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**The Effect of Possible EU Diversification Requirements
on the Risk of Banks' Sovereign Bond Portfolios**

Ben R. Craig, Margherita Giuzio, and Sandra Paterlini

Recent policy discussion includes the introduction of diversification requirements for sovereign bond portfolios of European banks. In this paper, we evaluate the possible effects of these constraints on risk and diversification in the sovereign bond portfolios of the major European banks. First, we capture the dependence structure of European countries' sovereign risks and identify the common factors driving European sovereign CDS spreads by means of an independent component analysis. We then analyze the risk and diversification in the sovereign bond portfolios of the largest European banks and discuss the role of "home bias," i.e., the tendency of banks to concentrate their sovereign bond holdings in their domicile country. Finally, we evaluate the effect of diversification requirements on the tail risk of sovereign bond portfolios and quantify the system-wide losses in the presence of fire-sales. Under our assumptions about how banks respond to the new requirements, demanding that banks modify their holdings to increase their portfolio diversification may mitigate fire-sale externalities, but it may be ineffective in reducing portfolio risk, including tail risk.

JEL codes: G01, G11, G21, G28.

Keywords: Bank regulation, sovereign-bank nexus, sovereign risk, home bias, diversification.

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Ben R. Craig is at the Federal Reserve Bank of Cleveland (ben.r.craig@clev.frb.org), Margherita Giuzio is at the European Central Bank (margherita.giuzio@ecb.europa.eu), and Sandra Paterlini is at the University of Trento (sandra.paterlini@unitn.it). The authors gratefully acknowledge the advice of Monica Reusser, Simone Varotto, Jochen Mankart, and participants in the following workshops: Italian Association for Mathematics Applied to Economic and Social Sciences Meeting 2016, International Conference of the ERCIM WG on Computational and Methodological Statistics 2016, Computational Management Science Conference 2017, European Financial Management Association 2017 Annual Meeting, EBA Policy Research Workshop.

Non-technical summary

In the current Basel framework, special treatment is reserved for exposures of European banks to domestic government bonds. Banks are not required to hold any capital buffer against their investments in sovereign bonds denominated in euro, which are considered de facto riskless. Furthermore, sovereign exposures are not subject to any concentration limits and can represent a large part of banks' capital. As a result, there are strong regulatory incentives for banks to hold disproportionate amounts of domestic sovereign debt for capital and liquidity reasons.

Recently, policymakers proposed the introduction of capital rules and diversification requirements for euro area government bond holdings (ESRB, 2015; Juncker et al., 2015; Arnold, 2016; Véron, 2017). The rationale behind this regulation goes beyond improving banks' risk management and resilience to sovereign risk. Regulators want primarily to weaken the so called *doom loop* between sovereigns and banks that has arisen especially after the financial crisis in 2007-2008. This strong nexus, represented by high balance sheet exposures of banks toward sovereigns, allows countries with weak finances to heavily affect their banking system, and banking sectors in distress to receive more likely government financial support. Furthermore, increasing diversification in banks' sovereign portfolios is considered a necessary step for the introduction of the joint European Deposit Insurance Scheme (EDIS), which requires the national deposit protection schemes to be combined (Juncker et al., 2015). However, if banks are largely exposed to their own sovereign debt, a joint deposit guarantee scheme might result in a sharing of fiscal risk (Weidmann, 2016).

To inform the policy discussion, this paper analyzes the effects of possible responses of banks to a new diversification requirement. We use a sample of 106 European banks included in the EBA stress testing dataset over the period June 2013 to December 2015. These banks cover approximately 70% of banking assets in each of their country and across the EU. Sovereign exposures represent a large part of their total assets and are much larger than banks' capital.

In this paper, we point out how the standard definition of diversification, quantified by looking at the distribution of asset holdings, might be too limited. Other dimensions, such as risk exposure and factor exposure, need to be explicitly taken into account to better describe the status quo of banks' portfolio allocations as well as to model the potential consequences of

a rebalancing, forced by the new regulation, which is intended to reduce home bias and favor more overlapping portfolios.

Given that the reduction of risk is a major reason for a diversification requirement, our results suggest caution before its adoption. We examine the question with a set of risk tools that have not been used in a banking regulation context, but are especially relevant to understanding the sources of risk for the current sovereign debt portfolios of European banks, and the impact of the likely responses to limits placed upon single sovereign exposures. First, we identify the common risk factors of European sovereign risk through an independent component analysis and introduce different diversification measures used to evaluate portfolios in the financial services industry. Using simple rebalancing rules, we find that the likely portfolios that result from such higher diversification requirements will generally increase the risk of most banks in the euro area. As a first step, we focus on portfolio variances of countries' banking system and of individual banks. Then, because tail risks play a key role during a crisis, we also estimate the impact of portfolio rebalancing on value-at-risk by using risk aggregation techniques developed by Bernard and Vanduffel (2015). Finally, we analyze possible benefits that rebalanced portfolios might offer in the event of fire-sales. We find that a diversification requirement such as the ones proposed can increase the variance and tail risk of the resultant portfolios, while having little effect on contagion risk.

We focus on the assumption that banks would choose a sovereign bond portfolio that most closely matches the risk-return profile of their current portfolio. This is a strong assumption and our results depend upon it, but it is not unrealistic on either theoretical or empirical grounds. Another possible scenario that we analyze is that banks will rebalance toward safer bonds, i.e., "flight-to-quality". We find that, under this assumption, banks would achieve lower return portfolios with similar or lower risk profiles to the current ones.

1 Introduction

The current Basel framework reserves a special treatment for banks' exposures to domestic government bonds, which can be financed totally by debt capital.¹ Banks are not required to hold any capital buffer against their investments in sovereign bonds denominated in domestic currency. Therefore, euro area sovereign exposures are considered de facto riskless by banks operating in the euro area.² Further, and more important for this paper, sovereign exposures are exempt from the large exposures regime, which requires banks to limit their position toward single issuers or creditors to 25% of their eligible capital, in order to prevent banks from incurring in large losses when an individual client fails. As a result, there are strong incentives for banks to hold disproportionate amounts of domestic sovereign debt (i.e., home bias) for capital and liquidity reasons.

Recent policy discussions have focused on the introduction of stricter capital rules and diversification requirements for euro area government bonds holdings (ESRB, 2015; Juncker et al., 2015; Arnold, 2016; Véron, 2017). The impact of this regulation on diversification and risk sharing within and across countries is uncertain, as numerous factors have to be taken into account. Among them, the most crucial aspect is to understand which sovereign bonds would be considered as substitutes for each other, how investor preferences would change, and how those changes would impact bond prices, CDS prices and entire markets. In fact, fire-sales of sovereign bonds could potentially originate from disbalanced bid–ask spreads and lack of attractiveness of bonds' returns, and can intensify contagion effects to the entire financial market and the real economy. Furthermore, as correlation typically increases during crises, the diversification achieved by investing in different sovereign assets might turn out to be ineffective. Finally, as recently shown by Kley, Kluppelberg, and Reinert (2018) in a network framework when focusing on extreme risks, the dependence structure of sovereign bonds might play an important role in assessing the impact of higher diversification, which could be beneficial at a

¹Each bank can choose between two risk-weighting schemes to calculate capital buffers: the standardized approach (SA) and the internal ratings-based approach (IRB). The so-called “permanent partial use” rule allows banks that usually implement an IRB scheme for risk-weighting to switch to the SA to account for their sovereign holdings.

²This is a requirement that applies only to euro area sovereign bonds denominated and funded in domestic currency. Therefore, it is not sovereign debt, per se, that receives the special treatment; non-euro area sovereign debt has a risk-weight associated with it.

bank or country level, but not necessarily at a system level, and vice versa.

This paper represents a first step to analyzing the response of banks to a proposed diversification requirement. Banks may implement different rebalancing strategies. They might for example select a balanced portfolio, by investing in different sovereigns proportionally to their outstanding debt; or they might reduce the size of their balance sheets by limiting the sovereign exposure altogether, and, perhaps, substituting other assets for their sovereign holdings. However, this response is very difficult to analyze empirically, as a careful analysis would require a complex structural model on banks' response to changes in liquidity and rates of return, as well as special knowledge of the risk and correlation profiles of all the available assets included in banks' balance sheets. We focus our analysis on the assumption that banks would choose a sovereign bond portfolio that most closely matches the risk-return profile of their current portfolio. This is a strong assumption and our results depend upon it, but it is not unrealistic on either theoretical or empirical grounds. Another possible scenario that we analyze is that banks will rebalance toward safer bonds, i.e., "flight-to-quality" (see Appendix E). We find that, under this assumption, banks would achieve lower return portfolios with similar or lower risk profiles to the current ones. As comparisons, we also analyze the risk of the aggregated portfolio of euro area banks (referred to here as an EU portfolio) and the equally weighted response (EW portfolio).

Using a sample of 106 European banks included in the EBA stress testing dataset over the period June 2013 to December 2015 (see Table 6 in Appendix A), we find that a diversification requirement such as the ones proposed can actually increase the risk of the resultant portfolios, while having little effect on the tail risk or contagion risk. Given that the reduction of risk is a major reason for a costly diversification requirement, our results suggest caution before its adoption. We examine the question with a set of risk tools that have not been used in a banking regulation context. We feel that these tools are especially relevant to understanding the sources of risk for the current sovereign debt portfolios of European banks, as well as the impact of the likely responses to limits placed upon any single sovereign exposure. In particular, we identify the common risk factors of European sovereign risk and introduce different diversification measures used to evaluate portfolios in the financial services industry. Using simple rebalancing

rules, we find that the likely portfolios that result from such higher diversification requirements will generally increase the risk of most banks in the euro area. As a first step, we focus on portfolio variances of countries and of individual banks, which capture what we can interpret as the “average riskiness”. However, because tail risks play a key role during a crisis, we also estimate the impact of portfolio rebalancing on value-at-risk and provide some bounds for value-at-risk of the sovereign portfolios of the major European banks using the techniques developed by Bernard and Vanduffel (2015). Our main findings suggest that for most portfolios, such new regulatory requirements have no effect on the tail risk. Finally, we analyze possible benefits that rebalanced portfolios might offer in case of a fire-sale and find that these benefits are, at best, limited even in a model of fire-sales that gives diversification its best chance.

This paper is organized as follows. In Section 2, we describe the dataset. In Section 3, we perform an independent component analysis (ICA) to identify the common factors driving European sovereign CDS spreads and capture the risk drivers and the dependence structure between sovereign risks. As ICA differs from the common approach of principal component analysis in identifying factors that are statistically independent and not requiring *ex ante* distributional assumptions, we compute and interpret the resulting factors. We then analyze the sovereign portfolios of European banks, relying on the EBA stress test dataset, by calculating their risk and diversification profiles, and discuss the implications of home bias. In Section 4, we study the potential impact of the new regulation on banks’ sovereign bond portfolios. We first focus on risk, as captured by the variance, and diversification. Then, in Section 4.1, we evaluate the effects on tail risk, as measured by their value-at-risk (VaR). We quantify bounds on VaR for current and rebalanced portfolios, both in the whole sample period and during the sovereign debt crisis to evaluate the effects on tail risk in a period of high volatility. When looking at the entire network of common holdings across banks and countries, we know that overlapping portfolios might become a channel of shock transmission, especially for common shocks of a certain entity (see, e.g., Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015)), implying that diversification at a single entity level might have negative consequences at the system level. We compute the effects of a contagion through fire-sales in Section 5 and show that the rebalancing requirement can reduce fire-sale losses under certain assumptions. Finally, Section

6 concludes.

1.1 Home bias in banks' sovereign bond portfolios

Besides the incentives stemming from the current regulatory framework, there are several reasons why banks may be willing to hold domestic sovereign debt, particularly during a financial crisis (Gennaioli, Martin, and Rossi, 2018). Political pressure and moral suasion from countries with weak finances, i.e., with low GDP growth and high debt, may bring domestic banks to hold additional sovereign exposure in order to prevent a deterioration of sovereign credit risk that could impair debt sustainability (Erce, 2015). Also, banks invest in domestic bonds to hedge against redenomination risk, in case of a collapse of the euro area (Fabozzi, Giacometti, and Tsuchida, 2015), and as a geographical hedge of their assets and liabilities. However, the 2011-2012 European sovereign debt crisis decisively showed that government bonds are not risk-free investments and are quite heterogeneous in their risk profiles, as also shown in the differing Moody's ratings (see Table 7 in Appendix B).

Sovereign exposures represent a large part of total assets on the balance sheets of the banks in our sample, comprising on average 26% percent of assets, and are much larger than banks' eligible capital, which is used to define large exposures. According to ESRB (2015), sovereign risk-weighted assets (RWA) represent less than 5% of total RWA. Several regulatory proposals have recently emerged from different policy discussions, proposals which aim at increasing diversification in banks' sovereign portfolios and preventing moral suasion and regulatory arbitrage. Among them, two particular measures are high on the agenda of regulators, capital buffers and the large exposure regime on banks sovereign holdings. The rationale behind the suggested regulatory changes goes beyond the risk management reasons of improving banks' resilience to sovereign risk and limiting excessive risk concentration in banks' sovereign portfolios.

Regulators want primarily to weaken the so called *doom loop* (or feedback loop) between sovereigns and banks that has arisen especially after the financial crisis in 2007-2008. This strong nexus, represented by high balance sheet exposures of banks toward sovereigns, allows countries with weak finances to heavily affect their banking system, and banking sectors in distress to receive more likely government financial support. For example, on the one hand,

Greek banks had to write down €29.9 bn on domestic debt between 2011 and 2012, requiring significant recapitalization, because of Greek sovereign debt restructuring. On the other hand, when the Irish banks suffered liquidity problems during the financial crisis in 2007-2008, the Irish government provided public guarantees to avoid further financial problems. Furthermore, increasing diversification in banks' sovereign portfolios is considered a necessary step for the introduction of the joint European Deposit Insurance Scheme (EDIS), which represents the third pillar of the European banking union (Juncker et al., 2015). The EDIS requires the national deposit protection schemes to be combined in order to prevent a major shock in one European country from being able to decrease the confidence in the corresponding banking system. However, if banks have large holdings of their own sovereign debt on their balance sheets, a joint deposit guarantee scheme might result in a sharing of fiscal risk (Weidmann, 2016).

Recently, Acharya and Steffen (2015) tried to explain the home bias in distressed countries (i.e., Greece, Ireland, Italy, Portugal, and Spain) with “carry trade” behaviors: EU banks may invest in their government bonds using short-term debt to earn higher returns. Banks in stressed countries may profit more from this carry trade opportunity because they can easily access high-yield bonds; they are hedged against redenomination risk if they invest in domestic sovereigns; and since they are usually less capitalized, they undertake risky strategies as a gamble for the upside potential (ESRB, 2015; Battistini, Pagano, and Simonelli, 2014). This mechanism results in risky countries borrowing more cheaply, in practice shifting their default risk to the common central bank (Uhlig, 2013). Increases in domestic exposure make twin crises, i.e., banking and sovereign defaults, more likely (De Bruyckere et al., 2013; Buch, Koetter, and Ohls, 2016; Acharya, Drechsler, and Schnabl, 2014) because government bonds represent the main transmission channel between sovereigns and banks. Countries with weak finances may affect their banking system, and banking sectors in distress may require government intervention. Risk spillovers work therefore in both directions. In some countries, the public sector was heavily supporting the banking system and was forced to seek bailouts (e.g., Ireland and Spain), while in others, the main source of risk was concentrated in high level of public debt (e.g., Greece, Portugal, and Italy). In this sense, an effective measure to break this loop

would have to target the amount of sovereign bonds held by banks.

However, Coeurdacier and Rey (2013) point out that home bias is present across countries, sectors, and asset classes, and it is not necessarily an inefficiency to correct. It could be explained by hedging strategies, transaction costs, and information advantage. Also, in most EU countries, home bias decreased from the introduction of the euro until the financial crisis, and increased afterwards. During the European debt crisis, banks increased their exposure to domestic sovereign bonds again. In the meantime, regulation was unchanged. Gaballo and Zetlin-Jones (2016) find that banks holding domestic debt make default more costly, but less likely. Also Gennaioli, Martin, and Rossi (2018) argue that domestic exposures can act as disciplinary device for governments. The authors show that default is more costly to the sovereign if a large share of public debt is held by domestic banks, and it becomes less likely the more exposed the domestic banks are. Broner et al. (2014) argue that sovereign bonds lead to higher returns for domestic than foreign creditors, especially during crisis periods. Therefore, financial stress in a country triggers a buy up of bonds by domestic banks. Choi et al. (2017) show that concentrated investment strategies in international markets can be optimal for institutional investors due to information advantage. According to this stream of the literature, home bias is efficient. We analyze only this trade-off between concentration risk and the doom-loop. What we find is that the benefits of diversification are possibly quite small or even negative.

2 Data Sources

We use two data sources, data on market credit default swaps (CDS) and individual bank balance sheet data. We use CDS spreads in our analysis because they provide a more direct measure of credit risk of a sovereign than bond spreads, as CDS spreads are less affected by interest rate risk, changes in bond supply, and liquidity risk (Ang and Longstaff, 2013; Kirschenmann, Korte, and Steffen, 2017). Robustness checks show that similar results hold both when using bonds or CDS spreads (Korte and Steffen, 2014). In particular, we construct a sample of daily sovereign CDS spreads with a maturity of 5 years for 10 EU countries, from January 2009 to November 2018. The 10 countries we consider account for more than 85% of

the EU GDP and include the countries involved in the European sovereign debt crisis, except for Greece, whose CDS were not traded between March 2012 and May 2014.³

We analyze the sovereign portfolios of European banks, relying on the EBA stress test dataset, covering approximately 70% of banking assets in each country and across the EU. For ease of exposition, we aggregate the sovereign portfolios of banks belonging to the same country and present the results for six country banks (i.e., Germany, Italy, France, Spain, Portugal, and Ireland) and for the entire EU system, including all banks in the EBA stress test dataset.

We construct the portfolio weight of country bank j , which includes the banks domiciled in country j , with respect to issuer i as

$$w_{ji} = \frac{\text{Exposure of } j \text{ to issuer } i}{\text{Tot. sovereign exposure of } j} . \quad (1)$$

Table 1 reports the portfolio weights of six countries' banking sectors with respect to the major European countries issuing sovereign bonds, i.e., Germany, Italy, France, Spain, Portugal, and Ireland. As a first step, we then compare the risk and diversification levels of sovereign portfolios and discuss the implications of home bias.

Country Bank	DE	IT	FR	ES	PT	IE
DE	62.31	5.07	3.39	3.13	0.65	0.34
IT	9.55	64.88	3.19	5.15	0.05	0.06
FR	3.97	7.86	51.49	2.48	0.56	0.55
ES	0.01	6.64	0.62	63.10	2.86	0.04
PT	3.14	3.53	0.68	0.86	61.87	-
IE	1.28	5.51	4.25	5.89	0.60	73.53

Table 1: Sovereign portfolio weights (in percentage), i.e., sovereign exposures as proportions of total holdings, of EBA banks in December 2015.

3 Risk of Current Portfolios

In order to study the common drivers of CDS changes in the EU, we perform a factor analysis and identify three independent components, as shown in Figure 1. We used the independent component analysis (ICA), proposed by Fabozzi, Giacometti, and Tsuchida (2015) to decom-

³Data are retrieved from Thomson Reuters, which reports annual-based spreads, \bar{s} , whose coupon is paid semi-annually. We use the continuously compounded and annual-based CDS rates, obtained as $s = 2 \log(1 + \bar{s}/2)$ (Ait-Sahalia, Laeven, and Pelizzon, 2014).

pose the CDS spreads. In contrast to the well-known principal component analysis (PCA), ICA identifies factors that are statistically independent from one another, without any ex ante distributional assumption related to the data. Furthermore, while the first PCA factor usually explains most of the variation in the sample, ICA factors typically share their explanatory power, thereby allowing us to link them to some financial interpretation. The easier interpretation of the risk factors is very important when comparing the diversification of two portfolios, in that it gives a clearer picture of banks' strategic exposures to financial and economic factors. In contrast, PCA analysis imposes strong distributional assumptions on how a shock will enter a portfolio of bonds. By measuring risk factors in terms of how much they "explain the data", the PCA factors undervalue small components in the diversification that may still provide a relevant contribution to the risk, as they represent factors that, when shocked, set off correlated losses within a portfolio. As a result, while the first PCA component of CDS spreads in our sample explains almost 80% of the variation in the data, the first two ICA components share a similar explanatory power, allowing us to disentangle two different risk sources.

In fact, the first and second independent factors explain 60.8% and 37.8% of the total variance of CDS rates, respectively, while the third factor only 1.3%. In Figure 2, we display the resulting loadings and the correlation coefficients between factors and CDS spreads. As the top panel displays, F1 maps well the evolution of the CDS spreads, especially of the distressed countries, with a period of low value and volatility until the end of 2010, followed by an increased in the level until 2014 and a consequent decrease up to 2018. F1 is also strongly and positively correlated to Italy, Spain, Ireland, and Portugal, all of which, except for Italy, have large loading coefficients. Such countries are all characterized by a credit rating below B. Germany, Austria, Belgium, the Netherlands, and the UK, which have ratings from A and above, have instead a correlation smaller than 0.6 as well as a small loadings, except for France. F2 is mostly positively correlated with A-rated countries and Ireland, with loadings close to zero for Italy, Spain, and Portugal. As shown in the second panel of Figure 1, the times series of F2 exhibits a break in 2012: This could be attributed to Draghi's statement that the ECB would do "whatever it takes" to establish trust in the markets, which led to a consequent decrease in the value of all CDS spreads. Such a statement had a large impact on reestablishing

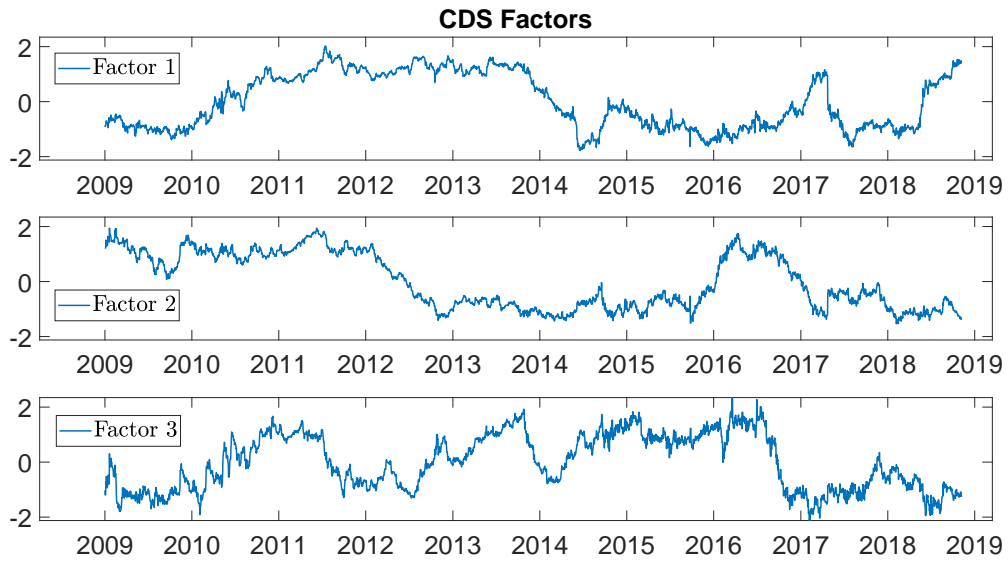


Figure 1: Time series of the three ICA factors of CDS rates.

trust and stopping the contagion effect from countries under more distress to countries with good credit. F2 seems to capture also the market uncertainty before and after the Brexit referendum in 2016. Finally, F3 is mildly correlated with countries' CDS spreads and has factor loadings around zero for all countries. Still, looking at its evolution in time, we might expect F3 also to be a common factor that mostly captures the volatility and uncertainty in the markets, while F2 could be interpreted as a common factor that maps the shift in spread levels after ECB intervention, especially for Ireland and countries with good credit ratings.

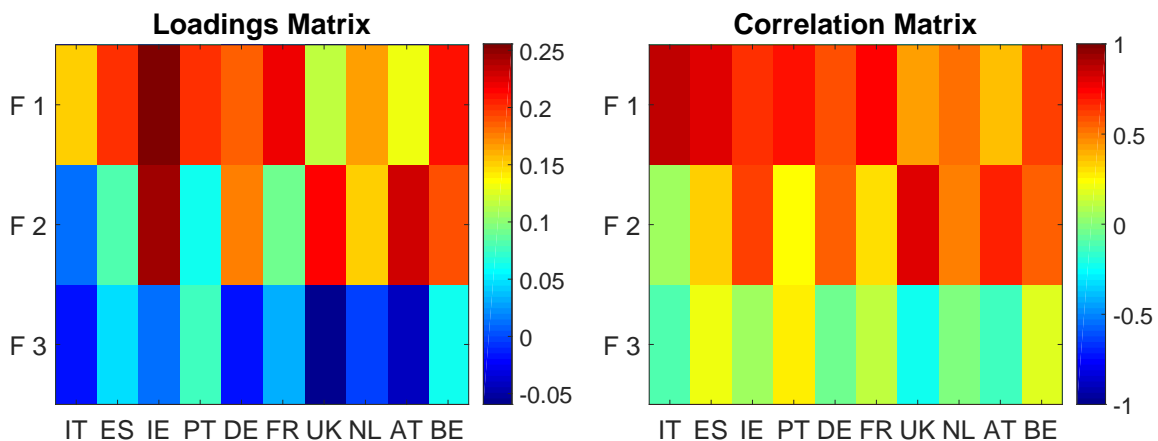


Figure 2: Loadings matrix of ICA factors (left panel); Correlation between ICA factors and CDS spreads (left panel).

The factor identification allows us to distinguish the hidden risk drivers of sovereign CDS spreads and their evolution over time. To confirm our interpretation, we construct three sovereign CDS indices for countries with a rating from B to below (i.e., IT,IE,ES,PT), countries with a rating from A to above (i.e., DE,FR,AT,BE,NL,UK), and the entire EU (i.e., $CDS_{\leq B}$, $CDS_{\geq A}$ and CDS Index EU), using the outstanding government debt of these countries as weights. In Table 2, we summarize the results obtained by regressing the CDS rates factors from the independent component analysis against each CDS index. We report the coefficients of the simple linear regressions and the corresponding adjusted R^2 . We notice that the first two IC components (F1 and F2) result in regressions with good explanatory power, as shown by the adjusted R^2 , while regressions with F3 have low explanatory power. F1 explains best the CDS index of countries with a rating below B. On the contrary, the second IC component (F2) explains best the CDS index of countries with a rating equal or above A. Such a factor allows us to map a shift in market confidence, mostly driven by the countries with good credit, to which it exhibits strong positive correlation through the entire period. The third IC component (F3) also captures some dependent relationship with respect to the CDS index of countries with a rating equal or above A. All factors are also significant and positively related to the global CDS Index EU. Hence, our analysis supports the interpretation of F1 as a factor that captures the evolution of CDS spreads for countries with lower credit ratings, while F2 and F3 are factors representing mostly countries with credit ratings greater than or equal to A, with F2 being a shift in levels and F3 a shift in volatility.

Regressor	F 1			F 2			F 3		
	Coeff	***	Adj R^2	Coeff	***	Adj R^2	Coeff	***	Adj R^2
CDS Rating $\leq B$	3.17	***	0.64	1.57	***	0.16	0.46	***	0.01
CDS Rating $\geq A$	1.91	***	0.33	1.96	***	0.34	-0.07	***	0.01
CDS Index EU	2.45	***	0.45	1.94	***	0.28	0.11	***	0.01
Explained Variance	60.81 %			37.84 %			1.35 %		

Table 2: Simple linear regression results of the independent component factors on GIIPS and core countries' CDS Indices, and EU CDS Index. Data are daily and cover the period from 01.01.2009 to 06.11.2018.

The diversification of a bank's sovereign portfolio, as well as any financial portfolio, is difficult to capture by a single measure. Most regulation, such as UCITS rules for investment funds, focuses typically on imposing threshold limits on portfolio weights to avoid too large an

exposure to a single asset (i.e., no more than 5% in a single asset) or on the entire portfolio's weight distribution (i.e., not more than 40% of the total portfolio can be invested in assets with weights larger than 5%). However, it is nowadays widely acknowledged that the number of active positions (i.e., in how many sovereigns the bank invests), the concentration of the vector of portfolio weights, and the contribution of each asset to the whole portfolio risk all contribute to quantify diversification.

Here, we consider the exposure of each country bank to 10 European sovereigns, i.e. Germany, Italy, France, Spain, Portugal, Ireland, Austria, Belgium, the Netherlands and the United Kingdom. Given the vector of portfolio weights $\mathbf{w} = [w_1, \dots, w_d]$ and a robust estimate of the $d \times d$ covariance matrix $\widehat{\Sigma}$ (Ledoit and Wolf, 2004) of d CDS rates, we first measure the diversification of banks' sovereign portfolios with the ICA factor decomposition to evaluate current portfolio performances. Given the loadings matrix \mathbf{A} for $m = 3$ ICA factors of CDS prices (i.e., F1, F2 and F3) and its Moore-Penrose inverse \mathbf{A}^+ , we compute a third measure of portfolio diversification, D_f , for each country bank as

$$D_f = \frac{1}{m \sum_{j=1}^m FC_j^2}.$$

FC_j represents the risk contribution of each ICA factor j to the overall portfolio risk (i.e., how much of the portfolio variance is due to the risk factor j), obtained by its Euler decomposition (Roncalli and Weisang, 2015)

$$FC_j = \frac{(\mathbf{A}'\mathbf{w})_j(\mathbf{A}^+\widehat{\Sigma}\mathbf{w})_j}{\sigma}.$$

D_f takes the maximum value of 1 for a fully diversified portfolio in terms of factor risk exposure and a minimum value of $1/m$ for a portfolio totally exposed to just one of the risk factors.

We also evaluate two more classical measures of diversification. If the portfolio risk is the variance $\sigma^2 = \mathbf{w}\widehat{\Sigma}\mathbf{w}'$, the classical diversification indices D_w and D_r are defined as

$$D_w = \frac{1}{d \sum_{i=1}^d w_i^2} \quad D_r = \frac{1}{d \sum_{i=1}^d RC_i^2}$$

RC_i measures the risk contribution of each country i to the overall portfolio risk (i.e., how

much of the portfolio variance is due to the risk of country i), such that

$$RC_i := w_i \frac{\partial \sigma}{\partial w_i} = w_i \frac{(\widehat{\Sigma}w)_i}{\sigma},$$

with $(\widehat{\Sigma}w)_i = \sum_{j=1}^d \sigma_{ij}w_j$ being the i -th component of the column vector $(\widehat{\Sigma}w)$, i.e., the product between the estimated covariance matrix and the weights' vector. Both D_w and D_r take the maximum value of 1 for a fully diversified portfolio and a minimum value of $1/d$ for a portfolio concentrated in one country. While D_w measures diversification in terms of portfolio holdings, D_r measures diversification with respect to risk contribution. D_w is the inverse of the so-called Herfindahl index, which represents a common measure of market concentration in economics, while D_r provides a measure of risk diversification, where risk is measured as the portfolio volatility, by means of the covariance matrix. Here, we focus on the risk diversification as captured by linear dependence across the mean values to provide an indicator for the average riskiness, while in Section 4.1 we also expand to evaluate the impact of regulation on tail-related risk measures. Relying on the covariance matrix allows also to benchmark the current status quo allocations at national and EU level with target benchmark portfolios, such as the minimum variance and the equal risk contribution portfolios (see Table 8 in Appendix D).

From Table 3, we notice that the home bias of sovereign holdings results in similar levels of D_w and D_r between different country banks, which means that the variance of banks' sovereign portfolios highly depends on the risk of their home countries. D_w and D_r are also far away from the levels of diversification of four benchmarks in portfolio theory (i.e., the equally weighted, the minimum variance, the equal risk contribution, and the equal factor contribution portfolios, summarized in Table 8 in the Appendix) (Markowitz, 1952; De Miguel, Garlappi, and Uppal, 2007; Roncalli, 2016; Meucci, Santangelo, and Deguest, 2014). Looking at the factor diversification D_f , we see that all country banks are close to the minimum level of 0.3, meaning that the variance of their portfolios is very concentrated in one single factor. By contrast, the aggregated EU portfolio, made up of the portfolios of all countries, is much better diversified and less risky than the portfolios of single countries.

This aspect is also shown in Figures 3 and 4, which display the relative risk and factor contributions for the sovereign portfolios, during the sovereign debt crisis and post crisis periods.

From Figure 3, we notice that the portfolio risk of all country banks is very concentrated in their home country (blue bar), especially for Portugal and Ireland. However, the first factor contributes the most to the volatility of such portfolios, particularly during the crisis. This means that, even if core countries, such as Germany and France, allocate a small part of their sovereign portfolio to peripheral countries, their resulting volatility is highly driven by the peripheral countries' factor (F1). A different picture is the one shown by the aggregated EU portfolio, in Figure 4, which achieves similar relative risk and factor contributions as the equally weighted and equal risk contribution portfolios, despite investing a larger amount in the largest countries, i.e., Italy, Germany, France, and Spain. Therefore, home bias in a single country still leads to a diversified EU portfolio.

As Choi et al. (2017) show, home bias as a result of information advantage also has a positive impact in terms of the performance of institutional investors. In fact, by investigating security holdings for 10,771 institutional investors from 72 countries, the authors show that concentrated investments result in excess risk-adjusted returns. A diversified EU portfolio could be also achieved as the sum of well-diversified portfolios at a single country level, i.e., eliminating home bias. However, the risk profile of each single country as well as the contagion dynamics would differ from the current status quo. As country banks would have overlapping portfolios, interdependent on each other, a shock on a single sovereign (e.g., a deterioration of its credit quality) would not stop at its domestic banking sector but could reach the entire system, possibly exacerbating the effects of such shocks, reducing the resilience of the whole banking system. In the next section, we evaluate the possible consequences on risk and diversification of the new regulation by simulating a rebalancing mechanism that banks might adopt as a response to new regulation on euro sovereign bond holdings.

Country Bank	σ^2	D_w	D_r	D_f
DE	3.12	0.17	0.33	0.53
IT	8.37	0.17	0.13	0.44
FR	4.72	0.21	0.27	0.49
ES	10.24	0.13	0.13	0.51
PT	18.94	0.12	0.11	0.42
IE	14.84	0.16	0.12	0.48
EU	5.47	0.65	0.51	0.12
Equally Weighted	7.40	1.00	0.60	0.50
Min Variance	1.98	0.22	0.22	0.51
Equal Risk Contrib	3.74	0.69	1.00	0.53
Equal Factor Contrib	22.53	0.10	0.10	0.96

Table 3: Average portfolio statistics of the country banks over the period June 2013 and December 2015: portfolio variance σ^2 , weight and risk diversification indices D_w and D_r ($D_w, D_r \in [1/d, 1]$), and factor diversification index D_f ($D_f \in [1/m, 1]$).

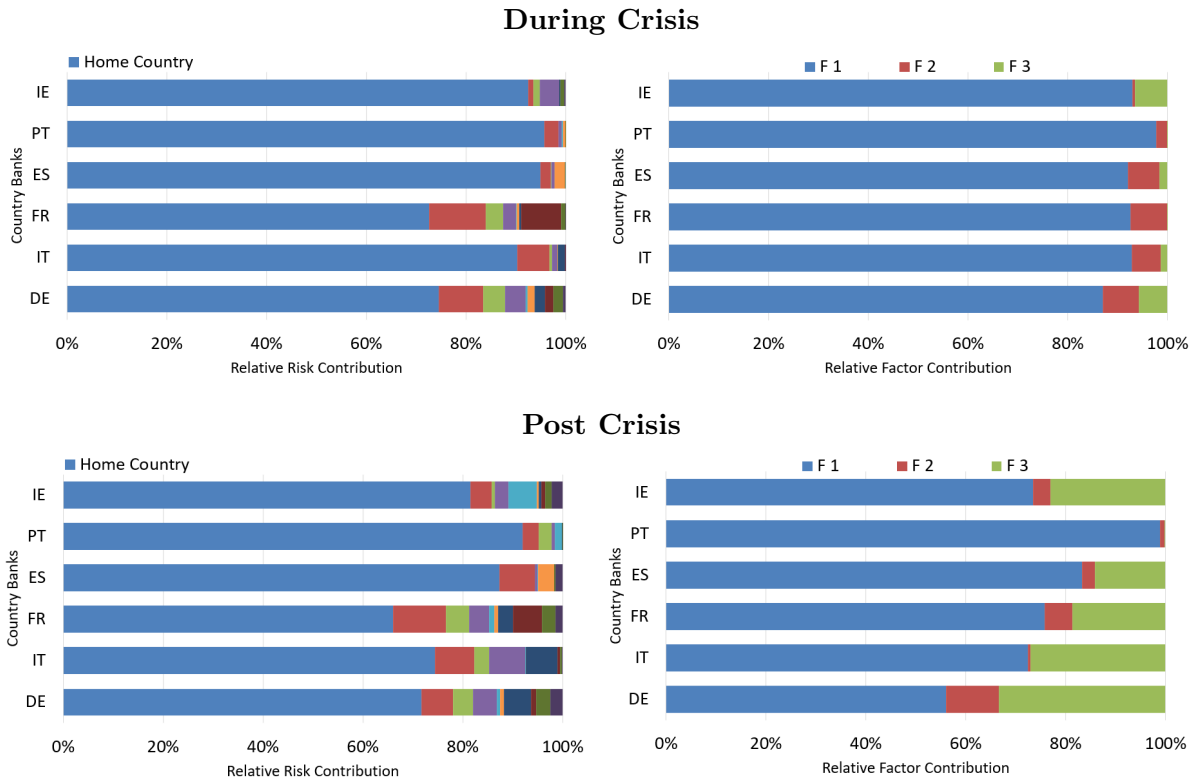


Figure 3: Relative Risk Contribution of sovereign CDS spreads and Relative Factor Risk Contribution of ICA factors for each country bank portfolio.

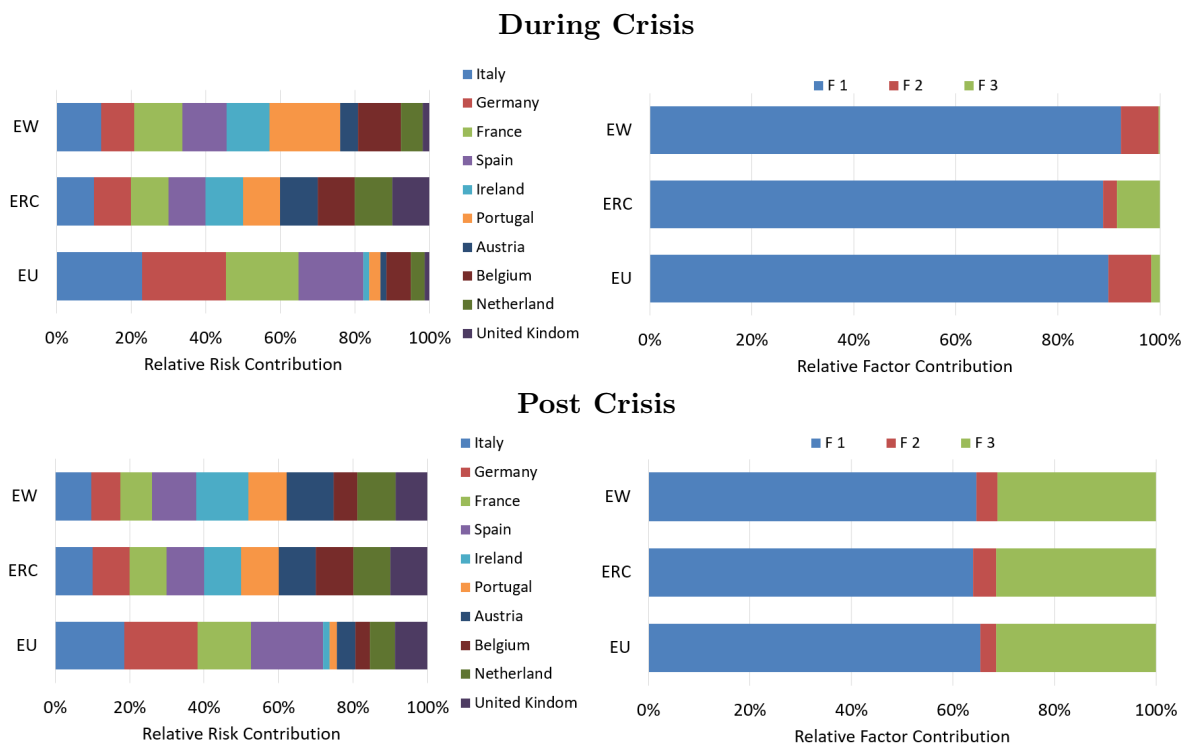


Figure 4: Relative Risk Contribution of sovereign CDS spreads and Relative Factor Risk Contribution of ICA factors for the EU and EW portfolios.

4 The Potential Impact of Diversification Requirements

The large exposure regime forces banks to control for counterparty risk by limiting the sum of all their exposures to a single counterparty, except for sovereigns, to 25% of banks' eligible capital. Let SE_{ji} be the exposure of bank j to country i , $SE_j = \sum_{i=1}^d SE_{ji}$ the total sovereign exposure of bank j , and C_j its eligible capital. Then, the diversification constraint acts as a limit on the single weights of the sovereign portfolio of bank j , defined as $w_{ji} = SE_{ji}/SE_j$,

$$w_{ji} \leq \frac{0.25 C_j}{SE_j} .$$

With the introduction of this constraint, most banks would have to rebalance their sovereign portfolios, as shown in Figure 5 for different values of limit on large exposures. Depending on the time in which they have to rebalance, the size of their portfolios and the sovereign risk/return characteristics, banks may apply different strategies to adjust their portfolios according to the new regulation (Lenarčič, Mevis, and Siklós, 2016).

Here, we assume that if there are sufficient substitutes in the sovereign bond market, banks would replace their excess exposure on sovereign i by investing in a sovereign k with a similar risk/return profile, i.e., requiring the same risk-weight and returning a similar yield. If there is no substitute with these characteristics, then banks would invest in a sovereign h with a lower risk/return profile, i.e., requiring a lower risk-weight and returning a lower yield.⁴ In fact, although sovereign h is not a perfect substitute for sovereign i and reduces profitability, it may be more liquid and easily accessible. In case no other sovereign in our sample has a lower risk/return profile or the exposure to that sovereign already reaches the limit, banks would reallocate the excess amount either in a sovereign outside the sample or in a different asset class, e.g., corporate bond.⁵ We implement this rebalancing scheme for each bank and compare the risk, as captured by both the variance and the value-at-risk of the resulting

⁴Alternative rebalancing strategies could be easily incorporated into our framework, such as a flight-to-quality rebalancing, in which Country Banks would substitute their excess sovereign holdings by buying the bonds of safer countries (see Appendix E).

⁵Recent literature and reports from the ECB (Becker and Ivashina (2015), ECB (2016), ECB (2017), Altavilla, Pagano, and Simonelli (2017), Albertazzi, Becker, and Boucinha (2018)) have in fact shown that after the sovereign crisis there has been an investor shift from sovereign holdings to bonds, both sovereign and corporate and with lower credit quality, to satisfy investors' *search for yield*.

portfolios, assuming that sovereign risk remains unchanged.

Figure 6 shows the percentage of sovereign bond holdings, i.e., the total portfolio weight, that country banks would rebalance and reinvest if the limit on large exposures were set to 25% (left panel) or 75% (right panel). Even with the highest limit on large exposures, the portfolio weight that would be rebalanced would be between 20% and 40% for most country banks, and in the case of Germany would exceed 60%. French banks instead would have to reallocate around 14% of their current sovereign portfolios into a different asset class, according to our rebalancing mechanism.

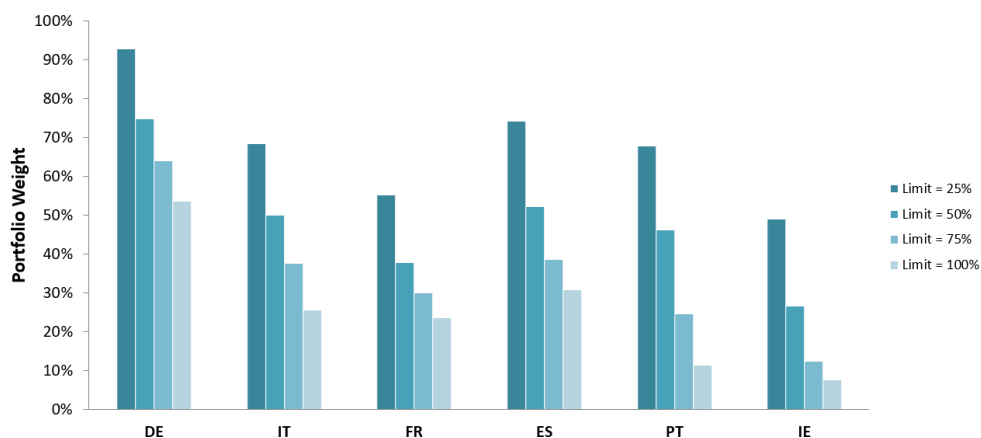


Figure 5: Total portfolio weight to rebalance for each country bank with different limits on large exposures.

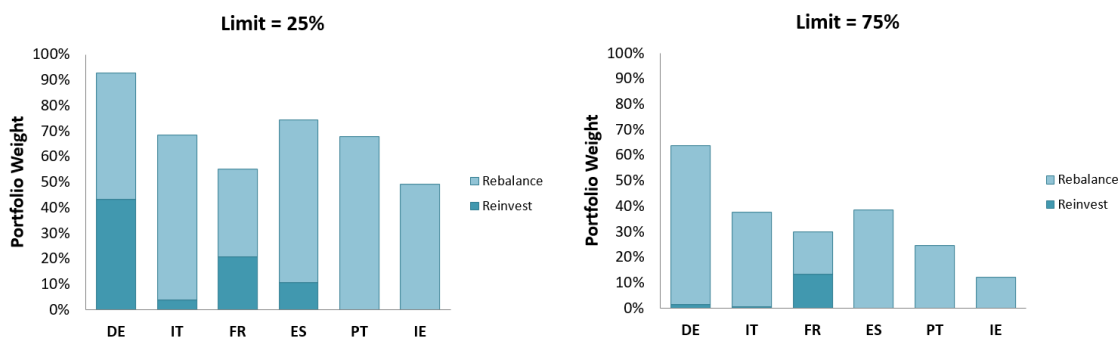


Figure 6: Total portfolio weight to rebalance and reinvest for each Country Bank with 25% and 75% limit on large exposures.

When considering the 25% limit on large exposures, Figure 7 shows that, as expected, such a constraint leads countries to sell mostly domestic bonds, due to the large home bias, while

increasing their holdings in countries with similar risk-return profiles, until the diversification constraint is again binding. On the one hand, according to our rebalancing mechanism, German and French banks substitute their domestic sovereign holdings with bonds issued by countries with a low risk/return profile, such as Austria, Belgium, the Netherlands, and the UK. On the other hand, Italy, Spain, Portugal, and Ireland first invest in a sovereign with similar risk/return characteristics, and, if necessary, buy bonds of safer countries.

We compute the risk and diversification measures for the rebalanced portfolios of country banks to determine whether higher diversification requirements, such as the limit on large exposures, result in a reduction of portfolio risk. As shown in Table 4, all portfolios are much more diversified, compared to the ones before the rebalancing (see Table 3), as D_w , D_r , and D_f are larger and closer to one, and in some cases they are higher than in benchmark portfolios. However, despite the lower home bias, the variance of all country banks' portfolios increases, except for Portugal. This result may be even stronger during a crisis, when the CDS spreads of different countries are generally highly positively correlated.

Figure 8 displays the Markowitz's mean variance frontier and the risk-return profile of the current and rebalanced portfolios of country banks and the EU, assuming the mean expected returns and covariance matrix are estimated in the period from 28.01.2009 to 31.12.2015. As we can see, all portfolios are dominated by the frontier. The current portfolios of countries with lower credit ratings, such as Italy, Spain, Ireland and Portugal, show higher returns, due to their large home bias, as investors are more prone to search for returns to compensate for the extra risk they are assuming. Instead, the portfolios of French and German banks are in the bottom left area of the figure, as a result of their home bias towards low risk/return sovereign bonds. Therefore, home bias at a domestic level results in mapping different countries' preferences and characteristics and possibly their access to information (Choi et al., 2017). Still, the status quo European portfolio, despite being composed of highly concentrated national portfolios, is not only well-diversified, as shown in Table 3, but also close to the minimum variance (MV) and the ERC portfolios. Lack of diversification at the country level results then in diversified and almost risk-optimal allocation at the aggregated level.

When we add the diversification constraint, the solution space shrinks as the limit on large

exposures is binding. As a result, all country banks' portfolios now cluster in the central part of Figure 8, with much closer risk-return profiles than the status quo portfolios. At the same time, the EU portfolio results in an overall limited rebalancing, mostly reducing the exposure on Germany, Italy and Spain, while increasing the one on Ireland, Portugal, Austria, and Belgium, as a consequence of the home bias distributions across countries⁶ (see Figure 7). This results in a new EU portfolio with a slightly better level of diversification and higher risk but almost the same return rate. All portfolios would be clustered in an area characterized by similar risk-return characteristics, due to the larger overlapping of their portfolio composition and the removal of the home bias at the domestic level. However, as shown by Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015) and Caccioli et al. (2014), common asset holdings are an important vector of contagion and may amplify the impact of a financial shock. Therefore, while diversification may be good for individual institutions or countries, it can lead to dangerous systemic effects, due to shock propagation through banks with overlapping portfolios.

Country Bank	σ^2	D_w	D_r	D_f
DE	5.40	0.80	0.82	0.54
IT	10.51	0.92	0.47	0.56
FR	5.32	0.57	0.56	0.56
ES	13.52	0.71	0.37	0.58
PT	15.12	0.56	0.36	0.59
IE	15.55	0.57	0.34	0.57
EU	8.80	0.95	0.56	0.16
Equally Weighted	9.06	1.00	0.53	0.55
Min Variance	2.01	0.10	0.10	0.52
Equal Risk Contrib	4.11	0.64	1.00	0.59
Equal Factor Contrib	29.36	0.10	0.10	0.64

Table 4: Portfolio statistics of the country banks after rebalancing: portfolio variance σ^2 , weight and risk diversification indices D_w and D_r ($D_w, D_r \in [1/d, 1]$), and factor diversification index D_f ($D_f \in [1/m, 1]$).

⁶The EU portfolio differs from the current portfolio because it is calculated with the additional sovereigns added to or subtracted from the total bank holdings after rebalancing.

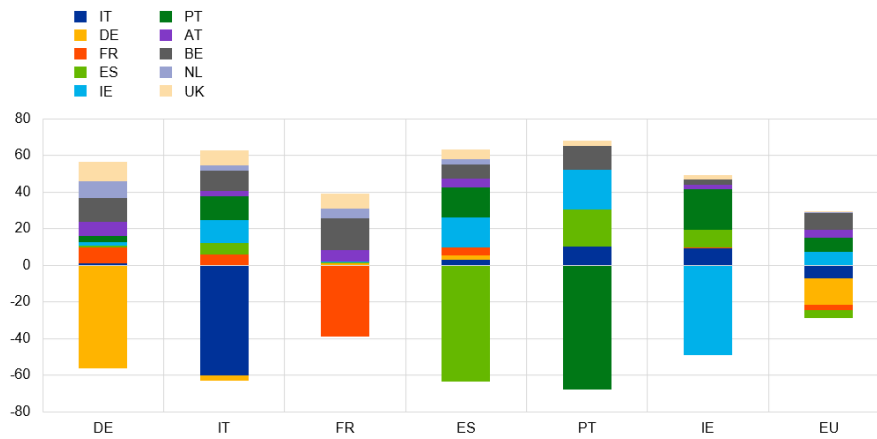


Figure 7: Portfolio Rebalancing

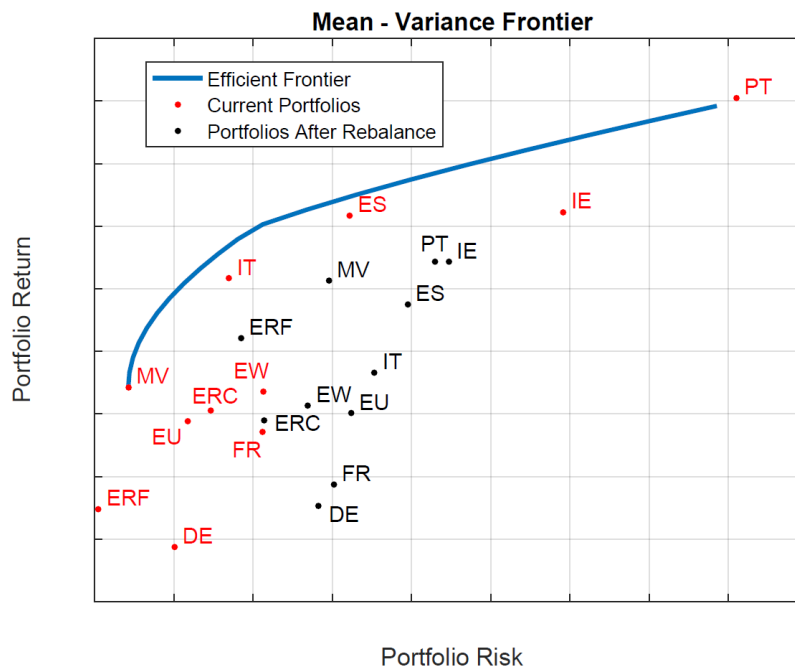


Figure 8: Mean-variance frontier, country banks portfolios and benchmark portfolios, before and after rebalancing.

4.1 Value-at-risk Estimation and Stress Test

Financial stability is probably more closely related to the new portfolios' tail risk than their variance. We capture tail risk with the value-at-risk (VaR) (i.e., the quantile at the 95% confidence level of the portfolio returns). In this section, we estimate the VaR of the current and rebalanced portfolios of country banks to evaluate the effects of the new regulation on tail risk. We implement the scenario approach of Bernard and Vanduffel (2015), which allows us to obtain VaR bounds. The width of such bounds depends on the information we have on the distribution of asset returns, i.e., how confident we are on the assumed distribution. Furthermore, we perform a stress test and compare the VaR bounds of the current and rebalanced portfolios of country banks in a period of crisis. By doing so, we assess the implications of the new regulation in a scenario where the volatility and correlations in the sovereign bond market increase.

For each country bank, given \mathbf{R} , the $N \times d$ matrix of daily CDS log-returns, and \mathbf{w} , the $1 \times d$ vector of its portfolio weights, we compute a matrix of returns as the dot product $\mathbf{X} = \mathbf{w} \cdot \mathbf{R}$, where N are the daily observations and d the sources of sovereign risk. We define then $\mathbf{S} = \sum_{i=1}^N \mathbf{X}_i$ as the $N \times 1$ joint portfolio. A common problem in risk evaluation of an aggregate portfolio of individual risks is that their dependence is usually unknown. This makes any risk estimation subject to model uncertainty. For this reason, in order to estimate the VaR of \mathbf{S} , we use the scenario approach of Bernard and Vanduffel (2015).

First, we assume we know the marginal distributions of \mathbf{X}_j on \mathbb{R}^d for $j = 1, \dots, d$ and we fit a joint distribution on \mathbf{X} , which represents our benchmark model. Due to partial or no information on the dependence structure of \mathbf{X} , we then split our data into two parts: \mathcal{F} , the trusted region, where we expect the fitted benchmark model to be appropriate, and $\mathcal{U} = \mathbb{R}^d \setminus \mathcal{F}$, the untrusted region. We account for model risk by attaching a probability $p_{\mathcal{F}} = P(\mathbf{X} \in \mathcal{F})$. A low $p_{\mathcal{F}}$ indicates low trust in the benchmark model, therefore high uncertainty in the VaR estimation. When $p_{\mathcal{F}} \neq 1$, we do not have full information on the dependence of risk factors and the VaR cannot be computed precisely. However, we can approximate the smallest and largest possible VaR by rearranging the data to obtain the best and worst dependence structures, as described in Embrechts, Puccetti, and Ruschendorf (2013). Adding dependence information can sharpen the bounds considerably (Bernard and Vanduffel, 2015).

Because Kolmogorov-Smirnov tests support Student's t-margins, we assume that \mathbf{X} follows a multivariate Student's t-distribution with 3 degrees of freedom. Moreover, we also take into account the possible presence of tail dependence. We assign different probabilities to the Student's t benchmark model, $p_{\mathcal{F}}$, and compute the lowest returns of the aggregated sovereign portfolios before and after rebalancing, at a 95% confidence level, that is $\text{VaR}_{95\%}$. In Figures 9 and 10, we compare the estimated VaR bounds with $p_{\mathcal{F}} = 0, 0.2, 0.5, 0.8$, for each country bank and for the entire EU portfolio. By increasing $p_{\mathcal{F}}$, we decrease the confidence in our model. As expected, we find that the lower the probability we attach to the benchmark model, $p_{\mathcal{F}}$, the larger the bounds are. Furthermore, we notice that rebalancing portfolios to increase diversification is not always desirable under our rebalancing assumptions, due to the correlation between sovereign tail risks: VaR decreases for only few countries, such as Italy and Ireland, but confidence intervals are still overlapping. At the aggregate EU level, no effect is detectable.

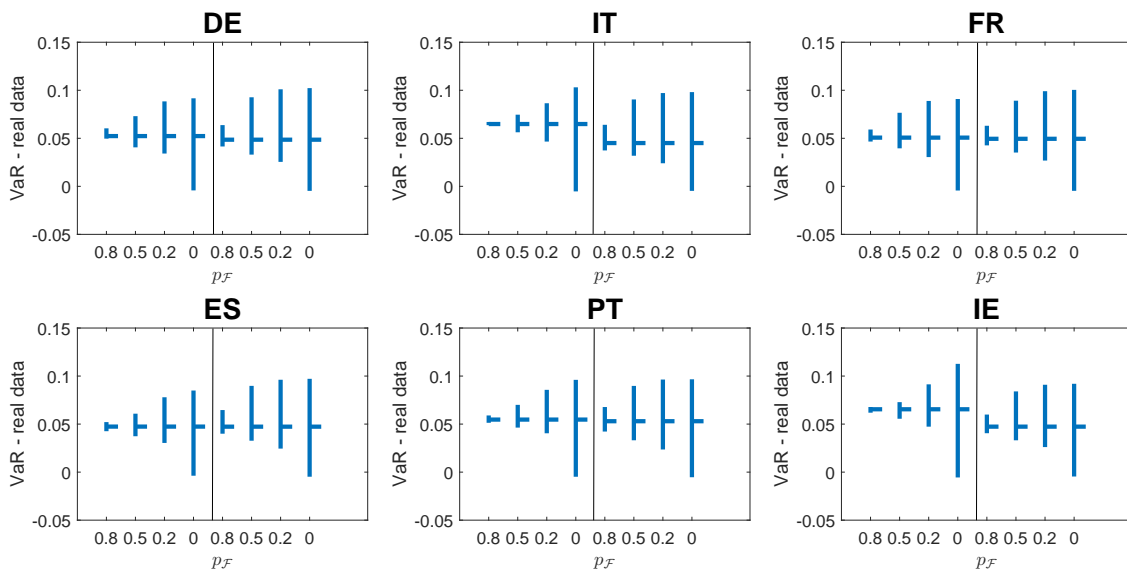


Figure 9: value-at-risk of the country banks sovereign portfolios before (left side) and after rebalancing (right side).

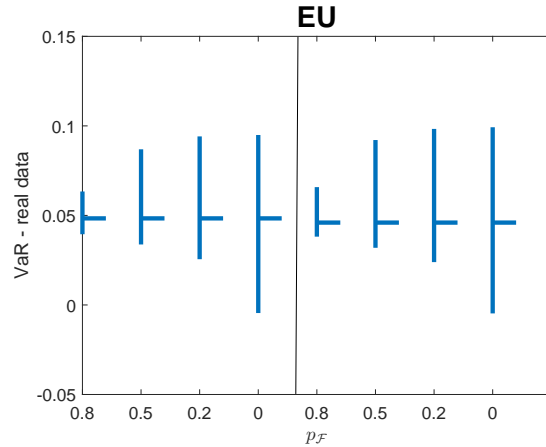


Figure 10: value-at-risk of the EU sovereign portfolio before (left side) and after rebalancing (right side).

One crucial assumption of the previous analysis is that the default risk of sovereigns represented by their CDS spreads remains unchanged after the rebalancing. However, we would expect volatility to increase due to the higher transaction volume within the sovereign bond market. Furthermore, it is interesting to test whether increasing diversification would be beneficial during crises, when correlation between sovereign CDS is unusually high. For these reasons, we simulate $t = 5000$ CDS spreads from a multivariate Student's t -distribution with 3 degrees of freedom and mean and covariance matrices equal to the ones estimated using real CDS spreads in the crisis period between January 2009 and December 2012. Then, we estimate the tail risk of banks' current and rebalanced portfolios by using the simulated data, and compare the VaR bounds in Figures 11 and 12 for single countries and for the entire EU. We notice that the rebalanced and current portfolios show similar levels of tail risk, both for single countries and for the EU banking system, which means that rebalancing portfolios to increase diversification may not decrease the tail risk when correlation between sovereign defaults is higher, as during a crisis.

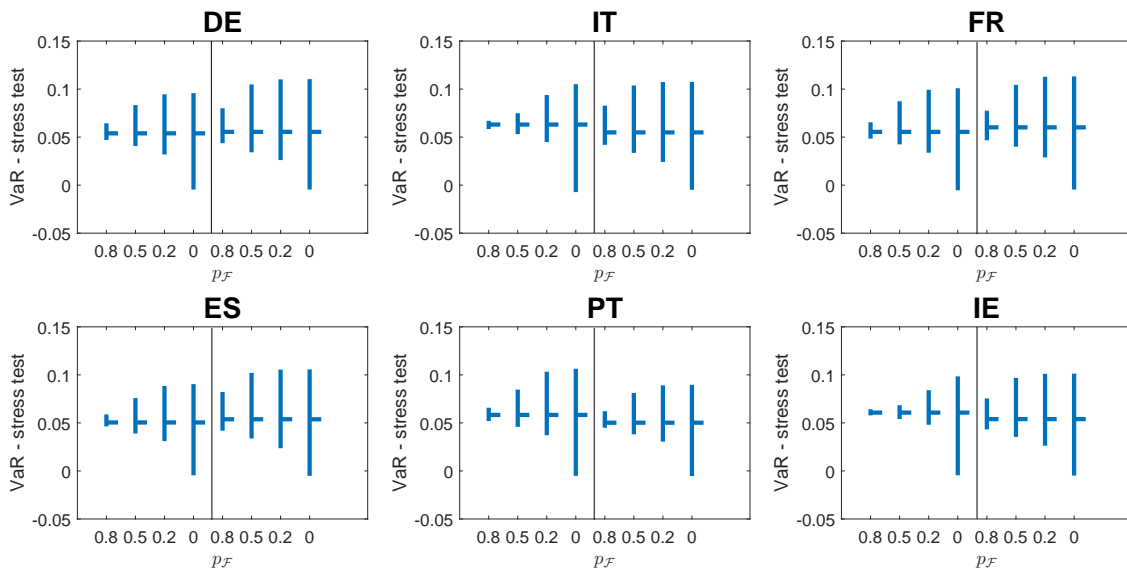


Figure 11: value-at-risk of the sovereign portfolios of country banks before (left side) and after rebalancing (right side), obtained using simulated data from a multivariate Student's t-distribution with 3 degrees of freedom, and mean and covariance matrix equal to the ones estimated using real CDS spreads in the crisis period, between January 2009 and December 2012.

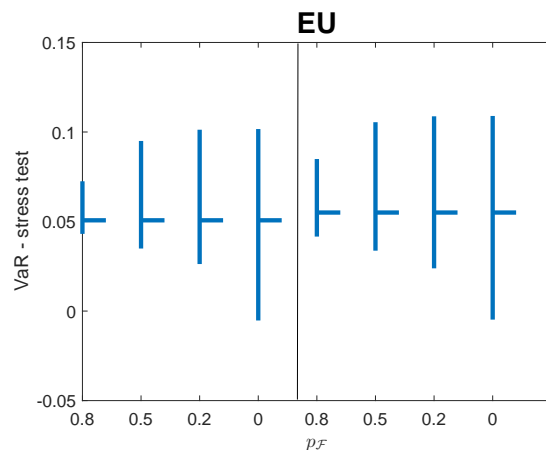


Figure 12: value-at-risk of the EU sovereign portfolios before (left side) and after rebalancing (right side), obtained using simulated data from a multivariate Student's t-distribution with 3 degrees of freedom, and mean and covariance matrix equal to the ones estimated using real CDS spreads in the crisis period, between January 2009 and December 2012.

5 Fire-sales and Contagion Risks

If there are fire-sales on shared exposures, the portfolios that are joined in this way create externalities for each other as the fire-sales of one bank reduce the value of the liquid assets of another. Are the rebalanced portfolios likely to have fewer and smaller fire-sale losses than the current portfolios? We choose one canonical model of fire-sales, Greenwood, Landier, and Thesmar (2015), which has already been applied to European banking data. We argue that this approach gives the rebalanced portfolios a very good chance to improve the fire-sale outcome compared to a model that emphasizes the contagion effects of the fire-sales. Given this approach, the outcome of our analysis suggests that the rebalanced portfolios do attenuate total fire-sale externalities when compared to the current portfolios.

We use the multivariate Student's t to simulate a distribution of fire-sale losses. In contrast to Greenwood, Landier, and Thesmar (2015), who include a stress test that focuses only on the losses associated with one extreme scenario, we can examine the trade-off between portfolios for the entire density of fire-sale losses. Further, we modify Greenwood, Landier, and Thesmar (2015) slightly to emphasize that fire-sales are not simple sales of assets. They are triggered when losses get large enough that the sovereign assets must be sold quickly and so cause an unusual price decline. Because of the need for rapid liquidity transformation, the fire-sale induces price changes that might be suboptimal for the banking sector. For a single draw of the return distribution, which we denote, G^0 , we measure the fire-sale externality by adding up all of the fire-sales in the banking sector.⁷ For this draw, we compute the total fire-sale loss, given the current portfolio weights, W_c , and compare it to the loss given the weights of the rebalanced portfolio, W_r . We simulate the returns from the same multivariate Student's t -distribution used in Section 4, for 1 million draws of G^0 to derive the distributions of fire-sale losses implied by the two sets of portfolios to assess whether rebalancing affects the probabilities of large fire-sale losses.

5.1 Classic Greenwood Fire-sales Model

Greenwood, Landier, and Thesmar (2015) make five strong assumptions to predict the effect

⁷Clearly, if the draw i does not have enough negative losses, there will be no fire-sale losses in the system.

of fire-sales on financial stability: 1) Leverage targets: each bank, i , sells or buys assets to maintain a constant leverage ratio, denoted here by l_i ; 2) Constant weights: banks sell off all of their assets to return to their leverage targets so that target exposure weights within their portfolios remain fixed, where the vector of weights of the d assets is denoted w_i ; 3) Linear price effect: fire sales generate a price impact according to a linear price schedule, which for asset j we denote, P_{jj} ; 4) Equal impact: additionally for their empirical work, they assume that the price impact is equal across all assets, or $P_{jj} = P_{kk}$; and 5) One-off: fire-sales take place in a “one-off” method, where additional losses from the fire-sales themselves do not generate more fire-sales⁸.

A shock to the returns of d assets, G^0 , affects the returns to the portfolios of B banks, r_B ,⁹ so that the portfolio return for these banks is then

$$r_B = WG^0, \quad (2)$$

where W is the $B \times d$ matrix of the d components of the stacked portfolio weights w_b for the B banks, written as weights of the total portfolio (that is, each row, W_b obeys $0 \leq W_b \leq 1$ and $W \cdot 1_d = 1_b$, where 1_d is a $1 \times d$ vector of ones.) Under the five assumptions outlined above, the fire-sale return, G^1 , given returns, r_B , (where r_B is an $B \times 1$ vector of outcomes to the B banks in the system) is

$$G^1 = PW'LA r_B. \quad (3)$$

P is a $d \times d$ diagonal matrix with components that represent the demand elasticities for the j^{th} asset.¹⁰ Each element P_{jj} represents the effect of selling a total quantity of the j^{th} asset on its return. In Greenwood, Landier, and Thesmar (2015), this is assumed to be linear (and in the empirical work is assumed to be the same across all bonds). L is the $B \times B$ diagonal

⁸This assumption is easily dropped and in Greenwood, Landier, and Thesmar (2015) is maintained only because results do not differ if the assumption is dropped.

⁹With a slight abuse of notation, we define here r_B to be the $B \times 1$ of banks' portfolio returns. In Section 4, \mathbf{R} was the $N \times d$ matrix of daily CDS simulated d assets log-returns from a multivariate Student's t-distribution. G^0 is then one row of the matrix \mathbf{R} in Section 4.

¹⁰The losses implicit in equation 3 differ from the losses described in the preceding section in that the losses, $PW'LA r_B$, are convex in W due to the assumption that banks recover their liquidity in a balanced sale of assets.

matrix of leverage ratios, $\frac{c_b}{e_b}$, the ratio of bank b 's leverage, c , and equity, e ; and A is the $B \times B$ diagonal matrix of bank assets, where each diagonal term is the sum $c_b + e_b$. In other words, the effect of the system shock, r_B , is translated into a fire-sale return through a leverage target, L , as well as asset size, A , which scales the amount that each bank buys or sells of the asset, given its weighting matrix, W , a $b \times d$ matrix of portfolio weights for each bank i 's ($i = 1, \dots, b$) holdings of the j^{th} portfolio asset ($j = 1, \dots, d$). This is multiplied by the weight that the asset has in its portfolio. The effect of the shock on the return of the portfolio to each of the banks is obtained by multiplying equation (3) by the matrix of portfolio weights, W .¹¹

$$G^2 = PW'LAWG^1 \quad (4)$$

Our data from the CDS prices gives a distribution on the returns, G^0 , which then lead to the distribution of total fire-sales directly from equation (3). We consider then the fire-sale distributions corresponding to the current set of portfolios, W_c , and the rebalanced portfolios, W_r . The current and rebalanced portfolios are restricted in that the total amount available to redistribute is fixed,¹² and the amount of total assets held by each individual bank is also fixed. This means that

$$1AW_c = 1AW_r \equiv T, \quad (5)$$

where T is a $1 \times d$ vector of the total sovereign debt within the system, and 1 is an $1 \times B$ vector of ones. Also trivially, A is kept the same in both systems, and W is a weighting matrix where each row sums to one in both the current and rebalanced portfolios. For a given shock, G^0 , analysis of the total fire-sale costs to the system is

$$1AWPW'LAWG^0 = TPW'LAWG^0 \quad (6)$$

¹¹This can lead to a second-round effect and so forth.

¹²This is not entirely correct, in that some available sovereign debt from countries within the EMU but outside the banking portfolios of the countries that are under study are available to the W_r . While the outside debt will be incorporated in the empirical study, we are making a simple point that the drivers of the differences should not lie in the differing amounts available for fire-sales.

so that the difference between the effect with the two portfolios is just

$$TP(W'_cLAW_c - W'_rLAW_r)G^0. \quad (7)$$

Equation (7) says that under the assumptions 1, 2, 3, and 5 of the Greenwood model, the only portfolio difference of the effect of a draw from the shocks' distribution on the total fire-sale losses lies in the difference in the matrices, $W'_cLAW_c - W'_rLAW_r$. The ij^{th} term of $W'LAW$ is just $\sum_b w_{ib}l_b a_b w_{bj}$, which can be interpreted as a diversification element, in that total fire-sale losses will be larger if the weighted asset is distributed more equally throughout the system, when weighted by $l_b a_b$. If, for example, all banks had equal assets and leverage targets, then the term $W'LAW$ (which in this case equals $LAW'W$) would be minimized in portfolios where each sovereign bond was distributed equally across all banks.

The distributions of fire-sale losses implicit in equation (7) gives a more “diversified portfolio” (in the sense of minimizing $W'LAW$) the best chance among many of the possible models of fire-sale losses. By optimizing these losses with a minimum $W'LAW$ portfolio, one abstracts from the contagion effects implicit in many network-based models. For example, Elliott, Golub, and Jackson (2014) show the well-known trade-off between integration and diversification, which has nonmonotonic effects in cascading defaults, and this tradeoff will also be true in possible models of fire-sale contagion as well. Models of cascades often show that the effects of increased connection will buffer a system when the shocks are small, whereas large shocks can amplify the losses through increased contagion. By focusing on the diversification effect of the increased connections between the rebalanced portfolios and ignoring the contagion effects altogether, the Greenwood, Landier, and Thesmar (2015) model gives the rebalanced portfolios their best chance of attenuating large shocks that occur with small probability, by ignoring the contagion effects.

Table 5.1 shows the difference matrix $TP(W'_cLAW_c - W'_rLAW_r)$ multiplied by a 100% loss in each of the ten sovereigns in the European portfolios (that is where G^0 is a vector of zeros with -1 in the i^{th} position, so that the losses are focused on a single sovereign bond). We look at this to determine, given the context of the leverage targets and total assets of the banking system, the losses of which bonds will favor the rebalanced (or conversely the current)

Sovereign Bond	Implied Difference from Fire-sale Loss (in euro millions)
IT	-3729.686293
DE	-5357.924779
FR	-2910.686102
ES	-3893.34583
IE	999.4069104
PT	923.6140687
AT	568.6995058
BE	1295.005709
NL	546.1907613
UK	913.5018036

Table 5: Implied difference $TP(W'_cLAW_c - W'_rLAW_r)$ from fire-sale loss for the system when a single sovereign bond has a huge loss ($g_i = -1$).

portfolios. A negative number indicates that the rebalanced portfolio has fewer losses than the current portfolio.

It implies that fire-sale losses will be larger for the current portfolio of banks than the rebalanced portfolio if the portfolio losses are more prevalent in the Italian, German, French or Spanish sovereign debt, which is likely to be the case with the larger banks within the Eurosystem. This intuition is confirmed by the simulations' results reported in Figure 13. This figure looks at a very simple analysis of the price change induced by the behavior given in a Greenwood, Landier, and Thesmar (2015) model. Figure 13 graphs the density of outcomes of 10,000 simulations, in which shocks are drawn from a multivariate Student's t-distribution with 3 degrees of freedom, and parameters are estimated from the sovereign crisis period, as in Section 4.1. Fire-sale losses in euro are graphed on the horizontal axis and are calculated using equation (6), given that fire-sale losses and "fire-sale gains" are treated symmetrically. The losses and gains appear to be a linear transformation of the original returns distribution. Further, this linear transformation is a weighted cross-sum of the portfolio components so that the forced diversification draws in the tails of the distribution for the rebalanced portfolio as compared to the current portfolio, as could be expected from a Greenwood, Landier, and Thesmar (2015) model.

5.2 Threshold Fire-sales Losses

In the classical model of fire-sales outlined above, the distinction between "fire-sale" and "normal demand-driven price change" is missing. Counting welfare losses due to total fire-sale

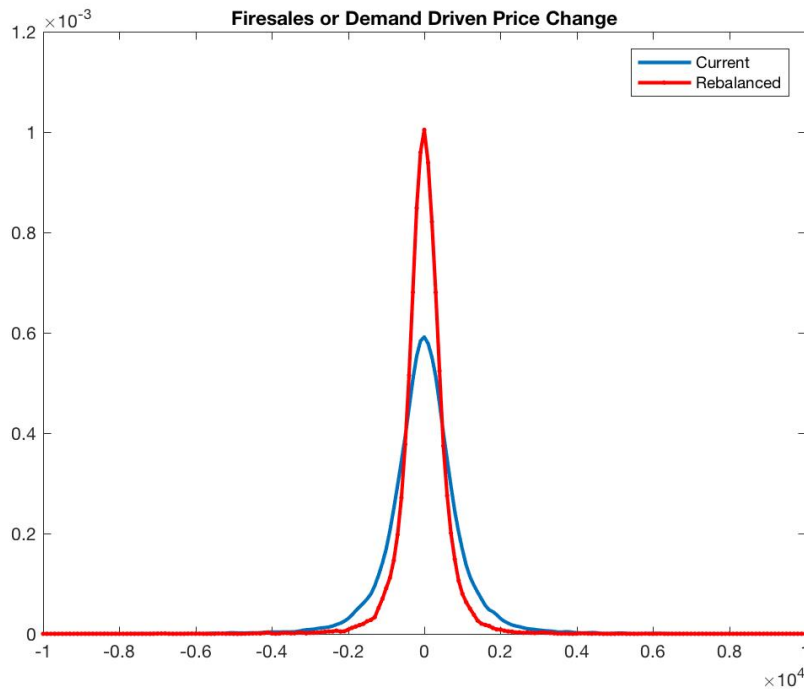


Figure 13: Kernel-fitted distribution of the total fire-sale “costs” (negative) or “benefits” (positive), $TPW'LAWG^0$, with the current and rebalanced portfolios.

losses thus seems debatable.¹³ Our analysis changes the Greenwood, Landier, and Thesmar (2015) model by suggesting that a bank does not replace small losses through the sale of assets, but only replaces it once its capital reaches a threshold level of loss. This captures the time element, in that with small losses, a bank has time to recover its liquidity target without a fire-sale reduction in the price, but with larger losses, it needs to recover liquidity quickly to maintain its reputation and prevent a run on its deposits, and thus suffers a fire-sale reduction.

Figure 14 captures the fire-sale probability histograms for negative losses if a fire-sale is triggered by a loss of two-tenths (top panel) of the bank’s capital, while the bottom panel displays the probability of having at least one fire-sale loss in any bank for different k proportions of capital, where $k = (0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4)$ for both the current and rebalanced portfolios. The top panel shows that, as expected, the rebalanced portfolios attenuate extreme fire-sale losses as compared to the current portfolios. This is what the rebalancing is designed

¹³All of this assumes interior solutions and abstracts from an important nonlinearity included in Greenwood, Landier, and Thesmar (2015). Banks can go bankrupt in the original model, which means that they stop demanding more liquidity when their asset value reaches a certain threshold because they are no longer existent. We also looked at a bankruptcy model with little effect on the results.

to do, and because the losses are concentrated on those elements of sovereign debt, the Italian, French, Spanish, and German, that favor the rebalanced portfolios, these portfolios do better with fire-sales. The bottom panel shows that when testing for the sensitivity of the k -th proportion of capital, the fire-sale probability of having at least one loss in the system gets much closer for the two portfolios as k increases, that is, for higher capital triggers.

The model seems to give contrasting results to the preceding sections of this paper. Further the contrast is notable, given that the fire-sale model we used was very consciously chosen to emphasize the similarities with our preceding portfolio analysis. However, the results depend on two very important aspects of the fire-sale structure. First, the model weights the fire-sale losses heavily toward the large banks, who are currently likely to hold larger quantities of the major sovereign debt that favors the rebalanced portfolio. Second, the analysis has focused on the fire-sale externality which is measured as a total loss to the system, rather than focusing on distributing these losses to specific banks. An analysis focusing on individual bank losses will not provide as much contrast to the preceding sections.

It is also important to note that more sophisticated models of contagion will reveal a more complicated story than that presented here. For example, a model of contagion where shared portfolios triggered more fire-sales in other banks might have the common property observed in Allen and Gale (2000) and Elliott, Golub, and Jackson (2014), that the more diversified portfolios after rebalancing indeed attenuate fire-sale losses for small losses, but amplify them for large losses. What we do observe in this simple exercise, however, is that more equal portfolios are more likely to attenuate fire-sale losses.¹⁴ As in the observations about the extreme risk in the preceding section, our conclusions in this section are sensitive to assumptions about how banks respond to changes: in this case, the extreme assumptions about the liquidity targets and balanced sales of the sovereigns favor the rebalanced portfolios and do not penalize possible new channels of contagion.

¹⁴Our results also depend on truncating the sovereign losses so that $\log(\text{return losses})$ are always less than one. When huge losses are allowed, the rebalanced and current portfolios are indistinguishable from each other at the extreme tail of the fire-sale losses.

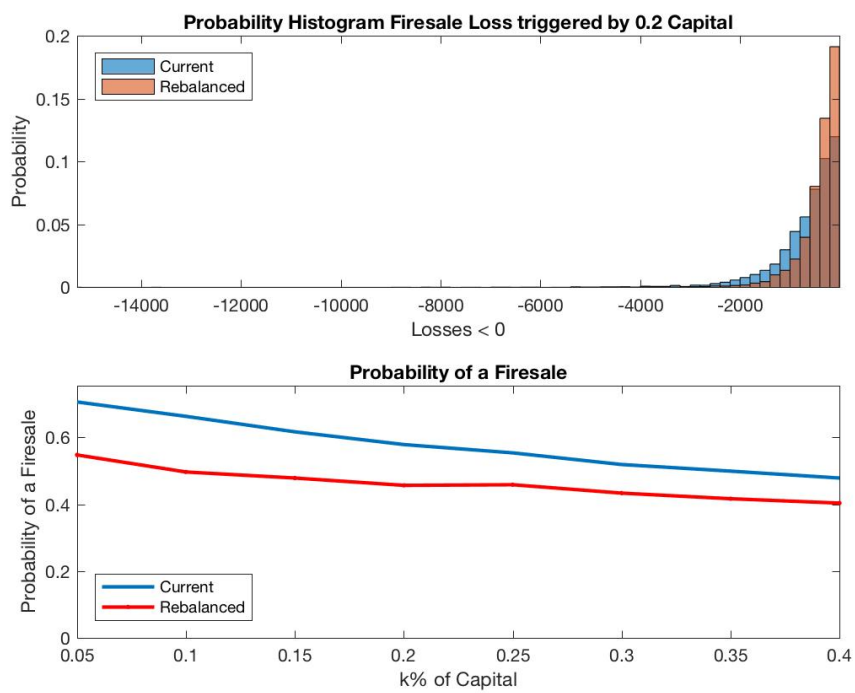


Figure 14: Probability Histograms of the fire-sale losses (which are negative), triggered by a loss of $k = 0.2$ of the bank's capital (top panel) and probability of having at least one fire-sale for different values of k , with current and rebalanced portfolios.

6 Conclusion

In this paper we contribute to the technical discussion on optimal sovereign exposure in several ways. First, we introduce an independent component analysis to identify the common factors driving European sovereign CDS spreads and capture the dependence structure between sovereign risks. Then, we analyze the sovereign portfolios of European banks, relying on the EBA stress test dataset, by calculating their risk and diversification, and we discuss the implications of home bias. Next, we evaluate the effect of capital and diversification requirements on the tail risk of sovereign portfolios, measured by their value-at-risk, at the level of single country banks and of the entire system, in different scenarios. Finally, we analyse the effect of diversification requirements on fire-sales losses.

Our empirical analysis shows that reducing home bias by forcing banks to hold less concentrated sovereign portfolios may not necessarily lead to a decrease in portfolio risk for all countries or to a more stable banking system, especially during crises, when the dependence structure of sovereign risks should be taken into account (Ibragimov, Jaffee, and Walden, 2011). In fact, higher diversification could result in lower risk for single monetary financial institutions but at the same time increase the risk of the banking system as a whole (Caccioli et al., 2014). While our analysis of fire-sales indicates that diversification reduces fire-sale losses, this result must be tempered by possible network effects that may work in the opposite direction. If the regulatory authority introduces a large exposure regime, it may force connections and dependence between banks through joint cross-holdings, which represent an important channel of contagion in the presence of financial distress. Contagion can indeed occur because of fire-sales that result in assets' devaluation, and contagion risk may thus increase with diversification (as in Elliott, Golub, and Jackson (2014)).

Our analysis focuses on the EBA stress test dataset. Despite covering approximately 70% of banking assets in each country and across the EU, the possible presence of selection bias in the EBA sample and its effect needs to be taken into account, and access to a larger database may be considered. This point is high in our agenda.

So far, we have analyzed two simple strategies to substitute sovereign bonds. Alternative rebalancing strategies beyond EU sovereigns could be incorporated in the proposed framework.

Indeed, while our assumptions about bank response to the diversification requirement include several "ideal" behaviors (in the sense that banks perfectly diversify along some dimension), our focus has been on only two possible responses: foremost, where banks choose the closest portfolio to what they already have, in terms of return and variance; and where banks experience a flight-to-quality. There are many other possible responses that could give different predictions in terms of the risk properties of the resulting portfolios. Estimating the most likely bank response to differing diversification requirements is an important task for future study. Methods illustrated in this paper could then be applied to the rebalanced portfolios to analyze their resulting risk properties.

References

- Acemoglu, Daron, Asuman Ozdaglar, and Alireza Tahbaz-Salehi. 2015. "Systemic Risk and Stability in Financial Networks." *American Economic Review* 105 (2):564–608. URL <https://doi.org/10.1257/aer.20130456>.
- Acharya, Viral V., Itamar Drechsler, and Philipp Schnabl. 2014. "A Pyrrhic Victory? Bank Bailouts and Sovereign Credit Risk." *The Journal of Finance* 69 (6):2689–2739. URL <https://doi.org/10.1111/jofi.12206>.
- Acharya, Viral V. and Sascha Steffen. 2015. "The greatest carry trade ever? Understanding Eurozone bank risks." *Journal of Financial Economics* 115 (2):215–236. URL <https://doi.org/10.1016/j.jfineco.2014.11.004>.
- Aït-Sahalia, Yacine, Roger J.A. Laeven, and Loriana Pelizzon. 2014. "Mutual excitation in Eurozone sovereign CDS." *Journal of Econometrics* 183 (2):151–167. URL <https://doi.org/10.1016/j.jeconom.2014.05.006>.
- Albertazzi, Ugo, Bo Becker, and Miguel Boucinha. 2018. "Portfolio rebalancing and the transmission of large-scale asset programmes: evidence from the Euro area." Working Paper Series 2125, European Central Bank. URL <https://doi.org/10.2866/665106>.

- Allen, Franklin and Douglas Gale. 2000. "Financial Contagion." *Journal of Political Economy* 108 (1):1–33. URL <https://doi.org/10.1086/262109>.
- Altavilla, Carlo, Marco Pagano, and Saverio Simonelli. 2017. "Bank Exposures and Sovereign Stress Transmission." *Review of Finance* 21 (6):2103–2139. URL <https://doi.org/10.1093/rof/rfx038>.
- Ang, Andrew and Francis A. Longstaff. 2013. "Systemic sovereign credit risk: Lessons from the U.S. and Europe." *Journal of Monetary Economics* 60 (5):493–510. URL <https://doi.org/10.1016/j.jmoneco.2013.04.009>.
- Arnold, M. 2016. "Sovereign debt rule changes threaten EU bank finances." URL <https://www.ft.com/content/d76b51a4-2ccb-11e6-a18d-a96ab29e3c95?mhq5j=e2>.
- Battistini, Niccolò, Marco Pagano, and Saverio Simonelli. 2014. "Systemic risk, sovereign yields and bank exposures in the euro crisis." *Economic Policy* 29 (78):203–251. URL <https://doi.org/10.1111/2F1468-0327.12029>.
- Becker, Bo and Victoria Ivashina. 2015. "Reaching for Yield in the Bond Market." *The Journal of Finance* 70 (5):1863–1902. URL <https://doi.org/10.1111/jofi.12199>.
- Bernard, Carole and Steven Vanduffel. 2015. "A new approach to assessing model risk in high dimensions." *Journal of Banking & Finance* 58:166–178. URL <https://doi.org/10.1016/2Fj.jbankfin.2015.03.007>.
- Broner, Fernando, Aitor Erce, Alberto Martin, and Jaume Ventura. 2014. "Sovereign debt markets in turbulent times: Creditor discrimination and crowding-out effects." *Journal of Monetary Economics* 61:114–142. URL <https://doi.org/10.1016/j.jmoneco.2013.11.009>.
- Buch, Claudia M., Michael Koetter, and Jana Ohls. 2016. "Banks and sovereign risk: A granular view." *Journal of Financial Stability* 25:1–15. URL <https://doi.org/10.1016/j.jfs.2016.05.002>.

- Caccioli, Fabio, Munik Shrestha, Christopher Moore, and J. Doyne Farmer. 2014. “Stability analysis of financial contagion due to overlapping portfolios.” *Journal of Banking & Finance* 46:233–245. URL <https://doi.org/10.1016%2Fj.jbankfin.2014.05.021>.
- Choi, Nicole, Mark Fedenia, Hilla Skiba, and Tatyana Sokolyk. 2017. “Portfolio concentration and performance of institutional investors worldwide.” *Journal of Financial Economics* 123 (1):189–208. URL <https://doi.org/10.1016/j.jfineco.2016.09.007>.
- Coeurdacier, Nicolas and H el ene Rey. 2013. “Home Bias in Open Economy Financial Macroeconomics.” *Journal of Economic Literature* 51 (1):63–115. URL <https://doi.org/10.1257%2Fjel.51.1.63>.
- De Bruyckere, Valerie, Maria Gerhardt, Glenn Schepens, and Rudi Vander Vennet. 2013. “Bank/sovereign risk spillovers in the European debt crisis.” *Journal of Banking & Finance* 37 (12):4793–4809. URL <https://doi.org/10.1016%2Fj.jbankfin.2013.08.012>.
- De Miguel, Victor, Lorenzo Garlappi, and Raman Uppal. 2007. “Optimal Versus Naive Diversification: How Inefficient is the 1/N Portfolio Strategy?” *Review of Financial Studies* 22 (5):1915–1953. URL <https://doi.org/10.1093/rfs/hhm075>.
- ECB. 2016. “Financial Stability Review.”
- . 2017. “Financial Stability Review.”
- Elliott, Matthew, Benjamin Golub, and Matthew O. Jackson. 2014. “Financial Networks and Contagion.” *American Economic Review* 104 (10):3115–3153. URL <https://doi.org/10.1257/aer.104.10.3115>.
- Embrechts, Paul, Giovanni Puccetti, and Ludger Ruschendorf. 2013. “Model uncertainty and VaR aggregation.” *Journal of Banking & Finance* 37 (8):2750–2764. URL <https://doi.org/10.1016%2Fj.jbankfin.2013.03.014>.
- Erce, Aitor. 2015. “Bank and sovereign risk feedback loops.” (227). URL <https://doi.org/10.24149/gwp227>.

- ESRB. 2015. "Report on the regulatory treatment of sovereign exposures." Tech. rep., European Systemic Risk Board. URL <https://www.esrb.europa.eu/pub/pdf/reports/esrbreportregulatorytreatmentsovereignexposures032015.en.pdf>.
- Fabozzi, Frank J., Rosella Giacometti, and Naoshi Tsuchida. 2015. "The ICA-based Factor Decomposition of the Eurozone Sovereign CDS Spreads." (15-E-04). URL <https://ideas.repec.org/p/ime/imedps/15-e-04.html>.
- Gaballo, Gaetano and Ariel Zetlin-Jones. 2016. "Bailouts, moral hazard and banks' home bias for Sovereign debt." *Journal of Monetary Economics* 81:70–85. URL <https://doi.org/10.1016/j.jmoneco.2016.04.002>.
- Gennaioli, Nicola, Alberto Martin, and Stefano Rossi. 2018. "Banks, Government Bonds, and Default: What do the data Say?" *Journal of Monetary Economics* 98:98–113. URL <https://doi.org/10.1016/j.jmoneco.2018.04.011>.
- Greenwood, Robin, Augustin Landier, and David Thesmar. 2015. "Vulnerable banks." *Journal of Financial Economics* 115 (3):471–485. URL <https://doi.org/10.1016/j.jfineco.2014.11.006>.
- Ibragimov, Rustam, Dwight Jaffee, and Johan Walden. 2011. "Diversification disasters." *Journal of Financial Economics* 99 (2):333–348. URL <https://doi.org/10.1016/j.jfineco.2010.08.015>.
- Jagannathan, Ravi and Tongshu Ma. 2003. "Risk reduction in large portfolios: why imposing the wrong constraints helps." *The Journal of Finance* 58 (4):1651–1683. URL <https://doi.org/10.1111/1540-6261.00580>.
- Juncker, J. C., D. Tusk, J. Dijsselblom, M. Draghi, and M. Schulz. 2015. "Completing Europe's economic and monetary union." URL [http://europeanmemoranda.cabinetoffice.gov.uk/files/2015/07/5-presidents-report_en_\(1\).pdf](http://europeanmemoranda.cabinetoffice.gov.uk/files/2015/07/5-presidents-report_en_(1).pdf).
- Kirschenmann, Karolin, Josef Korte, and Sascha Steffen. 2017. "The zero risk fallacy? banks' sovereign exposure and sovereign risk spillovers." URL <http://hdl.handle.net/10419/172521>.

- Kley, Oliver, Claudia Kluppelberg, and Gesine Reinert. 2018. "Conditional risk measures in a bipartite market structure." *Scandinavian Actuarial Journal* 2018 (4):328–355. URL <https://doi.org/10.1080/03461238.2017.1350203>.
- Korte, Josef and Sascha Steffen. 2014. "Zero risk contagion—banks' sovereign exposure and sovereign risk spillovers." In *22nd International Conference on Money, Banking and Finance*. 12–13. URL https://www.diw.de/documents/dokumentenarchiv/17/diw_01.c.483526.de/paper_korte_zero_risk.pdf.
- Ledoit, Olivier and Michael Wolf. 2004. "A well-conditioned estimator for large-dimensional covariance matrices." *Journal of Multivariate Analysis* 88 (2):365–411. URL <https://doi.org/10.1016/s0047-259x%2803%2900096-4>.
- Lenarčič, Andreja, Dirk Mevis, and Dóra Siklós. 2016. "Tackling sovereign risk in European banks." Discussion Paper 1, European Stability Mechanism.
- Markowitz, Harry. 1952. "Portfolio selection." *The Journal of Finance* 7 (1):77–91. URL <https://doi.org/10.2307/2975974>.
- Meucci, Attilio, Alberto Santangelo, and Romain Deguest. 2014. "Measuring Portfolio Diversification Based on Optimized Uncorrelated Factors." Working Paper.
- Roncalli, T. and G. Weisang. 2015. "Risk parity portfolios with risk factors." *Quantitative Finance* 16 (3):377–388. URL <https://doi.org/10.1080/14697688.2015.1046907>.
- Roncalli, Thierry. 2016. *Introduction to risk parity and budgeting*. Chapman and Hall/CRC. URL <https://doi.org/10.1201/b15151>.
- Uhlig, Harald. 2013. "Sovereign default risk and banks in a monetary union." *German Economic Review* 15 (1):23–41. URL <https://doi.org/10.1111/geer.12039>.
- Véron, Nicolas. 2017. "Sovereign concentration charges: a new regime for banks' sovereign exposures." (602.111). URL http://bruegel.org/wp-content/uploads/2017/11/IPOL_STU2017602111_EN.pdf.

Weidmann, J. 2016. "Solidity and solidarity in the euro area." URL https://www.bundesbank.de/Redaktion/EN/Reden/2016/2016_04_26_weidmann.html.

A EBA Banks

Country	Bank Name	Country	Bank Name
AT	Promontoria Sacher Holding N.V.	FR	BNP Paribas SA
AT	Erste Group Bank AG	FR	Credit Agricole Group
AT	Raiffeisen-Landesbanken-Holding GmbH	FR	Societe Generale SA
AT	Raiffeisen-Holding Niederösterreich-Wien	FR	Credit Mutuel Group
AT	Raiffeisenbankengruppe OÖ Verbund eGen	FR	Groupe BPCE
BE	KBC Group NV	FR	Bpifrance (Banque Publique d'Investissement)
BE	Belfius Banque SA	FR	CRH (Caisse de Refinancement de l'Habitat)
BE	Dexia NV	FR	La Banque Postale
BE	Investar	FR	Renault Credit International Banque
BE	AXA Bank Europe SA	FR	SFIL (Societe de Financement Local)
CY	Bank of Cyprus Public Company Limited	HU	OTP Bank Nyrt.
CY	Co-operative Central Bank Ltd	IE	Bank of Ireland
CY	Hellenic Bank Public Company Ltd	IE	Allied Irish Banks, Plc
DE	Deutsche Zentral-Genossenschaftsbank AG	IE	Permanent TSB Group Holdings Plc
DE	Landesbank Baden-Württemberg	IT	UniCredit SpA
DE	Deutsche Bank AG	IT	Banca Monte dei Paschi di Siena SpA
DE	Commerzbank AG	IT	Intesa Sanpaolo SpA
DE	HASPA Finanzholding	IT	Banco Popolare Società Cooperativa
DE	NORD/LB Norddeutsche Landesbank Girozentrale	IT	Veneto Banca SCpA
DE	Aareal Bank AG	IT	Banca Carige SpA
DE	Bayerische Landesbank	IT	Banca popolare dell'Emilia Romagna SC
DE	DekaBank Deutsche Girozentrale	IT	Banca Popolare di Milano Scarl
DE	Deutsche Apotheker-und Aerztebank eG	IT	Banca Popolare di Sondrio
DE	HSH Nordbank AG	IT	Banca Popolare di Vicenza SCpA
DE	Erwerbsgesellschaft der S-Finanzgruppe mbH	IT	Credito Emiliano Holding SpA
DE	Hypo Real Estate Holding AG	IT	ICCREA Holding
DE	Landesbank Hessen-Thüringen Girozentrale	IT	Mediobanca - Banca di Credito Finanziario
DE	Landeskreditbank Baden-Württemberg Förderbank	IT	Unione di Banche Italiane SCpA
DE	Landwirtschaftliche Rentenbank	LU	Banque et Caisse d'Epargne de l'Etat
DE	Münchener Hypothekenbank eG	LU	Precision Capital S.A.
DE	NRW.BANK, Düsseldorf	LV	ABLV Bank
DE	VW Financial Services AG	MT	Bank of Valletta Plc
DE	WGZ BANK AG Genossenschafts-Zentralbank	NL	N.V. Bank Nederlandse Gemeenten
DK	Danske Bank	NL	Nederlandse Waterschapsbank N.V.
DK	Jyske Bank	NL	SNS REAAL N.V.
DK	Nykredit Realkredit	NL	ABN AMRO Groep N.V.
DK	Sydbank	NL	ING Groep N.V.
ES	Banco Santander SA	NL	Cooperatieve Centrale Raiffeisen-Boerenleenbank
ES	Banco Bilbao Vizcaya Argentaria, SA	NO	DNB ASA
ES	Criteria Caixa Holding, S.A.	PL	Powszechna Kasa Oszczednosci Bank Polski SA
ES	Banco de Sabadell, SA	PT	Banco Comercial Portugues SA
ES	BFA Tenedora De Acciones, S.A.	PT	Caixa Geral de Depositos SA
ES	Banco Mare Nostrum	PT	Banco BPI SA
ES	Banco Popular Espanol SA	SE	Skandinaviska Enskilda Banken - group
ES	Bankinter SA	SE	Nordea Bank - group
ES	Banco de Credito Social Cooperativo SA'	SE	Swedbank - group
ES	Ibercaja Banco	SE	Svenska Handelsbanken - group
ES	Kutxabank	SI	Nova Ljubljanska Banks D.D., Ljubljana
ES	Liberbank	SI	Nova Kreditna Banks Maribor D.D.
ES	Abanca Holding Hispania	UK	Barclays Plc
ES	Unicaja Banco S.A.	UK	Lloyds Banking Group Plc
FI	OP-Pohjola Group	UK	HSBC Holdings Plc
		UK	The Royal Bank of Scotland Group

Table 6: List of banks included in the EBA 2015 EU-wide transparency exercise.

B Ratings

Year	France	Germany	Greece	Ireland	Italy	Portugal	Spain
2008	Aaa	Aaa	A1	Aaa	Aa2	Aa2	Aaa
2010	Aaa	Aaa	Ba1	Baa1	A3	A1	Aa1
2012	Aa1	Aaa	C	Ba1	Baa2	Ba3	Baa3
2014	Aa2	Aaa	Caa1	Baa1	Baa2	Ba1	Baa2
2016	Aa2	Aaa	Caa3	A3	Baa2	Ba1	Baa2

Table 7: Ratings of European countries from Moody's. Before the euro-area sovereign debt crisis, sovereign defaults were regarded as a problem of emerging economies only.

C Risk Decomposition

In risk management, it is important to quantify the contribution of each asset to the overall portfolio risk. One common indicator is given by the sensitivity of portfolio risk to a small change in asset allocation. In this section, we derive this measure for the portfolio standard deviation.

Let \mathbf{w} be the $n \times 1$ vector of portfolio weights and Σ be the $n \times n$ covariance matrix of n asset returns. Then, the risk of the portfolio, typically measured by the standard deviation of portfolio returns σ_p , can be expressed as follows:

$$\sigma_p = \sqrt{\mathbf{w}'\Sigma\mathbf{w}}.$$

In order to measure the contribution of each asset to the whole portfolio risk, we can compute the Marginal Risk Contribution of asset i as the partial derivative of σ_p with respect to w_i

$$MRC_i = \frac{\partial \sigma_p}{\partial w_i} = \frac{\sum_{j=1}^n \sigma_{ij} w_j}{\sigma_p}.$$

MRC_i can be also expressed as a function of $(\Sigma\mathbf{w})$, the product of the covariance matrix and the weights vector, as follows:

$$MRC_i = \frac{(\Sigma\mathbf{w})_i}{\sigma_p}$$

where $(\Sigma\mathbf{w})_i = \sum_{j=1}^n \sigma_{ij} w_j$ represents the i -th component of the column vector $(\Sigma\mathbf{w})$. The risk contribution of asset i is then defined as the weighted MRC_i and represents the share of

portfolio risk corresponding to the i -asset:

$$RC_i = w_i MRC_i = \sigma_i$$

$$\sum_{i=1}^n RC_i = \sum_{i=1}^n \sigma_i = \sqrt{\mathbf{w}'\Sigma\mathbf{w}}$$

The sum of all RC_i is the total portfolio risk, quantified by the standard deviation of the portfolio returns. The relative risk contribution of asset i is defined as

$$RRC_i = \frac{RC_i}{\sigma_p} = \frac{w_i(\Sigma\mathbf{w})_i}{\sigma_p^2} = \frac{w_i(\Sigma\mathbf{w})_i}{\mathbf{w}'\Sigma\mathbf{w}}$$

By construction, the equal risk contribution portfolio (ERC) has a $RC_i = \sigma_p/n$, which implies an $RRC_i = 1/n$.

Through the independent component analysis, we decompose the matrix of sovereign CDS prices, \mathbf{P} as

$$\mathbf{P} = \mathbf{A}\mathbf{F} ,$$

with \mathbf{F} being the vector of $m = 3$ factor returns and \mathbf{A} the loading matrix. We denoted the portfolio's risk factor exposures by the $m \times 1$ vector \mathbf{f} , which is related to the vector of CDS exposures \mathbf{w} as follows:

$$\mathbf{w}'\mathbf{P} = \mathbf{w}'\mathbf{A}\mathbf{F} = \mathbf{f}\mathbf{F} ,$$

where $\mathbf{f} = \mathbf{A}'\mathbf{w}$. The factor exposures \mathbf{f} represent the beta exposures of the portfolio to the ICA risk factors \mathbf{F} . Following Corollary 1 in Roncalli and Weisang (2015), we denote as FC_j the contribution of factor F_j , $j = 1, \dots, m$, to the portfolio volatility σ_p

$$FC_j = \frac{(\mathbf{A}'\mathbf{w})_j(\mathbf{A}^+\widehat{\Sigma}\mathbf{w})_j}{\sigma_p}$$

where \mathbf{A}^+ is the Moore-Penrose inverse of the loading matrix \mathbf{A} .

D Portfolio Selection Benchmarks

Strategy	Idea	Optimization	Reference
Equally Weighted	Weight diversification	$\mathbf{w} = [\frac{1}{d}, \dots, \frac{1}{d}]$	De Miguel, Garlappi, and Uppal (2007)
Minimum Variance	Minimize portfolio variance	$\min \sigma_p^2 = \mathbf{w}'\Sigma\mathbf{w}$	Markowitz (1952) Jagannathan and Ma (2003)
Equal Risk Contribution	Risk diversification	$\min \sum_{i=1}^d \left(\frac{w_i(\Sigma\mathbf{w})_i}{\sigma_p^2} - \frac{1}{d} \right)$	Roncalli (2016)
Equal Factor Contribution	Factor diversification	$\min \sum_{j=1}^m \left(\frac{(\mathbf{A}'\mathbf{w})_j(\mathbf{A}'\hat{\Sigma}\mathbf{w})_j}{\sigma_p^2} - \frac{1}{m} \right)$	Meucci, Santangelo, and Deguest (2014)

Table 8: Overview of the main benchmarks in portfolio selection.

E Portfolio Rebalancing Mechanism - Flight to Quality

In Section 4, we consider a rebalancing mechanism that assume investors would substitute an asset with one that has similar risk-return profile henceforth (*risk-return*), whenever possible. Clearly, other substitution schemes could be tested. As the *flight-to-quality* scheme could be considered also as a viable alternative, especially during crisis periods, we report results also in such case. Yet, empirical analysis on flows has shown that flight-to-quality toward German and French bonds has not occurred, due to the low level of interest rate (see references in footnote 5). Within this rebalancing scheme, we assume that, if there are sufficient substitutes in the sovereign bond markets, banks would replace their exceeding exposure on sovereign i by investing in a sovereign k with a better risk profile (i.e., a sovereign with the highest yield among the ones with higher credit rating). If there is no substitute with these characteristics or the limit has been reached, banks would reallocate the exceeding amount either in a sovereign outside the sample or in a different asset class, e.g. corporate bond.

Figure 15 shows that most countries have to rebalance due to the presence of home bias, but the substitutes are now asset with lower risk (i.e. Portugal still invests then in Italy and France but then prefers Germany, Netherland and UK to Spain and Ireland), ending up with much lower expected returns and risks. Clearly, with this scheme, especially Germany would become the preferred substitute. At EU level, this would require a slightly smaller total overall rebalancing, with an increase riskiness and lower returns than the status quo portfolios.

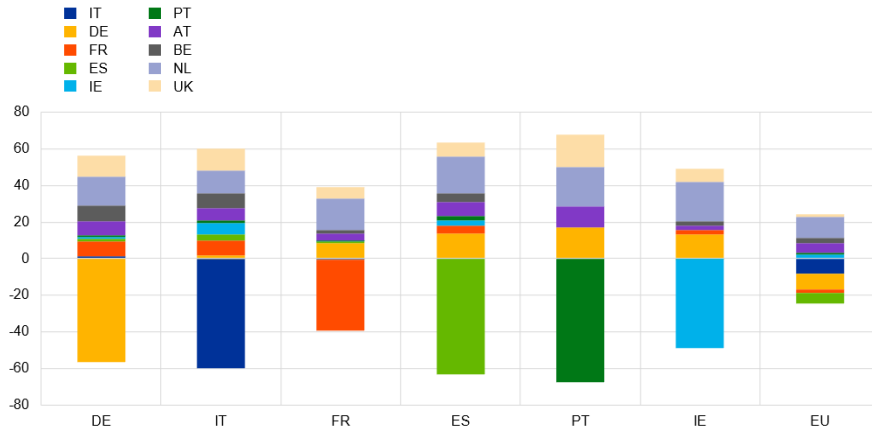


Figure 15: Portfolio rebalance with *flight-to-quality*.

Country Bank	σ^2	D_w	D_r	D_f
DE	4.56	0.75	0.88	0.56
IT	6.22	0.89	0.66	0.54
FR	4.77	0.62	0.61	0.53
ES	7.19	0.74	0.49	0.54
PT	8.00	0.54	0.17	0.57
IE	8.05	0.60	0.23	0.52
EU	5.72	0.83	0.77	0.57
EW	9.06	1.00	0.53	0.55
MV	3.22	0.59	0.54	0.58
ERC	4.28	0.69	1.00	0.59
EFC	7.08	0.59	0.19	0.58

Table 9: Portfolio statistics of the country banks after rebalancing *flight-to-quality*: portfolio variance σ^2 , weight and risk diversification indices D_w and D_r ($D_w, D_r \in [1/d, 1]$), and factor diversification index D_f ($D_f \in [1/m, 1]$).

As Table 9 and Figure 16 show, the *flight-to-quality* portfolios achieve smaller risks when comparing them with the ones from *risk-return* rebalancing mechanism, while only Spain, Ireland, Italy and Portugal have smaller volatility than the status quo portfolios and France and Germany would end up with larger ones. Still the diversification levels would increase compared to the status quo, as expected due to the new limits, while there are no large differences between the two schemes in terms of diversifications statistics.

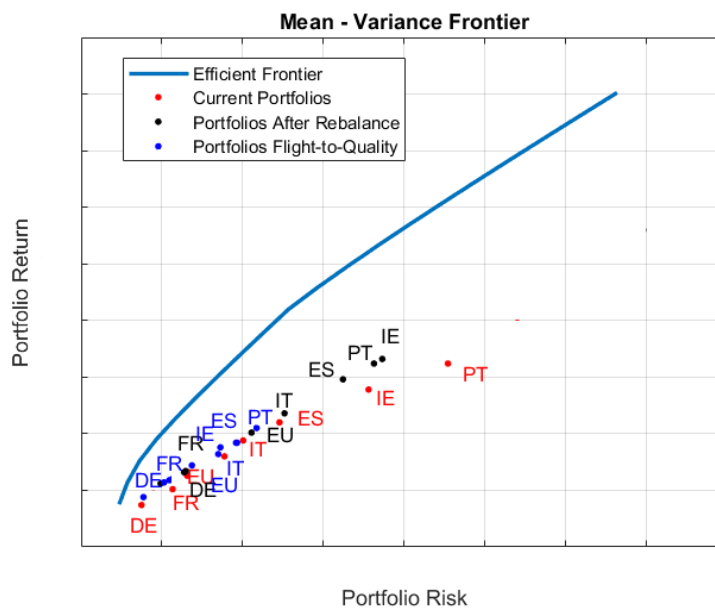


Figure 16: Mean-variance frontier, country banks portfolios, before and after rebalancing. We compare the rebalancing mechanism based on similar risk-return preferences (black dots) to the flight to quality (blu dots).