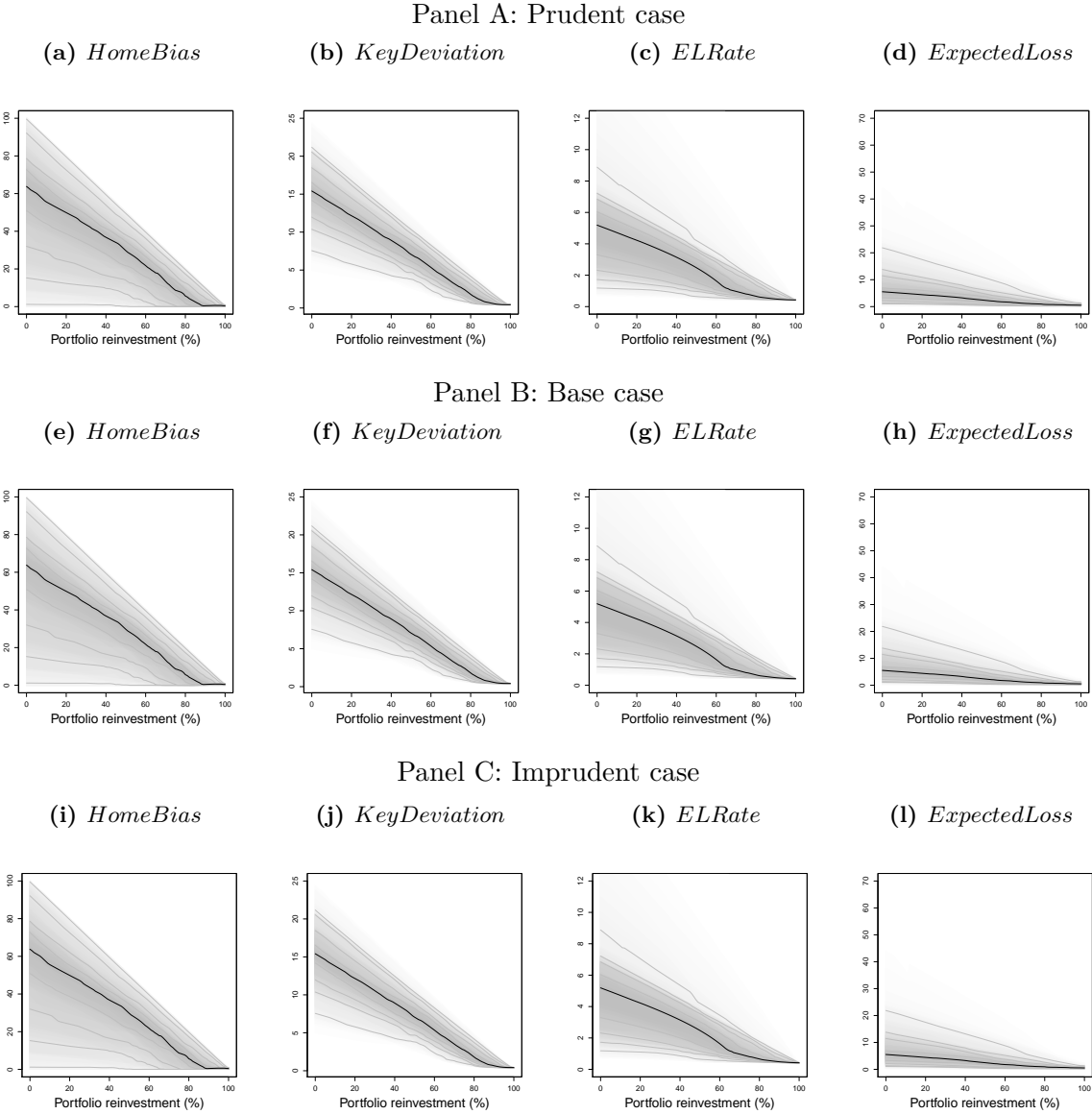
Note: This figure plots *HomeBias*, *KeyDeviation*, *ELRate* and *ExpectedLoss*, as defined in the note to Table 4, as a function of the percentage of banks' sovereign bond portfolios that is reinvested. 0% reinvestment corresponds to Table 4 and 100% reinvestment corresponds to Table F.1. In Panel A, 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 F.2: Price-based reform to target credit risk (with an area-wide low-risk asset and positive risk weight floor)

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 bond portfolios that is reinvested. 0% reinvestment corresponds to Table 4 and 100% reinvestment corresponds to Table F.2. 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.

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