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We examine bank strategies to rebalance residential mortgage portfolios toward other geographical regions in the context of the European sovereign debt crisis. For banks in Greece, Ireland, Cyprus, Italy, Portugal and Spain (GICIPS), we find evidence of flight-to-quality if banks were undercapitalized and had high funding cost, and evidence of risky-lending if banks were undercapitalized but without funding problems. For banks in core safe European countries, we find evidence of flight-to-quality among banks with high capital ratios, and risky-lending among banks with low funding cost. We rationalize these empirical results with a general equilibrium model of cross-border mortgage lending.

Introduction

The Great Recession ended a long period of credit expansion in European countries such as Spain and Ireland and, to a lesser extent, in other highly indebted countries such as Cyprus, Greece, Italy and Portugal. But it was not until the first quarter of 2010 that European periphery countries faced the harsh reality of a new unprecedented crisis—the so-called sovereign debt crisis. The borrowing costs of Greece, Ireland, Cyprus, Italy, Portugal and Spain (henceforth GICIPS) reached exceptional high levels, whereas other European countries, such as Germany, exhibited remarkably low interest rates on their government bonds. In addition, the sovereign debt crisis had a significant adverse effect on the housing and labor markets of the GICIPS countries, whereas many of the "core" European countries became safe havens for cross-border investments at the European level.

Previous research on the European sovereign debt crisis has focused on the trading of sovereign bonds during this period (Acharya and Steffen 2015)

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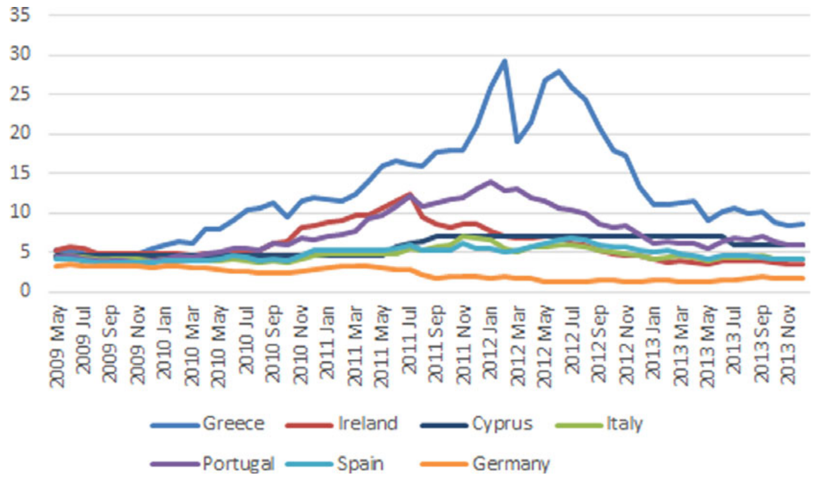
Figure 1 ■ This figure illustrates the change in long-term interest rates for German, Greek, Irish, Cypriot, Italian, Portuguese and Spanish sovereign bonds during the sovereign debt crisis.
[Color figure can be viewed at wileyonlinelibrary.com]



(*Source*: European Central Bank).

and, to some extent, the implications of this crisis on the productive sector of the economy (Acharya *et al.* 2015, Broner *et al.* 2014, Bocola 2016). This article examines an unexplored but still very relevant element of this crisis: the residential mortgage sector. We are interested in the geographies of the banks' residential loan portfolio rebalancing and the reasons behind those changes, with a particular emphasis on the roles of banks' capital ratios and funding costs.

European Banking Authority (EBA)'s European Union (EU)-Wide Stress Tests

To this aim, we constructed a novel database containing granular baseline data gathered by the EBA during EU-wide stress test exercises for consolidated year-ends 2009 and 2013. Unfortunately, the EBA does not provide data for other points in time. But, as shown in Figure 1 and the structural break tests in the Online Appendix, these two points in time are useful for our purposes: year-end 2009 roughly coincides with a period just before the onset of the European sovereign debt crisis (the first quarter of 2010);[1] and year-end 2013

[1]Tamakoshi and Hamori (2015) and Filoso *et al.* (2016) provide evidence for the beginning of the sovereign debt crisis being in the first quarter of 2010.

coincides with the time when credit conditions in the "periphery" regions had returned to precrisis levels.[2]

Our database is unique in two important respects. First, it includes information on banks' portfolio exposures, including outstanding cross-border residential loans immediately before and after the sovereign debt crisis. It also provides information on banks' exposures by geographical region, including each bank's exposure to its own home country. Second, our database includes information about *individual* bank characteristics, such as the core Tier 1 capital ratio, funding costs, provisions and losses.

Matching the databases of the two EBA consolidated year-end (2009 and 2013) financial statements by bank name yields a sample of 69 banks representative of cross-border lending behavior for the largest banks in each European country.[3] The sample represents 21 countries with 32 country counterparties, including European euro and non-euro countries, as well as other developed non-European countries (such as the United States and Japan).

Banks' Shifts in Residential Exposures by Geographical Region

By comparing baseline data sets for these two periods, we can estimate the *overall* changes in residential mortgage exposures of European banks by geographical region. We estimate that the banks' squeeze in total outstanding credit (including all loan types) for the entire EU was at least € 10.8tr. Of this, we found that at least € 3.2tr was specific to residential exposures. The residential mortgage credit crunch just in the crisis-hit "periphery" countries (GICIPS) was at least € 0.6tr, approximately half of the overall market size of residential loans in GICIPS countries.[4]

With these amounts in mind, our goal in this article is to examine how banks shifted their residential exposures geographically *within* their total residential mortgage holdings.[5] This allows us to understand the first-order

[2]We also ran the Zivot–Andrews test and found a structural break for Greece at the year-end 2013.

[3]With a sample of 69 representative banks, our estimates in euro terms can be seen as lower bounds.

[4]To put these numbers in perspective, recall that the 2012 Longer-Term Refinancing Operations (LTRO) loans made by the European Central Bank (ECB)—the so-called "big bazooka" —amounted to € 1tr.

[5]Because there was a significant credit squeeze during the sovereign debt crisis period, we focus on residential loan portfolio rebalancing—the active targeting of residential credit risk by geographical region—rather than on changes in total residential loan amount.

effects in overall residential shares. For this analysis, we consider two important portfolio rebalancing behaviors. First is "flight-to-quality" (FTQ), which occurs when a bank rebalances its residential loan portfolio exposures toward one or several "safe" countries. We consider safe countries to be (i) the "core" European euro countries Austria, Belgium, Finland, France, Germany, Luxembourg and the Netherlands, (ii) the European non-euro countries of Denmark, Iceland, Liechtenstein, Norway, Sweden and the United Kingdom, and (iii) the non-European countries Japan and the United States. The second important portfolio rebalancing behavior is "risky lending" (RL), which occurs when a bank rebalances its portfolio toward one or several GICIPS countries. We use these definitions to construct dummy variables for each bank's FTQ and RL behaviors.

We then use our database to run several logistic regressions using the FTQ and RL dummy variables as dependent variables and taking as independent variables bank-specific covariates such as the core Tier 1 capital ratio, the funding cost, provisions and the coverage ratio of residential loans. We also include macroeconomic and housing market covariates, such as GDP growth, building permits and nominal housing prices.

Our regression analysis reveals that the likelihood of FTQ in residential lending increases when the bank's counterparty country exhibits a growing housing market and strong macroeconomic fundamentals, consistent with the idea of "flight-to-quality." Our most interesting results are in terms of banks' capital ratios and funding costs, which we describe next.

Capital Ratio and Funding Cost

To understand the determinants of the banks' FTQ and RL behaviors, we provide a general equilibrium model of banking, following Geanakoplos' (2003) tractable marginal buyer approach, where banks can do cross-border residential mortgage lending in two regions, the A-region (safe) and the B-region (risky). The two main ingredients of our model are the banks' capital requirements and their funding costs.[6] Other considerations such as bank deposits are left aside. For the first ingredient, capital requirements, we consider a stylized version of the Basel Accord on capital requirements that says that equity must exceed a fraction c of the bank's Risk-Weighted Assets (RWA). The other key element, funding costs, is also relevant for our analysis because in the course of the European sovereign debt crisis, banks in GICIPS

[6]In our empirical analysis, the correlation between these two variables is close to zero for the two cross-sections of banks (A-banks and B-banks), suggesting that we can treat these two variables as independent.

countries, loaded with bad collateral (GICIPS sovereigns), saw their funding costs increase above what other banks in the safe region paid for.[7]

Our model predicts that banks from GICIPS countries exhibit an FTQ strategy, while banks from safe countries (with lower funding costs relative to GICIPS banks) exhibit an RL behavior when banks in the "crisis-hit" GICIPS region see their funding costs increase and have their capital constraints binding.[8] We also consider the possibility of banks in the GICIPS region having a nonbinding capital constraint, and show that a home bias for the group of B-banks induces these banks to engage in an RL strategy instead. The model also rationalizes that a negative shock to B-banks' capital induces these banks to do RL, while A-banks (better capitalized than B-banks) exhibit an FTQ behavior.[9]

Our theoretical results support our empirical findings, which we summarize with a typology table of banks' cross-border residential mortgage portfolio rebalancing strategies in terms of banks' geographical regions, core Tier 1 ratios and funding costs.[10] Specifically, in our empirical analysis we find that, for the set of banks in GICIPS countries, banks chose the conservative strategy of rebalancing their residential mortgage portfolios toward safe European countries if they had low capital ratios and high funding costs. Undercapitalized banks without funding problems opted to rebalance toward risky GICIPS countries other than their home country instead.[11] We also find some evidence

[7]Even in 2011 (at the peak of the crisis), large European banks were still funding 66% of their assets in wholesale funding markets, which is twice the level of U.S. or Asian banks (FSB 2012).

[8]The market mechanism behind this outcome is driven by the different valuations of mortgages originated in GICIPS countries (henceforth, B-mortgages) between banks in different regions. Roughly speaking, the binding capital constraint for B-banks makes them value the increase in the return of (riskier) B-mortgages (relative to preshock levels) less than A-banks do.

[9]The market mechanism is different from the previous one. Now, when banks in GICIPS countries become more undercapitalized, they require a higher discount price (lower return) on B-mortgages in order to meet their capital constraint. This price channel induces A-banks to rebalance toward the safe region, where mortgages now offer a higher return relative to preshock levels than mortgages in the risky B region. B-banks do not value the reduction on the return of B-mortgages as much as A-banks do, given the higher shadow price on the binding capital constraint. The difference in mortgage valuations between bank groups together with the market clearing condition imply that B-banks end up rebalancing toward mortgages in the risky region (RL).

[10]The core Tier 1 capital ratio compares the bank's core equity capital with its total RWA, and is thus a good indicator of the bank's capital adequacy (*e.g.*, well-capitalized vs. undercapitalized).

[11]This result resembles Acharya and Steffen's (2015) finding that during the sovereign debt crisis, banks with low capital ratios were more likely to increase their investments

that suggests a flight-home (FH) behavior among banks with high funding costs but whose capital constraints are non-binding.

For the set of banks in “safe” core European countries, we find evidence of an FTQ behavior among banks with high capital ratios, and evidence of RL behavior among banks with low funding costs. These strategies seem consistent with the market mechanism of our general equilibrium model.

To sum up, we find that the cross-border residential mortgage lending market became highly segmented geographically and by bank type in the period that goes from year-end 2009 to year-end 2013. Different combinations of shocks to funding cost and capital ratio levels resulted in different banks’ residential portfolio rebalancing strategies. In view of these results, it remains an open question whether the European financial authorities could have had any role in alleviating the serious economic imbalances within the union that were only aggravated by the banks’ loan portfolio geographical reallocation episodes we have described.

The rest of this article is organized as follows. The next section provides the theoretical model. Section “Data Description” describes the database. Section “Flight-to-Quality and Risky-Lending” formally defines FTQ and RL in terms of total residential loan exposures and provides estimates for the two cross-sections of banks. Section “Determinants of the FTQ and RL behaviors” explains the remaining data used for our regression analysis, presents our regression results, and discusses our empirical findings in view of the theoretical model. In the last section, we offer the conclusions. In the Online Appendix, we include supplementary material that complements the analysis in this article. Of particular interest in this supplementary material, we highlight our estimates of the banks’ residential credit squeeze by regions, as well as the reasons behind this squeeze.

Theoretical Model

Consider an economy with two dates, $t = 1, 2$, and two possible states of nature, at date $t = 2$, denoted by s_1 and s_2. There is also a nonatomic measure space of individuals $(\mathbf{I}, \mathcal{I}, \lambda)$, where $\mathcal{I}$ is a σ-algebra of $\mathbf{I}$ and λ is the associated Lebesgue measure. By individual we mean either a household or a lender. We will also refer to lenders as banks.[12]

in the risky (high-yield) sovereign debt of GICIPS countries (what they describe as a “risk-shifting channel”).

[12]Notice that denoting the set of banks by **B** (for banks) would confuse the reader because we already use the letter B for a specific region. For this reason, we use notation **L** and refer to banks as lenders.

There are two regions in this economy, **A** and **B**. In each region $R = \mathbf{A}, \mathbf{B}$, there is a continuum of both households and lenders, with respective sets denoted by $\mathbf{H}_R$ and $\mathbf{L}_R$. We denote by $\mathbf{I}_R \equiv \mathbf{H}_R \cup \mathbf{L}_R$ the set of households and lenders in region R, and assume that the measures of subsets $\mathbf{H}_R$ and $\mathbf{L}_R$ are such that $\lambda(\mathbf{H}_R) = \lambda(\mathbf{L}_R) = 1$, for $R = A, B$. In addition, let $\mathbf{I_A} \cup \mathbf{I_B} = \mathbf{I}$. If a household belongs to region R ($h \in \mathbf{H}_R$), we write h_R. Similarly, when a lender belongs to region R ($l \in \mathbf{L}_R$), we write l_R.

Households

Households only derive utility from the consumption of housing (for simplicity, we ignore the consumption of other goods). Formally, $u^h : x_1 \longrightarrow \mathbb{R}$ is continuous and monotonically increasing in x_1, where x_1 denotes the size of the house purchased. The housing consumption (x_1) and household's endowment (ω_1^h) are both in terms of the numeraire good, whose price we normalize to 1.[13]

A household h_R can finance the purchase of a house at date 1 with his own capital endowment $\omega_1^{h_R}$ (equity) and a mortgage (debt). The loan amount that this household receives at date 1 is $q_R y^{h_R}$, where $y^{h_R} \in \mathbb{R}$ denotes the mortgage face value of the mortgage and $q_R \in \mathbb{R}_+$ is the mortgage discount price.[14] Thus, a household h_R can buy

$$x_1^{h_R} = \omega_1^{h_R} - q_R y_R^{h_R} \tag{1}$$

units of housing at date 0, where $q_R y_R^{h_R} < 0$ if household h_R borrows to buy a house. The loan-to-value (LTV) for this household is then $q_R y_R^{h_R} / x_1^{h_R}$. As usual in the literature of general equilibrium, to guarantee existence of equilibrium we impose a lower bound on short sales, *i.e.*, $y_R^h \geq -K$, with $K > 0$.

Residential mortgages are recourse, as it happens in Europe, but the possibility of a deep crisis in the B-region introduces the possibility of a household's involuntary default due to, for example, unemployment.[15] Formally, we consider a mortgage contract such that a household with loan $q_R y^{h_R}$ must pay back $r_R(s) y_R^{h_R}$ at state $s = s_1, s_2$ of date 2. We assume that, for each unit of

[13]This endowment can vary between regions. For example, if $h \in \mathbf{H_A}$, we write $\omega_1^{h_\mathbf{A}}$. If instead $h \in \mathbf{H_B}$, we write $\omega_1^{h_\mathbf{B}}$.

[14]This modeling is standard in the general equilibrium literature of mortgage markets pioneered by John Geanakoplos (see, for example, Geanakoplos 2003).

[15]Unlike in the United States, strategic default (specific to nonrecourse mortgages) is not possible in Europe.

mortgage promise (*i.e.*, $y_R^{h_R} = 1$), households from region A ($\mathbf{H_A}$) are always able to pay $r_A(s) = 1$ at both states $s = s_1, s_2$. However, households from region B ($\mathbf{H_B}$) pay $r_B(s_1) = 1$ at state s_1, but only pay $r_B(s_2) = \gamma \leq 1$ at state s_2. We interpret the latter as a default situation if $\gamma < 1$, in which case the lender only recovers part but not all of the promised payment at the end of date 2. This specification of function $r_R(s)$ can be formalized by endowing each household h with endowments $\omega^h(s_1)$ and $\omega^h(s_2)$ at states s_1 and s_2 of date 2, respectively, and considering the following budget constraint at state $s = s_1, s_2$ of date 2:

$$0 \leq \omega^{h_R}(s) + r_R(s) y_R^h. \tag{2}$$

Then, by the monotonicity of the household's utility function, households in region A pay $r_R(s) y_A^{h_\mathbf{A}} = -\omega^{h_\mathbf{A}}(s)$, at both $s = s_1, s_2$. The debt payment for households in region B is $r_R(s_1) y_B^{h_\mathbf{B}} = -\omega^{h_\mathbf{B}}(s_1)$. $y_B^{h_\mathbf{B}}$ is compatible with households $h_\mathbf{B}$'s budget constraint at state s_2 of date 2 if $\omega^{h_\mathbf{B}}(s_1)/r_R(s_1) = \omega^{h_\mathbf{B}}(s_2)/r_R(s_2)$. The following choice of parameter values satisfies this condition: $r_R(s_1) = 1$, for $R = A, B$; $\omega^{h_\mathbf{A}}(s) = 1$, for $s = s_1, s_2$; $\omega^{h_\mathbf{B}}(s_1) = 1$; and $\omega^{h_\mathbf{B}}(s_2) = \gamma$. These parameter values imply that $y_A^{h_\mathbf{A}} = -1$ and $y_B^{h_\mathbf{B}} = -1$. By integrating over the mass 1 of households in each region, we obtain the following aggregate households' demand for mortgages in regions A and B: $Y_\mathbf{A} \equiv \int_0^1 y_A^{h_\mathbf{A}} = -1$ and $Y_\mathbf{B} \equiv \int_0^1 y_B^{h_\mathbf{B}} = -1$, respectively.

Banks

We consider a stylized version of banks, whose only business consists of buying mortgages from (*i.e.*, lending to) households in different regions at date 1. Banks from region R ($l \in \mathbf{L}_R$) finance these purchases at rate $\rho_R > 0$ and discount price $p_R \in \mathbb{R}_+$ in the international funding market; that is, for a face value of debt equal to $z^{l_R} \leq 0$, bank l_R borrows $-p_R z^{l_R} \geq 0$ at date 1 and pays back $(1 + \rho_R) z^{l_R} \leq 0$ at date 2, independently of the realization of state. We assume that the supply of funding to banks in region R is limited by $Z_R > 0$. In addition to debt, banks also use their own capital for lending purposes, here denoted by $\omega_0^{l_R} \geq 0$.

At date 1, banks can buy mortgages in both regions. The amount of mortgages extended by a bank from region A in region $R = \mathbf{A}, \mathbf{B}$ is $q_R y_R^{l_\mathbf{A}} \geq 0$. If instead the bank is from region B, we write $q_R y_R^{l_\mathbf{B}} \geq 0$. As before, q_R denotes the discount price of region R mortgages. Each bank $l_R \in \mathbf{L}_R$ uses its equity ($\omega_1^{l_R} > 0$) and funding ($p_R z_R \leq 0$) to buy mortgages, that is,

$$(\lambda^{l_R}) : \omega_1^{l_R} - p_R z_R^{l_R} = q_A y_A^{l_R} + q_B y_B^{l_R}, \tag{3}$$

where λ^{l_R} denotes the shadow value corresponding to the bank l_R's budget constraint at date 1.

Banks are also constrained by a capital requirement imposed by the regulator. In particular, we consider a stylized version of the Basel Accord on capital requirements that says that equity must exceed a fraction c of the bank's RWA. We refer to c as the "required" capital ratio (a proxy of the required core Tier 1 capital ratio). Let ϕ_A and ϕ_B denote the risk-weights on mortgages issued in regions A and B, respectively. Then, bank l_R's RWA index is given by $\phi_A y_A^{l_R} + \phi_B y_B^{l_R}$, and its capital constraint is

$$(\nu^{l_R}) : \omega_1^{l_R} \geq c \cdot \left(\phi_A y_A^{l_R} + \phi_B y_B^{l_R}\right), \tag{4}$$

where ν^{l_R} denotes the shadow value of the capital constraint for bank l_R. Motivated by the fact that in 2010, on average, banks in GICIPS countries had a substantially lower core Tier 1 ratio than banks in safe core European euro countries, below we will consider a situation where the capital constraint (4) is binding for B-banks, but not for A-banks.[16]

Bank l_R chooses $y_A^{l_R} \in \mathbb{R}_+$, $y_B^{l_R} \in \mathbb{R}_+$ and $z^{l_R} \in \mathbb{R}_-$ to maximize the following (risk-neutral) linear objective function, subject to constraints (3) and (4):

$$\Pi^{l_R} \equiv \delta\Big(\beta(l_R)\Big(y_A^{l_R} + y_B^{l_R} + (1+\rho_R)z^{l_R}\Big) + (1-\beta(l_R))\Big(y_A^{l_R} + \gamma y_B^{l_R} + (1+\rho_R)z^{l_R}\Big)\Big). \tag{5}$$

Here, δ and $\beta(l_R)$ denote the time discount factor and the probability that bank l_R assigns to the occurrence of state of nature s_1, respectively.[17] Notice that mortgage payoffs coincide with the ones described for households: mortgages bought in region A pay 1 at both states $s = s_1, s_2$, whereas mortgages bought in region B pay 1 at state s_1 and $\gamma \leq 1$ at state s_2. Because A-mortgages always pay off the same amount regardless of the state of nature, we assign them a zero risk-weight ($\phi_A = 0$). The risk-weight for B-mortgages is positive ($\phi_B > 0$) whenever $\gamma < 1$.

[16]This is consistent with our data, which shows that in 2010, on average, banks in GICIPS countries had a substantially lower core Tier 1 ratio than banks in safe core European euro countries (7.8 and 10.2, respectively). Our results hold as long as the capital constraint is more binding for B-banks than for A-banks.

[17]Fostel, Geanakoplos and Phelan (2015) follow a similar approach but without capital requirements. In particular, the bank's objective function in their model depends on date 2 returns, and is subject to a date 1 budget constraint. Their purpose is to understand the role of financial innovation on capital flows.

Marginal Approach to Equilibrium

We follow Geanakoplos' (2003) seminar paper and replace the usual marginal analysis of agents who have interior consumption with a marginal buyer approach and a continuum of banks in each region (see also Fostel, Geanakoplos and Phelan 2015 for a similar approach to cross-border capital flows in a context of financial innovation). In addition, we assume that subjective probability $\beta_s(l_R)$ is strictly monotonically increasing and continuous in l_R, for $R = \mathbf{A}, \mathbf{B}$. Because $\lambda(\mathbf{L}_R) = 1$ for $R = \mathbf{A}, \mathbf{B}$, we can represent the continuum of banks in each region by the closed interval [0, 1]. Thus, the closer l_R is to 1, the higher the probability that bank l_R assigns to state s_1. We denote the marginal bank of region R by $\hat{l}_R$. By definition, this bank is indifferent between holding A-mortgages (*i.e.*, mortgages whose buyers are in region A) and B-mortgages (*i.e.*, mortgages whose buyers are in region B).

The marginal buyer approach is convenient for our purposes because by finding the marginal bank in each region, we can determine the proportions of banks that hold A-mortgages and B-mortgages in that region. Proportions $\hat{l}_R$ and $1 - \hat{l}_R$ can, in turn, be seen as the A-mortgage and B-mortgage weights corresponding to the *representative mortgage loan portfolio of region R*, respectively. Next, we present the definition of equilibrium for this economy.

Definition 1. *An equilibrium consists of a vector of marginal banks* $(\hat{l}_\mathbf{A}, \hat{l}_\mathbf{B})$*, prices* $(\hat{q}_A, \hat{q}_B, \hat{p}_A, \hat{p}_B)$*, funding quantities* $(\hat{z}^{\hat{l}_\mathbf{A}}, \hat{z}^{\hat{l}_\mathbf{B}})$ *and shadow prices* $(\hat{\nu}^{\hat{l}_\mathbf{A}}, \hat{\nu}^{\hat{l}_\mathbf{B}}, \hat{\lambda}^{\hat{l}_\mathbf{A}}, \hat{\lambda}^{\hat{l}_\mathbf{B}})$*, such that*

$$\frac{\delta}{\lambda^{\hat{l}_\mathbf{A}}\hat{q}_A} = \frac{\delta\big(\beta(\hat{l}_\mathbf{A}) + (1-\beta(\hat{l}_\mathbf{A}))\gamma\big)}{\lambda^{\hat{l}_\mathbf{A}}\hat{q}_B + \nu^{\hat{l}_\mathbf{A}}c\phi_B}, \tag{6}$$

$$\frac{\delta}{\lambda^{\hat{l}_\mathbf{B}}\hat{q}_A} = \frac{\delta\big(\beta(\hat{l}_\mathbf{B}) + (1-\beta(\hat{l}_\mathbf{B}))\gamma\big)}{\lambda^{\hat{l}_\mathbf{B}}\hat{q}_B + \nu^{\hat{l}_\mathbf{B}}c\phi_B}, \tag{7}$$

$$\hat{l}_\mathbf{A}\frac{\omega_1^{l_\mathbf{A}} - \hat{p}_A\hat{z}^{\hat{l}_\mathbf{A}}}{\hat{q}_A} + \hat{l}_\mathbf{B}\frac{\omega_1^{l_\mathbf{B}} - \hat{p}_B\hat{z}^{\hat{l}_\mathbf{B}}}{\hat{q}_A} + Y_\mathbf{A} = 0, \tag{8}$$

$$(1-\hat{l}_\mathbf{A})\frac{\omega_1^{l_\mathbf{A}} - \hat{p}_A\hat{z}^{\hat{l}_\mathbf{A}}}{\hat{q}_B} + (1-\hat{l}_\mathbf{B})\frac{\omega_1^{l_\mathbf{B}} - \hat{p}_B\hat{z}^{\hat{l}_\mathbf{B}}}{\hat{q}_B} + Y_\mathbf{B} = 0, \tag{9}$$

$$\hat{\lambda}^{\hat{l}_R}\hat{p}_R = \delta(1+\rho_R)\ ,\ R = \mathbf{A}, \mathbf{B}, \tag{10}$$

$$\hat{z}^{\hat{l}_R} + Z_R = 0,\ R = \mathbf{A}, \mathbf{B}, \tag{11}$$

$$\hat{\nu}^{\hat{l}_R}\left(\omega_1^{\hat{l}_R} - c\cdot\left(\phi_A\frac{\omega-\hat{p}_A\hat{z}^{\hat{l}_R}}{\hat{q}_A}+\phi_B\frac{\omega_1^{\hat{l}_R}-\hat{p}_B\hat{z}^{\hat{l}_R}}{\hat{q}_B}\right)\right)=0,\ R=\mathbf{A},\mathbf{B}, \tag{12}$$

$$\lambda^{\hat{l}_R}\left(\omega_1^{\hat{l}_R}-p_R z_R^{\hat{l}_R}-q_A y_A^{\hat{l}_R}-q_B y_B^{\hat{l}_R}\right)=0,\ R=\mathbf{A},\mathbf{B}. \tag{13}$$

Conditions (6) and (7) capture the indifference between the return of holding A-mortgages and B-mortgages, for marginal banks $\hat{l}_{\mathbf{A}}$ and $\hat{l}_{\mathbf{B}}$, respectively.[18] The numerator of each term is the discounted expected income of the corresponding mortgage (a function of the bank's belief probability). In the denominator, we have the market price of the corresponding mortgage (times the shadow value of the bank's date 1 budget constraint) plus the bank's shadow cost associated with meeting the capital constraint (zero for A-mortgages because $\phi_A = 0$). Shadow cost ν^{l_R} is null when capital constraint (4) is nonbinding for that bank.

Conditions (8) and (9) are the market clearing equations for A-mortgages and B-mortgages, respectively. On the right-hand side of these equations, we have the households' aggregate supply of mortgages in the corresponding region. On the left-hand side, we have the banks' aggregate demand for mortgages. Banks $l_R < \hat{l}_R$ ($l_R > \hat{l}_R$) strictly prefer to hold A-mortgages (B-mortgages, respectively),[19] so they use all their resources to buy this type of asset. Mathematically, we use (3) to obtain corner solutions: $y_A^{l_R} = (\omega_1^R + p_R Z_R)/q_A$ and $y_B^{l_R} = 0$ if $l_R < \hat{l}_R$. If instead $l_R > \hat{l}_R$, we have $y_A^{l_R} = 0$ and $y_B^{l_R} = (\omega_1^{l_R} + p_R Z_R)/q_B$.

Conditions (10) and (11) are the no-arbitrage pricing and market clearing conditions for the R-banks' funding market, respectively. The remaining conditions (12) and (13) are the complementary slackness conditions of the marginal bank $\hat{l}_R$'s Khun–Tucker optimization problem.

Portfolio Rebalancing and Mortgage Credit in Absolute Terms

To define the portfolio rebalancing strategies flight-to-quality (FTQ henceforth) and risky lending (RL henceforth), we need to compute the

[18]Indifference conditions (6) and (7) follow from the first-order conditions of the bank's optimization problem. Conditions (6) and (7) follow from bank $\hat{l}_R$'s optimality conditions on mortgage purchases, and the marginal bank's indifference between the returns of holding A-mortgages and B-mortgages.

[19]Banks $l_R < \hat{l}_R$ ($l_R > \hat{l}_R$) strictly prefer to hold A-mortgages (B-mortgages, respectively) because they assign a high (low) probability to the default state s_2 and this makes these banks value A-mortgages (B-mortgages, respectively) more than market price $\hat{q}_A$ ($\hat{q}_B$, respectively).

representative mortgage loan portfolio of each region R for two different economies, thought of as different points in time, say $(\hat{l}_R, 1-\hat{l}_R)_t$ at date t and $(\hat{l}_R, 1-\hat{l}_R)_{t+1}$ at date $t+1$.

Definition 2. *We say that the representative mortgage loan portfolio of region R exhibits FTQ if $\hat{l}_{R,t+1} > \hat{l}_{R,t}$, and RL if $(1-\hat{l}_R)_{t+1} > (1-\hat{l}_R)_t$.*

Importantly, portfolio weights $(\hat{l}_R, 1-\hat{l}_R)$ also play a key role in identifying whether banks from region A or B are reducing mortgage credit *in absolute terms* to households in a given region R, as shown by the left-hand side of market clearing conditions (8) and (9).

The Role of Funding Cost

Our model can generate insights on the impact of funding cost on banks' rebalancing strategies.

Lemma 1 (Funding cost)**.** *A higher funding cost for B-banks induces A-banks to do RL and B-banks to do FTQ.*

We leave the proof of Lemma 1 for the Online Appendix. Here, we describe the market mechanism behind Lemma 1. When the funding cost of B-banks increases, B-banks with more optimistic beliefs about the no-default state $(l_{\mathbf{B}} \geq \hat{l}_{\mathbf{B}})$ can purchase fewer B-mortgages, which in turn decreases the price of B-mortgages. The price of A-mortgages also decreases, but not as much as the price of B-mortgages, given the B-banks' binding capital constraint. As a result, A-banks see a higher return if holding B-mortgages relative to A-mortgages, so the representative mortgage loan portfolio in the A-region rebalances toward the risky region (RL). B-banks do not see such a large return on B-mortgages, given the additional positive shadow price associated with their capital constraint when holding B-mortgages. In addition, the market pressure on A-mortgages has diminished given the RL behavior of A-banks. These market conditions together with market clearing then imply that the representative mortgage loan portfolio of banks in the B-region rebalances toward A-mortgages (FTQ). The next example illustrates the change in equilibrium portfolio weights and prices when funding costs increase for B-banks.

Example 1. *Consider first a benchmark case with the following parameter values: (i) $\omega_1^{l_{\mathrm{A}}} = 5.35$ and $\omega_1^{l_{\mathrm{B}}} = 5.00$, i.e., B-banks start with lower capital than A-banks; this assumption is needed to make the capital constraint* (4) *binding for B-banks with B-mortgages, but not for A-banks; (ii) capital requirements are such that $c = 4.5$, $\phi_A = 0$ and $\phi_B = 0.5$ (as before, we*

Table 1 ■ The table reports the loan portfolio composition of representative banks in regions $R = \mathbf{A},\mathbf{B}$ in the benchmark case and two additional cases, one with a higher funding cost for B-banks and another with lower capital for B-banks. In all cases the capital constraint is binding for B-banks that buy B-mortgages, but not for A-banks.

Leading example	$\hat{l}_A$	$\hat{l}_B$	$\hat{q}_A$	$\hat{q}_B$	$\hat{\nu}_B$
Benchmark case	0.5540	0.5721	3.4750	2.7000	0.0140
High funding cost for B-banks	0.5065	0.6403	3.4650	2.6100	0.1030
Low capital for B-banks	0.5603	0.5633	3.4632	2.7018	0.0023

assume that A-mortgages, which are riskless, bear a zero risk-weight); (iii) the value of the loss parameter γ for B-mortgages in the default state s_2 is $\gamma = 0.5$; (iv) funding capacities are the same for both banks and equal to $Z_A = Z_B = 1$; (v) households' aggregate demand for mortgages in each region is the same and equal to $Y_\mathbf{A} = Y_\mathbf{B} = -2$; (vi) banks' time discount rate and funding rate are $\delta = 0.909$ and $\rho_R = 0.1,\ R = A, B$, respectively.

For this economy, we find an equilibrium where the representative mortgage portfolio in the A-region is composed of 55% A-mortgages and 45% B-mortgages. The representative mortgage portfolio in the B-region is composed of 57% A-mortgages and 43% B-mortgages. Table 1 reports the equilibrium mortgage prices $\hat{q}_A$ and $\hat{q}_B$, as well as the identity of marginal banks $\hat{l}_\mathbf{A}$ and $\hat{l}_\mathbf{B}$.

Now consider a different economy, with a higher funding cost for B-banks. Using optimality conditions, we can represent this shock as a decrease in Z_B. So now assume $Z_B = 0.8$ and hold the other parameter values constant. The new equilibrium is such that the representative mortgage portfolio in the A-region is composed of 51% A-mortgages and 49% B-mortgages. The representative mortgage portfolio in the B-region is composed of 64% A-mortgages and 34% B-mortgages. Therefore, relative to the benchmark case, a higher funding cost for B-banks results in B-banks doing FTQ and A-banks doing RL.

The Role of Capital Requirements

Let us now examine the impact of a decrease in the capital of B-banks.

Lemma 2 (Capital requirements)**.** *A decrease in B-banks' capital induces B-banks to do RL and A-banks to do FTQ.*

We leave the proof of Lemma 2 also for the Online Appendix. The market mechanism behind Lemma 2 is that, when B-banks' capital decreases, these banks' capital constraint becomes more binding for the same amount of resources, which in turn induces the discount price of B-mortgages ($\hat{q}_B$) to increase. A-banks now require a higher expected payoff on B-mortgages (*i.e.*, $\hat{l}_{\mathbf{A}}$ in increases) to compensate for the lower return (with respect to preshock levels), so the representative mortgage loan portfolio of the A-region rebalances toward the safe A-region (FTQ). Price pressures and market clearing for B-mortgages then imply that B-banks offset the lower demand for B-mortgages by A-banks (RL). The following example illustrates the change in portfolio weights and prices when the capital of B-banks decreases.

Example 2. *Let us consider the same parameter values as in the benchmark case, with the exception of $\omega_1^{l_{\mathbf{B}}}$, which we now set equal to $\omega_1^{l_{\mathbf{B}}} = 4.98$. The new equilibrium for this economy with lower capital for B-banks is such that the representative mortgage portfolio in the A-region is composed of 56% A-mortgages and 44% B-mortgages. The representative mortgage portfolio in the B-region is similar to the one in the A-region. We report the new equilibrium mortgage prices $\hat{q}_A$ and $\hat{q}_B$, and the identity of marginal banks $\hat{l}_{\mathbf{A}}$ and $\hat{l}_{\mathbf{B}}$ in Table 1. We conclude that, relative to the benchmark case, lower capital for B-banks results in B-banks doing RL and A-banks doing FTQ.*

Home Bias and a Nonbinding Capital Constraint for B-Banks

So far, we have assumed that the capital constraint (4) is binding for B-banks. If instead we consider a situation in which this constraint is nonbinding, then we would obtain an equilibrium in which marginal banks in both regions would be the same, *i.e.*, $\hat{l}_{\mathbf{A}} = \hat{l}_{\mathbf{B}}$ (this result follows from indifference conditions (6) and (7), and $\nu^{\hat{l}_{\mathbf{A}}} = \nu^{\hat{l}_{\mathbf{B}}} = 0$).

The equilibrium outcome $\hat{l}_{\mathbf{A}} = \hat{l}_{\mathbf{B}}$ breaks down when one group of banks values B-mortgages differently than the other group of banks at state s_2. Here we think of this possibility in terms of a "home bias" exogenous effect for the group of B-banks (see Grinblatt and Keloharju 2000, Huberman 2001, Van Nieuwerburgh and Veldkamp 2009 and Seasholes and Zhu 2010 for previous studies that analyze the home bias effect).[20] In our model, for simplicity, we ignore the possibility of information acquisition (see Van Nieuwerburgh and Veldkamp 2009 for a more sophisticated model with asymmetric information and information acquisition). Our approach consists of modifying optimality condition (7) for B-banks by replacing parameter γ with $\gamma + \zeta$, where $\zeta > 0$ is what we call the "home bias" parameter (only B-banks experience this "home bias" effect). It stands to reason that when ζ increases enough, B-banks

[20]See also Arslanalp and Tsuda (2012) and Brutti and Saure (2013) for careful discussions of home bias during the sovereign debt crisis. Acharya *et al.* (2015) find a similar home bias effect in the corporate sector during the sovereign debt crisis.

find it optimal to rebalance their mortgage portfolios toward the B-region (*i.e.*, risky lending).[21]

Let us now consider an increase in funding cost for B-banks, but now with the B-banks' capital constraints being nonbinding.

Lemma 3 (Funding costs when B-banks' capital constraint is nonbinding and $\zeta > 0$)**.** *If* $\nu^{\hat{l}_A} = \nu^{\hat{l}_B} = 0$ *and* $\zeta \in (0, 1 - \gamma)$*, then both A-banks and B-banks do RL.*

We leave the proof of Lemma 3 for the Online Appendix. The following numerical example illustrates this result.

Example 3. *Let us take similar parameter values as in our benchmark example above, and let* $\zeta = 0.45$*. We find that if* $Z = 1$*, then* $\hat{l}_{\mathbf{A}} = 0.9091$*,* $\hat{l}_{\mathbf{B}} = 0.0910$*,* $q_{\mathbf{A}} = 3.1592$ *and* $q_{\mathbf{B}} = 3.0156$*. If instead* $Z = 0.8$*, then* $\hat{l}_{\mathbf{A}} = 0.9078$*,* $\hat{l}_{\mathbf{B}} = 0.0782$*,* $q_{\mathbf{A}} = 3.1091$ *and* $q_{\mathbf{B}} = 2.9651$*.*[22] *Thus, the representative portfolios in both regions rebalance toward the risky B-region (i.e., RL).*

Summary and Further Remarks

Summary: Our general equilibrium model of cross-border mortgage lending rationalizes the following results:

- First, when B-banks have a binding capital constraint, then an increase in funding costs for B-banks induces B-banks (with higher funding costs than A-banks) to do FTQ, while A-banks do RL. If instead there is a negative shock to B-banks' capital, then B-banks (with low capital) engage in an RL strategy, while A-banks (with more capital than B-banks) exhibit an FTQ behavior. Table 2 summarizes this first set of results.
- Second, if B-banks have a nonbinding capital constraint, then an increase in funding costs for B-banks induces both B-banks (with higher funding costs than A-banks) and A-banks to do RL.

Remark 1. *Our model allows banks from different regions to differ in several dimensions, such as funding cost and capital. We do not allow for such*

[21] An alternative interpretation of ζ could be a transfer (bailout) from the B-government to B-banks in case of default at state s_2 (only B-banks receive such a transfer).

[22] Notice that, for these equilibrium values, the B-banks' capital constraint in both cases ($Z = 1$ and $Z = 0.8$) is nonbinding. Thus, the hypothesis of Lemma 3 holds.

Table 2 ■ The table summarizes our main theoretical findings on the impact of higher funding cost and lower capital for B-banks on banks' portfolio rebalancing strategies.

If $\nu^{\hat{I}_B} > 0$	*FTQ*	*RL*
A-banks	*Well-capitalized*	*Low funding cost*
B-banks	*High funding cost*	*Undercapitalized*

a distinction within each region because that would complicate the model without significant new economic insights. Such an extension would require us to consider subsets of banks within each set/region, and find the marginal bank within each subset.

Remark 2. *In our model, banks differ in their beliefs about the occurrence of the state when mortgages issued in the B-region default. Several empirical works on the sovereign debt crisis motivate this assumption; see IMF (2012), European Commission (2012), Corsetti et al. (2013) and De Grauwe and Ji (2012) for evidence on potential mispricing/overpricing of debt in the course of the Eurozone sovereign debt crisis, and Grosse Steffen (2015) for direct evidence of disagreement between professional forecasters for different Eurozone countries.*

Remark 3. *The nature of mortgages in our model is that a bank incurs a loss on mortgages issued in the B-region if state* s_2 *occurs. Such a loss captures the borrower's inability to fulfill the promised mortgage payments, which in turn depends on the borrower's future expected income. Collateral requirements are not incorporated into our model because, unlike in the United States, mortgage loans in Europe are recourse loans.*[23] *For a general equilibrium model with nonrecourse mortgages, see Geanakoplos and Zame (2014), where lenders are restricted to the secured asset (they can foreclose, repossess the house and sell and collect the proceeds).*

Remark 4. *Explicit and implicit government guarantees in mortgage finance may influence a bank's decision to originate more residential mortgages. If a government's guarantee totally or partially insures the bank against the possibility of mortgage default, the bank would find originating a mortgage less risky. In the Online Appendix, we discuss the particularities of the government guarantees system in Europe and conclude that there are no reasons to incorporate differences in mortgage guarantees across countries in our model.*

[23]Mainly, mortgage loans in Europe are recourse loans. There are no credit market regulations or procedural rules that bar lenders from a full recourse to the borrowers' personal assets and future income.

Data Description

In an unprecedented attempt to increase transparency and confidence in the banking sector, the EBA, in cooperation with the ECB, the European Commission and EU national supervisory authorities, have recently released granular information on a bank-by-bank basis for year-end 2009 and year-end 2013. We cannot, by comparing banks' exposures in these two periods, get an understanding of the dynamics of bank portfolio allocations, nor can we claim that year-end 2013 positions fully reflect bank adjustments to the crisis that just ended. However, we can get a sense of how banks changed their residential mortgage exposures by geographical region in two separate points in time, one right before the sovereign debt crisis started and the other close to the end of the crisis.[24]

To ensure full transparency, the stress tests included full disclosure of all capital elements under baseline and adverse scenarios. We are only interested in the granular baseline data. The 2009 stress test samples 91 representative banks from 21 countries. These 91 banks represent at least 50% of the national banking sectors in Europe in terms of total assets. The second EU-wide stress test contains information from 123 representative banks across the EU, including Norway, for a total of 22 countries. Banks are chosen by descending order of size and represent approximately 70% of the EU banking sector by assets. Similar to the previous test, the 2013 sample contains information on a bank-by-bank basis and captures the consolidated figures as of year-end. We use bank names as an identifier in order to combine information from both data sets. Combining the available information from both exercises allows us to match a total of 69 representative banks—see the Online Appendix for a list of banks included in our database.

The EU-wide stress tests were conducted on the highest level of consolidation (bank group level), so subsidiaries of banks in the European Economic Area were excluded.

The baseline data set provides information on financial institutions' credit risk exposures by regulatory portfolio (residential and commercial mortgages, as

[24]See the Online Appendix for an argument and empirical test that establish year-end 2009 and year-end 2013 as appropriate points in time (precrisis and end-of-crisis, respectively) for our empirical analysis. Also, for the sake of brevity, in the Online Appendix we provide a brief chronology of the sovereign debt crisis and a discussion of the economic impact of the sovereign debt crisis (in terms of GDP growth rates, sovereign bond yields and mortgage rates). In the Online Appendix, we also provide estimates using our database of the credit squeeze and change in banks' portfolio weights between year-ends 2009 and 2013.

well as lending to financial institutions and corporations) and also by geographical region (EU countries, Japan and the United States). In addition, the data break out financial institutions' exposures to central and local government debt by geographical region, maturity and accounting portfolio. For each data point, exposures amount to the loan balance outstanding at the time when the baseline data were collected (a measure also known as EAD or "Exposures-At-Default").

Importantly, the data set also provides information on banks' exposures to their own country. This allows us to examine potential FH episodes. All tables with results from this database report numbers in million EUR or in percentage terms (loan portfolio weights). In total, our database contains 158,445 observations. This includes all banks, counterparty regions, loan types and time points (year-end 2009 and year-end 2013).[25]

Our sample of 69 banks represents 21 European countries: Austria, Belgium, Cyprus, Germany, Denmark, Spain, Finland, France, the United Kingdom, Greece, Hungary, Ireland, Italy, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Sweden and Slovenia. Notice that the list of country counterparties (32 countries) is larger than the list of countries that represent banks in our sample (21 countries). For some of the summary statistics we present below, we find that sorting the countries into seven groups yields more concise aggregate results.

We define Group A as "core" countries in the Eurozone: Austria, Belgium, Finland, France, Germany, Luxemburg and the Netherlands. Group B includes European "periphery" countries in the Eurozone that were hard hit by the crisis: GICIPS. Group C is composed of other smaller European "periphery" countries in the Eurozone, namely, Estonia*, Latvia*, Lithuania*, Malta, Slovakia* and Slovenia (* means there is no bank in the EU-wide stress test data from this country). Groups D and E contain European countries outside the Eurozone. Group D is composed of ex-soviet countries, namely, Bulgaria*, the Czech Republic*, Hungary, Poland and Romania*, while Group E contains the rest of the European non-euro countries, namely, Denmark, Iceland*, Liechtenstein*, Norway, Sweden and the United Kingdom. Finally, Group F is composed of the non-European countries Japan* and the United States* (the EU-wide stress test includes these two countries in order to understand the European banks' exposures there).

[25] In addition, we augmented our database with fundamental macroeconomic variables, such as the GDP growth differences between the bank's home country and its counterparty country. We also included important housing market variables for each country, such as the representative interest rate on new residential loans, the growth rate of building permits and the change in nominal residential housing prices.

For the sake of exposition, most of our discussion below will focus on groups A and B, which are interesting in terms of both policy implications for the EU and for the examination of cross-border bank lending behaviors within an economic and monetary union. Notice that although C contains countries belonging to the Eurozone, their contribution to the EU's budget only amounts to 1.5% (with individual contributions proportional to the EU member's GDP). In contrast, group A's contribution to the EU's budget amounts to 50.7%. We also decided to exclude groups D and E from our main analysis because these groups contain European countries outside the Eurozone, and this would complicate both our theoretical and empirical models with exchange rate considerations. For the same reason, we excluded group F, whose members, in addition to being non-euro countries, are also non-European countries.

Flight-to-Quality and Risky Lending

Our goal is to examine the extent to which banks in different geographical regions exhibited FTQ and RL behaviors in residential mortgage exposures.[26] Because five banks in our sample of 69 were nationalized between 2010 and 2013, we exclude them from our analysis of FTQ and RL.[27] These banks were Dexia (Belgium), Op-Pohjola (Finland), Irish Life (Ireland), SNS bank (the Netherlands) and Bankia (Spain). The last of these was only partially nationalized, with the Spanish government coming to own 45% of the shares. However, to avoid having banks in our sample change status during the period under investigation, we omit Bankia as well as the other four nationalized banks. Other banks in our sample were also nationalized (Allied Irish Bank, Bank of Ireland, ABN Amro, Royal Bank of Scotland and Lloyds), but because nationalization occurred before year-end 2009, we include them in our analysis.

Definitions

We can define FTQ and RL in terms of overall bank loan holdings (including all loan types) or in terms of total residential exposures. The former ignores the first-order effects in overall residential shares and, therefore, makes the analysis of reallocation within the asset class difficult to understand and interpret.[28] For this reason, we choose to define FTQ and RL in terms of total

[26]See Luque and Mello (2017) for an analysis of cross-border commercial mortgage lending in the European sovereign debt crisis.

[27]However, we have included these five banks in the Online Appendix when assessing the changes in cross-border residential mortgage lending during that period.

[28]Here is a simple example: suppose a bank reports 2009 holdings of {12,12,12} and 2013 holdings of {10,10,10} in regions I, II and III, respectively. There is clearly a first-order decrease in overall mortgage exposure, but there is no change in relative geographic exposure within the residential mortgage asset class at all.

residential exposures (see the Online Appendix for alternative definitions). This allows us to interpret any of the results as a shift in geographic exposure *within* residential mortgage holdings.

We define FTQ as the strategy of a bank rebalancing its residential loan portfolio toward a “safe” country. “Safe” countries include those in regions A, E and F. We do not include C countries and D countries in our definition of “safe” regions because some of their members had episodes characteristic of a banking crisis. For example, Cyprus had a financial crisis in 2012–2013, and Hungary suffered a sovereign debt crisis in June 2010 (the credit default swaps (CDS) on Hungarian debt jumped 83 basis points to 393 bp; by way of comparison, Portugal and Greece were around 376 and 787 at that time).[29]

We define RL (risky lending) as the strategy of a bank rebalancing its residential loan portfolio toward any of the B countries.

Notice that our definitions of FTQ and RL embed the possibility of FH, formally defined as the strategy of a bank rebalancing its residential loan portfolio toward its home country. In particular, this is the case for an A-bank rebalancing toward its home country (FTQ), and also for a B-bank rebalancing toward its home country (RL). See the Online Appendix for an exhaustive analysis that disentangles FH from FTQ and RL.

Formally, we constructed the FTQ and RL variables as follows. First, let $L^i_{j,\theta}$ denote the type θ of outstanding gross exposure (in euro) that bank j has to counterparties in country i. For a given point in time t, we can express the bank j's share of type θ loans in country i with respect to its total type θ exposures as follows:

$$\pi^i_{j,\theta,t} = \frac{L^i_{j,\theta,t}}{\sum_i L^i_{j,\theta,t}}.$$

Take loan type θ as residential mortgages. Formal definitions of our variables of interest follow. First, we denote by $FTQ^{sh,i}_{j,\theta}$ the FTQ dummy variable—in shares (sh)—that equals 1 when $\pi^i_{j,\theta,t+1} > \pi^i_{j,\theta,t}$, where $i \in \{A, E, F\}$, *i.e.*,

- for a {bank j, counterparty country i}-pair, $FTQ^{sh,i}_{j,\theta} = 1$ if $\pi^i_{j,\theta,t+1} > \pi^i_{j,\theta,t}$, where $i \in \{A, E, F\}$.

Similarly, we write the corresponding definitions for RL and FH as follows:

[29]Upon request the authors can provide results for alternative definitions of “safe regions,” including combinations among A, C, D, E and F countries.

- for a {bank j, counterparty country i}-pair, $RL^{sh,i}_{j,\theta} = 1$ if $\pi^{i}_{j,\theta,t+1} > \pi^{i}_{j,\theta,t}$, where $i \in \{B\}$.

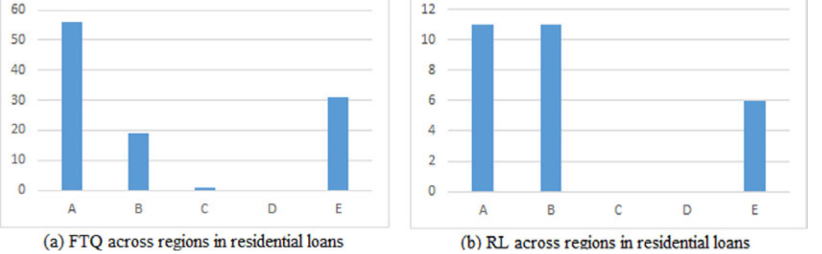
Because in our database $L^{i}_{j,\theta,t}$ is expressed in terms of EAD, the definition of $\pi^{i}_{j,\theta,t}$ captures the marked-to-market debt exposure level held in the bank's portfolio with respect to the bank's total residential exposures. Thus, $\pi^{i}_{j,\theta,t}$ represents the bank's asset θ credit exposure "share" in geographical region j at time t, and can be understood in terms of residential risk exposure in a given geographical region. Accordingly, the FTQ definition above should be understood in terms of rebalancing residential mortgage risk toward the safe region. Similarly, RL means rebalancing residential credit risk toward the risky GICIPS region.

A Comparison of FTQ and RL by Region

Next, we compare regions in terms of FTQ and RL bank behaviors as defined above. Figures 2a and b illustrate the number of FTQ residential loans and RL residential loans by bank region, respectively. The interpretation is in terms of pairs (bank, country counterparty) and exposure to residential mortgage loans.

For the above definitions, we find 19 $FTQ^{sh,i}_{j,\theta}$ pairs {B-bank j, safe country counterparty i}, where a B-bank j rebalanced its residential loan portfolio toward a country i in the "safe" region. On the other hand, there were 56 $FTQ^{sh,i}_{j,\theta}$ pairs {A-bank j, safe country counterparty i} for banks in the A region. Because the A region and the B region have 22 and 24 nonnationalized banks, respectively, we conclude that, on average, A-banks had 3.2

Figure 2 ■ These figures illustrate the number of FTQ residential loans and RL residential loans by bank region, respectively. The interpretation is in terms of pairs (bank, country counterparty) and exposure to residential mortgage loans with respect to total residential loans in portfolio. [Color figure can be viewed at wileyonlinelibrary.com]



(a) FTQ across regions in residential loans

(b) RL across regions in residential loans times more safe-country counterparties than B-banks in FTQ cross-border residential mortgage lending.

The number of $RL_{j,\theta}^{sh,i}$ pairs {bank j, risky country i}, where a bank j rebalanced its residential loan portfolio toward a country i in the "risky" B region, is the same (11) for both A-banks and B-banks. Again, because the A region and the B region have 22 and 24 nonnationalized banks, respectively, we conclude that, on average, A-banks had 1.1 times more risky-country counterparties than B-banks in RL cross-border residential mortgage lending.[†]

To sum up, we conclude that, on average, A-banks engaged in more FTQ and RL than B-banks.[30]

Determinants of the FTQ and RL Behaviors

This section examines the determinants of FTQ and RL behaviors using the definitions in terms of total residential exposures (see previous section). We start by describing the data used for our regression analysis. There are two major groups of variables: (1) granular data on bank exposures, credit risk and provisions, and (2) housing and macroeconomic variables. The main results from our regressions appear in Tables 4 and 5 at the end of this section.

Granular Data from the EU-Wide Stress Tests

The EU-wide stress tests include unique granular information at the individual bank level, which we use to understand the determinants of FTQ and RL lending behaviors. In particular, the following variables enter our regression specification (described below) either as percentages or as dummies (given that we use a logit regression model):

Bank credit risk. We incorporate important credit risk variables such as the bank's funding cost; the Tier 1 capital ratio; and coverage ratio in residential loans. The Tier 1 capital ratio compares the bank's core equity capital with its total RWA, and is thus a good indicator of the bank's capital adequacy (*e.g.*, well-capitalized vs. undercapitalized). Although our database has information about the bank's RWA, which captures the riskiness of a bank's assets, we

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[†][Correction added on 23 October 2017, after first online publication: "B-banks" and "safe-country" in this sentence have been corrected to "A-banks" and "risky-country", respectively.].

[30]In the Online Appendix, we demonstrate that this result does not change if we disentangle FH from FTQ and RL.

Table 3 ■ The table reports the correlation coefficients between funding costs and capital ratios for the whole set of banks in our sample, as well as for the subsets of A-banks and B-banks.

	All Banks	A-Banks	B-Banks
Corr (funding cost, capital ratio)	0.0756	0.0370	0.0652

chose not to include this variable to avoid collinearity issues with the Tier 1 capital ratio (one of our most important variables in our discussion below).

Because in our theoretical model we considered shocks to the funding cost and capital ratio of B-banks, a reasonable question is whether we can treat the funding cost and the capital ratio as independent variables for the two cross-sections of banks in our empirical analysis. In Table 3, we report the correlation coefficients between funding costs and capital ratios for the whole set of banks in our sample, as well as for the subsets of A-banks and B-banks. For each group of banks, we find a correlation coefficient close to zero, and thus we can regard funding cost and the core Tier 1 capital ratio as independent.

Bank exposures to GICIPS bonds and defaulted exposures. We include each bank's lending exposures to B-countries (GICIPS sovereign bonds) as a percentage of the bank's total exposures (including residential, corporate, commercial, sovereign and lending to financial institutions). This variable is important in understanding how exposed a bank is to the GICIPS countries. In addition, we include the ratio of defaulted exposures (D) to total exposures (T). Ratio D/T helps to capture the deterioration of the bank's balance sheet and stands as a proxy for the bank's default likelihood.[31]

Bank provisions. We include information on the bank's provisions for both nondefaulted and defaulted residential loans.

For each of the explanatory variables listed above, we chose values corresponding to the year-end 2009 baseline EU-wide stress data in order to avoid any endogeneity issues. Recall that we computed our dependent variables $FTQ^{sh,i}_{j,\theta}$ and $RL^{sh,i}_{j,\theta}$ by taking the difference between the year-end 2009 and

[31]We also considered including credit default swaps (CDS EUR 3Y D14 CORP) for each bank in our analysis. However, this information is only available for 47 of the 69 banks in our sample (in 2009), distorting values and making it difficult to generate significant results. Our D/T ratio is, to some extent, a good substitute for the banks' CDS.

year-end 2013 values of the corresponding loan portfolio shares (periods t and $t + 1$, respectively). Because the sovereign debt crisis hit the B countries in Q1 2010 for the first time, and because 10-year bond rates seemed quite stable for all countries before that quarter (see Figure 1), we do not expect endogeneity issues in our regressions. Therefore, we treat the results corresponding to the variables above as causation.

Macroeconomic and Housing Market Variables

In our regressions, we also include a macroeconomic variable that takes into account the difference in GDP growth rate between the bank home country and its counterparty country (referred to as "Domestic–Counterparty GDP growth diff" in the regression table). Again, values correspond to year 2009. In addition, we gather the following housing-related variables from the European Mortgage Federation's Hypostat 2014 document: (1) the change in building permits issued by the bank's counterparty country and (2) the change in nominal housing prices in the bank's counterparty country.[32] Variables (1) and (2) capture the change between 2009 and 2013, so we interpret their regression coefficients as correlation and not causation.

We construct variables (1) and (2) as follows. First, we denote by BP_09 and BP_13 the building permits issued in 2009 and 2013, respectively, in the bank's counterparty country. The change in building permits of the counterparty country, referred to as "Growth BP counterparty," is defined as follows: (BP_13/BP_09)-1. Second, the change in nominal residential housing prices of the counterparty, referred to as "Avg. growth house price counterparty," captures the average of the counterparty country's house price growth during the period 2010–2013.

These additional housing market variables allow us to control for the bank's incentives to rebalance its residential loan portfolio toward one region or another. This is particularly important because not all countries in the same group experienced the same evolution in their housing markets.[33] Also, notice

[32]Because house prices are highly correlated with the growth in interest rates of new residential loans, we chose to remove the latter from our regressions to avoid collinearity issues.

[33]For example, the housing market expanded for all countries in the A group except for the Netherlands between 2009 and 2013—even though the Netherlands was a country outside the sovereign debt crisis region. Variables such as the nominal house price capture to some extent the attractiveness of rebalancing toward a country such as the Netherlands. Also, the change in building permits issued captures whether the housing market of a country is expanding or contracting. In the Netherlands, building permits contracted between 2009 and 2013, whereas for other A countries building permits increased.

Table 4 ■ Determinants of the FTQ and RL behaviors in terms of total residential exposures for the subset of A-banks.

	FTQ A-Banks		RL A-Banks	
	Coef.	S.E.	Coef.	S.E.
Core Tier 1 ratio	0.708***	0.132	0.219	0.279
Funding costs	−0.162	0.271	−0.980**	0.428
Default exposures to total exposures	−0.567	0.351	−1.721***	0.524
B1 bond exposures to total exposures	−0.428***	0.134	−0.435***	0.171
Coverage ratio residential loans	0.021**	0.009	0.028	0.020
Provisions nondefaulted residential loans	−1.170***	0.197	−0.527*	0.315
Provisions defaulted residential loans	0.239***	0.051	0.098	0.086
Domestic–Counterparty GDP growth diff	−0.264***	0.032	0.129***	0.029
Growth BP counterparty	0.030***	0.005	−0.044***	0.004
Avg. growth house prices counterparty	0.016**	0.007	−0.014	0.010
Constant	−7.776***	1.841	−2.281	2.519

***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level. Standard error adjusted for 17 clusters.

that for this last group of housing-market–specific control variables, there was no data for Norway and the United Kingdom as countries that represent banks, nor was there data for Japan as a counterparty country. Thus, we omitted these countries for the purposes of our regression analysis.

Regression Results

We then ran two separate logistic models to regress our categorical dependent variables $FTQ^{sh,i}_{j,\theta}$ and $RL^{sh,i}_{j,\theta}$ with respect to the independent variables described above.[34] Here, θ stands for "residential loans." Because we are mainly interested in understanding the rebalancing of cross-border residential loans of banks in the A and B groups, we ran these regressions for each of these two groups of banks.[35] Each regression has 459 observations if the set of banks belongs to the A region and 648 if the set of banks belongs to the B region. We report the results of these regressions in Tables 4 and 5, respectively.

[34]We performed a collinearity test and found that for our set of independent variables there is no severe collinearity.

[35]We use the logistic distribution because it has larger tails than a normal distribution, and hence is a more robust estimation for our type of volatile data. Recall that a logistic econometric model estimates the best fit of a cumulative distribution function of the errors, which are assumed to behave as a joint logistic distribution.

Table 5 ■ Determinants of the FTQ and RL behaviors in terms of total residential exposures for the subset of B-banks.

	FTQ B-Banks		RL B-Banks	
	Coef.	S.E.	Coef.	S.E.
Core Tier 1 ratio	-0.682^{*}	0.358	-0.220	0.203
Funding costs	1.981^{**}	0.899	2.523^{**}	1.074
Default exposures to total exposures	-1.007^{***}	0.342	-0.170	0.128
B1 bond exposures to total exposures	-0.222^{**}	0.113	0.022	0.048
Coverage ratio residential loans	-0.082^{*}	0.045	-0.082^{**}	0.037
Provisions nondefaulted residential loans	-0.233	0.536	-0.349	0.479
Provisions defaulted residential loans	0.569^{***}	0.203	0.142	0.090
Domestic–Counterparty GDP growth diff	-0.275^{***}	0.058	-0.100	0.137
Growth BP counterparty	0.042^{***}	0.008	-0.064^{***}	0.018
Avg. growth house prices counterparty	-0.005	0.013	0.014	0.015
Constant	5.230	4.547	-7.866^{***}	2.392

***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level. Standard error adjusted for 24 clusters.

The logistic regressions in Tables 4 and 5 fit the data pretty well and are absent of severe multicollinearity (or collinearity for short). We achieved a quite high goodness-of-fit (R^2) considering the use of a logistic model. For the set of A-banks, we got $R^2 = 26.10\%$ for the FTQ and $R^2 = 18.99\%$ for the RL regression. And for the set of B-banks, we got $R^2 = 39.72\%$ for the FTQ regression and $R^2 = 32.03\%$ for the RL regression.

Preliminary Insights from Tables 4 and 5

Tables 4 and 5 reveal that a higher share of GICIPS sovereign bonds—"bad" collateral among European bonds—in the bank's loan portfolio (variable "B-bond exposures to total exposures") induced both A-banks and B-banks to rebalance less toward the safe region. In the case of A-banks, we also find that a higher share of GICIPS sovereign bonds in the bank's loan portfolio induces A-banks to rebalance less toward the risky region. This result complements Bocola (2016), De Marco (2014) and Acharya *et al.* (2015), who find empirical support for the hypothesis that banks with high exposures to the sovereign debt of "crisis-hit" countries encountered difficulty using these sovereign bonds as collateral for funding purposes, in turn reducing cross-border lending in the corporate sector.

Another interesting question is the following: Did banks rebalance their residential real estate exposures toward "core" European countries with

Table 6 ■ The table provides a typology of B-banks and A-banks' portfolio rebalancing strategies in terms of their funding cost and capital ratio characteristics. In this table, we also indicate the corresponding lemma of our theoretical model that supports each classification.

Typology	FTQ (Definitions 1 and 2)	RL∪FH (Definition 1)	RL\FH (Definition 2)
B-banks	**High Funding Cost** **Undercapitalized** (Lemma 1)	**High Funding Cost** Capital Ratio insignificant (Lemma 3)	Funding Cost insignificant **Undercapitalized** (Lemma 2)

Typology	RL (Definitions 1 and 2)	FTQ (Definitions 1 and 2)
A-banks	**Low Funding Cost** (Lemmas 1 and 3)	**Well-Capitalized** (Lemma 2)

strong economic fundamentals? Our FTQ regression results in Tables 4 and 5 validate this hypothesis in the context of the sovereign debt crisis. In particular, we find that there was a higher likelihood of FTQ in residential lending when the GDP growth rate of a bank's counterparty country increased with respect to the GDP growth rate of the bank's domestic country ("GDP growth diff" covariate). We also notice that the likelihood of FTQ in residential lending increased when the counterparty country experienced a growing housing market, *i.e.*, FTQ was more likely if the number of building permits increased between 2009 and 2013. These effects hold for both A-banks and B-banks, and are robust to the inclusion of the bank's home country in the construction of dependent variables FTQ and RL (see the Online Appendix for an alternative definition of FTQ and RL, and corresponding regressions).

Empirical Results Regarding the Funding Cost and Capital Ratio Variables Under the Lens of Our Equilibrium Model

We start our discussion by proving a typology (Table 6) that summarizes our main empirical results regarding the banks' portfolio rebalancing strategies, the funding cost and the core Tier 1 ratio, and their relationship with the lemmas stated in our theoretical model. Below, we elaborate on the mapping between theory and empirics to clarify the results in our typology table.

First, our equilibrium model of cross-border mortgage lending predicts that if banks in the "crisis-hit" GICIPS region have their capital constraint binding and their funding cost increases, then banks from GICIPS countries exhibit an FTQ strategy, while banks from safe countries (with low funding costs relative to GICIPS banks) exhibit an RL behavior (Lemma 1). Our regressions support this lemma.[36]

Notice that this first empirical result does not change if we disentangle FH from FTQ for the group of A-banks, and FH from RL for the group of B-banks. In the Online Appendix, we redefine variables FTQ and RL accordingly and run analogous regressions to the ones corresponding to Tables 4 and 5 (the respective tables in the Online Appendix are Tables 13 and 14). Here, for the sake of exposition, we refer to the two possible definitions of FTQ and RL as follows:

- **Definition I (embedding FH into FTQ and RL)**: *FTQ and RL include the home country for A-banks and B-banks, respectively.*
- **Definition II (without embedding FH into FTQ and RL)** : *FTQ and RL do not include the home country for A-banks and B-banks, respectively.*

Second, in Tables 4 and 5 (under definition I), we can also see that B-banks with high funding costs are more likely to engage in an RL strategy. This second empirical result is consistent with Lemma 3. Notice that the coefficient of the core Tier 1 ratio in the RL regression for B-banks is not statistically significant, which is in accordance with the hypothesis of Lemma 3 that the capital constraint of these banks is nonbinding. Also notice that A-banks with low funding costs (relative to B-banks) are more likely to follow an RL strategy.

Interestingly, if we use definition II of FTQ and RL, and run similar regressions to the ones in Tables 4 and 5, but with dependent variables FTQ and RL redefined in this alternative way, we find empirical support for Lemma 2. This lemma says that a negative shock to GICIPS banks' capital induces these banks to do RL, while banks in safe countries (with high capital relative to GICIPS banks) exhibit an FTQ behavior. We report the results of these alternative regressions in Tables 13 and 14 in the Online Appendix.[37]

[36] In particular, Table 5 shows that the coefficient of the "funding cost" covariate for the FTQ regression using the group of B-banks is positively and statistically significant, while Table 4 shows that this coefficient is negative and statistically significant for the RL regression using the group of A-banks. Moreover, we see that B-banks' RL strategy is more likely the more undercapitalized these banks are.

[37] In particular, in Table 14 in the Online Appendix, the coefficient of the core Tier 1 capital ratio for the RL regression among the set of B-banks is negative and statistically significant, consistent with our hypothesis in Lemma 2. Moreover, in Table 13 in the Online Appendix, the coefficient of the core Tier 1 capital ratio for the FTQ regression among the set of A-banks is positive and statistically significant, also consistent with Lemma 2.

What explains the difference in terms of the funding cost and capital ratio between the RL regressions for the subset of B-banks in Tables 5 and 14 in the Online Appendix? In both the FH regression for B-banks in Table 14 in the Online Appendix (using definition II) and the RL regression for B-banks in Table 5 (using definition I), the coefficient of funding costs is positive and statistically significant, while the coefficient of the core Tier 1 ratio is not statistically significant. This contrasts with the coefficients of these covariates in the RL regression for B-banks in Table 14 (statistically significant and negative coefficient for the core Tier 1 ratio covariate, and statistically insignificant coefficient for the funding cost covariate). This discrepancy suggests that a "rebalancing toward home" (FH) strategy can potentially be driving the results in the RL regression for B-banks in Table 5. As Lemma 3 suggests, this may be due to a home bias effect among a group of B-banks with nonbinding capital constraints.[38]

Conclusions

In recent years, there has been a spirited debate about the reasons and consequences of the sovereign debt crisis (see Lane 2012). This article examines the cross-border residential mortgage lending market in this turbulent period. For this, we construct a database from the EBA's EU-wide stress tests that allows us to examine the banks' residential portfolio rebalancing strategies for a sample of large European banks.

We find that in the period that goes from year-end 2009 to year-end 2013, the cross-border residential mortgage lending market became highly segmented geographically and by bank type (Table 6). GICIPS banks (B-banks), with high funding costs and low capital ratios ("fragile" banks), followed a conservative lending strategy by rebalancing their mortgage portfolios toward the safe region. When the B-bank was undercapitalized but had no funding problems, it found optimal to rebalance toward a risky B-country different from its home country. This result resembles Acharya and Steffen's (2015) finding that during the sovereign debt crisis, large banks with low capital ratios were more likely to engage in risk-shifting in sovereign bonds.[39] Last,

[38]Interestingly, under definition I, we find an average core Tier 1 ratio equal to 7.4815, whereas under definition II this coefficient is 7.1520. Roughly speaking, if we do not embed FH into RL (*i.e.*, no home bias effect), B-banks doing RL look more undercapitalized on average than if we embed FH into RL. Another interesting insight from our database is that the average funding cost for B-banks doing RL under definition I is higher than under definition II (1.9278 vs. 1.5862, respectively).

[39]Acharya and Steffen (2015) describe this as the "greatest carry trade ever." The intuition is the following: banks with distressed loan portfolios increased their exposures

we find some evidence that suggests that B-banks that experience funding problems, but have their capital constraints nonbinding, find it optimal to rebalance toward their (risky) home countries.[40]

For the case of banks in the safe region (A-banks), we also find different lending behaviors, both in terms of funding costs and capital ratios. A-banks with low funding costs find optimal to rebalance their mortgage loan portfolios toward risky countries (RL strategy). A-banks that are well-capitalized follow a more conservative strategy by rebalancing their mortgage loan portfolios toward safe countries, including their home countries.

Our analysis has public policy implications for understanding and preventing future banking crises by bringing the Regulator's attention to the role of funding costs and capital requirements on banks' residential portfolio rebalancing strategies. A related question is how the ECB could have been more efficient in alleviating the serious economic imbalances within the union that were only aggravated by the banks' loan portfolio geographical reallocation episodes we have described.

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in risky (high-yield) sovereign debt, hoping that sovereign default would not occur. In the same line, Acharya *et al.* (2015) find that "periphery" crisis-hit banks also engaged in risk-shifting behavior by buying domestic sovereign bonds, pointing out that this helps explain the negative real effects suffered by European firms. See also Bruno and Shin (2015a, 2015b), Diamond and Rajan (2011) and Crosignani (2014) for additional insights on the risk-shifting behavior.

[40]Because in our analysis, GICIPS banks that engage in FH do not appear as capital constrained, our result differs from Giannetti and Laeven's (2012) study of the syndicated loan market during financial crises, which found that the FH effect increases when banks experience negative shocks due to binding capital requirements.

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Supporting Information

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Online Appendix