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The effect of possible EU diversification requirements on the risk of banks' sovereign bond portfolios

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Abstract

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 analyse 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. Under our assumptions about how banks rebalance their portfolio to respond to the new requirements, demanding that banks modify their holdings to increase their portfolio diversification 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

Non-technical summary

In the current Capital Requirements Regulation, special treatment is reserved for exposures of European banks to government bonds denominated in domestic currency. Banks are not required to fund with capital 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, Veron, 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 emerged especially since the financial crisis in 2007-08. This strong nexus, represented by high balance sheet exposures of banks toward sovereigns, allows countries with weak finances to heavily affect their banking system, with banking sectors in distress more likely to receive government financial support. Additional to a reallocation of banks' sovereign exposures, other possible ways to break the *doom loop* would be to improve countries' fiscal soundness and/or enhance banks' equity requirements. 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 analyses 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 test dataset over the period June 2013 to December 2015. These banks cover approximately 70% of banking assets in each of their countries 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 favour 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 systems 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].

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, always preferring a less risky one. 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 of banks rebalancing 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 Capital Requirements Regulation (CRR) reserves special treatment for banks' exposures to government bonds denominated in domestic currency, which can be financed totally by debt capital.[1] Banks are not required to fund with capital their investments in sovereign bonds denominated in euro. 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 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, Veron, 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 imbalanced bid–ask spreads and the lack of attractiveness of bonds' returns and can intensify contagion effects spreading across 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 et al. [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 bank or country level, but not

[1]Each bank can choose between two risk-weighting schemes to calculate capital buffers: the standardised 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.

[2]This 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.

necessarily at a system level, and vice versa.

This paper represents a first step to analysing 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 analyse 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 specific 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 analyse is that of banks rebalancing 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 analyse 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 test dataset over the period June 2013 to December 2015 (see Table 5 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 particularly 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.

This paper is structured 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 which do not require ex ante distributional assumptions, we compute and interpret the resulting factors. We then analyse the sovereign portfolios of European banks, relying on the EBA stress test dataset, by calculating their risk and diversification profiles, and further 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. Finally, Section 5 provides our concluding remarks.

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 et al., 2018]. Political pressure and moral suasion from countries with weak finances, i.e. with low GDP growth and high debt, may incite domestic banks to hold additional sovereign exposures in order to prevent a deterioration of sovereign credit risk that could impair debt sustainability [Erce, 2015]. Also, banks may invest in domestic bonds to hedge against redenomination risk, in the event of a collapse of the euro area [Fabozzi et al., 2016], and as a geographical hedge of their assets and liabilities [3]. However, the 2011-12 European sovereign debt crisis decidedly 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 6 in Appendix B).

Sovereign exposures represent a large part of total securities holdings of the banks in our sample, comprising on average 26% percent, 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 to increase diversification in banks' sovereign portfolios and prevent moral suasion and regulatory arbitrage. Among them, two particular measures are high on the agenda of regulators, capital buffers and the large exposures regime on banks' sovereign holdings. The rationale behind the suggested regulatory changes goes beyond the risk management approach 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 emerged particularly since the financial crisis in 2007-08. This strong nexus, represented by high balance sheet exposures of banks toward sovereigns, allows countries with weak finances to heavily affect their banking system, with banking sectors in distress more likely to receive government financial support. For example, on the one hand, Greek banks had to write down €29.9 billion on domestic debt between 2011 and 2012, requiring significant recapitalisation, on account of Greek sovereign debt restructuring. On the other hand, when the Irish banks suffered liquidity problems during the financial crisis in 2007-08, the Irish government provided public guarantees to avoid further financial problems. Moreover, 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

[3] With redenomination risk we refer to the risk that an asset is redenominated into a devalued legacy currency [De Santis, 2019].

national deposit protection schemes to be combined in order to prevent a major shock in one European country from being able to lower 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" behaviours: 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 by buying higher-yielding bonds due to their home bias. They would also be hedged against redenomination risk if they invest in domestic sovereigns, if euro denominated bonds were to be redenominated into a devalued currency; and since they are usually less well capitalised, they undertake risky strategies as a gamble for the upside potential [ESRB, 2015, Battistini et al., 2014]. Increases in domestic exposures trigger twin crises, i.e. banking and sovereign defaults, more likely [De Bruyckere et al., 2013, Buch et al., 2016, Acharya et al., 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 levels 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. Additional to a reallocation of bank' sovereign exposures, other possible ways to break the *doom loop* would be to improve countries' fiscal soundness and/or enhance banks' equity requirements.

At the same time, there is no common agreement in the literature on the role of home bias. In fact, 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. A high portfolio concentration could be explained by hedging strategies, transaction costs, and information advantage [Choi et al., 2017]. Also, in most EU countries, home bias decreased starting with the introduction of the euro until the financial crisis, and increased thereafter. 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 et al. [2018] argue that domestic exposures can act as a 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 rather than foreign creditors, particularly 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. Here, we analyse purely this trade-off between concentration risk and the doom loop.

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 et al., 2016]. Robustness checks show that similar results hold both when using bonds or CDS spreads [Kirschenmann et al., 2016]. In particular, we construct a sample of daily sovereign CDS spreads with a maturity of 5 years for ten EU countries, including Austria, Belgium, Germany, Spain, France, Ireland, Italy, the Netherlands, Portugal and the United Kingdom, from January 2009 to November 2018. The ten 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 CDSs were not traded between March 2012 and May 2014.[4]

We analyse the sovereign portfolios of European banks, relying on the EBA stress test

[4]Data 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 $s = 2\log(1+\bar{s}/2)$ [Aït-Sahalia et al., 2014].

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

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

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 (as a 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 et al. [2016] to decompose 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 i.e. around 80%, ICA factors typically share their explanatory power more, thereby allowing us to link them to some financial interpretation. The easier interpretation of the risk factors is important when comparing the diversification of two portfolios, in that it gives a clearer picture of banks' strategic exposures to financial and economic factors. By contrast, PCA analysis imposes strong distributional assumptions on how a shock will impact 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, trigger 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 better allow us to disentangle two different risk sources, as they explain 60.8% and 37.8% of the total variance of CDS rates, respectively. 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 developments in the CDS spreads, particularly those of the distressed countries, with a period of low value and volatility until the end of 2010, followed by an increase 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 of below B. Germany, Austria, Belgium, the Netherlands and the United Kingdom, 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 re-establishing trust and stopping the contagion effects from those countries experiencing more distress than 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 to also 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 following ECB

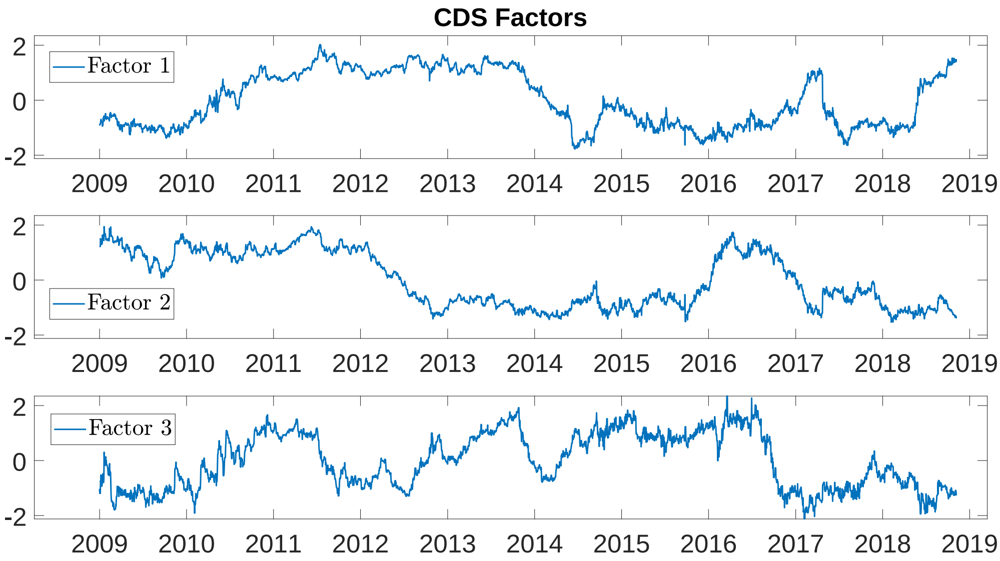


Figure 1: Time series of the three ICA factors of CDS rates

intervention, particularly for Ireland and countries with good credit ratings.

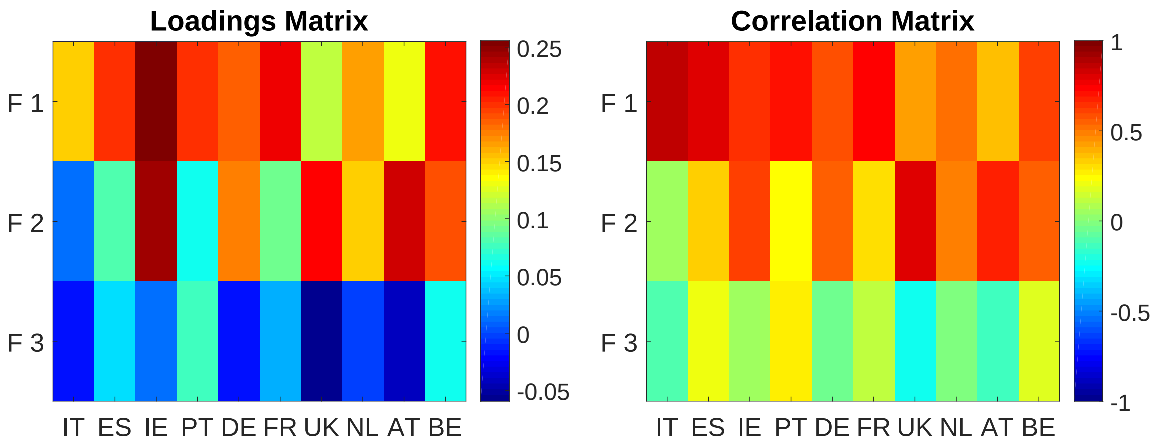


Figure 2: Loadings matrix of ICA factors (left panel); correlation between ICA factors and CDS spreads (left panel)

The factor identification allows us to distinguish the hidden risk drivers of sovereign CDS spreads and their development 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≤B, CDS≥A and CDS Index EU), using the outstanding government debt of these countries as weights. In Table 2, we summarise 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 a strong positive correlation through the entire period. The third IC component (F3) does not seem to be correlated to any specific countries. 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 developments in CDS spreads for countries with lower credit ratings and F2 as a factor representing mostly countries with credit ratings greater than or equal to A.

	F 1			F 2			F 3		
Regressor	**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 regulations, such as UCITS rules for investment funds, focus 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, nowadays it is 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 ten European sovereigns, these being Germany, Italy, France, Spain, Portugal, Ireland, Austria, Belgium, the Netherlands and the United Kingdom. Given the vector of portfolio weights $\boldsymbol{w} = [w_1, \ldots, w_d]$ and a robust estimate of the $d \times d$ covariance matrix $\widehat{\boldsymbol{\Sigma}}$ [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 $\boldsymbol{A}$ for $m = 3$ ICA factors of CDS prices (i.e. F1, F2 and F3) and its Moore-Penrose inverse $\boldsymbol{A}^{+}$, we compute the measure of portfolio diversification, D_f, for each country bank as

$$D_f = \frac{1}{m \sum_{k=1}^{m} FC_k^2} \ . \tag{2}$$

where FC_k represents the risk contribution of each ICA factor k to the overall portfolio risk (i.e. how much of the portfolio variance is due to the risk factor k), obtained by its Euler decomposition [Roncalli and Weisang, 2016]

$$FC_k = \frac{(\boldsymbol{A}'\boldsymbol{w})_k (\boldsymbol{A}^{+} \widehat{\boldsymbol{\Sigma}} \boldsymbol{w})_k}{\sigma}.$$

D_f takes the maximum value of 1 for a fully diversified portfolio in terms of risk factor 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 $\sigma^2 = \boldsymbol{w}\widehat{\boldsymbol{\Sigma}}\boldsymbol{w}'$, the classical diversification indices D_w and D_r are defined as

$$D_w = \frac{1}{d \sum_{i=1}^{d} w_i^2} \tag{3}$$

and

$$D_r = \frac{1}{d \sum_{i=1}^{d} RC_i^2} \tag{4}$$

where 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 $(\widehat{\Sigma}w)_i = \sum_{i,j=1}^{d} \sigma_{ij} w_j$ being the i-th component of the column vector $(\widehat{\boldsymbol{\Sigma}}\boldsymbol{w})$, 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 also allows us to benchmark the current status quo allocations at national and EU level against target benchmark portfolios, such as the market portfolio, a portfolio proportional to the aggregated capital key of euro area Member States, the minimum variance and the equal risk contribution portfolios (see Table 7 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, summarised in Table 7 in the Appendix) [Markowitz, 1952, De Miguel et al., 2009, Roncalli, 2014, Meucci et al., 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, the market portfolio and the capital key portfolio are much better diversified and less risky than the portfolios of single countries.[5] The EU portfolio can provide an idea of the level of diversification and risk at the aggregated level for Europe.

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.

[5]The EU portfolio is the weighted sum of all the portfolios of banks in the sample.

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, these being Italy, Germany, France and Spain. Therefore, home bias in a single country still leads to a diversified EU portfolio. Similar results to the EU portfolio in terms of risk and factor contribution are achieved by the market and capital key portfolios.

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. Still, by aggregating portfolios with no home bias but well-diversified at a single country level, we could obtain a well-diversified EU portfolio. 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 easily propagate to the entire system, possibly exacerbating the effects of such shocks, reducing the resilience of the entire banking system [Caccioli et al., 2014, Cont and Schaanning, 2019]. 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 regulations 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	0.51
Market Portfolio	7.35	0.60	0.66	0.51
Capital Key Portfolio	7.41	0.53	0.57	0.42
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 ($D_f \in [1/m, 1]$).

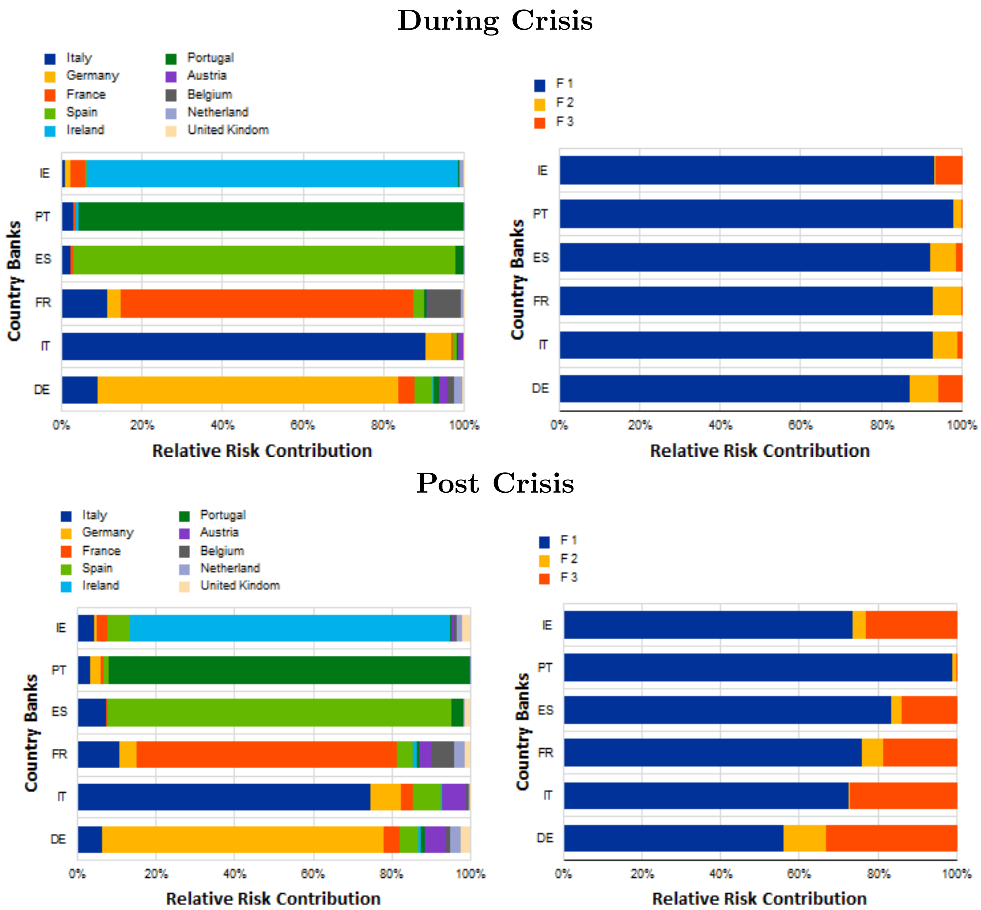
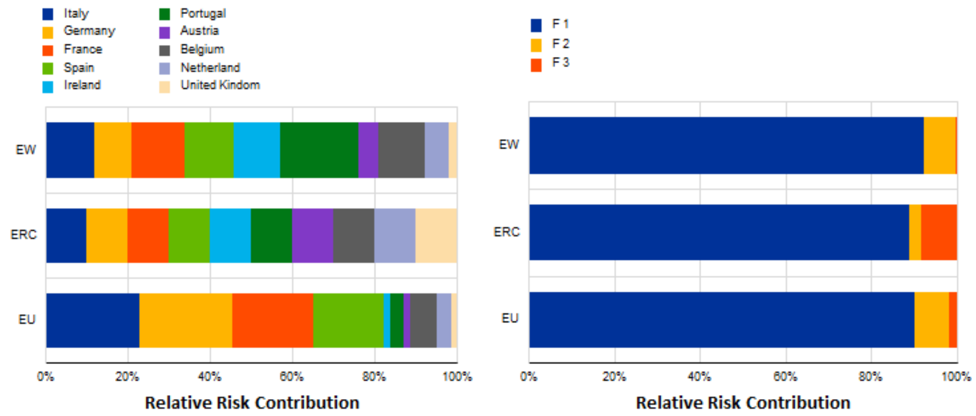


Figure 3: Relative Risk Contribution of sovereign CDS spreads and Relative Factor Risk Contribution of ICA factors for each country bank portfolio

During Crisis



Post Crisis

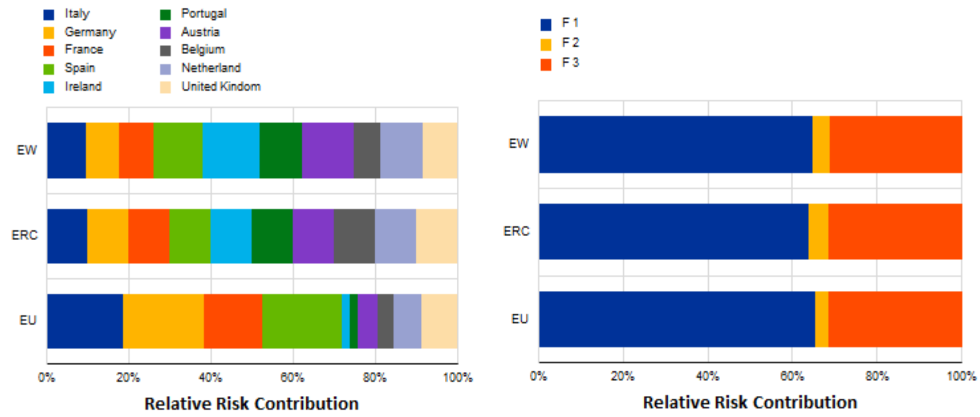


Figure 4: Relative Risk Contribution of sovereign CDS spreads and Relative Factor Risk Contribution of ICA factors for the EU and EW portfolios

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 $w_{ji} = SE_{ji}/SE_j$,

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

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 [Lenarcic et al., 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.[6] 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 the case where 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 to a sovereign outside the sample or in a different asset class, e.g. corporate bond.[7] 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

[6] Alternative 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).

[7] Recent literature and reports from the ECB (Becker and Ivashina [2015], ECB [2016], ECB [2017], Altavilla et al. [2017], Albertazzi et al. [2018]) have in fact shown that since 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*.

resulting 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 to a different asset class, according to our rebalancing mechanism.

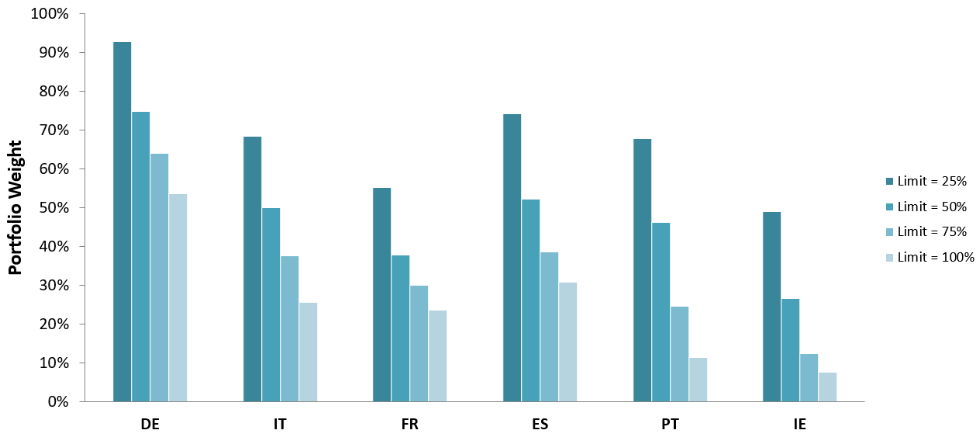


Figure 5: Total portfolio weight to rebalance for each country bank with different limits on large exposures

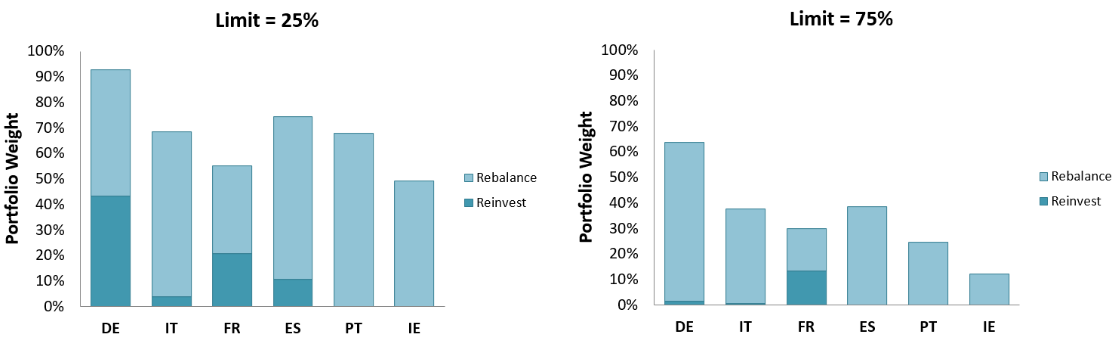


Figure 6: Total portfolio weight to rebalance and reinvest for each country bank with 25% and 75% limit on large exposures

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 United Kingdom. On the other hand, Italy, Spain, Portugal, and Ireland first invest in a sovereign with similar risk/return characteristics, and, if necessary, buy bonds from 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 1, 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 January 2009 to 31 December 2015. As we can see, all portfolios are dominated by the frontier. The current portfolios of country banks 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 additional 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 benchmark portfolios. Lack of diversification at the country level thus results in diversified and almost risk-optimal allocation at the aggregated level.

Figure 9 shows portfolio risk of country banks with respect to banks' average capital.

Portuguese and Irish banks in the sample are the ones with the highest level of sovereign portfolio risk and the lowest average capital. French banks are the most capitalised on average, while keeping the level of sovereign portfolio risk low. A similar relationship holds true at single bank level.

When we add the diversification constraint, the level of capital does not change and 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 for Germany, Italy and Spain, while increasing that of Ireland, Portugal, Austria, and Belgium, as a consequence of the home bias distributions across countries (see Figure 7).[8] 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 characterised 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 et al. [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 [Ibragimov et al., 2011, Cont and Schaanning, 2019]. This is left for further research.

[8] The 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.

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	0.57
Market Portfolio	7.61	0.71	0.74	0.56
Capital Key Portfolio	7.97	0.67	0.64	0.44
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 ($D_f \in [1/m, 1]$).

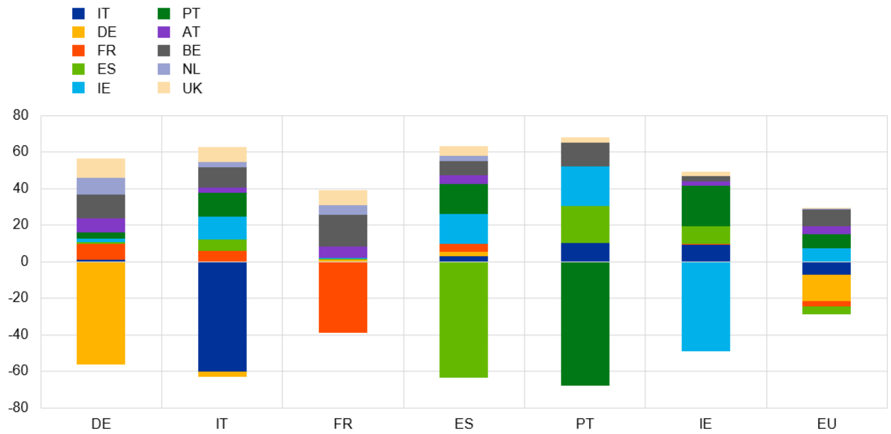


Figure 7: Portfolio Rebalancing

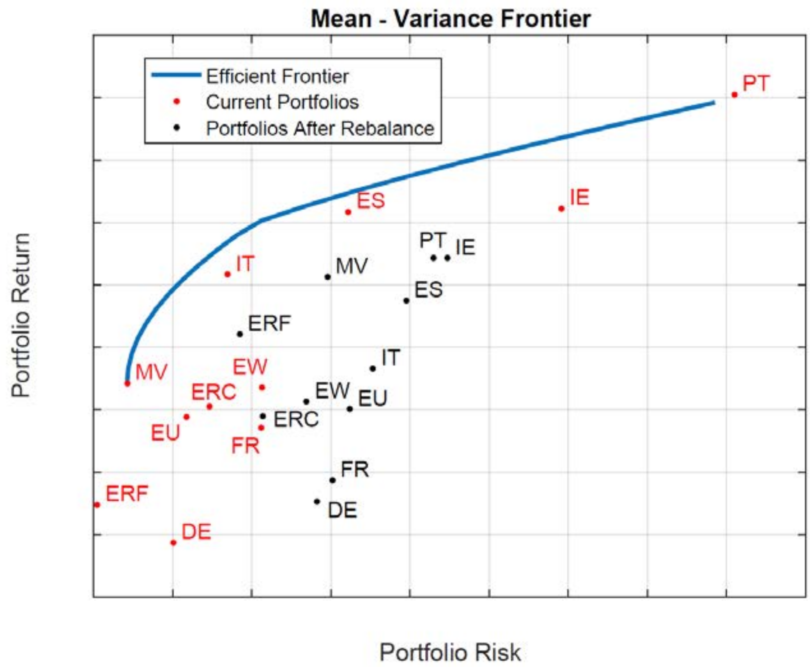


Figure 8: Mean-variance frontier, country banks portfolios and benchmark portfolios, before and after rebalancing. On the x-axis the Portfolio Risk is defined as $\sigma = \sqrt{\boldsymbol{w}\widehat{\boldsymbol{\Sigma}}\boldsymbol{w}'}$, while on the y-axis the Portfolio Return is $\mu = \boldsymbol{w}\boldsymbol{\mu}'$ with $\boldsymbol{\mu}$ being the vector of mean returns obtained from CDS spreads.

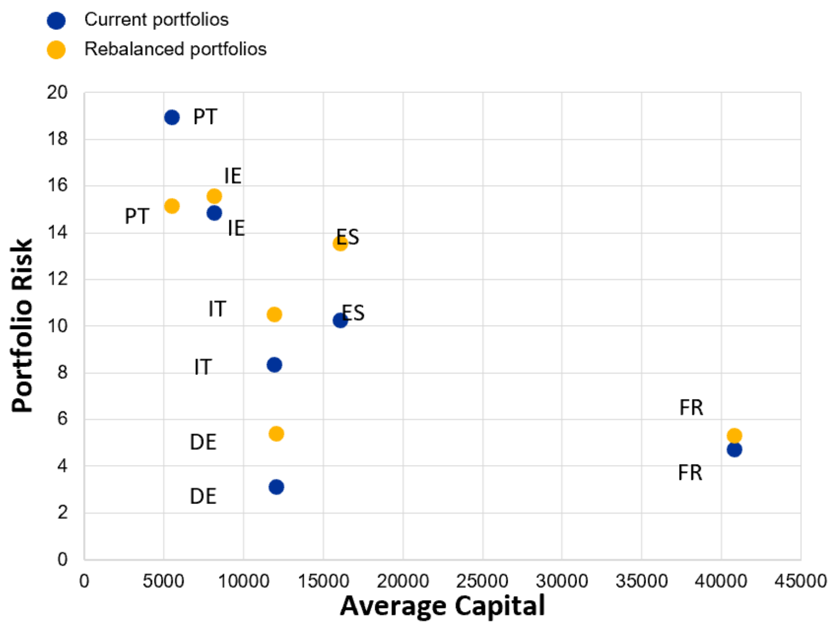


Figure 9: Average portfolio risk and bank capital, before and after rebalancing. The bank capital on the x-axis is measured in millions and is computed as the average capital of the country's banking sector.

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 of 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 $\boldsymbol{R}$, the $N \times d$ matrix of daily CDS log-returns, and $\boldsymbol{w}$, the $1 \times d$ vector of its portfolio weights, we compute a matrix of returns as the dot product $\boldsymbol{X} = \boldsymbol{w} \cdot \boldsymbol{R}$, where N are the daily observations and d the sources of sovereign risk. We define then $\boldsymbol{S} = \sum_{i=1}^{N} \boldsymbol{X}_i$ 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 $\boldsymbol{S}$, we use the scenario approach of Bernard and Vanduffel [2015].

First, we assume we know the marginal distributions of $\boldsymbol{X}_j$ on $\mathbb{R}^d$ for $j = 1, \ldots d$ and we fit a joint distribution on $\boldsymbol{X}$, which represents our benchmark model. Due to partial or no information on the dependence structure of $\boldsymbol{X}$, we then split our data into two parts: $\mathcal{F}$, the trusted region, where we expect the fitted benchmark model to be appropriate, and $\mathcal{U} = \mathbb{R}^d \backslash \mathcal{F}$, the untrusted region. We account for model risk by attaching a probability $p_{\mathcal{F}} = P(\boldsymbol{X} \in \mathcal{F})$. 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 et al. [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 $\boldsymbol{X}$ 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 Figure 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 a few countries, such as Italy and Ireland, but confidence intervals are still overlapping. At the aggregate EU level, no effect is detectable.

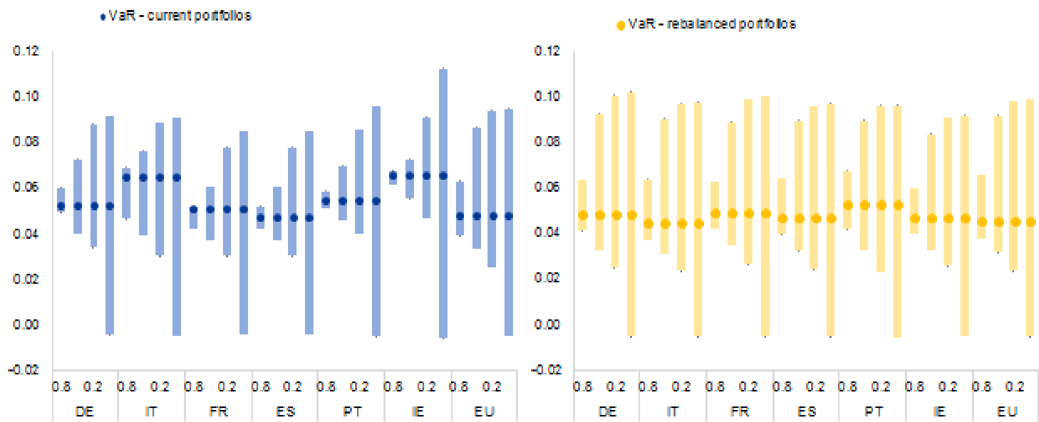


Figure 10: Value-at-risk of the country banks and EU sovereign portfolios before (left side) and after rebalancing (right side)

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 [Jones et al., 1994]. 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 Figure 11 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.

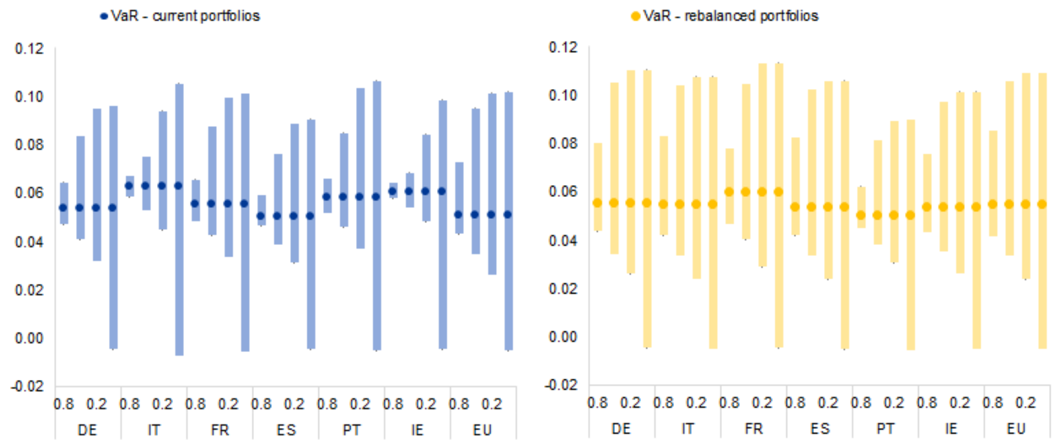


Figure 11: Value-at-risk of the sovereign portfolios of country banks and EU before (left side) and after rebalancing (right side), obtained using simulated data from a multivariate Student's t-distribution with 3 degrees of freedom, and a mean and covariance matrix equal to those estimated using real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

5 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 analyse 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.

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 et al., 2011]. So far, we have analysed 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" behaviours (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 analyse their resulting risk properties.

High on our agenda is the comparison among different state-of-art fire sale models to evaluate the effect of diversification requirements. In Craig et al. [2019], we consider the canonical model of fire-sales, Greenwood et al. [2015], which has already been applied to European banking data. Empirical results show that such model 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. More sophisticated models of contagion might lead to different results and it is important to provide a comprehensive discussion across models. In fact, 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, particularly for common shocks of a certain entity (see, e.g. Acemoglu et al. [2015]), implying that diversification at a single entity level might have negative consequences at the system level. 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 et al. [2014], that the more diversified portfolios after rebalancing indeed attenuate fire-sale losses for minor losses, but amplify them for larger losses. Models of indirect contagion, such as Cont and Schaanning [2019], might also provide similar results. 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 the model by Greenwood et al. [2015] might show 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 et al. [2014]).

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A EBA Banks

Country Bank	Bank Name	Country Bank	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 Societá 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 5: 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 6: 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 $\boldsymbol{w}$ be the $n \times 1$ vector of portfolio weights and $\boldsymbol{\Sigma}$ 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:

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

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

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

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

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

where $(\Sigma w)_i = \sum_{i,j=1}^{n} \sigma_{ij} w_j$ represents the i-th component of the column vector $(\boldsymbol{\Sigma w})$. 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:

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

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

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

By construction, the equal risk contribution portfolio (ERC) has a $\mathrm{RC}_i = \sigma_p/n$, which implies an $\mathrm{RRC}_i = 1/n$.

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

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

with $\boldsymbol{F}$ being the vector of $m = 3$ factor returns and $\boldsymbol{A}$ 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 $\boldsymbol{w}$ as follows:

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

where $\mathbf{f} = \boldsymbol{A}'\boldsymbol{w}$. The factor exposures $\mathbf{f}$ represent the beta exposures of the portfolio to the ICA risk factors $\boldsymbol{F}$. Following Corollary 1 in Roncalli and Weisang [2016], we denote as FC_j the contribution of factor F_j, $j = 1, \ldots m$, to the portfolio volatility σ_p

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

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

D Portfolio selection benchmarks

Strategy	Idea	Optimisation	Reference
Market Portfolio	Proportional to outstanding amount of debt		
Capital Key Portfolio	Capital key of euro area Member States in 2015		
Equally Weighted	Weight diversification	$\boldsymbol{w} = [\frac{1}{d}, \ldots, \frac{1}{d}]$	De Miguel et al. [2009]
Minimum Variance	Minimise portfolio variance	$\min \sigma_p^2 = \boldsymbol{w}'\Sigma\boldsymbol{w}$	Markowitz [1952] Jagannathan and Ma [2003]
Equal Risk Contribution	Risk diversification	$\min \sum_{i=1}^{d} \left(\frac{w_i(\Sigma w)_i}{\sigma_p^2} - \frac{1}{d} \right)$	Roncalli [2014]
Equal Factor Contribution	Factor diversification	$\min \sum_{j=1}^{m} \left(\frac{(\boldsymbol{A}'\boldsymbol{w})_j(\boldsymbol{A}^{+}\widehat{\boldsymbol{\Sigma}}\boldsymbol{w})_j}{\sigma_p} - \frac{1}{m} \right)$	Meucci et al. [2014]

Table 7: 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 a 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, particularly during crisis periods, we report results also in such cases. 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 rates (see references in footnote 7). 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 those with higher credit ratings). If there is no substitute with these characteristics or the limit has been reached, banks would reallocate the exceeding amount either to a sovereign outside the sample or in a different asset class, e.g. corporate bonds.

Figure 12 shows that most countries have to rebalance due to the presence of home bias, but the substitutes are now assets with lower risk (i.e. Portugal still invests in Italy and France but prefers Germany, the Netherlands and the United Kingdom to Spain and Ireland), ending up with much lower expected returns and risks. Clearly, with this scheme, Germany in particular would become the preferred substitute. At EU level, this would require a slightly smaller

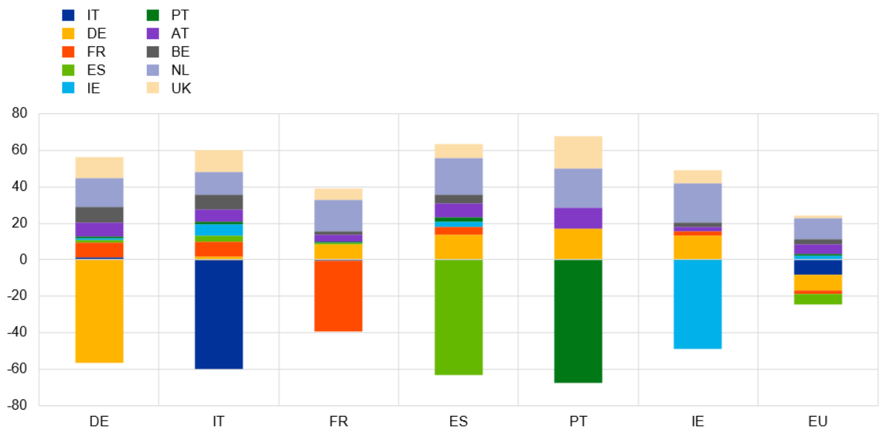

Figure 12: Portfolio rebalance with *flight-to-quality*

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
Market Portfolio	7.14	0.69	0.74	0.69
Capital Key Portfolio	6.76	0.67	0.72	0.62
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 8: Portfolio statistics on 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 ($D_f \in [1/m, 1]$).

total overall rebalancing, with an increase in riskiness and lower returns than the status quo portfolios.

As Table 8 and Figure 13 illustrate, the *flight-to-quality* portfolios are exposed to lower risks when comparing them with those from the *risk/return* rebalancing mechanism, while only Spain, Ireland, Italy and Portugal exhibit lower 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 significant differences between the two schemes in terms of diversifications statistics.

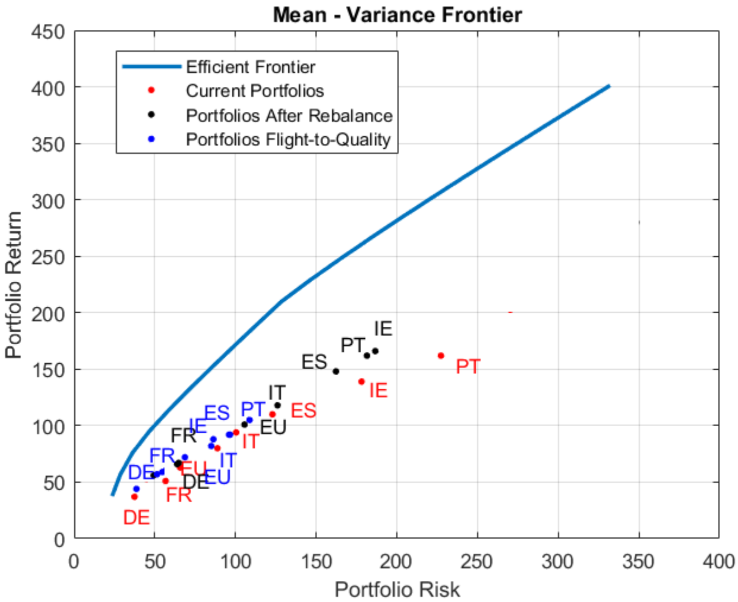

Figure 13: Mean-variance frontier, country banks' portfolios, before and after rebalancing. We compare the rebalancing mechanism based on similar risk/return preferences (black dots) to the flight-to-quality (blue dots).

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