The role of large banks in the context of financial (in)stability:

Studies on individual and systemic risk factors

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List of Abbreviations

Abbreviation	**Explanation**
AR	Abnormal Return
BIS	Bank for International Settlements
CAAR	Cumulative Average Abnormal Return
CDS	Credit Default Swaps
CES	Component Expected Shortfall
CoVaR	Conditional Value at Risk
CPM	Conduct Parameter Method
EMU	European Monetary Union
FSI	Financial Stress Index
GDP	Gross Domestic Product
GIIPS	Greece, Italy, Ireland, Portugal, Spain
LTD	Lower Tail Dependence
MES	Marginal Expected Shortfall
NEIO	New Empirical Industrial Organization
OECD	Organization for Economic Co-operation and Development
P-R	Panzar-Rosse
ROA	Return on Assets
ROE	Return on Equity
S&P	Standard & Poor’s
SCP	Structure-Conduct-Performance Paradigm
SES	Systemic Expected Shortfall
SIBs	Systemically Important Banks
SIFIs	Systemically Important Financial Institutions
TBTF	Too Big to Fail
VaR	Value at Risk

"If the crisis has a single lesson, it is that the too big to fail problem must be solved."

(Ben Bernanke, former Chairman of the Federal Reserve Bank, 2010)[3]

1 Introduction

Banks play a vital role in the global financial system. As intermediaries, they perform a number of transmission services that contribute to economic welfare and growth. However, the existence of very large banks[1] poses serious threats to financial stability, as observed during several financial crises and particularly during the recent global financial crisis. Starting with problems in the market for sub-prime residential property financing in the United States in 2007 and escalating after the collapse of Lehman Brothers in September 2008, the crisis evolved from a national to a global banking and sovereign debt crisis. Unprecedented public rescue packages were provided by public sector entities in terms of liquidity, capital support and guarantees, which were necessary to maintain financial stability and restore confidence in the solvency and liquidity of many institutions and of the financial system as a whole. In many cases, these institutions were remarkably large in terms of total assets or their share of the national banking market, which can be explained by a problem commonly referred to as being "too big to fail" (TBTF)[2]. The issues of TBTF and financial stability are intrinsically connected. A bank, either due to its size, interconnectedness, complexity or other factors, will not be bailed out if its failure will not endanger financial stability as a result of triggering contagion and further default cascades. Although bailing out large banks might be an effective approach to preserve financial stability in the short term, in the long run, such a policy could induce several serious disadvantages such as incentives for moral hazard behavior, competitive imbalances and increasing systemic risk. Additionally,

[1] Although the discussion in general is not limited to banks and also includes, for example, insurance companies, the focus of this thesis is banks only. Consequently, the term (financial) institution refers to banks or banking institutions interchangeably.

[2] A brief definition of the term TBTF and a description of how it is separate from related concepts are given in section 2.2.1.

there is consensus in political and economic discussions that TBTF must be solved, as stated, for example, by Ben Bernanke, the former Chairman of the Federal Reserve Bank, during testimony to the U.S. Financial Crisis Inquiry Commission on September 02, 2010.[3]

As a consequence of the financial crisis, banking regulation has changed in several ways at the national and the international levels, and some modifications directly address large institutions. For example, the Basel III framework requires a capital surcharge according to systemic relevance, and the Dodd-Frank Act in the United States established restrictions on individual banks' activities, as well as a size constraint that prohibits the creation of too-large institutions through mergers or acquisitions.[4] However, in the banking literature, there also exist substantial theoretic arguments that cast doubt on the benefits of such measures because large banks in particular should be able to take advantage of economies of scale (see, e.g., Mester, 2010; Boyd and Heitz, 2016) and increased diversification opportunities (Walter, 2009; Jonghe et al., 2015). Consequently, restrictions on size and scope may mitigate the problems associated with large banks at the cost of reducing scale efficiencies and international competitiveness (Inanoglu et al., 2015). Hence, the existence of large banks might be associated with social costs and social benefits, and solving TBTF requires a comprehensive assessment of both factors, as this issue might involve some kind of trade-off. Further, the stability of a banking system might not be exclusively affected by the size of banks but may also be impacted by other individual and systemic risk factors. In general, a variety of theories provide valuable arguments that are worth considering in the discussion about the role of large banks in the context of financial (in)stability. This thesis is aimed at combining these issues while three aspects are investigated in detail, namely, the contribution of large banks to systemic risk (chapter 2), large banks' exposure to international spillovers (chapter 3) and their competitive stance in the German banking market (chapter 4).

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[3] https://www.federalreserve.gov/newsevents/testimony/bernanke20100902a.htm.

[4] Further examples are the Financial Services Act in the UK and the regulatory framework in Switzerland. See Financial Stability Board (2014c) or Barth and Wihlborg (2016) for an extensive discussion.

The problem that single banking institutions pose significant risks to the financial system as a whole initially appeared in 1984 during the U.S. savings and loans crisis, when banking regulators decided to bail out the Continental Illinois National Bank in Chicago. Regulators at that time had no resolution plan for any bank of Continental Illinois's size. Hence, the expression "too big to fail" was born (Kaufman, 2002). Consequently, the size of a financial institution, either in absolute terms or in relation to the real economy, is a frequently used synonym for systemic importance. An important research question in this context is whether the pure size, as suggested by the expression, is really a valid risk factor that determines the systemic risk that an institution poses to financial stability. This question is (still) one of the key issues in banking literature since it determines the conditions for adequate regulation, financial stability and economic welfare. Furthermore, large financial institutions can affect financial stability by either contributing to systemic risk or by being extremely exposed to sources of systematic risk and contagion. Against the background of the global financial crisis and the debate about TBTF, chapter 2 reviews 30 papers from 2009 to 2017 to provide an overview of the existing literature on the interconnection of large banks and systemic risk. This part is motivated by the observation that more than 20 years after the Continental Illinois bailout, governments around the world were again forced to use huge amounts of public money to stabilize large banks and preserve financial stability. Further, the structural developments after the most recent crisis have reinforced the formation of larger and more complex entities, and hence, the issue of TBTF might be more meaningful than ever.

As described above, dealing with the role of large banks and their risks to the financial system also requires the consideration of the positive externalities they might create by taking advantage of economies of scale. This consideration is important because *"the systemic risks posed by large, complex institutions might still outweigh the efficiencies gained by scale, but without estimating these efficiencies, it is impossible to compare costs against benefits"* (Mester, 2010, p. 10). Scale economies can be socially desirable in several ways. Banks can pass them on to customers in terms of better services or provide services at lower costs. Alternatively, they can make use of those lower production costs and increase profitability, strengthen their capital base, and therefore strengthen their solvability.

According to some authors, scale economies are at least one driver of consolidation in the banking industry (see, e.g., Wheelock and Wilson, 2012). The literature has attempted to capture this effect for several decades (see Walter, 2009; Mester, 2010; Laeven et al., 2014; Boyd and Heitz, 2016), but recent crisis experiences and the subsequent regulatory proposals have revived attention to this issue. Further, improvements in the methods used for examining scale economies[5] and environmental changes (e.g., digitalization, financial innovation, and globalization) have motivated researchers to review the results of earlier studies. Providing an empirical analysis on this issue in detail is beyond the scope of this thesis. However, for a comprehensive evaluation of TBTF, it is valuable to consider the results of these studies, which are briefly presented here.

Reviewing the studies of Feng and Serletis (2010), Wheelock and Wilson (2012), Bertay et al. (2013), Dijkstra (2013), Hughes and Mester (2013), Davies and Tracey (2014), Beccalli et al. (2015), Inanoglu et al. (2015) and Boyd and Heitz (2016) yields a variety of evidence that is far from unambiguous. For example, while Feng and Serletis (2010) find that banks' annual productivity growth is driven by technical change instead of economies of scale, Wheelock and Wilson (2012) find strong evidence for increasing returns to scale in each period throughout the entire distribution of sizes. Davies and Tracey (2014) find that estimated economies of scale for large banks are in fact cost advantages arising from implicit TBTF subsidies, while Hughes and Mester (2013) criticize these results due to several methodical caveats and find a significant increase in economies of scale with size by controlling for endogenous risk-taking, which allows them to distinguish funding cost advantages from managerial risk preferences. However, Bertay et al. (2013) find increasing returns to scale only until a certain threshold at which banks may have run out of profitable business opportunities in their domestic markets or encountered higher funding costs associated with a "too big to save" expectation. Inanoglu et al.

[5] A major improvement here is that recent research incorporates management risk preferences and the endogenous choice of risk taken by a bank, which is reflected in, e.g., the asset portfolio, funding strategies or capital structure (Mester, 2010). For example, Demsetz and Strahan (1997) mention that large banks realize a cost advantage because they operate with lower capital ratios – an effect that was not considered by some earlier studies.

(2015) find no measurable returns to scale, and according to their results, efficiency is even negatively correlated to size, and the level of efficiency decreases over time. Beccalli et al. (2015) take into account different business models and risk-taking features and find that the largest banks, whose total assets exceed 550 billion EUR, realize the most benefits. Additionally, benefits are driven mainly by investment banking activities, while small national financial systems and operations in countries most affected by financial crises impair the realization of scale economies. Finally, Boyd and Heitz (2016) choose a different strategy to shed light on this issue. They compare the costs of real per capita output losses attributed to TBTF banks and associated with the most recent banking crisis to economies of scale measured by previous studies. Boyd and Heitz (2016) conclude that even the highest observed benefits and unobservable benefits (e.g., due to technological advances or better diversification) are unable to compensate for output losses and that at least a small number of large banks contribute more to systemic risk than can be outperformed by benefits of scale. Against the findings of Cardarelli et al. (2011), such outperformance will additionally be difficult to achieve because recessions associated with banking crises tend to have a much more severe macroeconomic impacts, as they last twice as long and are as twice as intense.

In addition to scale efficiencies, a second argument in favor of large banks is that they should be able to take advantage of increased diversification opportunities, which are usually expected to increase with size. Diversification benefits may reduce a bank's idiosyncratic risk as long as the cash flows from the various activities are uncorrelated and the portfolio of investments is broadly diversified (Walter, 2009; Jonghe et al., 2015). Hence, some authors (e.g., Dermine and Schoenmaker, 2010; Dijkstra, 2013) argue that reducing or limiting the size of banks can lead to the unintended effect that geographical (credit) risk diversification opportunities are restrained with negative consequences for an individual bank's risk profile. However, this argument is valid only if banks make use of these benefits. An important question in this context is therefore whether large banks use risk diversification to reduce their overall level of risk or opt for riskier business models instead, relying on TBTF subsidies. Indeed, many studies document more risk taking by the management and owners of large banks (see, e.g., Demsetz and Strahan, 1997;

Pop and Pop, 2009; Dam and Koetter, 2012; Abreu and Gulamhussen, 2013; Boyd and Baxamusa, 2013; Laeven et al., 2014), which is probably a result of moral hazard behavior. According to Laeven et al. (2016), particularly large banks are considered to have *"a natural tendency to take on excessive risks"* (Laeven et al., 2016, p. S26) for several reasons. First, the *unstable banking hypothesis* expects large banks to engage in more risky activities and inappropriate risk taking due to asymmetric information sharing and agency problems (*agency cost hypothesis*). This problem is even worsened by assumed asymmetries in cost sharing in the case of a failure through the expectation of a government bailout as a consequence of the *TBTF hypothesis*. This possibility seems reasonable at first glance since studies such as that of Rose and Wieladek (2012) provide empirical evidence that a bank's size relative to the whole banking system significantly increases the probability of public intervention in the financial sector. Consequently, Molyneux et al. (2014), for example, exploit a sample of 162 bank mergers and acquisitions in Europe between 1997 and 2007 and find that the benefits associated with being TBTF are valued so much that an additional merger premium is paid to extend access to the safety net.

Another concern with regard to the benefits of diversification arises in the banking literature due to a possible trade-off between an institution's individual risk and its independence from the entire banking system, which will be described in detail in section 2.4. While diversification can, if actually executed by the management, reduce a bank's idiosyncratic risk, it may increase exposure to systematic risk and, hence, in the cases of large banks, decrease financial stability. In other words, "*although diversification generates risk diversification benefits ex ante, it also generates contagion ex post*" (Bolton and Jeanne, 2011, p. 162). Bandt and Hartmann (2000) describe two main channels of contagion in banking markets that can trigger a systemic crisis: the real (or exposure) channel, and the information channel. Paltalidis et al. (2015) empirically investigate systemic risk and financial contagion within the European banking system. They find that interbank, asset price, and sovereign credit risk markets trigger severe losses and cascades of defaults, with the sovereign credit risk channel being the dominant and primary source of financial contagion. Consequently, as sovereigns and banks are strongly interconnected in many ways, the transmission of shocks is an interesting field for economic research to investigate systemic risk within the financial system. The Committee on the Global Financial System defines four main transmission channels that may trigger the contagion of sovereign credit risk to banks, namely, the *asset holdings channel*, the *collateral/liquidity channel*, the *ratings channel* and the *guarantee channel* (Committee on the Global Financial System, 2011). According to Paltalidis et al. (2015), the transmission of shocks across borders depends on the amount of foreign exposure of the banking sector in a foreign financial system. Additionally, Buch et al. (2017) find that these cross-border exposures are also a source of systemic risk because average systemic risk seems to be higher in countries in which banks maintain significant cross-border activities than in financially less open countries.

Against this background, chapter 3 empirically investigates the transmission of shocks from sovereigns to banks and whether foreign asset holdings might represent an individual risk factor that exposes banks to sovereign credit risk to a disproportionally high extent instead of providing benefits of diversification. Standard & Poor's (S&P) sovereign ratings assessments from 1983 to 2014 are used to analyze the effects of rating events on foreign banks' share prices in 23 OECD member countries. In particular, three research questions are proposed and investigated. First, do sovereign rating assessments spill over to foreign banks' stock prices more severely than to foreign markets in general? Second, how important is the role played by banks' foreign asset holdings in the transmission of spillovers? Third, is the importance of foreign asset holdings amplified by the magnitude of the shock in the event country? The results obtained from this analysis are related to large banks in particular because they are based on daily stock return indices from Datastream. This step naturally reduces the sample to listed banks only, which are, in most cases, also considered to be large according to the definition in this thesis.

The degree of competition in the banking market is also discussed as a structural risk factor for financial stability. In the academic literature, there exist two conflicting theories on the relationship between competition and financial stability. The *competition-stability view* assumes a positive relationship between competition and financial stability. The reasoning here is that competition lowers the prices for loans and reduces incentives for borrowers to choose riskier projects, which, in turn, increases the quality of banks' loan portfolios and decreases individual banks' default risk (Boyd and Nicoló, 2005). On the other hand, the *competition-fragility hypothesis* supposes a high degree of competition to decrease financial stability because banks in such an environment take on excessive risks (Besanko and Thakor, 1993; Boot and Greenbaum, 1993; Hellmann et al., 2000). In any case, large banks' ability to earn monopoly rents and build up higher capital buffers is lower when the market is highly competitive. Furthermore, the competition-fragility view derives individual bank risk from moral hazard behavior. Against this background, the TBTF problem is so much worse because the common market mechanisms that reduce incentives for hazardous behavior of banks are distorted. Diamond (1984) argues that depositors have a limited need to monitor a bank's performance since the benefits of diversification in bank assets reduce the probability of default. However, even if one of the major economic functions of banks is the reduction of agency costs associated with monitoring and signaling in an asymmetric information environment, there remains a need to monitor the monitor (Pais and Stork, 2013). Usually, this task should be performed by financial markets and market participants. However, because banks are assumed to be TBTF, incentives for efficient monitoring are lowered, and hence, disciplining mechanisms are disturbed. Examples of such a lack of market discipline are well documented in previous literature (see, e.g., Cubillas et al., 2017 or Moenninghoff et al., 2015 for a short overview). The empirical banking literature also provides numerous examples in favor of both the competition-fragility hypothesis and the competition-stability hypothesis (see, e.g., Hovakimian et al., 2012; Dijkstra, 2013; Jonghe et al., 2015 and examples in section 4.1), and the relationship between competition and financial stability remains dubious. Recently, this strand of literature has begun to combine measures of competition with the newly developed measures of systemic risk (see., e.g., Anginer et al., 2014; Leroy and Lucotte, 2017). Unfortunately, competition is often assessed with structural measures based on market concentration or on the number of institutions, which do not explicitly account for the conduct of banks. The methodical weaknesses of these approaches consequently produce an estimation bias, particularly for fragmented banking systems.

Chapter 4 addresses this issue because the implementation of effective political or regulatory measures to solve TBTF and to improve financial stability with regard to the effects of market competition definitely requires sound knowledge on the competitive stance of large banks. In particular, the analysis evaluates the degree of competition in the German banking industry and provides answers to the question of whether there exist potential imbalances in competitive conduct that could discriminate against large banks and negatively affect these institutions. To overcome various methodological shortcomings of earlier studies, the competitive stances of 1,888 universal banks from 2001 to 2009 are assessed by using the Panzar-Rosse revenue test. The analysis focuses on Germany because of all the EU member states, Germany has the largest banking market, but not all German banks necessarily face fierce competition. The industry is highly fragmented, and the strict separation of the three existing banking pillars may impede competition.

Finally, chapter 5 summarizes the results and provides an overall conclusion, as well as ideas for further research.

2 The contribution of large banking institutions to systemic risk: what do we know? A literature review.

2.1 Introduction

The last global financial crisis has revitalized a well-known social, political and scientific discussion about the dangers and advantages emerging from large financial institutions for economic welfare and growth. As a consequence of the collapse of Lehman Brothers in September 2008, governments around the globe were forced to decide either to allow more banks to fail or to bail banks out with high social and economic costs and negative consequences for public finances. In many cases, banks were bailed out to protect creditors from substantial losses and impede further contagion into the financial system with negative impacts on the real economy (see, e.g., Molyneux et al., 2014). In those circumstances, decision makers always have to address some kind of dilemma: First, they must evaluate whether the benefits of bailing out one or more systemically important institutions to preserve financial stability outweigh the economic costs to the public sector. Second, they need to anticipate that such bailout decisions do not increase future social costs and moral hazard because private agents might interpret such a bailout policy as implicit or explicit insurance against future losses and will hence have incentives for undesirable behavior.[6]

In numerous cases when governments decided to bail out a certain institution, those banks in question were remarkably large in terms of total assets or in relation to their share in the national banking market. Moreover, the size of the banking sector itself in relation to the real economy has disproportionately increased in recent decades (see, e.g., Bertay et al., 2013; Demirgüç-Kunt and Huizinga, 2013; Laeven et al., 2016). For example, the total assets of the 50 biggest banks worldwide relative to world GDP increased from 15 percent in 1970 to 83 percent by June 2015 (Barth and Wihlborg, 2016). Similarly, due to rapid technological progress (digitalization), the

[6] For a specific discussion of an "optimal" decision maker's behavior see, e.g., the work of Keister (2016) or Gong and Jones (2013), as this specific issue goes beyond the scope of our paper.

development of new financial products (financial innovation) and the disappearance of geographic restrictions (globalization), the size and complexity of single banking institutions have increased, and some institutions have reached dimensions that reach far beyond the national GDP of their home countries (Abreu and Gulamhussen, 2013; Freixas and Rochet, 2013; Jonghe et al., 2015; Barth and Wihlborg, 2016). In addition, regulators have favored the formation of even larger and more complex institutions by encouraging the acquisition of failing banks by other banking firms to limit the negative economic consequences during the crisis (Walter, 2009; Dermine and Schoenmaker, 2010; Vallascas and Keasey, 2012; Barth and Wihlborg, 2016).

As a result of experiences in the financial crisis, banking regulation at the national and the international levels has changed in several ways and, as announced by the Leaders of the Group of Twenty (Leaders of the Group of Twenty, 2009a, 2009b), especially with regard to large financial institutions. Regulatory proposals include restrictions of bank size, structure or scope of activities as well as enhanced regulatory and supervisory requirements and procedures to reduce the cost of failures and enhance resolvability (Goldstein and Véron, 2011; Financial Stability Board, 2014c; Bongini et al., 2015; Barth and Wihlborg, 2016). Nevertheless, there also exist substantial theoretic arguments in favor of large banks since they might be able to take advantage of economies of scale (see e.g., Mester, 2010; Boyd and Heitz, 2016) as well as increased diversification opportunities (Walter, 2009; Jonghe et al., 2015). Hence, there arises some kind of trade-off that can be expressed as follows: *“Whether or not governments should bail out large institutions under any circumstances, risking moral hazard, competitive imbalances and systemic risk; restrictions on the size and scope of banks may mitigate these problems but at the cost of reducing banks’ scale efficiencies and international competitiveness”* (Inanoglu et al., 2015, p. 113).

Along with these circumstances and questions raised to reduce the probability of future crises, we can observe a growing body of literature analyzing causes for financial crises and interrelations in global financial networks, developing new tools to measure financial risks and proposing new rules for effective banking regulation. As we will review, research has shown that the pure size of a banking institution is not a distinct indicator for its systemic relevance. However, size is still a necessary condition for systemic importance, and hence, size increases the probability for a positive bailout decision by national governments (see, e.g., Rose and Wieladek, 2012). Consequently, larger banking institutions face stricter regulation than their smaller counterparts in several ways.

Against this background, the aim of this paper is to provide an overview of the existing literature dealing with the contribution of large banking institutions to systemic risk. From our point of view, this question is (still) one of the key issues in banking literature since it determines the conditions for adequate banking regulation, financial stability and therefore nothing less than economic welfare. We will separate differing concepts and definitions in section 2.2 before providing the classification and coding mechanism for the literature that is part of our survey sample in section 2.3. In section 2.4 we will review the literature and summarize our results with implications for future research in section 2.5.

2.2 Terminology

2.2.1 Too big to fail and related problems

The main concern arising from the existence of large banks is that their failure *"is seen as posing significant risks to other financial institutions, to the financial system as a whole, and possibly to the economic and social order"* (Stern and Feldman, 2004, p. 1). In this context, during the U.S. Savings and Loans Crisis in 1984, banking regulators decided to bail out the Continental Illinois National Bank in Chicago. Unlike previous banks' failures (see Kaufman, 2002 for a review), this specific institution simply seemed to be too important to be closed since it was the seventh largest bank in the country at that time, having interbank relationships with more than 2,200 other banks (Kaufman, 2003). Further, regulators at that time had no resolution plans for any bank of size comparable to Continental Illinois. Hence, the expression of banks being "too big to fail" (TBTF) was born (Kaufman, 2002). Consequently, the size of a financial institution, either in absolute terms or in relation to the real economy, is a frequently used synonym for systemic importance, and there exists much literature that empirically tries to demonstrate that pure size measures are no good proxy for systemic importance (see e.g., Zhou, 2009; Barth and Schnabel, 2013; Gravelle and Li, 2013; Balla et al., 2014; Lu and Hu, 2014; He and Chen, 2016).

Already in 1984, the term itself was misleading since size per se was not the unique criteria for regulators' decision. In fact, a main driver to bail out Continental Illinois was the bank's interconnection to other institutions and the fear of initiating a far-reaching financial crisis due to serious contagion effects (Kaufman, 2003). Moreover, the number of interpretations of the term has increased over the years, and additional variations have been formulated to differentiate the causes requiring a bank bailout, such as "too systemically important to fail", "too complex to fail", "too interconnected to fail" or "too central to fail" (Kaufman, 2014; Lu and Hu, 2014; He and Chen, 2016). For our purpose, we adopt the definition of the Financial Stability Board for systemically important financial institutions (SIFIs), as follows: *"whose disorderly failure, because of their size, complexity and systemic interconnectedness, would cause significant disruption to the wider financial system and economic activity"* (Financial Stability Board, 2010, p. 1).[7] We slightly modify their definition in two ways. First, we further refer to SIFIs as being banks only and hence prefer the designation as systemically important banks (SIBs) as done by the Basel Committee on Banking Supervision (2013). Second, we focus on the aspect of size although knowing that this is not a distinct indicator of systemic importance but certainly *"a key measure of systemic importance [since] the larger the bank, the more difficult it is for its activities to be quickly replaced by other banks and therefore the greater the chance that its distress or failure would cause disruption to the financial markets in which it operates. The distress or failure of a large bank is also more likely to damage confidence in the financial system as a whole"* (Basel Committee on Banking Supervision, 2013, p. 7).

Having such large banks that cannot be liquidated with common resolution processes due to concerns about financial stability implies several problems and costs

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[7] Very similar is the definition of the Basel Committee on Banking Supervision (2013), which includes size, interconnectedness, substitutability, complexity, and cross-border-activities.

that often depend on the complex interconnections in financial markets leading to possible contagion and subsequent effects. Additionally, bailing out large banks theoretically generates further social costs and moral hazard, as such a policy affects the behavior of market participants in several ways (for an extensive discussion, see, for example, Stern and Feldman, 2004). The existence of systemically important banks that are implicitly or explicitly deemed too big to fail distorts the competitiveness of financial markets. Market participants have less incentive to exert market discipline, which leads to a competitive advantage that is well documented in previous literature (see e.g., Ueda and Weder di Mauro, 2013; Gandhi and Lustig, 2015; Moenninghoff et al., 2015; Nitschka, 2016; Cubillas et al., 2017). Further, limited market discipline creates incentives for increased risk-taking behavior since higher profits remain private, while the risk of failure is borne by the government and taxpayers (Dam and Koetter, 2012; Freixas and Rochet, 2013; Ellis et al., 2014; Lu and Hu, 2014; Laeven et al., 2016; Cubillas et al., 2017). Consequently, banks also have strong incentives to grow and obtain a sufficient size that enables them to make use of these advantages (Molyneux et al., 2014; Moenninghoff et al., 2015; Barth and Wihlborg, 2016). This, in turn, may reduce incentives to innovate and lead to inefficient resource allocation on the firm level when banks dedicate resources to grow beyond their optimal size and operate in a cost-inefficient manner (Stern and Feldman, 2004; Völz and Wedow, 2011). Both is undesirable from a macroeconomic perspective because innovative capacity is a major source for economic growth and inefficient resource allocation also occurs on the macro-level: if creditors of banks trust in government protection, they will allocate disproportionately high resources to the banking sector, which leads to inefficient growth and becomes a potential source of financial instability (Knot and van Voorden, 2013; Inanoglu et al., 2015). This instability is long-lasting due to the absence of incentives to put inefficient banks out of the market (Pop and Pop, 2009).[8]

[8] Barth and Wihlborg (2016) further enumerate social costs related to what they call “regulatory capture”, referring to the ability of few large banks “to have a very strong influence on regulators, supervisors and legislatives” as a result of intense lobbying efforts or financial support in elections. This view is also expressed by Mullineux (2014) who states that these banks are “*simply too […] politically influential and powerful, to serve the public good*” (p. 93).

2.2.2 *Financial stability and the concept of systemic risk*

The issues of too big to fail and financial stability are intrinsically tied to each other. An institution, either due to its size, interconnectedness, complexity or other factors, will not be deemed too big (too interconnected, too complex, etc.) to fail if its failure will not endanger financial stability. However, finding a generally agreed definition of financial stability is a difficult task due to various existing definitions, some of which refer to the condition of financial *in*stability. To review this discussion even briefly goes far beyond the scope of our paper, and for this purpose, we refer to the works of Smaga (2013) or Vlahović (2014). We adopt the definition of Smaga (2013), who characterizes financial stability as a condition of the financial system, which is able to properly fulfill its economic functions (e.g., intermediation, liquidity transformation, capital allocation, risk transfer and pricing), limit systemic risk or macro-financial imbalances, resist internal and external shocks, restore its functions on its own and resist transfer of negative impulses within the system and between the financial system and the real economy. The fragility of financial stability and the causes of financial instability seem to have been misevaluated prior to the last financial crisis. Affected by the lessons learned from former events related to the failure of single institutions, regulatory supervision has mainly focused on the protection of private investors and depositors from losses by supervising the safety and soundness of individual banks (microprudential regulation), while the surveillance of risks regarding stability and proper functioning of the financial system as a whole (macroprudential regulation) has been circumstantial. Consequently, the lesson recently learned is that it is equally important to regulate each bank as a function of both its individual (bank-specific) risk and its joint (correlated) risk with other banks (Acharya, 2009).

The latter aspect refers to the concept of systemic risk, which had been addressed before the global financial crisis but which has since then become one of the most rapidly growing themes in the finance literature. Systemic risk in the broader sense can be defined as the probability that endogenous or exogenous events or developments are of such an intensity to bring the financial system out of its desired condition capable of fostering economic welfare and growth (see, e.g., Bongini et al., 2015 or Weiß et al., 2014a). For our purpose, we adapt a definition in a narrower sense and refer to systemic risk as the danger that financial problems or the default of *a single financial institution* may have negative externalities on the broader financial system or the real economy (Vallascas and Keasey, 2012; Knot and van Voorden, 2013; Bluhm and Krahnen, 2014). This definition includes the fact that systemic risk can have idiosyncratic as well as systematic components as mentioned by Tarashev et al. (2016). Consequently, a large financial institution can affect systemic risk in two different ways. First, the institution itself could cause a negative externality to the system in case of a default and hence *contribute* to systemic risk. Second, an institution could be extremely *exposed* to sources of systematic risk, which might create second-round effects through contagion and trigger a default cascade. As it is unclear which of these possibilities is the greater threat for financial stability, our investigation will refer to both of them. Further, both types of risk should be addressed by regulators, although in different ways. While a strategy for institutions in the first group (high *contribution*) might be to reduce individual default risk (e.g., through higher capital buffers or increased monitoring), the second group (high *exposure*) may be more specifically addressed with measures to reduce their common exposure (e.g., through guidance on asset allocation or restrictions on specific business activities) (Helwege, 2010).

Against this background, it is obvious that systemic risk is closely related to the concept of too big to fail since a main research task is the development of measures to identify the institutions posing the major systemic risks to the financial system. We make use of this line of literature by analyzing the results provided with regard to large banks and their characteristics that increase or decrease systemic risk. A discussion of the variety of emerging techniques is not part of our paper as they are still in their infancy (Laeven et al., 2016). For this purpose, we refer to the work of Danielsson et al. (2016) or recent surveys, for example from Silva et al. (2017), Benoit et al. (2017), Benoit et al. (2013), Bisias et al. (2012) and VanHoose (2011) or Bandt and Hartmann (2000) in advance of the subprime crisis. Further, Bisias et al. (2012) emphasize that due to the variety of aspects of systemic risk and potential transmission channels, a single measure of systemic risk might be hard to develop and probably undesirable since it is unlikely to be complete or universally applicable (Ellis et al., 2014).

2.3 Classification of literature

To provide an overview of the literature included in our survey, we follow the method used by Silva et al. (2017) and implement a classification scheme with various dimensions coded with numbers and letters. For this purpose, we apply the following categories and specifications to the 30 articles included in our survey and further show their distribution in the sample:

Category	Meaning	Encryption	Sample distribution
1	Type of study	A - Theoretical	7 *(23%)*
		B - Empirical	22 *(73%)*
		C - Both	1 *(3%)*
2	Approach	A - Quantitative	28 *(93%)*
		B - Qualitative	2 *(7%)*
3	Scope	A - One country	9 *(30%)*
		B - Region	5 *(17%)*
		C - World	9 *(30%)*
		D - Not specified	7 *(23%)*
4	Context	A - Developed country	15 *(50%)*
		B - Mixed	7 *(23%)*
		C - Not specified	8 *(27%)*
5	Type of bank	A - Commercial banks	6 *(20%)*
		B - Mixed	9 *(30%)*
		C - Not specified	15 *(50%)*
6	Studied periods	A - Up to 2 years	3 *(10%)*
		B - From 2 to 5 years	2 *(7%)*
		C - From 5 to 10 years	2 *(7%)*
		D - More than 10 years	17 *(57%)*
		E - Not specified	6 *(20%)*
7	Results:	A - …is a major determinant”	16 *(53%)*
	“With respect to	B - …is not significant”	5 *(17%)*
	systemic risk, bank size…	C - …is a major determinant under certain conditions”	9 *(30%)*

Table 1: Classification and coding used to analyze the articles in sample

Table 2 offers a complete overview of the reviewed articles and the application of the coding mechanism to each study. We particularly focused our sample on the literature that emerged during or after the last global financial crisis, of which more than 85 percent was published after 2011. Further, through the combination of different categories, we are able to provide more detailed information on connections or dependencies among different aspects and results. For example, reviewing the combined classifications of category 1 ("Type of study") and category 7 ("Results") reveals interesting aspects regarding our primary research question. Specifically, we observe that none of the theoretical studies (1A) finds that bank size is per se a major determinant for systemic risk (7A), as the combination of 1A and 7A does not exist. Conversely, the combination of 1B and 7A appears sixteen times, meaning that the majority of empirical evidence finds size to be a major determinant for systemic risk. Additionally, we observed that among these sixteen empirical studies, twelve studies cover a long observation period or more than ten years (joint appearance of 1B, 6D and 7A).

Study	Type	Approach	Scope	Context	Bank	Periods	Results
Acharya et al. (2017)	1B	2A	3A	4A	5B	6A	7A
Adrian and Brunnermeier (2016)	1B	2A	3A	4A	5B	6D	7A
Arinaminpathy et al. (2012)	1A	2A	3D	4C	5C	6E	7C
Balla et al. (2014)	1B	2A	3A	4A	5A	6D	7A
Banulescu and Dumitrescu (2015)	1B	2A	3A	4A	5B	6D	7A
Battiston et al. (2012)	1A	2A	3D	4C	5C	6E	7C
Brunnermeier et al. (2012)	1B	2A	3A	4A	5A	6D	7A
Buch et al. (2017)	1B	2A	3B	4A	5C	6D	7A
Caccioli et al. (2012)	1A	2A	3D	4C	5C	6E	7C
Castro and Ferrari (2014)	1B	2A	3B	4A	5C	6D	7A
Gravelle and Li (2013)	1B	2A	3A	4A	5B	6D	7B
Hovakimian et al. (2012)	1B	2A	3A	4A	5A	6D	7A
Huang et al. (2012)	1B	2A	3B	4B	5C	6B	7A

Jonghe (2010)	1B	2A	3B	4A	5B	6D	7A
Jonghe et al. (2015)	1B	2A	3C	4C	5B	6D	7C
Knaup and Wagner (2010)	1B	2A	3A	4A	5A	6B	7B
Krause and Giansante (2012)	1A	2A	3D	4C	5C	6E	7C
Laeven et al. (2014)	1B	2A	3C	4B	5B	6D	7A
Laeven et al. (2016)	1B	2A	3C	4B	5B	6A	7A
López-Espinosa et al. (2012)	1B	2A	3C	4A	5C	6C	7B
López-Espinosa et al. (2013)	1B	2A	3C	4A	5C	6C	7B
Lu and Hu (2014)	1A	2B	3D	4C	5C	6E	7C
Pais and Stork (2013)	1B	2A	3C	4B	5C	6D	7A
Puzanova and Düllmann (2013)	1B	2A	3C	4B	5A	6D	7A
Tarashev et al. (2016)	1C	2A	3D	4C	5C	6A	7A
Vallascas and Keasey (2012)	1B	2A	3B	4A	5A	6D	7A
Wagner (2010)	1A	2B	3D	4C	5C	6E	7C
Weiß et al. (2014a)	1B	2A	3C	4B	5B	6D	7C
Weiß et al. (2014b)	1B	2A	3C	4B	5C	6D	7C
Zhou (2009)	1A	2A	3A	4A	5C	6D	7B

Table 2: Articles in sample

2.4 Is size per se a relevant determinant for systemic risk?

Recently, many studies have investigated the relationship between an institution's individual exposure to system-wide crises or its contribution to systemic risk due to size and connectivity. These works reveal the theory regarding the advantages of diversification in a different light. The assumption that the systemic importance of a particular bank is closely associated with the variety of risky banking activities in which it participates, leads to *"a tradeoff between managing individual risk and keeping independency from the entire banking system"* (Zhou, 2009, p. 20). Since it is reasonable to assume that large banks are typically more diversified, Baele et al. (2007) already mentioned that larger banks are more exposed to market-wide events and systematic risk. They decompose total bank risk into a systematic and an idiosyncratic component and find that diversified banks have a higher systematic risk as they are more exposed to market volatility. Further, Baele et al. (2007) find that the exposure of those banks to systematic risk increases with size and even dominates positive effects on idiosyncratic risk so that, overall, pure size and bank total risk are positively correlated. In other words, while diversification can reduce a bank's idiosyncratic risk, it may increase exposure to systematic risk. From a systemic perspective, it could therefore be desirable to have large but isolated banks, whereas large banks that diversify banking activities, probably to reduce their idiosyncratic risk, may become a threat for financial stability.

We will review the recent literature regarding the contribution of large banking institutions to systemic risk in three different subsections. First, we will refer to works that address this issue theoretically or by using network simulation models. Second, we consider empirical works using a variety of heterogeneous measures before taking a closer look on empirical works that rely on more homogenous techniques which appear to evolve as a common standard in this area of research.

2.4.1 Theoretical evidence on systemic risk based on the architecture of the financial system

Zhou (2009) creates an artificial banking system to distinguish size from systemic importance. Theoretically, Zhou (2009) agrees that a large bank that is more diversified may become systemically important. In a second step, this researcher investigates systemic importance with three different measures[9] based on daily equity returns of 27 U.S. banks before checking the correlation with various bank size parameters. He finds that for his sample, the systemic importance measures are not correlated with the size measures and concludes that size per se is no valid indicator for the contribution to systemic risk. Against this background, Wagner (2010) presents a model with two banks to illustrate theoretically that diversification

[9] In particular, they use the PAO ("probability that at least one bank becomes distressed") measure introduced by Segoviano and Goddhart (2009) and two new measures they propose, namely the "systemic importance index" (SII) measuring the expected number of bank failures in the banking system given that one particular bank fails and the "vulnerability index" (VI) reflecting the probability of a particular bank's failure given that there exists at least one another failure in the system.

makes systemic crises more likely, since it exposes banks to the same idiosyncratic risk of jointly held assets. This author concludes that perfect diversification is always inefficient from a systemic perspective, while an arbitrary low amount is always desirable. It is important to mention that the adverse effects of diversification are even higher when contagious spillovers (e.g., bank runs on solvent banks due to solvency problems at other banks) occur. This result is also found by Battiston et al. (2012), who use a theoretical model to explore the dynamics of default cascades in a network of credit interlinkages. Lu and Hu (2014) further analyze the relationship between size and systemic risk by constructing a theoretical model with three banks (large, medium, and small) in the financial system. These researchers find that size is an important but not the dominant factor for systemic importance, which is also affected by the interconnection of banks. In other words, systemic importance must not follow the size of a bank, but below a certain size, systemic importance is difficult to achieve.

To develop these thoughts further, we consider the works of Arinaminpathy et al. (2012), Caccioli et al. (2012) and Krause and Giansante (2012), who use network models to examine financial stability in a systemic perspective. Caccioli et al. (2012) use a model of contagion in financial networks and study how the stability of a system is affected by the size distribution of banks inside the network. Their results show that the contribution of large banks to systemic risk or the risk of size per se for financial stability is conditional on the properties of the system. While in slightly connected systems, highly connected banks (too interconnected to fail) are a greater threat for financial stability, in systems with a high degree of connectivity, size is clearly more dangerous (too big to fail). The rationale here is that, in the case of a loosely connected banking system, the failure of a large bank would only affect a few other banks with finite potential for system-wide contagion, while the failure of a highly connected bank whose interbank liabilities are spread to many other (loosely connected) banks would be contagious since those banks make less use of risk sharing opportunities and will hence share many of their interbank assets with the failed bank. On the other hand, in a highly interconnected system, the existence of large banks may imply that the assets within the banking system are non-uniformly distributed and that larger banks receive a disproportionately high share of assets from their creditors. Thus, the failure of a small (highly connected) bank would not endanger financial stability, whereas the failure of a large bank would have disproportionately adverse effects on numerous banks, which are in turn interconnected and may trigger a default cascade that turns into a financial crisis. Consequently, since financial markets today are generally highly interconnected networks, Caccioli et al. (2012) conclude that the largest banks in this network pose a risk for financial stability simply due to their asset size. A similar investigation is made by Krause and Giansante (2012), who find quite similar results. First, for a strong banking system that is shocked by the collapse of a single bank, they find that the larger the bank is, the more likely and widespread a banking crisis will be on average. The rationale behind this is again that larger banks typically have more connections and their interbank loans granted and taken are larger. Second, once contagion occurs through the initial failure of a large bank, the topology of the financial network, e.g., the interconnectedness of the interbank loan network, is an equally important determinant of systemic risk as also found by Battiston et al. (2012). Arinaminpathy et al. (2012) also use a dynamic network model of a banking system and complement the works of Caccioli et al. (2012) and Krause and Giansante (2012) by integrating different transmission channels of contagion among banks as well as confidence effects linked to capital and liquidity strength of banks. Their simulations yield several important results. First, allowing for liquidity hoarding and asset price contagion, as seen during the last crisis, disproportionately increases the risk pure size poses to financial stability. Second, similar to Caccioli et al. (2012), they also observe an asymmetry regarding the stabilizing effects of additional capital buffers that are more effective in mitigating contagion when exercised on large banks. Third, in highly concentrated banking systems where the largest banks are several times the size of small banks, this disparity is amplified. Finally, Arinaminpathy et al. (2012) confirm the results of Baele et al. (2007), Wagner (2010) and Battiston et al. (2012) by finding that diversification in fact lowers individual bank risk but clearly increases systemic risk since it exacerbates the potential for asset contagion to cause a system collapse.

Thus, as an intermediate result, we note that none of the aforementioned theoretical studies provides a line of reasoning to assume that banks, solely due to their size, are a threat to financial stability. This result is indeed little surprising because reducing "too big to fail" to a single aspect, asset size in this case, inevitably oversimplifies this issue against the background of the complexity and economic interconnections of present day global financial markets. However, from a theoretical perspective, nearly all reviewed studies, with Zhou (2009) being the only exception, find that under several surrounding conditions and properties of the financial system, size is one of the most important factors for systemic risk. First, in systems with a high degree of connectivity, size is clearly more dangerous, and allowing for liquidity hoarding and asset price contagion disproportionately increases the risk pure size poses to financial stability. Second, contagious spillovers also increase the adverse effects of diversification and large banks that diversify their activities make systemic crises more likely, since they are exposed to multiple idiosyncratic risks and exacerbate the potential for a system collapse. Furthermore, systemic risk arising from the existence of (very) large banks is supposed to scale more than proportionately with size.

2.4.2 Empirical evidence based on a variety of heterogeneous systemic risk measures

Tarashev et al. (2016) empirically verify the previous results obtained from network models. They use the Shapley Value, a concept well-known in game theory, to allocate system-wide risk to individual institutions. It represents the change in the risk of a financial system that is due to the inclusion (exclusion) of a specific bank into the system (out of the system). They demonstrate for a sample of 60 large banks by the end of 2007 as well as for a hypothetical banking system that size is by far the most important determinant of systemic importance. Further, an increase in bank size disproportionately increases the contribution of a particular institution to systemic risk.

Puzanova and Düllmann (2013) apply a credit portfolio model to measure systemic risk and each institution's individual contribution to it for a portfolio of the world's largest commercial banks from 1997 to 2010. They find that in the time dimension, an individual bank's systemic risk contribution is not sensitive to changes in relative bank size. In contrast, at a given point in time and with a given level of systemic risk, the risk allocation among the banks in the banking system is to a large extent driven by the banks' relative size. The largest banks in the sample always disproportionately contribute to overall risk, a result that is again consistent with the findings of Arinaminpathy et al. (2012) and Tarashev et al. (2016). Unfortunately, Puzanova and Düllmann (2013) do not explicitly investigate whether these findings must be attributed simply to the pure (relative) size of banks or whether there are other observable (or even unobservable) individual bank characteristics that yield these results. Regardless, they note an important observation in this context that is in line with previous studies, namely, that it is not only individual characteristics that affect the systemic importance of a bank, but the characteristics of the system itself do, as well (e.g., the size of other banks, default probabilities or return correlations). Hence, they conclude that regulatory instruments concentrating simply on the size of banks would inadequately address systemic risk which should necessarily be analyzed in a portfolio context.

This portfolio aspect is addressed by market-based systemic risk measures. A common feature of most systemic risk measures is that they rely on public market data, such as asset prices or CDS premiums. They typically consider an aggregate risk measure for the whole system, and the systemic risk analysis is closely related to portfolio theory in the sense that each institution within a financial system partly contributes to overall risk (Banulescu and Dumitrescu, 2015).

According to the results of Jonghe (2010), the absolute size of a bank is a main driver of individual bank systemic risk under adverse economic conditions and seems to play a vital role in determining the exposure to shocks. For a sample of listed European commercial banks and bank holding companies from 1992 to 2007, the author measures systemic risk by estimating a bank's tail beta, which equals the probability of extreme stock price devaluations conditional on a crash in the market index. He finds that larger banks appear to be in a worse position than smaller banks. None of the observed bank-specific control variables contributes more to bank-specific exposure to an extreme market downturn. This positive correlation is further corroborated by an additional dummy variable for large and complex banking groups. Further, Jonghe (2010) finds that banks focusing on traditional lending activities are less exposed to systemic risk than diversified banks shifting to non-traditional business, especially to trading activities. Knaup and Wagner (2010) propose a forward-looking measure of a bank's exposure to systemic risk, as they estimate share price sensitivities to changes in far out-of-the-money put option prices. Similar to Jonghe (2010), they find that traditional banking activities lower the exposure to systemic risk, while for trading activities the opposite holds. Contrary to Jonghe (2010), they find that systemic risk exposure decreases with size, which could be caused by sample selection and chosen time period or more likely by several methodological differences. First, they consider a large prolonged market downturn instead of daily crashes induced by a systemic shock. Second, their systemic risk measure identifies changes in perceived exposures to a hypothetical crash, while other market-based measures rely on realized historical price developments. This, in turn, makes their measure susceptible to too big to fail distortions and might explain why they find a negative influence of bank size on systemic risk exposure. Hovakimian et al. (2012) use a long period of stock market data from 1974 to 2010 for a sample similar to that of Knaup and Wagner (2010) to measure the fragility of the banking sector as the value of a put option insuring the aggregate assets of a portfolio of banks and each bank's systemic risk as its individual contribution to this insurance premium. Contrary to Knaup and Wagner (2010), they find that size is a key driver of systemic risk, as an individual bank's contribution increases with size, and the largest banks in the sample represent the main source of systemic risk.

These results are confirmed by the work of Pais and Stork (2013), who find that size is not a relevant driver of individual bank risk (measured as the probability of large negative stock returns) but that large banks have significantly higher systemic risk (measured as the probability of a simultaneous crash in stock prices) and that this relationship is non-linear. Further, this effect increases along with financial market integration since it amplifies the common exposure to market-wide risks. Huang et al. (2012) verify these results for a sample of 22 banks in the Asia-Pacific region. Although using a different systemic risk measure, they find that bank size is the primary factor in determining the contribution of a single institution to systemic risk. Consistent with the works of Jonghe (2010) and Pais and Stork (2013), this is attributable to stronger interdependencies with the rest of the banking system, which is also a reason for their finding that correlations among equity returns are important to determine the degree of systemic distress in case of a failure. Balla et al. (2014) propose a new measure to identify systemically important financial institutions which is derived from multivariate extreme value theory to capture the tail dependencies between stock returns. They find that size, measured by total assets, is a key predictor for a banks' vulnerability to the occurrence of a systemic crisis. In particular, they find that pairs of large institutions experience stronger asymptotic dependence. However, their method does not allow for the interpretation of a causal relationship between size and tail dependence, and further, it might reflect financial markets' perception of similarity rather than their economic exposure to systemic risk.

Vallascas and Keasey (2012) focus on a sample of 153 listed European commercial banks from 1992 to 2008 since the integration process in Europe favors the growth of banks beyond national borders and the deregulation increases the scope for diversification. They observe the systemic context for large banks by investigating large banks' exposure to systemic events and their contribution to systemic risk.[10] In line with Jonghe (2010) and Knaup and Wagner (2010), they find that certain bank characteristics such as an increase in non-traditional lending activities or higher leverage increase a bank's vulnerability to systemic shocks. Most importantly, the economic impact of pure size[11] on a bank's exposure and contribution to systemic risk generally outreaches all other bank-specific control variables. This evidence supports the assumption that simply due to their size, large banks are a threat for financial stability, a result that holds in normal times as well as under extreme stress conditions. Hence, against this background, Vallascas and Keasey (2012) argue that

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[10] They define a bank's exposure to systemic risk by estimating a distance to default beta ($ß_{DD_{i,t}}$) that expresses how the default risk of bank i reacts to changes in banking system risk and a bank's contribution to systemic risk by estimating a contribution distance to default beta ($ß_{C\_DD_{i,t}}$) that measures the sensitivity of the distress of the banking system to changes in the default risk of bank i.

[11] Vallascas and Keasey (2012) distinguish between absolute (total assets) and systemic size (bank total assets relative to country GDP). While both variables significantly contribute to a banks' *exposure* to systemic risk, the economic effect of absolute size is dominant. However, when looking at the *contribution* to systemic risk rather than the exposure, the relative size appears to be more important.

implementing a (country-specific) size-cap as a possible regulatory restriction might be beneficial for systemic stability, although the possible negative consequences of such a constraint and the issue of a potential trade-off are not part of their work.

Gravelle and Li (2013) propose a new market-based measure which they apply to a sample of Canadian, U.S., European and Asian banks in the Canadian banking market. They define systemic risk *"as an event in which at least a certain fraction of financial institutions (...) crash simultaneously"* (p. 2197) and measure an institution's (or a group of institutions) contribution to it. They capture idiosyncratic effects as well as institutions' exposure to common factors but eliminate this exposure to isolate the effects of an idiosyncratic shock from one institution to another. Their results are interesting in two ways. First, they observe that the largest crash dependence risk for Canadian institutions comes from other Canadian institutions and thus seems to be "home biased". Second, among the international institutions large U.S. banks (JPMorgan, Citigroup and Wells Fargo) in particular are the largest dependence risk factors to the Canadian banking sector. They conclude their analysis by arguing that size should not be considered as a proxy of systemic importance, a result that we put into question for two reasons. First, the three banks with the highest systemic importance are at the same time the three largest Canadian banks. Second, the U.S. banks posing the highest systemic risk to the Canadian banking industry were ranked top two, three and four in the U.S. (or top nine, ten and twenty-four globally) by the end of 2009 in terms of total assets. Against this background, it seems plausible to assume that the size of an institution is indeed a major determinant of systemic risk in the relevant market as Gravelle and Li (2013) do not relate their systemic importance measure to an institution's market share or other characteristics.

In this section, we find a plurality of empirical evidence in line with the results from theoretical network studies regarding the exposure of large banks to common shocks, as well as their contribution to systemic risk. We have reviewed ten studies, of which eight equally find that large banks have significantly higher systemic risk and that size is a key predictor for a banks' vulnerability to the occurrence of a systemic crisis. These studies use a variety of different approaches, as well as diverse sample compositions and periods that apparently conform to the necessary surrounding conditions and properties of the financial system, which make size one of the most important factors for systemic risk, as discovered by the theoretical models specified in section 2.4.1. Furthermore, the relationship between size and systemic risk seems to be non-linear as the largest banks disproportionately contribute to overall risk. Again, banks focusing on traditional lending activities are found to be less exposed to systemic risk than diversified banks. Only two studies (Knaup and Wagner, 2010; Gravelle and Li, 2013) find different results but they should, in our view, be interpreted with caution due to several methodological differences and caveats, as described above.

2.4.3 Empirical results from evolving standard techniques

While the systemic risk measures used in the previous section vary, there is also a line of literature using more homogenous techniques. One of these is the so-called ΔCoVaR, initially proposed by Adrian and Brunnermeier (2008), which captures the marginal contribution of a particular institution to the overall systemic risk. It compares the losses of the financial system when a specific financial institution experiences large losses to the losses of the system when the institution is in a normal state (Castro and Ferrari, 2014; Weiß and Mühlnickel, 2014). For example, Brunnermeier et al. (2012) use ΔCoVaR and the Systemic Expected Shortfall (SES) to analyze the contribution to systemic risk for a sample of listed bank holding companies in the U.S. over the period 1986 to 2008. They find that a bank's stock returns during the last financial crisis significantly decrease with bank size, and bank size is positively correlated with systemic risk. Even when controlling for several other bank characteristics, larger banks contribute more than proportionally to both measures of systemic risk. López-Espinosa et al. (2012) and López-Espinosa et al. (2013) also use ΔCoVaR to empirically investigate which factors mainly determine a systemically important bank's contribution to systemic risk. They find that individual liquidity risk represents the main component of financial instability and that investment banking and international activities reinforce each other through loss spirals. In their samples, which are in both studies composed of large international banks only, neither absolute nor relative size can be identified as predictors of systemic risk, which could be due to the homogenous sample selection and does not necessarily imply that size per se is not a source of systemic risk. Further studies using ΔCoVaR were conducted by Castro and Ferrari (2014) and Adrian and Brunnermeier (2016). Both studies find that bank size clearly increases the systemic risk contribution of financial institutions. Castro and Ferrari (2014) further enhance ΔCoVaR and develop a test of significance to determine whether institutions can be ranked according to their systemic risk contribution. Applying their method to a sample of 26 large European banks, they find that only a few banks can be ranked on the basis of ΔCoVaR but that a simple scaling of ΔCoVaR with total assets increases the number of banks whose systemic importance dominates other banks'. They conclude that this result is due to the properties of ΔCoVaR that attributes banks of different sizes the same systemic risk contribution if they are otherwise identical. Hence, without explicitly accounting for bank size and other characteristics, it is difficult to measure the effect of pure size on systemic risk with ΔCoVaR.

Other market-based measures frequently used are the Marginal Expected Shortfall (MES) or the Systemic Expected Shortfall (SES) proposed by Acharya et al. (2010). The MES is defined as the average return on a firm's stock in a defined period of time when the financial sector experienced its VaR% lowest returns beyond the confidence level. The SES represents the expected amount of a bank's undercapitalization in a systemic crisis when the overall financial system is undercapitalized.[12] Hence, compared to ΔCoVaR, the conditioning of the MES has been switched, and therefore, the MES captures an institution's exposure rather than its contribution to a systemic crisis (Acharya et al., 2010; Weiß and Mühlnickel, 2014; Banulescu and Dumitrescu, 2015; Jonghe et al., 2015). Acharya et al. (2017) show that the MES and SES are able to predict systemic risk during the recent crisis. Additionally, they find that the size in terms of total assets is significant in predicting realized SES during the crisis but loses part of its explanatory power when MES and leverage are included in the regression. Further, the top 6 institutions most

[12] Acharya et al. (2017) differentiate between distress and a systemic crisis using MES to cover "moderately bad days" while using extreme value theory to show that SES is predicted by MES and leverage to estimate the effects during a real crisis.

contributing to the loss in market capitalization were also in the top 7 in terms of total assets, demonstrating that the contribution to financial sector capital deterioration is naturally tied to the size of the institution.

Weiß et al. (2014a) review several international crises to identify individual bank characteristics that determine an institution's exposure to systemic risk and whether these are persistent over time. They apply the MES and lower tail dependence (LTD)[13] to a global sample of banks from different regions over six crises periods from 1994 (Mexico crisis) to 2008 (Lehman collapse). They find that, among other factors, bank size generally is not a powerful variable in explaining a bank's exposure to moderate systemic risk, with the latest crisis in 2007/2008 being the only exception. Looking at extreme systemic events, bank size is positively related to systemic risk only during the Mexican and Asian crises. Further and quite important regarding moderate systemic risk, size actually seems to lower banks' systemic risk exposure for most crises under investigation except the Lehman collapse. Looking at extreme systemic risk, size loses its explanatory power. They also perform their analysis on a subsample of large banks only (total assets above 50 billion USD) and verify that bank size is not a relevant and persistent driver of a bank's exposure to systemic risk. On the other hand, Weiß et al. (2014b) use the same measures to examine a sample of 440 global bank mergers between 1991 and 2009 and state that the exposure of the combined bank (after the merger) to systemic risk is significantly larger than the sum of the acquirer's and the target's individual pre-merger systemic risk exposure. This in turn could be interpreted as further evidence that systemic risk disproportionately increases with an institution's size as already found by other studies using different methods (see, e.g., Caccioli et al., 2012; Puzanova and Düllmann, 2013; Tarashev et al., 2016). Jonghe et al. (2015) question that size and complexity have multiplicative or interaction effects and extend the previous literature by analyzing their joint and interactive impact on banks' MES. Looking at an international sample of listed banks from 1997-2011, they find that diversification

[13] As Weiß et al. (2014a) note, their LTD is conceptually quite similar to the MES with the differences that (a) LTD considers the left tail of the joint distribution of the market and the individual institution instead of the marginal distribution of the market and (b) LTD captures extreme tails, while MES is based on moderate losses.

benefits dominate for large banks. In particular, while absolute size always increases exposure to systemic risk, scope expansion and innovation into non-interest income activities significantly reduces risk for the largest banks above a certain size-threshold (in their case 964 million USD). This result is contrary to the findings of Baele et al. (2007), Jonghe (2010), Knaup and Wagner (2010), Vallascas and Keasey (2012) and others and further is strongly dependent on institutional country characteristics (transparent information, concentration in the banking market and the value of a reputation of avoiding conflicts of interest for various stakeholders) since Jonghe et al. (2015) also find that the benefits of diversification for large banks disappear when the information environment is non-transparent and asymmetric, corruption is higher and the market is highly concentrated.

Following the same intention as Weiß et al. (2014a), Laeven et al. (2014) also identify bank-specific factors that determine systemic risk. Nevertheless, their approach significantly differs, as they focus on the recent crisis only from July 2007 to December 2008 and use a slightly different measure for systemic risk, namely, SRISK.[14] They find that the systemic risk contribution increases with bank size and is statistically and economically significantly higher for large banks with assets above 50 billion USD. A lower capital base, less stable funding or a high share of non-interest income further increases contribution to systemic risk. This last finding again indicates that revenue diversification may be beneficial from a microprudential perspective, while it seems to be detrimental from a macroprudential angle. Banulescu and Dumitrescu (2015) propose the Component Expected Shortfall (CES)[15], to identify the contribution of each institution to the overall systemic risk. They find that risk is very concentrated since a significant amount of total risk can be attributed to a small number of firms and that these institutions are quite large in

[14] SRISK, proposed by Acharya et al. (2012), Acharya et al. (2017) and Brownlees and Engle (2012, 2017), represents the expected capital shortfall of a bank in case of a systemic event over a given time horizon and is a function of the bank's degree of leverage, size and MES. Hence, SRISK measures the contribution of a specific bank to the deterioration of capital in the financial system as a whole.

[15] As mentioned by Banulescu and Dumitrescu (2015), CES corresponds to the product of MES and the weight of the institution in the system and is by construction very similar to SRISK with the main difference that it does not require balance sheet data and no assumption is made about constancy of liabilities or leverage.

terms of market capitalization or total assets. Unfortunately, Banulescu and Dumitrescu (2015) do not explicitly investigate whether size is a major determinant of CES or whether other institutional factors are responsible for the contribution of these particular firms to systemic risk.

In a later version, Laeven et al. (2016) use ΔCoVaR and SRISK to capture systemic risk for a sample of 339 publicly traded deposit-taking institutions from 32 countries with assets above 10 billion USD. As a first result, they find that both measures are highly correlated with bank size and that they also capture different aspects of systemic risk. Further, they find that, during the crisis, size per se was a main driver for standalone bank risk. This tendency also holds when looking at the impact of bank size on systemic risk. Laeven et al. (2016) find strong evidence that bank size substantially increases the systemic risk contribution measured by either ΔCoVaR or SRISK and that, unlike other bank characteristics, a higher capital ratio is particularly important for lowering the systemic risk for large banks. In a recent study, Buch et al. (2017) confirm these results for a sample of banks in the euro area from 2005-2013 also using the SRISK measure. A bank's contribution to systemic risk is significantly and robustly positively related, among other factors, to its (absolute as well as relative) size even after controlling for business model characteristics, complexity, quality of the loan portfolio, liquidity risk or a dummy variable for banks assigned as globally systemically important.

Summing up the results of this section, the thirteen empirical studies in our sample using evolving standard techniques reassure the findings from sections 2.4.1 and 2.4.2. Eight studies find size and systemic risk to be positively correlated. Systemic risk increases statistically and economically significantly with both absolute and relative size, even after controlling for business model characteristics, and seems to be naturally tied to the size of an institution and highly concentrated to a small number of large firms. Furthermore, several studies again find that larger banks contribute more than proportionally to systemic risk. Only two studies (López-Espinosa et al., 2012; López-Espinosa et al., 2013) do not find size to be a relevant predictor for systemic risk, at least in their samples, which are composed only of large international banks. Three studies provide ambiguous evidence and indicate that the impact of bank size on systemic risk is not persistent over time or dependent on institutional country characteristics.

2.5 Conclusions

The aim of our paper was to provide a brief overview of the existing literature dealing with the contribution of large banks to systemic risk. To this end, we particularly focused on the literature that emerged during or after the last global financial crisis to take into account the plurality of methodical improvements that have been developed. Our literature sample contains thirty studies, of which a majority of sixteen studies (53%) find that financial stability is negatively affected by large banks through a higher *contribution* to systemic risk or an increased *exposure* to common shocks. Nine studies (30%) find that bank size is a major determinant for systemic risk if certain other conditions are met, while a minority of five studies (17%) find that size per se is not a relevant factor in this context.

From a theoretical perspective, six out of the seven the studies reviewed in section 4.1 argue that large banks are not necessarily a threat for financial stability. However, certain characteristics of a financial system, such as the degree of connectivity and the potential for contagious spillovers, might fundamentally change the importance of bank size and cause this determinant to become one of the most important factors for systemic risk. This hypothesis is verified by a considerable number of sixteen empirical studies in sections 2.4.2 and 2.4.3 finding that against the background of the constitution of present-day real financial systems, a higher contribution to financial instability can indeed be attributed to pure size. This relationship is assumed to be non-linear, as systemic risk disproportionately increases with bank size, and the relationship is found in samples of different composition, for various periods and with different measures covering diverse aspects of systemic risk. This finding is important, since the work of Kleinow et al. (2017) suggests that systemic risk assessments based on a single risk metric should be taken with caution, and the measures for exploring this important issue are still developing. However, it is important to mention that potential regulatory actions to address the problem of being “too big to fail” require a clear distinction between the determinants of systemic risk, but no common standard has evolved to separate the effects of pure size from other observable or even unobservable factors.

Nevertheless, structural developments in the aftermath of the last crisis should be critically reviewed. Specifically, research has shown that in highly interconnected financial networks, the size of institutions is clearly more dangerous, and the failure of a large bank has the potential to trigger a serious default cascade. In the context of ongoing globalization, this issue becomes increasingly important. The impact of size on systemic risk is also amplified in highly concentrated banking systems in which the largest banks are a multiple of the size of small banks. Reviewing the formation of larger and more complex (and hence non-transparent) institutions after the recent crisis and hypothesizing that consolidation among banks will proceed during the next few years indicated that this issue is far from being solved.

We believe that important lessons have been learned in the last few years to address the problem of "too big to fail". Several advances were made by regulators around the world to improve microprudential regulation of banks, as well as macroprudential regulation of the financial system as a whole. Other proposals, such as cutting the size of large banks, have not been implemented to date, as this would require the definition of an optimal bank size. This task might also become an interesting issue for further research along with the ongoing analysis on the determinants of large financial institutions' contribution to systemic risk if future analyses verify the results reviewed in our sample and if the recently established regulatory measures fail to serve their purpose.

3 Sovereign Rating Spillover Effects on Foreign Banks: The Importance of Banks’ Foreign Asset Holdings

3.1 Introduction

The most recent European debt crisis highlighted the strong interconnection between sovereigns and banks and the various transmission channels that may trigger the contagion of credit risk among both. Governments directly or indirectly protected or even bailed out distressed financial institutions at the expense of increasing sovereign credit risk. This, in turn, induced intensifying feedback loops, also called ‘diabolic loops’ by some authors (see Singh et al., 2016), by eroding the value of banks’ government guarantees and significant amounts of sovereign debt, as recently observed (Gross and Kok, 2013; Acharya et al., 2014; Alter and Beyer, 2014). These ‘diabolic loops’ typically arise in times of crisis or may even be the reason for a crisis (Alter and Beyer, 2014; Poon et al., 2017). Additionally, the role of credit rating agencies has been subject of numerous debates, as was the case prior to the European debt crisis. Against the background of the U.S. subprime crisis and global banking crisis, it is argued that on the one hand, rating assessments referring to asset-backed securities did not reflect the true asset quality of those instruments and thus stimulated the global impact caused by the collapse of the asset-backed securities market. On the other hand, frequent sovereign rating assessments during crisis periods are assumed to exacerbate current problems and force policy makers to take additional actions to stabilize financial markets. In any case, in modern financial markets, credit ratings are commonly accepted as providing a professional and allegedly independent appraisal of the creditworthiness of a debtor. Especially in the case of sovereign ratings, credit ratings address the specific default risk of national governments. Consequently, due to their general importance for investment decisions, changes in credit ratings – and thus in perceived creditworthiness – should have effects on financial markets.

Four main transmission channels have been identified that may trigger contagion of sovereign credit risk to banks (Committee on the Global Financial System, 2011). Although these channels have been investigated by several researchers who focused on domestic banks (see, e.g., Bruyckere et al., 2013; Mink and Haan, 2013; Alter and Beyer, 2014; Correa et al., 2014; Caselli et al., 2016), empirical evidence on spillover effects on foreign banks in particular is rather scarce. Furthermore, although banks' exposures to sovereign debt are usually home-biased (Committee on the Global Financial System, 2011), in some cases, banks might hold relevant amounts of foreign sovereign debt to make use of asset diversification benefits; hence, they are exposed to market-wide events and systematic risk (Baele et al., 2007) and foreign asset holdings might represent a serious source of international spillover effects. To fill this research gap, we propose three research questions that we want to answer in this paper. First, do sovereign rating assessments spill over to foreign banks' stock prices more severely than to foreign markets in general? Second, how important is the role played by banks' foreign asset holdings in the transmission of spillovers from sovereign rating assessments to foreign banks? Third, is the importance of foreign asset holdings amplified by the magnitude of the shock in the event country? In the context of evaluating the systemic risk of the whole financial system, we believe these to be important issues due to the ongoing globalization and interconnection of financial markets.

We apply traditional event study methodology to a sample of 23 member countries of the Organization for Economic Co-operation and Development (OECD) from 1983 to 2014 to test the effect of sovereign rating events, particularly on foreign (non-event) country bank stock returns. The four main transmission channels that have been verified, at least for domestic banks, give rise to multiple ways of triggering the contagion of sovereign credit risk to banks. Consequently, although studies such as Chen et al. (2016) show that sovereign ratings also affect economic growth, we expect that banks are more exposed to sovereign credit risk than are non-financial firms in general, as non-financial firms do not face all spillover channels. Hence, we investigate abnormal returns of banks using a (risk-adjusted) market model to see whether spillover effects on banks are stronger than on general stock market indices. Then, we use the panel structure of our dataset and integrate abnormal bank returns into a double fixed effect regression model to investigate both the importance of the foreign asset holdings and whether the strengths of spillovers increase with the severity of the event. We find evidence that negative sovereign rating events induce spillovers to foreign banks and that these effects are more severe if banks in the non-event country hold larger assets in the event country. An increase in banks' foreign exposure in the re-rated country leads to more negative abnormal returns in the case of a negative foreign sovereign rating assessment. Furthermore, the impact of foreign asset holdings significantly increases along with the severity of the rating event, and the economic effect is huge, as a one-standard-deviation increase in foreign claims leads to a decrease in abnormal returns of more than 54% of the CAAR's standard deviation of banks. This finding is robust both to various model specifications and to differing sample periods or return country sample compositions. However, we find that our results are not similarly valid for rating upgrades.

Our research contributes to the existing literature, which we describe in detail in the following section, in three important ways. First, a plurality of studies investigating spillover effects of sovereign ratings look at the stock market reaction in general (see, e.g., Kaminsky and Schmukler, 2002; Brooks et al., 2004; Ferreira and Gama, 2007; Li et al., 2008; Bissoondoyal-Bheenick, 2012; Fatnassi et al., 2014), while we specifically investigate bank stock returns. Bank stock returns are even of greater importance than general stock markets because of banks' role in financial stability and financial soundness. Second, to the best of our knowledge, we are the first to directly test whether banks' foreign asset holdings are a relevant factor for the strength of stock market spillovers. We investigate this transmission channel directly, which we expect to be relevant because of banks' international investment activity. Previous literature on spillovers in financial markets has not found portfolio investments to significantly determine the size of the spillover (see, e.g., Gande and Parsley, 2005; Ferreira and Gama, 2007). In banking, however, Poon et al. (2017) have shown that European banks have higher rating downgrade likelihoods with more exposure in GIIPS countries (Greece, Ireland, Italy, Portugal and Spain). We add to their analysis by showing that bank stock returns are also affected and by finding that the spillover effects are not limited to European countries. Even when excluding GIIPS countries, the effect is substantial. Third, we are the first to test whether the strength of the transmission is moderated by the size of the shock in the event country. To model the shock, we consider not only rating changes in the event country but also a very direct measure, namely, event-country banks' stock market reaction to rating changes. We analyze a broad and worldwide sample of OECD economies during a long sample period of more than thirty years, covering several financial and economic crisis periods.

The remainder of our paper is structured as follows. Section 3.2 reviews the existing literature concerning the effects of sovereign rating events on financial markets and develops our hypotheses. Section 3.3 introduces the main data used in our study and provides descriptive statistics regarding our sample countries. Section 3.4 discusses the foreign banks' stock market reactions to sovereign rating events and investigates the role of banks' foreign asset holdings in international spillover effects. We critically review our results by performing a series of robustness tests and provide some extensions of our analysis in section 3.5 before concluding the paper in section 3.6.

3.2 Related research and hypotheses development

Our paper adds to a growing body of literature concerning the market effects of sovereign rating actions. Recently, research has started to focus on the banking sector. As shown by the Committee on the Global Financial System, four main transmission channels may trigger the contagion of sovereign credit risk to banks, namely, the *asset holdings channel*, the *collateral/liquidity channel*, the *ratings channel* and the *guarantee channel* (Committee on the Global Financial System, 2011). The asset holdings channel refers both to the direct holdings of sovereign debt by banks and to losses on those portfolios in the event of an increase in sovereign risk. Furthermore, banks might be exposed to sovereign credit risk when they act as counterparties to sovereigns in over-the-counter derivative markets. The collateral/liquidity channel causes risk transmission because sovereign securities are usually used by banks as collateral for refinancing operations with central banks, private repo or covered bond markets. Consequently, deterioration in the value of these collaterals due to rating downgrades will either decrease banks' funding capacity or increase funding costs. The ratings channel highlights the importance of sovereign ratings for banks because sovereign downgrades often lead to downgrades of domestic banks, resulting in negative consequences for funding, market access and profitability. Additionally, sovereign ratings often represent a factual ceiling for domestic non-sovereign issuers (Shen et al., 2012; Borensztein et al., 2013; Huang and Shen, 2015; Singh et al., 2016). Finally, some banks benefit from implicit or explicit government guarantees and will be negatively affected by a sovereign downgrade through the guarantee channel.

All of these channels may have adverse and reinforcing effects on banks. In most cases, the effects will primarily concern domestic banks in those countries whose sovereigns experienced a rating change; consequently, this issue has been investigated. For example, Alter and Schüler (2012) empirically investigate the relationship between government and banks' CDS spreads in seven EU member countries. Though the results are heterogeneous across countries, evidence indicates that within the same country, government default risk is an important determinant of bank default risk (after government interventions) and vice versa (in the period before government interventions). This result is further supported by Gross and Kok (2013) for a sample of 23 sovereigns and 41 international banks from Europe, the U.S. and Japan. Alter and Beyer (2014), and Bruyckere et al. (2013) also use CDS spreads to investigate interdependencies between sovereign and domestic bank risk. Alter and Beyer (2014) find increasing domestic sovereign-bank spillover effects during periods of stress. Singh et al. (2016) directly test for causality between sovereign and bank risk and strongly underline the interconnection between sovereigns and their local banks. Mink and Haan (2013) find that during the Greek sovereign debt crisis, news about Greece's economic situation affected the market value of Greek banks, and Correa et al. (2014) find negative excess returns in the case of sovereign downgrades for domestic banks that are expected to receive government support. This result is stronger in advanced economies in which governments are in a better position to provide that support. Williams et al. (2013b) find that sovereign rating changes have strong effects on bank rating changes. Alsakka et al. (2014) confirm the results of Williams et al. (2013b) for European countries before and during the European debt crisis. Drago and Gallo (2017) additionally verify that rating downgrades negatively affect capital ratios and the lending supply of domestic banks. Finally, Klusak et al. (2017) find that the adverse effects on bank ratings are even stronger if sovereign rating revisions are unsolicited.

Caselli et al. (2016) confirm that sovereign rating downgrades affect domestic European bank share prices negatively, especially during the crisis and in GIIPS countries. It is important to note that none of the aforementioned studies explicitly test for any spillover effects from the re-rated countries on banks in other countries.

Another part of the literature has investigated within- and cross-country spillover effects of sovereign rating assessments without putting much emphasis on banks' share prices. This literature finds evidence for the cross-country spillover effects of negative rating actions (a rating downgrade or negative outlook), meaning that rating news about one country affects the sovereign yield spreads not only of the re-rated country but also of other countries (Gande and Parsley, 2005; Afonso et al., 2012; Claeys and Vašíček, 2012; Alsakka and ap Gwilym, 2013; Mink and Haan, 2013; Alsakka et al., 2014; Santis, 2014; Böninghausen and Zabel, 2015). Moreover, various researchers observe significant negative effects on the re-rated countries' financial markets (Reisen and Maltzan, 1999; Kaminsky and Schmukler, 2002; Brooks et al., 2004; Li et al., 2008; Ismailescu and Kazemi, 2010; Afonso et al., 2012; Alsakka and ap Gwilym, 2013) and on foreign stock market indices (Kaminsky and Schmukler, 2002; Ferreira and Gama, 2007; Arezki et al., 2011; Bissoondoyal-Bheenick, 2012; Fatnassi et al., 2014).

The stream of literature dealing with the European debt crisis is also relevant to our study. Arezki et al. (2011), for example, provide evidence for foreign spillover effects on selected European banking sub-indices during the European debt crisis. Barth et al. (2012) find cross-country interdependency between sovereign and bank risk using CDS spreads and correlations before, during and after the financial crisis. Williams et al. (2013a) test the impact of sovereign credit signals on the share prices of 51 European banks. They find evidence for cross-border spillover effects from European sovereigns to European banks. Due to a lack of other control variables and the observation that share prices were also changing prior to rating events, there is no evidence that sovereign rating actions are the dominant force influencing banks' share prices. This hypothesis is supported by Mink and Haan (2013), who find that speculation about Greece's economic situation does not induce spillovers to banks outside Greece. This finding might reflect that market participants did not expect bank losses to be highly interconnected with the probability of a Greek default. Furthermore, news about a Greek bailout does have a significant impact on the market value of European banks, even if they do not have exposure to Greece or any other GIIPS country. Although the transmission mechanism remains unclear, Mink and Haan (2013) interpret this as a signal of European governments' general willingness to use public funds to protect private investors against losses; hence, those authors implicitly refer to the guarantee channel.

Summarizing the existing literature so far, sovereign rating events can induce spillovers to other sovereigns, to domestic and foreign financial markets and to domestic banking institutions. Research on the spillover effects of sovereign rating assessments on foreign banks in particular is rather scarce. We believe this gap to be a valuable research focus due to the strong connection between sovereigns and banks and its relevance in the context of evaluating systemic financial risk. Our research tries to fill this gap by testing our first hypothesis:

H1: A sovereign rating change of an event country impacts the share prices of banks in non-event countries.

Poon et al. (2017) determine whether sovereign rating changes in GIIPS countries from 2001 to 2015 induce bank rating events in other European countries. They find evidence for cross-border rating spillovers in the European Union and that larger asset holdings of GIIPS debt increase the probability of a bank being downgraded. It is reasonable to assume that sovereign asset holdings increase risk transmission due to the asset holdings channel. Although banks' exposures to sovereign debt are usually home biased (see Committee on the Global Financial System, 2011), in some cases, banks also hold relevant amounts of debt issued by foreign sovereigns, possibly due to considerations of diversification. Additionally, banks have global interbank exposures and hold claims on non-financial debtors in re-rated countries that are also affected by a home-country's rating event (Drago and Gallo, 2017). Consequently, banks are exposed to market-wide events and systematic risk (Baele et al., 2007) and foreign exposure might also be a relevant source of contagion for foreign banks, which leads to our second hypothesis:

H2: ***Banks' foreign asset holdings determine the strength of sovereign rating spillover effects on foreign banks' stock prices.***

To develop our third hypothesis, we refer to the existence of a guarantee channel and the strong interconnection between banks and sovereigns. Governments directly or indirectly protect banks against losses, whereas banks hold significant amounts of sovereign debt. As recently observed, this can induce intensifying feedback loops (Acharya et al., 2014; Alter and Beyer, 2014), also denoted 'diabolic loops' by some authors (see Singh et al., 2016). Hence, it is reasonable to assume that financial markets take into account the severity of the sovereign rating event and react more strongly to large rating changes, as they are aware of the interdependencies between sovereigns and banks. Consequently, if we find banks' foreign asset holdings to be a relevant driver for the strength of international spillover effects, we can propose our final hypothesis:

H3: ***Spillover effects through banks' foreign asset holdings are stronger for large than for small rating shocks in the event country.***

3.3 Data and sample selection

The credit ratings used in our empirical investigation stem from Standard & Poor's Ratings Services (S&P). We focus on S&P ratings because they appear to be more active in sovereign ratings changes, they tend not to be anticipated by the market and they precede changes by other rating agencies (Reisen and Maltzan, 1999; Brooks et al., 2004; Gande and Parsley, 2005; Hill and Faff, 2010; Alsakka et al., 2014; Reusens and Croux, 2017). We refer to foreign currency ratings and distinguish between a country's long-term sovereign rating (LT) and its rating outlook. The dataset consists of ratings from January 1975 to June 2014 and covers a sufficient period of time that fully includes the European debt crisis that ended in 2013. To measure sovereign rating events, we transform the ratings of S&P into a numerical scale using a maximum value of 29 for the highest rating (AAA), decreasing to a value of 1 for the lowest rating (SD). Furthermore, we assign absolute values to the different outlook categories, as shown in Appendix A.1. Here we follow the methodology of Correa et al. (2014) and use values from -0.2 to 0.2 in increments of

0.1 for the five different outlook stages, ascending from negative outlook (-0.2) to positive outlook (0.2). Hence, a country's comprehensive rating is the result of the numerical value of its alphabetical rating and the numerical value of its credit outlook. Thus, we observe a positive rating event if the numerical value of the comprehensive rating increases, while a negative event is characterized by a decreasing numerical value. In our empirical analysis, we investigate positive and negative events separately to allow for asymmetric effects of downgrades and upgrades. We focus our analysis on OECD member countries and identify 272 events by applying this methodology, of which 147 are downgrades and 125 are upgrades. The sovereigns and the corresponding rating events in our final sample are shown in Table 3.

Rating country	Events	Upgrade	Downgrade	Pos. outlook	Neg. outlook
Australia	7	4	3	2	1
Austria	2	0	2	0	1
Belgium	4	1	3	1	2
Canada	1	1	0	0	0
Chile	1	1	0	0	0
Czech Republic	5	4	1	2	0
Denmark	1	1	0	0	0
Estonia	5	3	2	1	1
Finland	4	2	2	1	2
France	3	0	3	0	1
Germany	2	1	1	1	1
Greece	27	9	18	3	7
Hungary	16	8	8	5	3
Iceland	21	9	12	7	7
Ireland	11	4	7	2	2
Israel	1	1	0	0	0
Italy	9	1	8	1	3
Japan	10	3	7	2	3
Korea	14	9	5	2	1
Luxembourg	2	0	2	0	2
Mexico	12	8	4	3	2
Netherlands	3	0	3	0	2
New Zealand	10	5	5	3	3
Poland	12	8	4	5	4
Portugal	16	7	9	4	3
Slovakia	10	8	2	2	1
Slovenia	6	1	5	1	1

Spain	12	4	8	2	2
Sweden	2	2	0	1	0
Turkey	37	18	19	12	13
UK	3	1	2	1	2
USA	3	1	2	1	1
Total	272	125	147	65	71

Notes: The table shows the number of S&P rating events during our sample period.

Table 3: Sovereign rating events

To test our second hypothesis regarding banks' foreign claims, we make use of the consolidated banking statistics of the Bank for International Settlements (BIS). The BIS measures banks' country risk exposures and captures the worldwide consolidated claims of banks headquartered in BIS reporting countries. The consolidated statistics include claims of banks' foreign affiliates but exclude intragroup positions. To the best of our knowledge, these data have been part of only a limited number of studies, for example, Poon et al. (2017), Buch et al. (2017) and Buch et al. (2010). In opposition to Poon et al. (2017), who use data on sovereign exposures only, we use the consolidated foreign exposure to all counterparties in the event country as a measure of banks' financial connections with foreign countries. The BIS has provided these data since 1983, and the number of reporting countries has gradually increased.

We investigate spillover effects from sovereign rating events on foreign bank returns for a sample period of nearly 31 years from Q4/1983 to Q2/2014, although not all BIS reporting countries provide data about foreign claims for the entire observation period. We list the return countries of our analysis and summary statistics of banks' foreign claims in Table 4. Our 23 return countries include 19 advanced economies (Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Korea, Netherlands, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States) while the remaining countries are classified as emerging markets (Chile, Greece, Mexico, Turkey).

Return country	Mean	Std. dev.	Min.	Max.	Quarters	Reporting since
Australia	499	189	207	768	47	Q4/2003
Austria	173	199	12	614	127	Q4/1983
Belgium	325	395	6	1,633	127	Q4/1983
Canada	360	393	24	1,268	127	Q4/1983
Chile	6	5	1	17	51	Q4/2002
Denmark	93	115	1	355	127	Q4/1983
Finland	17	18	3	74	119	Q4/1985
France	1,239	1,329	71	4,264	127	Q4/1983
Germany	1,555	1,447	34	4,702	127	Q4/1983
Greece	113	51	34	179	47	Q4/2003
Ireland	181	243	0	799	127	Q4/1983
Italy	352	386	11	1,323	127	Q4/1983
Japan	1,229	1,064	61	3,527	127	Q4/1983
Korea	125	14	103	147	15	Q4/2011
Mexico	5	2	2	10	47	Q4/2003
Netherlands	695	759	7	2,473	127	Q4/1983
Portugal	102	43	39	175	63	Q4/1999
Spain	542	588	12	1,586	119	Q4/1985
Sweden	288	350	3	990	127	Q4/1983
Switzerland	904	898	17	2,685	127	Q4/1983
Turkey	20	6	9	31	59	Q4/2000
UK	1,528	1,602	85	4,284	127	Q4/1983
USA	1,046	1,114	142	3,378	127	Q4/1983

Notes: The table shows summary statistics of banks' foreign asset holdings in billions of USD taken from the consolidated banking statistics (Bank for International Settlements, http://www.bis.org). *Mean* denotes the average value, *Min.* and *Max.* denote minimum and maximum value of foreign claims during our sample. *Std. dev.* is the standard deviation.

Table 4: Foreign asset holdings of BIS reporting banks

3.4 Sovereign rating spillover to foreign banks' stock prices

3.4.1 Event study

We first verify whether sovereign rating events provide new information that leads to significant effects on the stock returns of foreign banks. As mentioned in section 3.2, previous research has shown that sovereign rating events can induce spillovers to other sovereigns, domestic and foreign financial markets and domestic banking institutions, while research on spillover effects – particularly on foreign banks – is rather scarce. In this section, we focus on rating downgrades only. In section 3.5.2 below, we will turn our attention to rating upgrades.

We apply traditional event study methodology to daily stock returns to test the effect of sovereign rating events on non-event-country bank stock returns and assume that foreign banks are, or at least are supposed to be, in some way connected to the event country. We use a market model to define abnormal returns as the difference between the realized bank stock returns and the general stock market indices returns during the event window. We apply a risk-adjusted market model in robustness tests. The event days (*t=0*) are defined by sovereign rating actions for event country *j*, causing abnormal returns to be observed in non-event country *i* as the result of international spillover effects. To test whether the observed abnormal returns are significantly different from zero, we apply the parametric test statistic proposed by Kolari and Pynnönen (2010), which accounts for both event-induced variance and cross-sectional correlation in returns. Additionally, to validate that the abnormal returns are not biased by the assumption of the parametric test, we apply the non-parametric generalized sign test according to Cowan (1992).

In Table 5, we present the results of using several symmetric and asymmetric event windows to calculate cumulative abnormal returns. We divide our sample of return countries according to the share of foreign asset holdings of banks relative to the return country's gross domestic product and create three groups (low, medium, high), using the 33% and 66% percentiles of the full foreign claims' distribution as differentiators.

	Low foreign claims (Below 33% percentile)				Medium foreign claims (Between 33% and 66% percentile)					High foreign claims (Above 66% percentile)				
# Obs.	742				772					688				
	CAAR	PT	NPT		CAAR	PT		NPT		CAAR	PT		NPT	
[-10;10]	-0.78%	-1.00	-1.49		-2.15%	-1.93	*	-2.13	**	-2.93%	-1.71	*	-4.13	***
[-5;5]	-0.62%	-0.43	-0.39		-1.45%	-1.59		-0.47		-2.94%	-1.89	*	-2.84	***
[-3;3]	-0.36%	0.26	0.35		-0.84%	-1.15		-1.26		-2.56%	-2.34	**	-3.60	***
[-1;1]	-0.35%	-0.98	-1.71	*	-0.90%	-2.49	**	-3.71	***	-1.55%	-2.49	**	-5.20	***
[0;1]	-0.29%	-0.95	-1.93	*	-0.78%	-2.89	***	-5.37	***	-1.51%	-3.66	***	-7.56	***
[-1;5]	-0.66%	-0.87	0.50		-1.13%	-2.03	**	-2.13	**	-2.49%	-2.53	**	-4.06	***
[-5;1]	-0.32%	-0.45	-0.68		-1.22%	-1.78	*	-1.98	**	-1.99%	-1.64		-1.54	
[-5;-3]	0.11%	0.09	-0.53		-0.25%	-0.53		-2.41	**	-0.08%	0.01		-0.78	

Notes: This table shows the cumulative average abnormal return CAAR [t1,t2], starting on t1 and ending at t2 relative to a rating downgrade on the event day (t0). CAARs are calculated for non-event country bank stocks. PT reports test statistics and statistical significance levels based on the parametric test statistic proposed by Kolari and Pynnönen (2010), while NPT comes from the non-parametric generalized sign test according to Cowan (1992). ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

Table 5: Abnormal bank returns in non-event countries after downgrades

Focusing on the [0,1] window first, the results shown in Table 5 provide strong evidence for our first hypothesis that spillover effects do exist and that those effects spread, particularly to banking sectors in other countries. Abnormal returns are approximately -0.78% and strongly significant at the 1% level for banks with foreign asset holdings between the 33% percentile and the 66% percentile. This result is in line with the findings of Williams et al. (2013a), who find negative returns of -0.77% for the same event window investigating share price reactions of European banks on negative S&P credit signals during the 2007-2011 financial crisis.

In addition to the results of Williams et al. (2013a), we further differentiate our sample of banks and can therefore observe that abnormal returns reach -1.51% if banks in non-event countries have high foreign exposure in the event country. However, if the foreign asset holdings of banks are low (below the 33% percentile), CAARs are clearly smaller and lose their statistical significance. This result is robust throughout nearly all event windows under investigation and provides a first indication in favor of our second hypothesis, which is that the strength of the spillover effect depends on the banks' foreign claims in the event country.

With respect to the length of the event windows, we observe that the negative effect of the rating event further increases if we consider longer windows. For banks with high foreign claims, we observe the highest abnormal returns of approximately -2.94% during the [-5,5] window, while an extension to the [-10,10] window slightly reduces abnormal returns. In contrast, for banks with medium foreign asset holdings, the highest abnormal returns are observable in the [-10,10] window. The statistical significance however, is highest in the shortest event window with abnormal returns significantly different from zero at the 1% level for both the parametric and the non-parametric test in the [0,1] window for banks holding medium and high foreign assets.

Following Michaelides et al. (2015), Table 5 also reports results from a [-5,-3] event window to capture possible effects of information leakage prior to rating announcements. While Michaelides et al. (2015) find significant general stock reactions prior to sovereign rating events, our test statistics turn out to be insignificant. This non-finding indicates that capital markets anticipate bank stocks to decline as much as general stock indices. Therefore, we can conclude from not finding evidence for information leakage prior to rating announcements that the results of our further analysis are not biased thereby.

3.4.2 Multivariate Analysis

In the previous section we have shown that the magnitude and significance of abnormal returns of foreign banks after negative sovereign rating changes increases along with the amount of foreign claims of banks in the event country, indicating that these are a relevant determinant to stimulate international spillover effects. However, as we have not yet controlled for other potential influencing factors, we cannot be confident about the relationship between foreign asset holdings and abnormal returns. To shed light on this issue, we perform a multivariate analysis and apply equation (3.1) to our sample of events:

$$CAAR_{i,j,t} = \alpha_1 Log(FC_{i,j,t}) + \alpha_2 Severe_{j,t} + \sum_{l=1}^{4} \beta_l \, Controls + \mu_i + \mu_j + \varphi_t + \varepsilon_{i,j,t} \quad (3.1)$$

$CAAR_{i,j,t}$ denotes the cumulative average abnormal stock return of banks during the event window in the non-event country i after the sovereign bonds of the event country j have been downgraded at point in time t. To save space, we will focus on the [0,1] event window in our subsequent analysis (following Correa et al., 2014). In a robustness section, we will verify whether the choice of this specific event window distorts our conclusion. To eliminate extreme values, we apply an outlier correction to the highest and lowest 1.0% values. Alternative cutoff levels do not change our results. α_1 tests our second hypothesis that banks' foreign asset holdings determine the strength of sovereign rating spillover effects on foreign banks' stock prices. We expect a negative coefficient estimate on foreign claims because a strong financial connection should yield significant market reactions. We use the logarithm of consolidated foreign claims from return country i in rating country j divided by the return country's gross domestic product because the ratio is highly skewed.

Severe captures the strength of the event. We use two proxies to capture how severe the sovereign rating downgrade is. First, we use the change in the rating. A more negative value means that the shock is more severe. Second, we use abnormal returns of banks in the event country (AR_j) to proxy for the severity of the rating downgrade. Again, a more negative value means that the shock is more severe. We calculate abnormal returns of banks in the event country with a market model and consider only the event day so that we can obtain the most precise and prompt measure of the shock. The second measure has some advantages over the first. First, the change in rating may fail to pick up that a one-notch rating change might have different implications depending on whether the country starts with a very good or a medium rating. This type of non-linearity is captured by considering how the stock market in the event country responded to the news of the rating change. Second, the change in rating may fail to pick up differences in how banks respond. For banks in some countries, a rating change may have severe effects and in others, it may have only moderate effects, depending, for instance, on whether the economy is market based or bank based. Thus, a potential non-linearity between banking and sovereign is better controlled for by using bank abnormal returns as a severe measure. One drawback of using our second measure is that we cannot consider all event countries in our empirical analysis because of missing bank return data.

We employ the following control variables; descriptive statistics of the sample are shown in Appendix A.3. We integrate the numerical value of the (current) rating of the non-event country as well as (post-event) rating of the event country into the regression, as in Ferreira and Gama (2007). Rating events that occur only shortly after the last rating event of a specific country have the potential to amplify concerns about the fiscal strength of that sovereign. To address this issue, we introduce a dummy variable ($Revision_j$) that takes the value of one if there have been previous rating events in the event country in the last 60 days prior to the event day. We also control for geographical distance between the event and the non-event countries by using $Distance_{i,j}$. According to the results of Li et al. (2008), geographical closeness seems to be a relevant factor for spillover effects, although the information asymmetry hypothesis would suggest that a greater distance reduces the ability of an investor to monitor its debtor. Consequently, the information content of a rating event should increase along with the geographical distance. We follow Ferreira and Gama (2007) and model for each non-event country *i* and for each country *j* a fixed effect to control for all time-invariant characteristics of these countries, and we use heteroscedasticity-consistent standard errors (White, 1980) clustered at the i-country and j-country pair level. In addition, we add time-fixed effects. Table 6 reports our regression results. In column (1) we present the result from a simple regression considering only foreign claims as the economic explanatory variable, while in column (2) we add our controls to the model. We find that the banks' foreign claims determine – with a high statistical significance – how much sovereign rating changes spill over to their stock prices. As we expected, a negative rating assessment of a foreign sovereign increases uncertainty about the future value of foreign assets of banks, leading to a decrease in abnormal bank stock returns. This supports our second hypothesis. Regarding the economic effects, the impact of banks' foreign asset holdings on abnormal returns is only moderate: A one-standard-deviation increase in foreign claims leads to a decrease in the abnormal return of approximately 9.2% of the CAAR's standard deviation for banks in our simple regression. When we consider controls, this effect increases to 13.4%.

	(1)	(2)	(3)	(4)	(5)	(6)
Severe definition		$\Delta Rating_j$	$\Delta Rating_j$	AR_j	$\Delta Rating_j$	AR_j
$Log(FC_{ij})$	-0.137***	-0.198***	-0.151***	-0.169***	-0.185***	-0.158***
	(0.042)	(0.048)	(0.054)	(0.058)	(0.048)	(0.060)
$Severe_j$		0.186***	0.122*	0.015		
		(0.055)	(0.068)	(0.050)		
$Log(FC_{ij}) \times Severe_j$			0.053*	0.056***		
			(0.032)	(0.019)		
D_Severe_j					-0.154	0.176
					(0.376)	(0.270)
$Log(FC_{ij}) \times D\_Severe_j$					-0.309*	-0.584***
					(0.182)	(0.125)
$Rating_i$		-0.008	-0.013	-0.046	-0.010	-0.050*
		(0.027)	(0.028)	(0.030)	(0.027)	(0.030)
$Rating_j$		-0.091***	-0.090***	-0.027*	-0.053***	-0.031**
		(0.026)	(0.026)	(0.016)	(0.020)	(0.015)
$Revision_j$		0.224*	0.245*	0.107	0.258*	0.172
		(0.131)	(0.129)	(0.157)	(0.132)	(0.143)
$Log(Distance_{ij})$		-0.230**	-0.220**	-0.201*	-0.216**	-0.243**
		(0.092)	(0.091)	(0.109)	(0.091)	(0.110)
FE country i	yes	yes	yes	yes	yes	yes
FE country j	yes	yes	yes	yes	yes	yes
year FE	yes	yes	yes	yes	yes	yes
# Obs.	2,559	2,477	2,477	1,861	2,477	1,861
F-statistics	6.651***	6.575***	6.493***	6.516***	6.388***	6.442***
Economic effect (1 SD $Log(FC_{ij})$/ $SD(CAAR_{ij})$)						
Full	-9.23%	-13.36%				
D_Severe_j=1					-33.38%	-54.01%
D_Severe_j=0					-12.52%	-11.53%

Notes: The dependent variable is the cumulative average abnormal return CAAR [0,1] of bank stocks in non-event countries after sovereign rating downgrades. The subscript i refers to characteristics of the return country, j refers to characteristics of the rating country and i,j denotes interconnection variables between both countries. All variables are defined in Appendix A.2. Results come from a double fixed effect ('within') regression with heteroscedasticity-robust standard errors (White, 1980) clustered at the i-country and j-country pair level. ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

Table 6: Multivariate regression results for foreign sovereign downgrades

The results on the severity of the rating event in column (2) suggest that the size of the shock is important for stock prices' response of foreign banks. The more severe the rating downgrade (which means a more negative number in the rating change variable), the lower foreign banks' abnormal returns. The economic effect of severity is not very high. A one-standard-deviation increase in the rating change accounts for only 11% of the CAAR's standard deviation for banks.

To test our third hypothesis, which states that the importance of the asset holdings channel for international spillovers depends on the severity of the shock in the event country, we modify our model in the following way:

$$CAAR_{i,j,t} = \alpha_1 Log(FC_{i,j,t}) + \alpha_2 Severe_{j,t} + \alpha_3 Log(FC_{i,j,t}) \times Severe_{j,t} + \sum_{l=1}^{4} \beta_l \, Controls + \mu_i + \mu_j + \varphi_t + \varepsilon_{i,j,t} \quad (3.2)$$

In columns (3) and (4) of Table 6, we use our two proxies for severity ($\Delta Rating_j$ and AR_j) and run interaction terms as specified in equation (3.2). In column (3), we see that foreign asset holdings become more important when the rating change is large. All rating changes are negative because we investigate only downgrades here. A change in rating might, however, only imperfectly describe the severity of the shock in the event country. Therefore, in column (4) we use the abnormal returns of banks in the event country on the event day (AR_j) and repeat our interaction term approach. The coefficient on foreign claims keeps its sign and significance. In addition, we find a highly significantly positive coefficient on the interaction term, indicating that the effect of foreign claims on banks' stock prices becomes much more pronounced when the shock is severe.

While using continuous measures of the shock severity has its own appeal, it makes it difficult to propose reasonable calculations of economic effects, which must be based on assumptions about severity. We therefore replace the continuous measure of shock severity with two dummy variables that are equal to 1 when the shock is severe and zero otherwise. For rating changes, we specify that severity equals a multi-notch downgrade if the numerical value of the event country's comprehensive rating decreases by more than 2.5 points, which equals at least three categories in the alphabetical rating. For the bank abnormal returns in the event country, we specify severity as those events in which the national stock market returns of banks belong to the lower 10% percentile, which equals -2.4% in our sample.

In columns (5) and (6), we use the two severity dummy variables in our interaction term approach. Column (5) shows that the multi-notch variable itself is statistically not significant in explaining abnormal returns of foreign banks but that the economic effect of foreign asset holdings clearly increases in those cases. A one-standard-deviation increase in foreign claims for severe shocks leads to a decrease in the abnormal returns of more than 33% of the CAAR's standard deviation, while a one-standard-deviation increase in foreign claims for non-severe shocks leads to a decrease in the abnormal returns of only 12.5%. Column (6), in which we use abnormal returns of banks in the event country to define severity, highlights our most remarkable result.[16] For severe events, a one-standard-deviation increase in foreign claims leads to a decrease in abnormal returns of banks of more than 54% of the CAAR's standard deviation, which is by any standard a huge effect. For non-severe events, a one-standard-deviation increase in foreign claims leads to a decrease in abnormal returns of foreign bank stocks of approximately 11.5% of the CAAR's standard deviation, which is comparable to the results obtained in our baseline specification.

We yield mixed results for our controls. The rating of the return country does not seem to be relevant for financial markets, while a lower rating of the event country decreases the abnormal returns of foreign banks. Rating revisions within 60 days after the last event increase abnormal returns, although the statistical significance is relatively weak. For the distance variable, we find strong statistical evidence that increasing distance decreases abnormal returns. This finding is opposed to Kaminsky and Schmukler (2002), Li et al. (2008) and Böninghausen and Zabel (2015), but in our view it is consistent with the information asymmetry hypothesis. Thus, we assume that despite the global availability of information, the monitoring ability of investors declines with increasing geographical distance. Consequently, a rating downgrade is more informative for financial markets if both countries are distant.

To conclude this section, we find strong evidence for our hypotheses two and three. Banks' foreign asset holdings determine the strength of sovereign rating spillover effects on foreign banks' stock prices and are even more important for large than for small shocks in the event country. For severe rating events, a one-standard-deviation

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[16] It is important to note that the difference in economic effects between the models presented in columns (5) and (6) is not driven by different sample sizes. Estimating the model of column (5) and considering only events for which AR_j can be calculated (which reduces the sample to the 1861 observations used in column (6)) gives results similar to the ones in column (5); only positions after the decimal point differ.

increase in foreign claims might lead to a decrease in abnormal returns of more than one-half of the CAAR's standard deviation for foreign banks. Hence, as demonstrated with different specifications of our baseline model, disregarding these surrounding conditions of the rating event would crucially underestimate the economic importance of foreign asset holdings for international spillover effects to foreign bank stocks.

3.5 Robustness analysis and extension

3.5.1 Robustness analysis

We perform a series of robustness tests to ensure the validity of the huge economic effect found for the importance of foreign asset holdings on abnormal foreign bank returns during severe events. The robustness analysis is based on the definition of severity used in column (6) of Table 6.

Since the 'diabolic loops' mentioned in section 3.2 typically arise in times of crisis or may even be the reason for a crisis (Alter and Beyer, 2014; Poon et al., 2017), it is reasonable that during such periods, financial markets are more sensitive to rating information and consequently should react more strongly to rating events. To test whether foreign asset holdings have a stronger economic impact on banks' share price reactions after sovereign rating events during economic or financial crises, we repeat our estimation for crisis and non-crisis periods separately and present the results in columns (1) and (2) of Table 7, Panel a. To identify those periods, we combine various sources. For years after 1996, we adapt the definition of Brooks et al. (2015), which includes the Asian financial crisis (1997/1998), the Russian debt crisis (1998), the Brazilian crisis (1999), the Technology/Terrorist crisis (2000-2002), the Turkish crisis (2001), the global financial crisis (2007-2010) and the European debt crisis (2008-2013). For the period before 1997, we primarily refer to the financial stress index (FSI) of Cardarelli et al. (2011). Those authors rely on financial market information and use market-based indicators (e.g., volatility, spreads, market returns, beta factors) in real time and high frequency to build a country-specific measure of financial stress. This approach is important for our purposes because Cardarelli et al. (2011) find that episodes associated with banking crises tend to have a much more severe macroeconomic impact in the sense that recessions associated with banking crises tend to last twice as long and to be twice as intense. The FSI is constructed for 17 countries, 16 of which equal our return countries.[17] This fact makes the FSI highly applicable to our research and preferable to the literature's other definitions of crisis periods. Nevertheless, we consult Reinhart and Rogoff (2008) to ensure that our definition also covers periods commonly identified by other researchers. Applying this methodology, we extend the definition of Brooks et al. (2015) and consider the stock market crash in the United States (1987), the Nikkei crash in Japan and the junk-bond market collapse in the United States (1989/1990), the Scandinavian banking crisis (1990/1991) and the European exchange rate mechanism crisis (1992/1993).

We observe that the majority of severe rating events appear during crisis periods and that consequently, the economic effect of foreign asset holdings for severe events is comparable to the average effect found above, as a one-standard-deviation increase in foreign claims leads to a decrease in abnormal returns of foreign bank stocks of approximately 54% of the CAAR's standard deviation in crisis periods compared to 12.6% for non-severe events (column 1). For non-crisis periods (column 2), however, the number of severe events is only moderate and we fail to have a sufficient number of severe events where we have information on abnormal returns of banks in the event country. Therefore, we apply the model of column (2), Table 6, to verify whether foreign claims load significantly negatively in non-crisis periods, which we find to be the case.

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[17] The corresponding countries are Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom, and the United States. Norway is not a return country in our study.

Panel a

Severe definition	(1) AR_j	(2) $\Delta Rating_j$	(3) AR_j	(4) AR_j	(5) AR_j
	CRISIS	non CRISIS	before 2007	from 2007	w/o GIIPS
$Log(FC_{ij})$	-0.181***	-0.176**	-0.231**	-0.140*	-0.117*
	(0.064)	(0.084)	(0.093)	(0.075)	(0.068)
D_Severe_i	0.198		0.540	0.122	0.208
	(0.272)		(0.409)	(0.414)	(0.307)
$Log(FCij) \times D\_Severe_i$	-0.596***		-0.742**	-0.572***	-0.778***
	(0.126)		(0.366)	(0.140)	(0.143)
$Severe_i$		0.026			
		(0.203)			
$Rating_i$	-0.064*	0.037	-0.093	-0.089**	-0.065*
	(0.034)	(0.125)	(0.138)	(0.042)	(0.039)
$Rating_i$	-0.029*	0.093	0.159***	-0.036*	0.023
	(0.016)	(0.070)	(0.045)	(0.020)	(0.054)
$Revision_i$	0.175		0.769***	0.086	0.385
	(0.143)		(0.207)	(0.193)	(0.265)
$Log(Distance_{ij})$	-0.241**	-0.291	0.079	-0.260**	-0.233*
	(0.110)	(0.220)	(0.176)	(0.118)	(0.124)
FE country i	Yes	yes	yes	yes	yes
FE country j	Yes	yes	yes	yes	yes
year FE	Yes	no	yes	yes	yes
# Obs.	1,626	346	649	1,212	1,361
F-statistics	6.097***	1.441*	4.828***	6.319***	7.185***
Economic effect (1 SD $Log(FC_{ij})$/ $SD(CAAR_{ij})$)					
D_Severe_i=1	-54.13%		-68.74%	-49.87%	-64.00%
D_Severe_i=0	-12.63%		-16.35%	-9.78%	-8.36%

Panel b

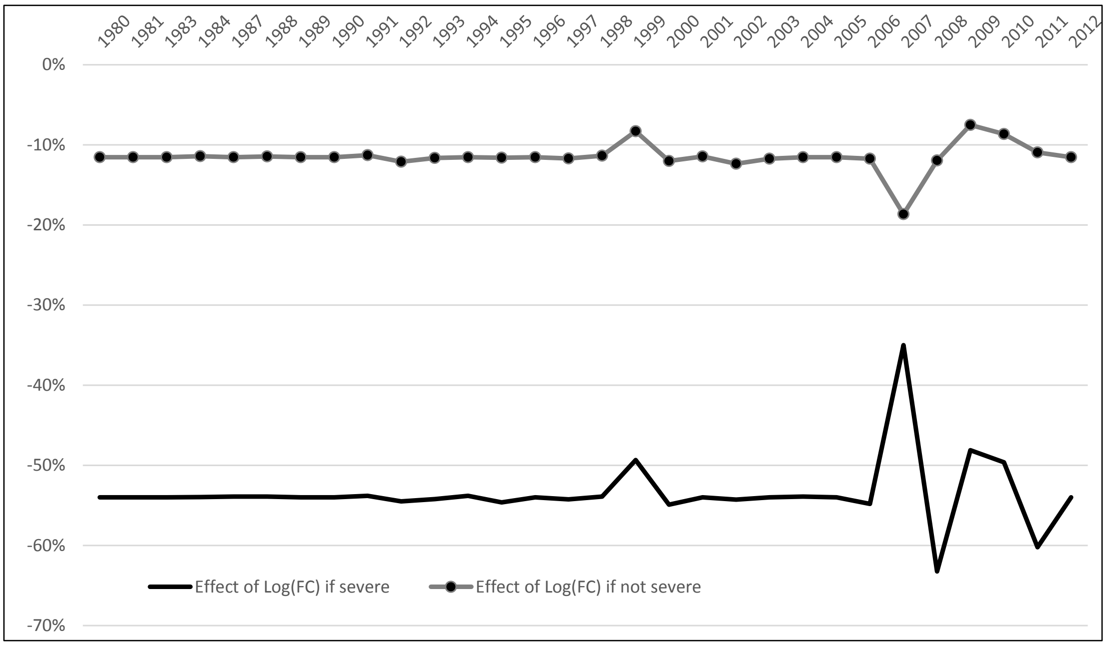
Severe definition	(1) AR_j	(2) AR_j	(3) AR_j	(4) AR_j	(5) AR_j
	MACRO	PortInv	CAAR[-1,1]	CAAR[-3,3]	risk-adj CAAR[0,1]
$Log(FC_{ij})$	-0.162***	-0.121*	-0.277***	-0.536***	-0.085*
	(0.060)	(0.066)	(0.078)	(0.115)	(0.050)
D_Severe_i	0.174	0.089	-0.035	-0.027	0.229
	(0.270)	(0.349)	(0.304)	(0.491)	(0.260)
$Log(FC_{ij}) \times D\_Severe_i$	-0.583***	-0.558***	-0.625***	-0.541**	-0.506***
	(0.125)	(0.133)	(0.152)	(0.255)	(0.133)
$Rating_i$	-0.051*	-0.056	-0.181***	-0.349***	-0.044
	(0.030)	(0.034)	(0.041)	(0.083)	(0.033)
$Rating_i$	-0.031**	-0.043**	-0.039**	0.038	-0.021
	(0.015)	(0.017)	(0.018)	(0.039)	(0.015)

$Revision_i$	0.172	0.120	0.069	0.168	0.268**
	(0.143)	(0.176)	(0.142)	(0.243)	(0.123)
$Log(Distance_{ij})$	-0.245**	-0.269**	-0.490***	-0.851***	-0.202**
	(0.110)	(0.113)	(0.137)	(0.190)	(0.090)
$Log(RelSize_{ij})$	-0.057				
	(0.159)				
$Log(GovDebt_j)$	0.006				
	(1.002)				
$Log(PortInv_{ij})$		-0.021			
		(0.318)			
FE country i	Yes	yes	yes	yes	yes
FE country j	Yes	yes	yes	yes	yes
year FE	Yes	yes	yes	yes	yes
# Obs.	1,861	1,436	1,861	1,861	1,861
F-statistics	6.438***	6.355***	11.63***	15.16***	5.995***
Economic effect (1 SD $Log(FC_{ij})$/ $SD(CAAR_{ij})$)					
D_Severe_j=1	-54.21%	-49.52%	-49.60%	-37.16%	-46.26%
D_Severe_j=0	-11.78%	-8.83%	-15.23%	-18.49%	-6.66%

Notes: The dependent variable is the cumulative average abnormal return CAAR [0,1] of bank stocks in non-event countries for sovereign rating downgrades. The subscript i refers to characteristics of the return country, j refers to characteristics of the rating country and i, j denotes interconnection variables between both countries. All variables are defined in Appendix A.2. Results come from a double fixed effect ('within') regression with heteroscedasticity-robust standard errors (White, 1980) clustered at the i-country and j-country pair level. ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

Table 7: Robustness tests

The next two columns (3) and (4) split the sample before and after 2007. For the sub-period before 2007, the economic effect even outreaches the result found for the whole observation period, as a one-standard-deviation increase in foreign claims leads to a decrease in abnormal returns of foreign bank stocks of nearly 69% of the CAAR's standard deviation compared to approximately 50% in the years since 2007. For a deeper investigation on the impact of single sample years on this result, we show in Figure 1 how the economic effect for severe and non-severe events varies if the corresponding year is excluded from the analysis. The economic impact of banks' foreign claims is in general very robust throughout the sample period but we also find that some years, as for example 1999, 2007, 2008 and 2011, strongly affect the average effect. We observe the most extreme effects for 2007 and 2008 representing the peak of the recent financial crisis. For example, the exclusion of the year 2007 reduces the average economic effect from -54% for the whole sample period to -35% in case of severe events, while the exclusion of the year 2008 increases the economic impact of foreign claims from -54% up to -63%.

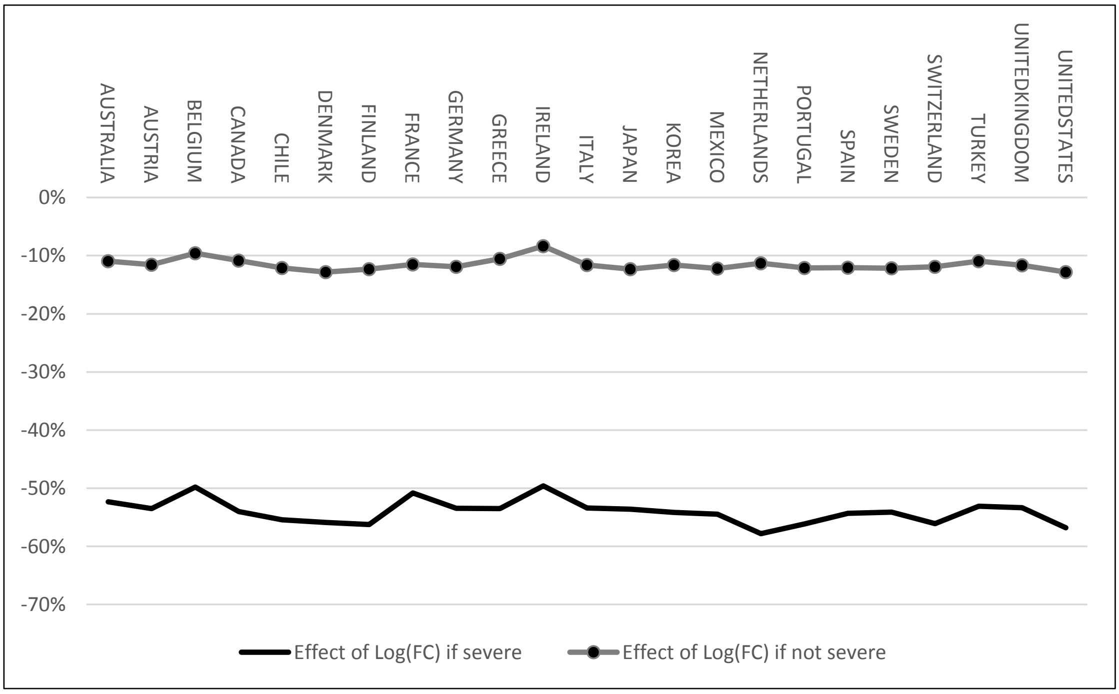


Notes: This figure shows the economic effects (1 SD Log(FC_{ij})/ SD($CAAR_{ij}$)) if the specific year (x-axis) is excluded from the regression sample. The underlying model is the one depicted in column (6) of Table 6.

Figure 1: Excluding single years

Column (5) of Panel a is built on the works of Mink and Haan (2013), Caselli et al. (2016) and Poon et al. (2017) and investigates whether the uncertainties about the solvency of GIIPS countries that emerged during the recent crisis are important for our results. Hence, we repeat our estimation but exclude all events in GIIPS countries that occurred later than 2007. Since Poon et al. (2017) find that GIIPS sovereign rating events induce rating events in other European countries' bank ratings, we want to make sure that economic effects found in our study are not simply driven by these sovereigns but also hold in a broader context. We find that excluding these events even increases the economic effect of banks' foreign claims for severe events (-64.0%) and yields only a slight reduction for non-severe events (-8.4%).

As a final robustness test with respect to the country and time dimension of our sample, we investigate whether the average economic effect of foreign claims is driven by specific return countries. To do so, we repeat the approach used above and show how the economic effect for severe and non-severe events varies if the corresponding return country is excluded from the analysis. From Figure 2 we can see that although there is a small variation, the economic effect of severe and non-severe events is strongly robust to the exclusion of return countries.



Notes: This figure shows the economic effect (1 SD Log(FC_{ij})/ SD($CAAR_{ij}$)) if the specific return country (x-axis) is excluded from the regression sample. The underlying model is the one depicted in column (6) of Table 6.

Figure 2: Excluding singe countries

Next, we extend our robustness analysis by using alternative controls and different specifications of the dependent variable. All results of these tests are depicted in Panel b of Table 7. Before explaining the alternative regressions in detail, we can initially confirm the robustness of our main results. All specifications yield a huge economic effect of the banks' foreign claims for severe events, and the difference between severe and non-severe shocks is highly significant at the 1% level in four of five estimations, as the significance of the interaction term variables indicate.

In line with other research (see, e.g., Gande and Parsley, 2005; Ferreira and Gama, 2007; Ismailescu and Kazemi, 2010; Bruyckere et al., 2013; Williams et al., 2013b; Santis, 2014; Böninghausen and Zabel, 2015), we add several macroeconomic factors to explain the spillover effects in column (1) of Table 7, Panel b. $GovDebt_j$

indicates whether the corresponding sovereign is a significant debtor on the international bond markets. Additionally, $RelSize_{i,j}$ serves as an indicator for the size of the two countries relative to each other. We expect that in addition to financial interconnection, the economic importance of the re-rated country – and thus the ability to influence the supply or demand of goods and services in other economies – might be a relevant factor for financial markets because it determines future earnings. This effect should be stronger if the non-event country itself possesses lower economic power, measured in terms of gross domestic product. We find that the macroeconomic variables do not affect our main result, as the economic effect found on banks' foreign claims is robust. For severe events, a one-standard-deviation increase in foreign claims again leads to a decrease in abnormal returns of banks of more than 54% of the CAAR's standard deviation. In our estimation, none of the macroeconomic variables appears to be a statistically relevant determinant. This result is in line with Caselli et al. (2016), who focus on domestic bank share prices and determine that macroeconomic variables at the country level (in their case, real GDP per capita, inflation and domestic credit provided by the banking sector) are not relevant factors for stock price reactions to a sovereign rating event.

Gande and Parsley (2005) and Ferreira and Gama (2007) investigate the importance of portfolio and trade flows on information spillover effects. While Gande and Parsley (2005) mainly find differential spillovers for downgrades, Ferreira and Gama (2007) find significant effects for upgrades only. This aspect is also partially addressed by Bissoondoyal-Bheenick (2012), who finds that both trade links and financial links promote negative spillover effects from downgrades but that financial links are more significant.[18] We address this issue and control for the amount of portfolio investments, with the results presented in column (2) of Table 7, Panel b. We focus on portfolio investments only, because Aviat and Coeurdacier (2007) found trade flows (defined as imports and exports of goods between both countries)

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[18] It should be noted that their measure of financial links was a rather indirect one, as they define financial links with a correlation coefficient of greater than 20 percent between national stock market returns.

to be highly correlated to capital flows.[19] We find that the inclusion of this variable does not challenge our main result. The economic effect of foreign asset holdings is still huge and the amount of portfolio investments from the return country in the event country is insignificant.

We also modify our dependent variable to ensure that the choice of the event window and the market model for determining normal returns does not distort the determined relevance of foreign asset holdings for international spillover effects on foreign banks' stock prices. As alternative dependent variables, we apply our regression model to abnormal bank returns during the [-1,1] and the [-3,3] event windows. Finally, we use abnormal returns from a risk-adjusted market model (instead of a market model only) to take into account the fact that the risk loading of banks may differ from the corresponding stock markets in general. We report results on the risk-adjusted abnormal returns in the [0,1] event window in column (5). The results presented in columns (3)-(5) of Table 7, Panel b provide further evidence in favor of our second and third hypotheses and do not substantially differ from the results obtained for the [0,1] event window.

3.5.2 Extensions

In this section, we repeat the analysis by investigating upgrades instead of downgrades. Information on rating assessments seems to be asymmetric, at least for Standard & Poor's ratings (Bissoondoyal-Bheenick, 2012), in the sense that the absolute impact of positive rating events is smaller than the impact of negative events; this asymmetry is well documented (e.g., Gande and Parsley, 2005; Ferreira and Gama, 2007; Hooper et al., 2008; Li et al., 2008; Afonso et al., 2012; Correa et al., 2014; Caselli et al., 2016). As in section 3.4.1, we start by dividing our sample of return countries according to the share of foreign asset holdings of banks relative to the return country's gross domestic product and perform an event study for each group separately with the results being presented in Table 8. We find mixed results with respect to abnormal foreign bank returns following rating upgrades and upon

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[19] In our sample, the correlation between trade flows and foreign claims is approximately 60%.

the influence of foreign asset holdings. There is no evidence to support the proposition that abnormal returns increase with the amount of banks' foreign exposure. Additionally, abnormal returns found are of low statistical significance.

	Low foreign claims (Below 33% percentile)					Medium foreign claims (Between 33% and 66% percentile)					High foreign claims (Above 66% percentile)				
# Obs.	649					648					649				
	CAAR	PT		NPT		CAAR	PT		NPT		CAAR	PT		NPT	
[-10;10]	-0.25%	0.33		1.16		-0.22%	0.20		0.49		0.44%	0.69		2.17	**
[-5;5]	0.07%	0.02		0.69		0.63%	1.00		2.53	**	0.42%	0.47		1.22	
[-3;3]	0.30%	0.58		2.42	**	0.45%	0.55		3.32	***	0.46%	0.91		2.40	**
[-1;1]	0.05%	0.96		1.47		0.26%	0.65		2.22	**	0.29%	1.43		2.33	**
[0;1]	-0.09%	0.49		0.06		0.34%	1.62		2.53	**	0.14%	1.25		1.30	
[-1;5]	0.46%	1.85	*	2.49	**	0.82%	1.40		3.63	***	0.61%	2.26	**	2.09	**
[-5;1]	-0.35%	-0.62		1.08		0.07%	0.37		1.04		0.09%	-0.03		0.52	
[-5;-3]	-0.34%	-1.00		-0.26		-0.12%	0.04		0.01		-0.16%	-0.66		-0.35	

Notes: This table shows the cumulative average abnormal return CAAR [t1,t2], starting on t1 and ending at t2 relative to a rating upgrade on the event day (t0). CAARs are calculated for non-event country bank stocks. PT reports test statistics and statistical significance levels based on the parametric test statistic proposed by Kolari and Pynnönen (2010), while NPT comes from the non-parametric generalized sign test according to Cowan (1992). ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

Table 8: Abnormal bank returns in non-event countries after upgrades

Comparing the results from Table 5 and Table 8, we can indeed observe the asymmetry between negative and positive rating events as described in earlier studies because the absolute magnitude of abnormal returns for downgrades exceeds that for upgrades. Generally, these results are consistent with Ferreira and Gama (2007) and Caselli et al. (2016), who find positive stock market returns abroad of 0.22% and 0.39%, respectively, by considering country characteristics. For the crisis period from 2007 to 2011, Williams et al. (2013a) also find comparable returns for 2007 (0.73%) and 2009 (0.53%), while they find negative returns for banks in 2010 (-0.48%).

To deeper investigate the role of banks' foreign asset holdings in the case of sovereign upgrades, we perform the multivariate analysis used in section 3.4.2 and apply equations (3.1) and (3.2) to our sample of positive rating events. The regression results presented in Table 9 show that banks' abnormal returns increase with the amount of foreign asset holdings, as coefficients are positive throughout all specifications. However, the statistical significance is definitely lower for rating upgrades than for downgrades and the economic effect is small and below 10%.

	(1)	(2)	(3)	(4)	(5)	(6)
Strenght definition		$\Delta Rating_j$	$\Delta Rating_j$	AR_j	$\Delta Rating_j$	AR_j
Log(FC_{ij})	0.076*	0.103**	0.106**	0.125**	0.100**	0.135**
	(0.042)	(0.048)	(0.052)	(0.058)	(0.048)	(0.057)
$Strenght_j$		0.043	0.047	0.053		
		(0.036)	(0.041)	(0.054)		
Log(FC_{ij})×Strenght $_j$			-0.003	-0.008		
			(0.023)	(0.026)		
D_$Strength_j$					0.084	0.146
					(0.445)	(0.350)
Log(FC_{ij})×D_Strenght $_j$					-0.016	-0.196
					(0.213)	(0.139)
$Rating_i$		0.039	0.038	0.034	0.038	0.034
		(0.038)	(0.038)	(0.041)	(0.038)	(0.041)
$Rating_j$		0.059**	0.059**	0.029	0.052*	0.032
		(0.029)	(0.029)	(0.032)	(0.029)	(0.034)
$Revision_j$		0.334	0.332	0.336	0.358	0.392*
		(0.224)	(0.224)	(0.224)	(0.235)	(0.237)
Log($Distance_{ij}$)		0.070	0.071	-0.072	0.068	-0.083
		(0.064)	(0.064)	(0.073)	(0.064)	(0.073)
FE country i	yes	yes	yes	yes	yes	yes
FE country j	yes	yes	yes	yes	yes	yes
year FE	yes	yes	yes	yes	yes	yes
# Obs.	2,013	1,888	1,888	1,246	1,888	1,246
F-statistics	4.349***	4.316***	4.411***	5.681***	4.270***	5.871***
Economic effect (1 SD Log(FC_{ij})/ SD($CAAR_{ij}$))						
Full	5.46%	7.43%				
D_$Strenght_j$=1					6.11%	-4.42%
D_$Strenght_j$=0					7.24%	9.86%

Notes: The dependent variable is the cumulative average abnormal return CAAR [0,1] of bank stocks in non-event countries after sovereign rating upgrades. The subscript i refers to characteristics of the return country, j refers to characteristics of the rating country and i,j denotes interconnection variables between both countries. All variables are defined in Appendix A.2. Results come from a fixed effect ('within') regression with heteroscedasticity-robust standard errors (White, 1980) clustered at the i-country and j-country pair level. ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

Table 9: Multivariate regression results for foreign sovereign upgrades

Additionally, we find that the size of the rating upgrade does not affect foreign banks' stock prices compared to the market index. As in section 3.4.2, we use two different proxies for the strength of the rating event, but neither our proxy for the change in the rating (*$\Delta Rating_j$*) nor the abnormal returns of banks in the event country (*AR_j*) yield significant results when integrated either as an additional control variable (column 2) or as interaction terms in columns (3) and (4). As shown in columns (5) and (6), this result also holds when we again replace the continuous measures with dummy variables that are equal to 1 when the upgrade is strong and zero otherwise. For rating changes, we specify that strength equals one if the numerical value of the event country's comprehensive rating increases by more than 1.8 points, which equals at least two categories in the alphabetical rating and represents the 95% percentile. For the abnormal bank returns in the event country, we specify strength as those events in which the national stock market returns of banks belong to the upper 10% percentile, which equals 2.9% in our sample.

With respect to our control variables, the observed coefficients are consistent with the observed asymmetry between upgrades and downgrades. The return country rating is not important for financial markets, while a higher event country rating gradually increases abnormal returns of foreign banks in some specifications. Rating revisions are of weak significance in one specification only, and the geographical distance, which is highly significant for downgrades, is not relevant for positive rating events.

To summarize the findings of our analysis for rating upgrades, we find minor evidence in favor of our second hypothesis and no evidence supporting our third hypothesis. Banks' foreign asset holdings slightly affect the strength of sovereign rating spillover effects on foreign banks in cases of positive events, and the strength of the rating upgrade is no moderating determinant for the pricing in financial markets.

3.6 Conclusion

The existing literature has proven that sovereign rating actions not only interfere with domestic financial markets but also impact foreign sovereign bond spreads and foreign financial markets. One aim of our analysis was to determine whether sovereign rating events caused by S&P rating assessments induce significant abnormal returns in foreign bank shares and if these abnormal bank returns are more severe than the response of foreign stock markets in general. Even today, this issue has been investigated by only a limited number of studies. Second, we investigate whether banks' foreign asset holdings play an important role in the transmission of spillovers from sovereign rating assessments to foreign banks.

In the first stage of our analysis, we use a traditional event study approach and provide strong evidence for our first hypothesis that spillover effects do exist and that those effects spread in particular to banking sectors in other countries. Additionally, since we find the magnitude of abnormal returns to increase along with the amount of banks' foreign asset holdings, our results provide a first indication in favor of our second hypothesis that the strength of the spillover depends on the banks' foreign exposure in the event country. In the second stage of our analysis, we perform a multivariate analysis and control for other potential influencing factors to confirm our findings of the importance of foreign asset holdings for the international spillover effects of rating downgrades. Unlike previous studies, we use consolidated foreign exposure to all counterparties in the event country to assess the relevance of transmission effects, and we find that financial interconnection is indeed an important determinant of international spillover effects.

While the economic effect of foreign claims on abnormal returns of banks in non-event countries in our baseline regression is moderate, for severe events, defined as a strong stock market reaction of event-country banks to the rating change, we find huge economic effects with a one-standard-deviation increase in foreign claims leading to a decrease in abnormal returns of non-event country banks of more than one-half of the CAAR's standard deviation. This effect is robust throughout various model specifications and robustness analyses and we find even higher economic effects for the years before 2007 and for subsamples from which GIIPS countries are excluded.

4 Competition in fragmented markets: new evidence from the German banking industry in the light of the subprime crisis

4.1 Introduction

The current financial crisis has clearly demonstrated the importance of a stable financial system to economic growth and welfare. In this system, banks play a vital role because they attract short-term deposits from many small investors and grant long-term loans to borrowers. In addition, the banks' role as intermediaries allows them to provide liquidity to depositors while also protecting borrowers from the liquidity needs of their investors (Diamond and Dybvig, 1983; Diamond and Rajan, 2001). The banks' abilities to diversify by financing independent projects further reduces information asymmetry and the costs of delegation (Diamond, 1984) and enables banks to transform indivisible, illiquid and risky assets into divisible, liquid and (nearly) riskless liabilities. These transformation activities traditionally explain the advantage of financial intermediation. However, at the same time, they expose banks to the risk of runs in that the expectation of a bank's failure may, in the sense of a self-fulfilling prophecy, actually initiate the failure. Further, the failure of a single bank may have contagion effects on the whole banking system either by creating a panic among depositors or by affecting the interbank lending relationships.

In this context, large banks are of particular importance because their failure could pose significant risks to other financial institutions and the financial system as a whole. Specifically, a large bank's failure could trigger a systemic crisis that negatively affects the monetary system and real production (Diamond and Dybvig, 1983; Stern and Feldman, 2004). To ensure financial stability, those institutions considered as "too big to fail" might implicitly or explicitly be protected by public guarantees or subsidies, as observed during the subprime crisis.

The probability of default of a systemically important bank may depend on the degree of competition in the financial industry. According to the *charter value hypothesis,* banks facing a lower degree of competition can earn monopoly rents and will hold higher capital buffers to preserve those rents for the future. Consequently, increasing competition will erode rents, trigger excessive risk-taking (Besanko and

Thakor, 1993; Boot and Greenbaum, 1993; Hellmann et al., 2000) and thus decrease financial stability. Though not undisputed (for a deeper investigation, see Carletti and Hartmann, 2002; Jiménez et al., 2010; Vives, 2010), this theory is supported by a significant number of empirical studies. For example, Keeley (1990) analyses the U.S. banking market and finds that competition is negatively related to bank solvency and positively related to the perceived bankruptcy risk (measured as the risk premiums for uninsured certificates of deposits). He concludes that decreasing charter values induced by liberalisation and deregulation encourage risk-taking. Thus, he argues that increasing competition at least partially contributes to the fragility of the banking sector. Additionally, Beck et al. (2006) analyse data for 69 countries from 1980 to 1997 and support this view by finding that concentrated banking systems are less likely to experience systemic crises.

In contrast, Boyd and Nicoló (2005) develop a theoretical model and claim that market power leads to higher loan rates, which, in turn, create moral hazards. Specifically, entrepreneurs will choose riskier projects and thereby lower the quality of banks' loan portfolios while simultaneously increasing bankruptcy risk. However, both studies rely on structural measures of competition, as they assess competition based on concentration measures (Beck et al., 2006) or the number of institutions in the market (Boyd and Nicoló, 2005). Those measures are, in fact, a weak proxy for competition because they do not explicitly account for the conduct of banks, as mentioned by Shaffer (1982b) and empirically verified by Claessens and Laeven (2004) and Schaeck et al. (2009).

This shortcoming becomes even more important in fragmented banking systems, such as those in Germany or the U.S., where a large number of institutions operate in a specific local area with only a limited number of rivals. Those institutions may even operate as monopolists, a fact that remains undiscovered by those studies using structural measures as well as the multi-country studies using non-structural measures relying on the average degree of competition in a country. In particular, the German banking market is often criticised for being outdated and 'overbanked' by the Directorate-General for Competition of the European Commission and by large private banks. Especially savings and cooperative banks – also known as trustee savings banks and credit unions in other jurisdictions – often apply regional or territorial principles to their business models, which means that a specific local area, such as a city or administrative district, is reserved for an individual institution that is not directly competing with other similar institutions (through its network of branches) but is at least indirectly competing with other institutions of the respective pillar through other means, such as electronic banking (for a brief description of the German banking market, see Gischer and Stiele, 2009). The claim is that regional demarcation or a possible non-profit-maximizing behavior of the savings and cooperative banking group – in addition to the legal protection of these institutions provided by the rules governing their ownership structures – prevent a competitive equilibrium from emerging with negative effects on private banks. In this context, it should be noted that large private banks experienced significant losses during the subprime crisis and received partial governmental support, whereas small and medium-sized cooperative and savings banks seemed to play a stabilising role; these observations may be consistent with the charter value hypothesis.

Following this line of reasoning might create conflicts for political and regulatory decision makers, as they will struggle with a possible trade-off between competition and financial stability. Although financial stability may benefit because of hypothetical competitive advantages of cooperative and savings banks, this might also increase the risk of having to bail out large private institutions that suffer from competitive disadvantages. As a result, these banks may be unable to build up adequate capital buffers or may have incentives to take excessive risks, which might negatively affect financial stability.

The aim of this paper is to evaluate the degree of competition in the German banking industry and to reveal potential imbalances in competitive conduct. To that end, we complement and extend the existing literature on this issue in several respects. First, to the best of our knowledge, this study is the first since Lang (1997) to empirically investigate the competitive environment of universal banks in Germany. Analysing this issue is important because these banks provide a wide range of financial services to the entire German population and may therefore be more vulnerable to bank runs than more specialised institutions (e.g., savings and loan associations, business development banks, central institutions, specialised financing institutions or the so-called Landesbanken), whose inclusion in the sample could distort the results. Second, whereas previous empirical studies have assessed the average competitive stance of German banks within the context of multi-country studies, we will explicitly consider the high level of fragmentation in this industry by dividing the sample into characteristic groups according to the sector and size of the banks. In this manner, we will provide appropriate evidence addressing whether certain institutions show different competitive behaviors than others and whether the three-pillar structure of the market might generate competitive discrimination against private banks. Third, we will overcome the various methodological shortcomings of earlier studies. Unlike structural measures, the Panzar-Rosse revenue test allows us to explicitly assess the competitive conduct of banks. Further, because nearly all of the works applying this methodology to the German banking industry contain a critical misspecification or misinterpretation bias, the generalisability of their results may be limited. These problems create a need for further research to fill this gap. Fourth, this study is also the first to investigate how the experiences and various public rescue programs related to the subprime crisis have influenced the competitive stance within the German banking industry.

The remainder of this paper is structured as follows. Section 4.2 summarises the existing research techniques used to assess the degree of competition in a market. Section 4.3 briefly describes the Panzar-Rosse methodology used in this study and summarises the existing literature on this issue. Sections 4.4 and 4.5 contain the empirical model and the data used, respectively. The empirical results are presented and discussed in section 4.6, and section 4.7 concludes.

4.2 Measures of Competition

The existing research techniques used to assess the degree of competition in a market can be divided into two major streams: structural and non-structural approaches (see Bikker and Haaf, 2000, for a detailed overview). As the name suggests, structural approaches aim to measure the degree of competition by examining the market structure with concentration ratios (e.g., the k-bank ratio, which is the share of assets held by the top k institutions) or indices (e.g., the Hirschman-Herfindahl Index).

Those measures rely on the theoretical predictions of the traditional Structure-Conduct-Performance paradigm (SCP) of Mason (1939) and Bain (1956) and the efficiency hypotheses developed by Demsetz (1973) and Peltzman (1977).

Structural measures of competition may lead to theoretically and empirically ambiguous results for two main reasons (for a detailed overview, see Berger et al., 2004 or Shaffer, 2004): First, the contestability theory of Baumol (1982) raises questions about the linkage between the concentration of a market and the competitive behavior in it. Second, according to Shaffer (2004), observed anti-competitive behavior (i.e., the ability to set prices above marginal costs) may be caused by either conduct or efficiency.

Consequently, the structure of the banking market is a weak measure for drawing conclusions on competition or market power because *"competition is actually a property of conduct rather than structure"* (Shaffer, 1982b). This notion is also supported empirically by studies from Claessens and Laeven (2004) and Schaeck et al. (2009). Hence, there is a need for methods that go beyond structural approaches. The non-structural techniques from the New Empirical Industrial Organization (NEIO) literature try to assess competitive conduct without referring to detailed information about market structure. Instead, they focus on estimating market power by observing the behavior of banks.

The two most popular non-structural approaches (see Shaffer, 2004 for an extensive comparison) that have often been applied to the banking industry are the conduct parameter method (CPM) (Bresnahan, 1982; Lau, 1982; Bresnahan, 1989) and the revenue test developed by Panzar and Rosse (Rosse and Panzar, 1977; Panzar and Rosse, 1982, 1987).

However, because the CPM has certain disadvantages compared with the revenue test, the CPM is not applied in this study. Specifically, we do not apply the CPM for two main reasons: First, the necessary data requirements concerning the market demand function and the firms' marginal cost function are not met. Second and more importantly, the CPM can exhibit an anti-competitive bias if the sample fails to cover complete markets (Shaffer, 2001). Considering the characteristics of the fragmented

German banking market, the latter argument raises reasonable doubts concerning the appropriateness of the CPM, whereas Panzar and Rosse's revenue test is robust to the extent of the market covered in the study. Thus, the following section describes the revenue test in greater detail as the model used in this study.

4.3 The Panzar-Rosse revenue approach

4.3.1 Underlying economic theory

To assess the competitive behavior of firms, Panzar and Rosse (Rosse and Panzar, 1977; Panzar and Rosse, 1982, 1987) use a standard comparative statics equilibrium model in which each firm maximises its profits by setting its marginal costs (MC) equal to its marginal revenues (MR): $MC_i\ (y_i,\ w_{i,j},\ t_i) = MR_i\ (y_i,\ n,\ z_i)$. At the market level, the zero profit constraint holds: $R_i^*\ (y^*,\ n^*,\ z) - C_i^*\ (y^*,\ w,\ t) = 0$.[20] Based on a reduced-form revenue equation, Panzar and Rosse derive an index, the so-called '*H*-statistic', that estimates market power based on the extent to which changes in input prices are reflected in revenues. This market power is defined as the sum of elasticities of total revenues with respect to each input price (w_j):

$$H = \sum_{j=1}^{n} \left(\frac{\partial R_i^*}{\partial w_{j_i}} \frac{w_{j_i}}{R_i^*} \right). \tag{4.1}$$

Following the theory of the firm, Panzar and Rosse show that *H* must be zero or negative for a neoclassical monopolist, collusive oligopolist or conjectural-variations short-run oligopolist.[21] Any increase in input prices will shift the firms' marginal cost curve upwards, which would cause the equilibrium output to fall. Depending on the firms' perceived elasticity of demand (e_i), *H* will equal zero in the case of a constant unitary elastic demand ($e_i = 1$) and will be negative if $e_i > 1$.[22] Panzar and Rosse

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[20] Here, y = bank output, n = number of banks in the market, z = exogenous variables shifting the revenue function, w = vector of m factor input prices, t = vector of exogenous variables shifting the cost function and the asterisk (*) represents the equilibrium values.

[21] Vesala (1995) proves that this result also holds for monopolistic competition, where the threat of entry does not exist. A visual proof of the formal Panzar-Rosse approach can be found in Shaffer (1982a) or Vesala (1995).

[22] The condition of an elastic demand curve is complied with the second-order conditions for a profit-maximising monopolist because they require the marginal cost curve to cut the marginal revenue

(1987) also show that if the monopolistic firm employs a constant returns to scale Cobb-Douglas technology, the absolute magnitude of H is also relevant because it yields an estimate of the Lerner Index of monopoly power $L = (e_i - 1)/e_i = H/(H - 1)$ and H can thus be interpreted as a decreasing function of e_i, where lower values indicate more monopoly power.

In contrast, Panzar and Rosse (1987) use the symmetric Chamberlinian model of a free entry equilibrium to prove that positive values of H are consistent with monopolistic competition. Under monopolistic competition, firms produce more, and the price (P) is lower than the price under monopoly conditions. Thus, monopolistic competition prevents firms from maximising their individual profits. In this model, the revenues of each firm depend on the decisions made by their actual or potential rivals. However, the model also recognises the differences among firms (e.g., differences in product differentiation strategies, product quality and reputation, although their core business is quite homogenous; Bikker and Haaf, 2002) by assuming an inverse demand function for each firm.

In the limit case, where firms' products are considered to be perfect substitutes, the Chamberlinian model produces the perfectly competitive solution as e_i approaches infinity (Vesala, 1995). In this situation, an increase in input prices will shift the firms' average and marginal cost curves upwards and reduce (individual and aggregate) output because $MR_i = MC_i = P$. Because each firm initially produced at the minimum point of its average cost (AC) curve in equilibrium, the output reduction will result in losses for the individual firm if we assume that the profits are zero at the market level. These losses will occur because $AC_i > MR_i = MC_i = P$, which will induce some firms to exit the market. As market demand remains unchanged, these exits will, in turn, lead to excess demand in the market and an upward shift in the demand curve for each surviving firm until the original (individual) output level is attained at $P = MC_i = AC_i$. As a result, the increases in

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curve from below. This requirement indicates that the monopolist always operates on the upward-sloping part of the revenue curve, where the marginal revenues are positive. Thus, a monopolist would never choose to produce on the inelastic part of the demand curve (Shaffer 1982a; Vesala, 1995).

price and total revenue equal the shift in input prices such that $H = 1$ (Shaffer, 1982a; Panzar and Rosse, 1987).[23]

Vesala (1995) further proves that in a free entry Chamberlinian model H is an increasing function of e_i, where higher values indicate that the firms exercise less market power. Together with a central assumption of the Chamberlinian model, which states that the elasticity of perceived demand facing each individual firm is a non-decreasing function of the number of rival firms, this result provides a positive relationship between H and the number of banks. Additionally, as mentioned by Bikker and Haaf (2002), this result could, if loosely interpreted, create a link between the Panzar-Rosse approach and the structural competition measures in the form of an inverse relationship between H and firm concentration. However, the results of studies from Shaffer and DiSalvo (1994), Shaffer (2002) or Coccorese (2009), who find high values of H even for monopolistic firms or duopolies, suggest that this link is an explanatory indication rather than a causal relationship.

4.3.2 Misinterpretation and misspecification of the Panzar-Rosse H-statistic

Previous empirical literature applying the P-R test has interpreted competitive conduct according to the values of H in accordance with the economic theory described above. However, the economic theory itself is based on the assumption that banks behave like profit-maximising firms operating in a contestable market with normally shaped and homogenous cost functions. As shown by Bikker et al. (2012), the interpretation of H crucially depends on two basic properties related to the original derivation of the model: First, it is assumed that marginal costs, like total costs, are homogenous of degree 1 in all input prices. Second, the marginal cost function is required to be stable, meaning that firms' production technology remains unchanged throughout the observation period, thereby permitting the conclusion that all changes in marginal costs are driven by changes in input prices.

[23] Shaffer (1982a) also shows that the cases of a natural monopoly in a perfectly contestable market and a sales-maximising firm subject to a breakeven constraint are also consistent with $H = 1$.

It is also important to note that the inclusion of scaling factors fundamentally changes the nature of the model and may cause significant bias. As mentioned by Vesala (1995), because models using the ratio of revenues to total assets as a dependent variable provide a price equation instead of a revenue equation, *H* will be seriously biased towards unity in some cases of monopoly or oligopoly and lead to the wrong inference about the degree of competition (Bikker et al., 2006). Moreover, a similar misspecification will occur if explanatory variables are included to account for economies of scale (e.g., total assets, sum of deposits or equity) because the coefficients that comprise *H* will represent the response of total revenue to input prices at a fixed output scale. This fixed output scale equals the change in price times the fixed output and would thus render a revenue equation with scaling variables indistinguishable from a price equation (Bikker et al., 2006; Bikker et al., 2012). As a result, neither a reduced-form price equation nor a scaled revenue equation can be used to infer the degree of competition, and only the unscaled revenue equation can yield a valid measure of competitive conduct (Bikker et al., 2012).

Another piece of information needed to verify the results of the Panzar-Rosse approach is whether the sample observations represent long-run equilibrium points, meaning that firms have already exited the market after a cost increase. It has been shown that even competitive firms can exhibit negative values of *H* if the market is in structural disequilibrium. For empirical testing, Shaffer (1982a) suggests that researchers rerun the Panzar-Rosse test with the return on assets (ROA) or the return on equity (ROE) as the dependent variable, as long as accounting profits are sufficiently correlated with economic profits (Bikker et al., 2012).[24] According to the common interpretation of this equilibrium test, a finding of $H^{ROA} < 0$ would indicate disequilibrium, whereas a finding of $H^{ROA} = 0$ would confirm equilibrium. The rationale behind this approach is that in a free-entry equilibrium with zero economic profits, market forces should equalise the risk-adjusted rates of return across homogenous firms such that the equilibrium rates of return are not correlated with

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[24] In this context, it is worth mentioning that the use of ROE as a dependent variable is restricted to cases in which equity is measured at market value Shaffer (1982b). Further, because ROA or ROE can take negative values, the ratios need to be adjusted (e.g., ln (1+ROA)) to be included as logarithms. This fact seems to have been ignored in several studies.

input prices (Shaffer, 1982a). Bikker et al. (2012) show that since its introduction, this test has been widely used without further scrutiny. They prove that a rejection of $H^{ROA} = 0$ does not necessarily imply disequilibrium because under imperfect competition, economic profits are positive and ROA may respond to input prices so that H^{ROA} need not equal zero, even if the market is in structural equilibrium. Therefore, unlike the traditional application, the test provided by Shaffer should be considered a joint test of both competitive conduct and long-run structural equilibrium.

As a result, there are several caveats to consider when assessing competitive conduct, even when *H* is calculated correctly on the basis of an unscaled revenue equation. Furthermore, meaningful interpretation requires additional information about costs, market equilibrium and, possibly, market demand elasticity. However, obtaining such information is not a straightforward task, and in the case of market demand elasticity, it is an extra step that is not necessary for a standard P-R approach. Consequently, following Bikker et al. (2012), the *H*-statistic boils down to a one-tail test of conduct that is neither an ordinal nor a cardinal measure and therefore is less informative than previous literature has suggested. Despite these constraints, the P-R test can still be used to differentiate whether or not firms possess market power. Assuming a correctly specified unscaled revenue equation, *H* can be interpreted as follows (making clear that without further information about cost functions, we cannot distinguish between long-run competition and monopolistic competition, and also that a significantly positive value of *H* is inconsistent with standard forms of imperfect competition):

competitive conduct	AC function	H (unscaled revenue eq.)	H^{ROA}
long-run competition	U-shaped flat	H=1 H<0 or 0<H<1 possible	$H^{ROA}=0$ $H^{ROA}=0$
short-run competition	U-shaped	H<0 possible (Shaffer 1982a, 1983a) 0<H<1 possible (Rosse and Panzar, 1977)	$H^{ROA}<0$ $H^{ROA}<0$
monopoly	U-shaped flat	H<0 H<0	$H^{ROA}<0$ and $H^{ROA}=0$ possible
oligopoly	U-shaped flat	H<0 H<0	$H^{ROA}<0$ and $H^{ROA}=0$ possible
monopolistic competition	U-shaped	0<H<1 (Rosse and Panzar, 1977), but H<0 possible	$H^{ROA}<0$ and $H^{ROA}=0$ possible

Table 10: Summary of properties for interpreting the H-statistic[25]

Additionally, for empirical application, the transfer of the NEIO approaches from the "classical" industry to banks requires that the inputs and outputs be specified according to some model of a banking firm. Given the existing empirical literature (Hughes and Mester, 1993b, 1993a; Hughes et al., 2001; Shaffer, 2004) and the fact that the Panzar-Rosse methodology was originally developed for single-product firms (Panzar and Rosse, 1987), this study, similar to the majority of other Panzar-Rosse studies, adopts the intermediation approach (see Sealey and Lindley, 1977; Colwell and Davis, 1992). We consider banks to be intermediaries of financial services that use labor and physical capital to collect and transform deposits and other funds into loans and other investments.[26] Consequently, we assume that all funds are inputs to the banks' production function, and we include the interest payments on deposits in a bank's cost function. Furthermore, Hempell (2002) discusses whether the assumption of perfect competition in input markets, where banks act as price takers, collides with the use of individual, bank-specific input prices. She concludes that this conflict might also be interpreted as the result of local factor markets, especially for deposits. Additionally, downward biases might arise if the banks in the sample typically use long fixed-rate maturities in their contracts and are, even in perfectly competitive markets, unable to make direct price adjustments, implying lower elasticities (Hempell, 2002).

[25] Source: Based on Bikker et al. (2012).

[26] Sealey and Lindley (1977) further consider the banks' production as a multi-stage process that uses deposits as an intermediate output for the production of loans. As Hempell (2002) points out, this view is supported by the rising importance of interbank deposits, which certainly do not meet the criteria of final outputs.

Despite the described assumptions and limitations, the Panzar-Rosse approach incorporates several advantages that render it a valuable and efficient tool for assessing the competitive conditions of banks. Because this approach uses revenues (which can easily be obtained from banks' profit and loss accounts) instead of output prices and quantities, data availability becomes less of a constraint, and the reduced form revenue equation can be estimated even though the structural equations cannot be estimated (Hempell, 2002). Additionally, the methodology allows for differences in the production function and type of operation by utilising bank-level data (Staikouras and Koutsomanoli-Fillipaki, 2006). Another important aspect in this context is that the Panzar-Rosse approach does not require a market to be identified a priori and is thus robust to any implicit market definition. Because the *H*-statistic is based on firm-level data, the estimation measures the average conduct of a firm in each of its markets (if it operates in more than one market) (Shaffer, 1994). Nevertheless, the researcher implicitly defines the market under consideration with the selection of firms included in the sample (Gutiérrez de Rozas, 2007). According to Bikker et al. (2012), the coexistence of firms of different sizes within the same market is strong evidence either of disequilibrium or of locally constant average costs, both of which undermine the reliability of the P-R test and create the need for further testing before estimating a P-R model. In contrast, a sample of firms from multiple markets could exhibit a wide range of sizes without apparent problems for the P-R approach. In this context, it is important to realize that the German banking market is characterised by regional demarcation and high fragmentation. Thus, the coexistence of differently sized banks is not necessarily evidence of disequilibrium or flat average costs; the P-R test is therefore a valuable tool for assessing competitive conduct in Germany.

4.3.3 Related Literature

The Panzar-Rosse methodology has been extensively applied to the banking sector since Shaffer's (1982a) pioneering study. Whereas Shaffer observes a limited sample of New York banks, later researchers focus on the competitive conditions of banking markets in other countries by conducting single-country or multi-country studies. Despite the differences in the general estimation method, the functional form of the estimation equations, the specification of the variables used, the strategy used to identify time dependencies and the weights of the individual banks in the sample, monopolistic competition is determined to be the predominant condition in most banking markets (for a detailed overview, see Bikker et al., 2012).

The German banking market, which is of interest in this study, was initially included in the multi-country study of Molyneux et al. (1994). They, as well as several other researchers (see Bikker et al., 2012), find monopolistic competition to be the prevalent market condition for German banks. To the best of our knowledge, only three studies focus on the German banking market in the context of single-country studies, even though this market is the largest in the European Union (measured by the number of operating banks and total assets) and despite criticism that the market is uncompetitive because of the three-pillar structure and the regional demarcation of savings and cooperative banks.

The first study focusing on German banks was conducted by Lang (1997), who uses an unbalanced sample of 1,432 universal banks from all three banking sectors (private, cooperative and savings banks) from 1988 to 1992. He finds monopolistic competition for all groups and years, with increasing values of H over time, and the values are lower for savings and cooperative banks than for private banks.

Hempell (2002) examines bank data derived from the balance sheet and profit and loss statistics at the Deutsche Bundesbank for a wide unbalanced sample of 3,473 cooperative, savings, credit and foreign banks from 1993 to 1998. She distinguishes among small, medium-sized and large banks to account for size effects and also determines whether competition changes between two sub-periods (1993-1995 and 1996-1998). The observed behavior for all banks is consistent with monopolistic competition, but the credit, foreign and savings banks have significantly higher values of H than the cooperative banks. Furthermore, she finds that the cooperative and savings banks suffer a significant reduction in their H-values over time, whereas the credit banks and the overall sample do not. Finally, she discovers that H increases with bank size but does not change over time. This finding indicates that the differences between the two sub-periods are group-specific rather than size-specific.

Further, Gischer and Stiele (2009) apply the Panzar-Rosse methodology to a balanced sample of 428 savings banks from 1993 to 2002. They estimate *H* for the whole sample as well as for small and large banks separately and find that monopolistic competition is the prevalent market condition for all banks, even if the *H* for small banks is significantly lower than for large banks. The researchers also test whether the banks' competitive behavior varies over time and find a significant increase of *H* from the pre-EMU phase (1993-1997) to the period after the determination of the Eurozone member countries (1998-2002). Anyway, as described in section 4.3.2, neither differing *H*-values nor an increase in the value of *H* over time may be interpreted as an indication of differences in competitive conduct or increasing competition for each of the three studies discussed above.

Generally, the results of the studies assessing the competitive conditions in the German banking market indicate that banks behave in a manner consistent with the model of monopolistic competition (as defined by the traditional economic theory described in section 4.3.1), even though varying values of the estimated *H*-statistics are observed. This diversity may be due to different estimation techniques, the choice and definitions of variables, the database or the banks included in the sample. Given the fragmentation of the German market, we do not know whether the results stemming from multi-country studies are adequately differentiated to permit reliable conclusions. In addition, all of the studies (Lang, 1997 and Goddard and Wilson, 2009 being the only exceptions) contain either a critical misspecification bias from using a price equation or including scaling variables or both, or the studies interpret the P-R statistic as a continuous measure of competition, which limits their ability to assess competitive conduct. The studies also do not contain any information about cost structures or market demand elasticity, and they make use of the common interpretation of Shaffer's equilibrium test, which is misleading, as shown by Bikker et al. (2012). Hence, we can neither interpret the estimated *H*-statistics from these studies as an indication of monopolistic competition nor can we be sure that changes in *H* over time arise from changes in competitive conduct.

Consequently, the aim of this paper is to overcome these shortcomings by avoiding misspecifications and misinterpretation and accounting for the fragmented structure of the German banking market by dividing the sample into sub-groups according to bank size and by independently estimating *H* for each pillar. Moreover, our study is the first with respect to Germany since Lang (1997) that focuses on universal banks and on the changes in their competitive behavior throughout the course of the financial crisis.

4.4 Estimation Methodology

To translate the economic interrelations of the Panzar-Rosse approach into an applicable empirical model, Bikker and Haaf (2002) derive the reduced-form revenue equation for the empirical operationalization, which can generally be written in the following form:

$$\ln REV_{i,t} = \alpha + \sum_{i=1}^{m} \beta_i \ln FIP_{i,t} + \sum_{j=1}^{p} \gamma_j \ln BSF_{i,t} + e, \tag{4.2}$$

where *REV* represents the revenues, *FIP* is the factor input prices, *BSF* is the set of exogenous factors that refer to bank *i*'s cost or revenue function at time *t*, and *e* is a stochastic error term. The estimation is performed in logarithms to determine the required elasticities of revenues with respect to each input price, whereas *H* is calculated as the sum of all βs (Gischer and Stiele, 2009; Bikker et al., 2012). Consequently, to apply the approach of Panzar and Rosse to the set of German banks at hand and estimate the degree of competition as the sum of the factor price elasticities, we establish the following reduced-form revenue equation:[27]

$$\begin{aligned} \ln II_{i,t} &= \alpha + \beta_1 \ln FC_{i,t} + \beta_2 \ln PL_{i,t} + \beta_3 \ln PCE_{i,t} + \beta_4 \ln EC_{i,t} \\ &+ \gamma_1 \ln LNStTA_{i,t} + \gamma_2 \ln DPStSTF_{i,t} + \gamma_3 \ln EQtTA_{i,t} + \gamma_4 \ln LICtTL_{i,t} \\ &+ \gamma_5 \ OItII_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{4.3}$$

Following the majority of the existing literature, we use interest income (II) as the dependent variable to estimate the *H*-Statistic (Model I). This decision is consistent with the intermediation approach because financial intermediation is still the core

[27] To account for the yearly macroeconomic effects, we also included but did not explicitly report time dummy variables.

business of most universal banks. Alternatively, we estimate equation 4.3 with total income (TI) instead to account for the growing importance of non-interest income (Model II). In any case, the dependent variables are included with their absolute values to avoid the previously described misspecification bias. To check whether scaling does in fact change the results, we also estimate *H* for the full sample with the models primarily applied in the previous literature: a price equation using II/TA as the dependent variable (Model III) and the same equation including total assets (TA) as the scaling variable (Model IV).

With regard to the input factor prices, FC represents the funding costs, PL denotes the price of labor and PCE stands for the price of physical capital expenditure. We agree with Gischer and Stiele (2009) that equity is an important input for banks that is not considered by the majority of studies assessing the degree of competition in the banking sector. As capital adequacy rules limit the extent of outstanding credit and thus the opportunities to generate interest revenues, the input price for equity (EC) should be included in the estimation equation. Because the four input prices cannot be observed directly, several proxies have to be used instead. Therefore, the ratio of interest expenses to total funds (IE/TF) serves as a proxy for the annual funding rate; personnel expenses divided by the number of employees (PE/EMPL) reflect the price of labor.[28] The ratio of other operating expenses to fixed assets (OOE/FA) proxies for the price of capital expenditure[29], and the ratio of pre-tax profit to equity (PTP/EQ) measures the equity yield rate.[30]

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[28] Alternatively, the ratio of personnel expenses to total assets and the ratio of personnel expenses to the sum of loans and deposits are also applied to the dataset, but they turn out to be rather poor proxies.

[29] Resti (1997) argues that the book-value of fixed assets may be subject to distortions and thus proposes the use of an adjusted version. To verify this line of reasoning, we included alternative measures into the regression as a robustness check, but neither a modeled version (following Bikker et al., 2006) nor a version using the ratio of other operating expenses to total assets (OOE/TA) revealed fundamentally different results.

[30] As already mentioned by Shaffer (1982b) and admitted by Gischer and Stiele (2009), the return to capital is not an optimal measure for the price of equity capital at the individual bank level. However, as most of the institutions are not listed on the stock exchange and market models are inapplicable, another proxy is not available. Because we use natural logarithms in our model, 264 observations from 197 banks (approximately 2.1 percent of our final sample) were excluded from the estimation because of negative profits in some years.

Additionally, a number of control variables at the individual bank level may affect the banks' revenue and cost functions. The ratio of customer loans to total assets (LNStTA) mainly reflects the banks' business mix and asset composition. The ratio of customer deposits to total deposits and short-term funds (DPStSTF) mirrors the characteristics of the funding mix. According to Bikker et al. (2006), the equity to total assets ratio (EQtTA) accounts for leverage, which reflects the differences in the banks' risk preferences, and the ratio of other income to interest income (OItII) accounts for the increasing role of banking activities other than financial intermediation. Following Bikker et al. (2006), this explanatory variable is used in its natural form because all inputs are used to generate total income, such that $\ln(TI) = \ln(II + OI) \approx \ln(II) + OI/II$.[31] To account for the risk levels of the individual banks' loan portfolios, we also include the ratio of loan impairment charges to total loans (LICtTL) in the model. With regard to the expected signs of the bank-specific control variables, LNStTA and LICtTL should be positively related to the dependent variable because a higher ratio of loans offers more potential to generate interest revenues, and banks usually price riskier loans with higher interest rates. In contrast, a higher ratio of other income implies less interest income, which should lead to a negative sign of OItII. The coefficient for EQtTA might be negative because less equity may imply more leverage and hence more interest income (Molyneux et al., 1994). The coefficient might also be positive given that capital requirements increase proportionally with the risk level of a bank's portfolio (Bikker and Haaf, 2002). Variables are included with their natural logarithms (ln) to determine the required elasticities of bank i in year t.[32]

Equation 4.3 is estimated with a fixed effect ('within') regression, which makes explicit use of the panel structure of the dataset. Thus, we assume that the stochastic error term $\varepsilon_{i,t}$ can be divided into a bank-specific constant (u_i) and a remaining error term ($e_{i,t}$). The u_is do not vary over time, but they do vary between the different

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[31] Certainly, OItII was not a part of the regression when TI was used as the dependent variable (Model II).

[32] Because the numerator of LICtTL was negative for 477 observations from 343 banks (3.8 percent of our final sample observations), a natural logarithm was not available in those cases. However, the inclusion or exclusion of this variable has no significant effect on the overall results of our estimation.

banks and thus account for the differences across banks by reflecting the unobserved variables (which may or may not be correlated with the other variables included in the estimation equation) that shift the revenue function of a bank (Gischer and Stiele, 2009). To test whether the fixed effects model is appropriate to measure the significance of the bank-specific effects, we apply a series of specification tests. In a first step, an F-test (fixed effects) and a Breusch-Pagan-LM test (random effects) rejects the pooled OLS in favor of the individual effects. Finally, for private and savings banks, the Hausman test suggests performing a random effects estimation. However, because the overall results are robust to the type of test, the fixed effects estimation is applied to any sub-sample.

To explore whether the degree of competition varies among private, cooperative and savings banks as well as among banks of different size classes, we include group-specific interaction terms in the regression. Therefore, banks are classified into three sub-groups according to their size in terms of total assets in 2001, with small banks below 500 million EUR, large banks above 4 billion EUR and medium-sized banks somewhere in between. To account for natural macroeconomic growth, we allow those borders to increase by two per cent each year and categorise the banks into the size classes in which they have the most observations. According to this classification, approximately five per cent of the banks in the sample are considered to be large, whereas fifty-five per cent are small (for further details, see Appendix A.4). To test for significant changes over time, we multiply all of the variables with the interaction terms for two sub-periods: 2001-2006 (pre-crisis period) and 2007-2009 (crisis period).

To verify the competitive conditions based on the value of H, we apply several hypotheses tests. In this context, Bikker et al. (2006) mention the important distinction between one-sided and two-sided tests because it may strongly affect the outcomes of the tests. Therefore, we perform a one-sided test with H_0: $H \leq 0$ versus H_1: $H > 0$. Further, we perform a two-sided test with H_0: $0 < H < 1$ versus H_1: $H \leq 0$ or $H \geq 1$ and a two-sided test for perfect competition with H_0: $H = 1$ versus H_1: $H \neq 1$.

4.5 Data

The data used in this study are obtained from Bankscope, a global database containing banks' financial statements and other comprehensive information at a micro-level. Bankscope data have been used in a number of other studies addressing competition among banks (e.g., Claessens and Laeven, 2004). The values reported in this database were tested to be consistent with those reported in primary sources (see also Bhattacharya, 2003). The empirical analyses are based on an unbalanced panel including all private, savings and cooperative banks that were operating as universal banks in Germany from 2001 to 2009. We use data from consolidated accounts if available and from unconsolidated accounts otherwise. The full sample includes 2,554 banks. From this sample, 477 institutions are dropped because we lack data from the observation period for these banks. An additional 184 institutions are excluded after controlling for the banks with special functions, the central institutions from the savings and cooperative banking sector and the subsidiaries that are included in consolidated accounts of their mother banks (to avoid double-counting). Five more banks must be excluded from the dataset because of implausible observations.

Therefore, the final sample consists of 1,888 banks. Our sample contains a total number of 12,424 bank-year observations (on average, 1,380 banks per year).[33] We do not adjust the sample for bank mergers. In other words, merged banks are treated as two separate entities up to the year of merger, after which we only account for the acquiring institution. As noted by Kishan and Opiela (2000) and Hempell (2002), this approach implicitly assumes that the behavior of the merged banks (in terms of competitive stance and business mix) does not change because of the merger.

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[33] As the biggest German institution, the Deutsche Bank changed its accounting standards from US GAAP to IFRS in 2006. Therefore, to avoid distortions of the within estimator due to incomparable balance sheets, we treated the bank as two independent entities by using the US GAAP balance sheets until 2005 and the IFRS balance sheets from 2006 to 2009. Nevertheless, all of the reported results are robust to the inclusion or exclusion of this particular institution.

4.6 Empirical Results

4.6.1 Average degree of competition in the German banking industry

With regard to the average degree of competition for the sample of German universal banks, the estimated *H*-statistic ranges from zero to unity. This result is robust to the choice of either interest income or total income as the dependent variable, as the estimated *H* varies only slightly between 0.66 and 0.62. In any case, the main factor driving the *H*-statistic is the price for funds. The influence of the price for labor is clearly lower but positive. The costs of physical capital and equity hardly affect *H* although they are both positive and significantly different from zero. The control variables LICtTL, OItII and LNStTA show the expected signs and the ratio of equity to total assets is negatively related to the dependent variable, as predicted by Molyneux et al. (1994). This finding suggests that banks with a lower equity ratio – and a higher leverage – earn more interest income. Reflecting the differences in banks' risk preferences, a higher risk appetite might be caused by primary risk shifting from bank owners to depositors and other outside creditors. Finally, the ratio of customer deposits to total deposits and short-term funds is also negatively linked to interest income. One possible explanation for this relationship might be that customer deposits are a relatively stable and cheap source of funding compared to the wholesale and interbank lending market. As a result, banks with a high ratio of customer deposits might try to attract borrowers by sliding down the loan supply curve and charging lower interest rates on loans than competitors.

Model	I	II	III	IV
Funds	0.520***	0.466***	0.430***	0.434***
	(0.057)	(0.062)	(0.059)	(0.058)
Labour	0.099***	0.110***	0.071**	0.072**
	(0.035)	(0.037)	(0.034)	(0.034)
Physical Capital	0.028**	0.033***	0.026***	0.026***
	(0.012)	(0.012)	(0.008)	(0.008)
Equity	0.011***	0.015***	0.017***	0.017***
	(0.004)	(0.004)	(0.003)	(0.002)
***H*-statistic**	**0.66*** **	**0.62*** **	**0.54*** **	**0.55*** **
	(0.093)	**(0.099)**	**(0.099)**	**(0.099)**
Hypotheses testing	$0 < H < 1^a$	$0 < H < 1^a$	$0 < H < 1^a$	$0 < H < 1^a$
Equilibrium Test	$H^{ROA}=0^b$	$H^{ROA}=0^b$	$H^{ROA}=0^b$	$H^{ROA}=0^b$
LNStTA	0.099**	0.097**	0.119***	0.118***
	(0.049)	(0.048)	(0.020)	(0.020)
DPStSTF	-0.351***	-0.345***	0.141***	0.115***
	(0.090)	(0.087)	(0.018)	(0.017)
EQtTA	-0.163***	-0.124***	0.040***	0.029**
	(0.045)	(0.045)	(0.012)	(0.017)
LICtTL	0.025***	0.030***	0.020***	0.021***
	(0.004)	(0.004)	(0.002)	(0.002)
OItII	-0.308***	./.	-0.029***	-0.290***
	(0.009)		(0.012)	(0.017)
TA	./.	./.	./.	-0.052***
				(0.006)
F-value for fe	556.70	540.47	25.83	24.76
p-value	0.000	0.000	0.000	0.000
Chi^2 for re	17,910	17,854	8,930	9,012
p-value	0.000	0.000	0.000	0.000
Chi^2 for Hausman	204.17	214.88	2,588	2,930
p-value	0.000	0.000	0.000	0.000
R^2	0.35	0.26	0.84	0.84
F of regression	223.13	86.02	1,079	1,049

Notes: Fixed effects regression with 1,813 banks and 9,396 observations; heteroscedasticity-robust standard errors (White, 1980) in parentheses; time dummies included but not explicitly reported; *** = p < 0.01, ** p < 0.05, * = p < 0.1. [a] Null hypotheses for H ≤ 0 as well as H=1 were rejected (at a five per cent level); [b] H^{ROA} is either economically or statistically not different from zero. Model I = revenue equation with II as dep. var.; Model II = revenue equation with TI as dep. var.; Model III = price equation with II/TA as dep. var.; Model IV = price equation with II/TA as dep. var. and TA as scaling variable.

Table 11: Estimation results for the whole sample

The results shown in Table 11 are consistent with those of previous studies; however, their interpretation is not. Because we have no information about cost structures or market demand elasticity for the sample of German universal banks, we can only rule out any form of imperfect competition when hypothesis-testing reveals a significant positive value of *H*. In addition, comparing the correct specified revenue equations to the price equations that contain a misspecification bias reveals that the results differ in terms of changing signs for some control variables (DPStSTF and EQtTA) and the characteristically high model fit of the equations containing the scaling factors. However, we cannot confirm the expected bias towards unity; instead, the estimated *H*-values are lower than the *H*-values in the revenue model.

This result is another indication that German banks behave neither as monopolists nor collusive oligopolists, those cases where the impact of the bias is crucial.

The equilibrium test shows that the rates of return are not correlated with the input prices because the estimated H^{ROA} equals zero. Following Bikker et al. (2012) and considering the equilibrium test as a joint test of competitive conduct and long-run structural equilibrium, only two remaining interpretations are possible. The first is that German universal banks behave like long-run competitors with flat average cost functions. The second is that the competitive conduct of German universal banks is characterised by monopolistic competition in long-run equilibrium. In either case, the existence of monopoly power is definitely ruled out.

4.6.2 The influence of fragmentation on the estimated H-statistic

To investigate whether the high degree of fragmentation in the German banking industry distorts interpretations concerning the competitive stance based on average *H*-statistics for the whole market, we estimate equation 4.3 with interaction terms that refer to each of the different pillars and size groups. The results shown in Table 12 and Table 13 clearly indicate that average measures of *H* do not necessarily provide an adequate assessment of German banks' competitive conduct on submarkets.

The estimated *H*-values for the different groups show that *H* increases with bank size. Additionally, the inclusion of interaction terms allows us to test for the significance of the differences among the banks. The estimated *H* of small and medium-sized banks is significantly different from that of large banks, while the difference between small and medium-sized banks could not be verified. Because we have no further information, we can only confirm that none of the groups possess monopoly power. While small- and medium-sized banks may behave like long-run competitors with flat average cost functions or monopolistic competitors in long-run equilibrium, we have strong evidence that large banks operate in long-run competitive equilibrium because we cannot reject the null hypotheses of H=1 as well as H^{ROA}=0.

As in previous studies, the main driver of the difference in the *H*-statistic is the revenue elasticity for funds. The coefficient is 0.40 for the small banks and 0.75 for the large banks. The elasticity of labor is, as well as the elasticity for funds, also increasing with bank size while the costs of physical capital slightly impact the small and large banks but are of neither economic nor statistical significance for the medium-sized banks. With elasticities between 0.01 and 0.04, equity costs play a minor role for *H*, though they seem to be more relevant for the large banks.

	Small banks	**Medium-sized banks**	**Large banks**
Funds	0.401*** (0.047)	0.484*** (0.041)	0.746*** (0.042)
Labour	0.045** (0.021)	0.097*** (0.037)	0.164*** (0.061)
Physical capital	0.027** (0.013)	0.009 (0.017)	0.080** (0.038)
Equity	0.009* (0.005)	0.005 (0.005)	0.042*** (0.010)
***H*-statistic**	**0.48*** (0.062)**	**0.60*** (0.067)**	**1.03*** (0.072)**
Hypotheses testing	$0 < H < 1$[a]	$0 < H < 1$[a]	$H=1$[b]
Equilibrium Test	$H^{ROA}=0$[c]	$H^{ROA}=0$[c]	$H^{ROA}=0$[c]
LNStTA	0.158*** (0.055)	0.046 (0.078)	0.103 (0.088)
DPStSTF	-0.379** (0.189)	-0.285*** (0.075)	-0.549*** (0.117)
EQtTA	-0.188*** (0.057)	-0.169*** (0.060)	-0.050 (0.096)
LICtTL	0.026*** (0.006)	0.020*** (0.004)	0.043*** (0.007)
OItII	-0.318*** (0.066)	-0.304*** (0.007)	-0.197 (0.221)
No. of banks	1,045	691	77
No. of obs.	4,761	4,190	445

Notes: Fixed effects regression with heteroscedasticity-robust standard errors (White, 1980) in parentheses; R^2 of regression = 0.38; time dummies included but not explicitly reported; *** = $p < 0.01$, ** $p < 0.05$, * = $p < 0.1$. [a] Null hypotheses for $H \leq 0$ as well as H=1 were rejected; [b] Null hypothesis for H=1 could not be rejected (at a five per cent level); [c] H^{ROA} is either economically or statistically not different from zero

Table 12: Estimation results with interaction terms for different size groups

In addition to the differences among the size classes, Table 13 shows that the estimated value of *H* also depends on the pillar into which the bank is categorised. Testing for differences reveals that *H* is statistically significantly lower for cooperative banks than for savings banks. This difference is mainly due to the lower impact of funding costs on H for the cooperative banks. It is notable that the price of labor, with a coefficient of 0.37, has by far the greatest impact on private banks compared to cooperative and savings banks, which have coefficients of 0.04 and 0.08, respectively. However, we can again only confirm that none of the sectors possess monopoly power. Cooperative and savings banks seem to face long-run competition with flat average cost functions or monopolistic competition in long-run equilibrium. Additionally, we cannot reject the null hypotheses of H=1 as well as H^{ROA}=0 for private banks, which is strong evidence that they operate in long-run competitive equilibrium.

	Cooperative banks	**Savings banks**	**Private banks**
Funds	0.315*** (0.028)	0.471*** (0.042)	0.583*** (0.060)
Labour	0.044** (0.019)	0.079** (0.036)	0.366*** (0.092)
Physical capital	0.029** (0.012)	-0.005 (0.022)	0.132** (0.056)
Equity	-0.003 (0.004)	0.010** (0.005)	0.049*** (0.016)
***H*-statistic**	**0.39*** (0.037)**	**0.55*** (0.070)**	**1.13*** (0.060)**
Hypotheses testing	$0 < H < 1^a$	$0 < H < 1^a$	$H=1^b$
Equilibrium Test	$H^{ROA}=0^c$	$H^{ROA}=0^c$	$H^{ROA}=0^c$
LNStTA	0.048 (0.058)	0.275*** (0.069)	0.234** (0.096)
DPStSTF	-0.271*** (0.072)	-0.406*** (0.089)	-0.417* (0.225)
EQtTA	-0.103** (0.043)	-0.196*** (0.072)	-0.291** (0.136)
LICtTL	0.021*** (0.003)	0.020*** (0.004)	0.056** (0.027)
OItII	-0.380*** (0.042)	-0.726*** (0.174)	-0.318*** (0.008)
No. of banks	1,205	524	84
No. of obs.	5,788	3,275	333

Notes: Fixed effects regression with heteroscedasticity-robust standard errors (White, 1980) in parentheses; R^2 of regression: 0.42; time dummies included but not explicitly reported; *** = p < 0.01, ** p < 0.05, * = p < 0.1. [a] Null hypotheses for $H \leq 0$ as well as H=1 were rejected; [b] Null hypothesis for H=1 could not be rejected (at a one per cent level); [c] H^{ROA} is either economically or statistically not different from zero

Table 13: Estimation results with interaction terms for different sectors

Altogether, we find evidence that the estimated H-values of German banks differ substantially among institutions. These values depend on the relevant banking pillar and bank size because the estimated *H*-statistics of the respective subsamples significantly differ from one another. In this context, it is commonly argued that cooperative and savings banks maximise their profits and simultaneously fulfil other objectives (such as pursuing the public interest for savings banks and fostering the interests of their members for cooperative banks) that might cause differences in their competitive behavior. Nonetheless, the evidence of legal discrimination against private banks is rather weak. Neither cooperative banks nor savings banks possess monopoly power and we cannot be certain whether those institutions do not behave like long-run competitors with flat average cost functions. Additionally, the difference in *H*-values between the private banking sector and the other banking pillars is mainly defined by the costs of funds and labor. However, the price elasticity of labor clearly does not depend on the fact that certain employers operate as cooperative, savings or private banks or that certain of these institutions may be privileged by both their legal forms and because they are not allowed to merge with banks from other pillars.

Similarly, it seems reasonable to assume that the price elasticity for funds is less influenced by the legal form of an institution and more by its dependency on particular funding sources (such as stable regional retail funding with diversified customer deposits or volatile wholesale and interbank funding) based on its individual business model, which is free of choice and not subject to legal regulation. Thus, because we have no additional information about cost structures or market demand elasticity for our different subsamples, we have no definite proof of differing competitive conduct. Consequently, we are unable to unambiguously identify either particular institutional objectives or legal protection as a serious source of competitive imbalance.

4.6.3 Competitive stance and the subprime crisis

Another important question that this paper should answer is whether the experiences and various public rescue programs related to the subprime crisis have influenced the competitive stance in the German banking industry. Therefore, equation 4.3 is independently estimated for each pillar and size group, whereas each of the estimations contained interaction terms for the pre-crisis period (2001-2006) and the years of crisis (2007-2009).

Table 14 shows the results of this estimation for both the particular groups and for the whole sample. Regarding the German banks, the average *H*-statistic has clearly increased during the financial crisis, and hypothesis testing verifies that the two periods are significantly different from each other. This difference is due to the rising elasticities of all factor prices, although it is important to note that only the elasticities of labor and equity costs are significantly different in the pre-crisis and the crisis period (for further details, see Appendix A.5). Anyway, we cannot confirm that the observed changes affected competitive conduct among German banks because both hypothesis-testing for *H* and the equilibrium test show no difference between the two periods.

Sample	2001-2006		2007-2009		
	H-statistic (H_1)	*Hypotheses testing*	*H*-statistic (H_2)	*Hypotheses testing*	H_0: $H_1 = H_2$ p (F-test)
Overall Sample	0.57*** (0.074)	$0 < H < 1^a$ $H^{ROA}=0^c$	0.72*** (0.102)	$0 < H < 1^a$ $H^{ROA}=0^c$	0.010
Cooperative banks	0.38*** (0.043)	$0 < H < 1^a$ $H^{ROA}=0^c$	0.42*** (0.042)	$0 < H < 1^a$ $H^{ROA}=0^c$	0.286
Savings banks	0.49*** (0.096)	$0 < H < 1^a$ $H^{ROA}=0^c$	0.34*** (0.075)	$0 < H < 1^a$ $H^{ROA}=0^c$	0.068
Private banks	1.03*** (0.106)	$H=1^b$ $H^{ROA}=0^c$	1.12*** (0.045)	$H=1^b$ $H^{ROA}=0^c$	0.418
Small banks	0.44*** (0.082)	$0 < H < 1^a$ $H^{ROA}=0^c$	0.56*** (0.068)	$0 < H < 1^a$ $H^{ROA}=0^c$	0.025
Medium-sized banks	0.53*** (0.083)	$0 < H < 1^a$ $H^{ROA}=0^c$	0.57*** (0.071)	$0 < H < 1^a$ $H^{ROA}=0^c$	0.490
Large banks	0.82*** (0.111)	$0 < H < 1^a$ $H^{ROA}=0^c$	1.07*** (0.052)	$H=1^b$ $H^{ROA}=0^c$	0.032

Notes: Fixed effects regression with heteroscedasticity-robust standard errors (White, 1980) in parentheses; *** = p < 0.01, ** p < 0.05, * = p < 0.1. [a] Null hypotheses for H ≤ 0 as well as H=1 were rejected (on a ten percent level); [b] Null hypothesis for H=1 could not be rejected; [c] H^{ROA} is either economically or statistically not different from zero

Table 14: Estimated H-statistics for the pre-crisis and crisis period

Investigating the differences among the three pillars and size groups during the two sub-periods generates mixed results. Although the estimated *H*-values of the pillars seem to have changed during the crisis period, the difference is not significant because the null hypothesis of $H_1 = H_2$ could not be rejected for the cooperative and private banks but could be rejected for the savings banks only at a ten per cent level. Especially for private banks, we find strong evidence for long-run competitive equilibrium in both periods because we cannot reject the null hypothesis of $H = 0$ and H^{ROA} is not different from zero. This tendency also holds for the coefficients of the input prices for each factor. Although the elasticity of funds seems measurably lower for the savings banks during the crisis, the coefficients are not significantly different between the two periods for the savings banks and the private or cooperative banks. However, we cannot be sure whether cooperative and savings banks do not face long-run competition with flat average costs or monopolistic competition in long-run equilibrium in both periods.

In determining whether bank size is an indicator of changes in competitive conduct, the results are quite similar. The estimated *H*-values have increased for all of the size groups and those differences are significant for the small and large banks on a five percent level. Nevertheless, the interpretation of competitive conduct is not affected by these changes. In both periods, small- and medium-sized banks operate as either long-run competitors with flat average cost curves or monopolistic competitors in long-run equilibrium. For large banks, on the other hand, we find strong evidence for long-run perfect competition during the crisis. Nevertheless, the available information does not confirm a change in the competitive conduct of large banks because long-run competition (with flat average costs) is also a feasible interpretation for the pre-crisis period.

Again, the driving forces behind this development are mainly the costs of funds and labor, although the changes are not significant for all of the size groups. Even though the elasticities of funds increased for the small and large banks and decreased for the medium-sized banks, we cannot confirm the significance of those changes for any group. Given that some banks received partial governmental support, the constant elasticity of funds suggests that those instruments served to ease the situation in the funding market for all banks. However, this aspect needs further investigation that goes beyond the scope of this paper.

The importance of labor costs to interest revenues significantly increased for the medium-sized and large banks but did not change significantly for the small banks. The price of equity capital is also of growing importance. The increasing relevance of equity costs for interest revenues might be based on two associated developments. First, the uncertainty concerning the solvency of banks during the crisis caused investors to charge higher risk premiums, which raised the price of equity capital. Second, regulators ("Basel III") and the capital markets simultaneously expect banks to hold more equity to stabilise the financial industry and make it more resistant to future crises, which creates the need for extra equity. Thus, increasing equity prices and higher equity capital requirements might motivate banks to include equity costs into their pricing, which results in the increasing relevance for interest revenues.

Finally, it is important to note that the crisis has impaired the long-run equilibrium of the German banking market and that its effects on the lending portfolios of German banks will become more noticeable in the long run because of adjustments in banking regulations. Consequently, this issue needs additional research in the future when the Basel III regulations are fully implemented and more accounting data from the entire crisis period become available.

4.7 Conclusion

Using data for 1,888 universal banks operating in Germany from 2001 to 2009, this paper provides answers to three important questions concerning the competitive conduct in the banking industry. First, we find evidence that measuring competition at an average country level (as previous studies have done) not necessarily generates valid evaluations of fragmented markets, as a sophisticated investigation reveals significant differences among the estimated *H*-statistics of the banks in the three existing banking pillars and the different size classes. Second, although there are differences among the particular subsamples, we find no clear indication that either the particular objectives of cooperative and savings banks or the legal protection of those institutions impedes competition because monopoly power is ruled out for all of our subsamples. Additionally, we cannot be certain about significant differences in competitive conduct among German universal banks without further information about cost structures or market demand elasticity. Third, according to our data, estimation results do not confirm that there was a change in competitive conduct among German universal banks during the subprime crisis. However, this issue requires further investigation and analysis in the future using additional data from the entire crisis period.

With respect to the policy implications arising from these main findings, it is difficult to identify clear indications of discrimination against (large) private banks. Neither cooperative nor savings banks possess monopoly power, and differences in estimated *H*-values – which do not necessarily indicate differences in competitive conduct – might be related to diverging corporate objectives instead of legal protection. From this perspective, we find no distinct empirical evidence supporting the argument that the German banking system is outdated or overbanked and no evidence that large private institutions might suffer from competitive disadvantages or are at increased risk of being bailed out with negative consequences for financial stability. Consequently, the effects of initiatives aiming to equalise the competitive conditions of private banks and cooperative or savings banks – such as increasing the permeability of the three-pillar structure – are unpredictable from a competitive point of view if we cannot unambiguously confirm differences in competitive conduct.

With respect to financial stability, the consequences of such initiatives are even more ambiguous under the charter value hypothesis. According to this hypothesis, lowering the level of competition for systemically important financial institutions, allowing them to earn monopoly rents and build up capital buffers, might improve financial stability. However, this causes multiple problems. First, reducing the degree of competition, if possible at all, is exactly the opposite of the aim of the Directorate-General for Competition of the European Commission. Second, strengthening the competitive position of (large) private banks or systemically important financial institutions to (possibly) foster financial stability would certainly have negative effects on the competitive position and solvency of (small) cooperative and savings banks. Based on the stabilising role of those institutions during the subprime crisis, policy makers must ensure that increasing the stability of (large) private banks is not achieved by decreasing the stability of cooperative and savings banks. Third, the relationship between competition and financial stability – and the validity of the charter value hypothesis itself – is hotly debated in the economic literature.

Thus, questions continue about the remaining uncertainties about differences in competitive conduct among German universal banks, the effectiveness – in terms of overall effects and social costs or benefits – of political measures on banking sector competition and the relationship between competition and financial stability in general. These questions demonstrate the need for future research in this field and highlight the conflicts facing political and regulatory decision makers.

5 Conclusion

In advance of the last global financial crisis, Stern and Feldman (2004, p. xii) mention that *"too big to fail is not unsolvable, and this is the right time to address the problem – waiting for the next banking crisis can hardly improve our lot"*.

The objective of this thesis was to enrich the academic and political discussion on the role of large banks in the context of financial (in)stability, given that TBTF and financial stability are intrinsically connected. The failure of large banks might pose significant risks to the financial system as a whole and to the economic and social order. However, because these banks' existence might be associated with both social costs and social benefits, solving TBTF requires a comprehensive approach that takes into account a variety of individual and systemic risk factors that affect the role of large banks in the context of financial (in)stability. In particular, three aspects were investigated in detail, and answers to the following questions were discussed: "Is the size of a bank a valid risk factor that determines the systemic risk an institution poses to financial stability?", "Are foreign asset holdings an individual risk factor that exposes large banks to sovereign credit risk to a disproportionally high extent instead of providing benefits of diversification?" and, finally, "Do imbalances in competitive conduct in the German banking market discriminate against large banks and negatively affect these institutions?".

The first question, "Is the size of a bank a valid risk factor that determines the systemic risk an institution poses to financial stability?" was answered in chapter 2. Reviewing the results of 30 theoretical and empirical papers from 2009 to 2017 revealed a considerable number of studies providing evidence that against the background of the structure of real, present-day financial systems, bank size is a key predictor of systemic risk and that the largest banks disproportionately contribute to overall risk. This relationship is found in samples of different compositions, for various periods and with different measures covering diverse aspects of systemic risk. For future research on this issue, it is important to know that no common standard has yet evolved to distinguish different dimensions of systemic risk and to separate the effects of size from other individual or systemic risk factors. Another important finding in chapter 2 was that asset price contagion increases the risk that bank size poses to financial stability, as large banks could be extremely exposed to systematic risk, having negative implications for financial system stability.

This aspect of being exposed to market-wide events and systematic risk was addressed in chapter 3 by analyzing the second question, “Are foreign asset holdings an individual risk factor that exposes large banks to sovereign credit risk to a disproportionally high extent instead of providing benefits of diversification?”. In particular, it was investigated whether sovereign rating events induce spillover effects on listed foreign banks in 23 OECD member countries. Using S&P ratings assessments from 1983 to 2014 and applying a traditional event study methodology and a double fixed effect regression model, evidence of spillover effects on foreign banks' share prices was found, and they were more severe than those for foreign stock markets in general. Furthermore, for severe downgrade events, evidence is provided that banks' foreign asset holdings play an important role in the transmission of spillovers, as a one-standard-deviation increase in banks' foreign claims in the re-rated country leads to a decrease in the banks’ abnormal returns of more than one-half of the CAAR's standard deviation. This effect is huge by any standard and is robust to various model specifications, sample periods and return country sample compositions. These results are, to the best of the authors’ knowledge, unique in the existing literature, as this is the first attempt to directly test the importance of asset holdings for international spillovers to foreign banks. Consequently, chapter 3 provides new empirical evidence supporting the findings of Paltalidis et al. (2015) and Buch et al. (2017) and identifies banks’ foreign asset holdings as a significant individual risk factor for large banks in the context of financial (in)stability.

The last part of the thesis dealt with the degree of competition in a banking market as a structural risk factor for financial stability, and the third question, “Do imbalances in competitive conduct in the German banking market discriminate against large banks and negatively affect these institutions?”, was answered in chapter 4. To do so, the Panzar-Rosse revenue test was used, overcoming various methodological shortcomings of earlier studies, and the sample was divided into characteristic groups according to the sector and size of banks. Being the first study since Lang (1997) to empirically investigate the competitive environment of universal banks in Germany, chapter 4 provides evidence that measuring competition at an average country level does not necessarily generate valid evaluations of fragmented markets. In addition, no clear indication is found that either the particular objectives of cooperative and savings banks or the legal protection of these institutions impedes competition or discriminates against private banks. Consequently, large banks in Germany cannot generate monopoly rents, but other banks cannot, either. Therefore, as long as the relationship between competition and financial stability is dubious, the overall effect and the social costs or benefits of political measures that influence the structure of the German banking market are at least questionable. Although this analysis was the first to investigate how the experiences and various public rescue programs related to the subprime crisis have influenced the competitive stance within the German banking industry, the sample period ends with the year 2009. For future research, it could be interesting to investigate this issue again, as consolidation in the German banking market has proceeded since then, the Basel III regulations are nearly fully implemented, and more accounting data from the entire crisis period is currently available.

Which implications can finally be derived from this thesis for academics, regulators and political decision makers in terms of the role of large banks in the context of financial (in)stability and the assumed trade-off between social benefits and social costs?

Although the putative benefits have not been investigated empirically within this thesis, reviewing the existing literature on the issues of economies of scale and diversification raises serious concerns about the practical importance of these advantages for several reasons. First, as mentioned in chapter 1, empirical evidence from the recent literature on economies of scale is strongly ambiguous. Performing a meta-analysis might provide additional insights on this issue and could also be a starting point for future research. However, nevertheless, concluding the debate about economies of scale in banking is a challenge that requires isolating the pure impact of size against the background of limited data availability. Second, the findings of Cardarelli et al. (2011) that recessions associated with banking crises tend to last twice as long and are as twice as intense, and those of Boyd and Heitz (2016) that even the highest observed benefits of scale are unable to compensate for these output losses, strongly challenge the macroeconomic benefit. Third, the observation of economies of scale and diseconomies of scale will be attributable to the quality of the management's use of the full range of production factors rather than simply to the size of the bank (Walter, 2009). Fourth, large banks in general do not necessarily make use of diversification benefits. The increased risk taking behavior of large banks can be derived theoretically from both the agency cost hypothesis and the TBTF hypothesis and has been detected empirically by a variety of studies, as presented in chapter 1. Fifth, even if the management aims at reducing a bank's idiosyncratic risk by choosing a portfolio of uncorrelated cash flows, this approach may increase the bank's exposure to systematic risk. Hence, from a systemic perspective, large banks that diversify their business activities may become a threat to financial stability, and diversification in general seems to be a questionable argument in favor of large banks in this context.

Important lessons have been learned and several advances were made by regulators around the world to improve the microprudential regulation of banks, as well as the macroprudential regulation of the financial system as a whole. The additional capital surcharge depending on the systemic relevance of an institution established in the Basel III framework is supposed to be an effective example of measures addressing TBTF, as it increases the loss-absorbing capacity and decreases the capacity to take on risks. The effectiveness of other measures, such as the implementation of a sound risk culture (see, e.g., Financial Stability Board, 2014a) or an effective resolution regime (see., e.g., Financial Stability Board, 2014b), is difficult to evaluate. Other proposals, such as cutting the size of large banks, have not been implemented to date.

Taking into account the structural developments in the aftermath of the crisis, the formation of larger and more complex institutions, as well as the ongoing globalization and consolidation among banks, leaves the impression that the TBTF problem has become even increasingly important and is far from being solved. This hypothesis is supported by the estimations of Schich et al. (2017), who find that financial sector reforms have contributed to a reduction in the costs associated with bank failures but that the annualized value of expected costs is above its 2008 level. Consequently, there is still a need for future research on the role of large banks in the context of financial (in)stability and on individual and systemic risk factors that determine the interconnection of both. This thesis has highlighted specific demand for such research and contributed to the existing literature by providing additional evidence on this field. Both contributions might be helpful for academics, politicians and regulators in their quest to find a solution to the (still current) problem of TBTF.

Appendices

Appendix A.1: Numerical scale of S&P sovereign credit ratings

Sovereign rating	Numerical value	Sovereign rating	Numerical value
AAA	29	CC+	10
AA+	28	CC	9
AA	27	CC-	8
AA-	26	C+	7
A+	25	C	6
A	24	C-	5
A-	23	DDD	4
BBB+	22	DD	3
BBB	21	D	2
BBB-	20	SD	1
BB+	19		
BB	18		
BB-	17		
B+	16	Credit outlook	add to numerical value
B	15	Positive	0.2
B-	14	Developing	0.1
CCC+	13	Stable	0
CCC	12	Watch negative	-0.1
CCC-	11	Negative	-0.2

Appendix A.2: Variable definitions

Variable	Definition and source
CAAR	Abnormal returns of banking indices in non-event countries following a sovereign rating change in event countries. Abnormal returns are cumulated for the defined lengths of event windows. Normal returns are calculated using a market model. *Source*: Authors' calculation based on daily stock returns using return indices from Datastream
FC	Foreign asset holdings of BIS reporting banks measured in millions of USD divided by the return country's gross domestic product measured in billions of USD. *Source*: Bank for International Settlements (http://www.bis.org); IMF Data Warehouse (http://data.imf.org/regular.aspx?key=60587804)
Severe	Two proxies are used to measure the severity of rating downgrades: (1) Rating change in event country j, $\Delta Rating_j$. (2) Abnormal returns of banks (calculated with a market model) in the event country on the day of the rating event, AR_j.

D_Severe	Two dummy variables are used to measure the severity of rating downgrades. They take on a value of one if (1) the numerical value of the event country rating decreases more than 2.5 points, (2) abnormal returns of banks (calculated with a market model) in the event country on the day of a rating event are below -2.4%.
Rating	Standard & Poor's foreign currency ratings. We distinguish between a country's long-term sovereign rating and rating outlook. Ratings are transformed into a numerical scale using a maximum value of 29 for the highest rating (AAA), decreasing to a value of 1 for the lowest rating (SD). See, Appendix A.1.
Revision	Dummy variable taking on a value of one if there have been previous rating events in event country in the last 60 days prior to the event day *t=0*. *Source*: Authors' definition
Distance	Geographical distance in kilometers between the most important cities/agglomerations (in terms of population) of the event and the non-event country. *Source*: Centre d'Études Prospectives et d'Informations Internationales (CEPII). We use the *dist* variable which reflects geodesic distances that are calculated following the great circle formula, using the latitudes and longitudes of the most important cities/agglomerations (in terms of population) as described by Mayer and Zignago (2011).

For robustness tests we use	
Crisis	Dummy variable taking on a value of one if the event takes place in a year that is classified as crisis period. *Source*: Brooks et al. (2015) for the period later than 1996 and Cardarelli et al. (2011) as well as Reinhart and Rogoff (2008) from 1987 to 1996
GovDebt	Public debt of a country relative to all public debt outstanding in billion USD. *Source*: Authors' calculation based on International Monetary Fund Fiscal Affairs Department: Historical Public Debt Database (http://www.imf.org/external/pubs/ft/wp/2010/data/wp10245.zip) To the best of our knowledge, this database is the first truly comprehensive historical public debt database for the countries in our sample. For further details see Ali Abbas et al. (2010)
RelSize	Ratio of gross domestic product of event country *j* and non-event country *i*. *Source*: IMF Data Warehouse (http://data.imf.org/regular.aspx?key=60587804)
PortInv	Total portfolio investments of a country, including equity and investment fund shares, long-term debt instruments, and short-term debt instruments taken from the IMF Coordinated Portfolio Investment Survey (CPIS) divided by the country's gross domestic product. *Source:* IMF Data Warehouse (http://data.imf.org/regular.aspx?key=60587804)
Strength	Two proxies are used to measure the strength of a rating improvement: (1) Rating change in event country j. (2) Abnormal returns of banks (calculated with a market model) in the event country on the day of a rating event.
D_Strength	Two dummy variables are used to measure the strength of a rating improvement. They take on a value of one if (1) the numerical value of the event country rating increases more than 1.8 points, (2) abnormal returns of banks (calculated with a market model) in the event country on the day of a rating event are above 2.9%.

Appendix A.3: Summary statistics of independent variables in the downgrade sample

Variable	Mean	Std. Dev.	Min	Max	# Obs.
Log(FC_{ij})	1.914	1.506	-0.192	7.120	1861
$\Delta Rating_j$	-1.008	1.447	-10.800	-0.100	1861
D_$\Delta Rating_j$	0.065	0.247	0.000	1.000	1861
AR_j	-0.313	1.825	-5.592	5.226	1861
D_AR_j	0.092	0.290	0.000	1.000	1861
$Rating_i$	27.060	3.321	14.000	29.000	1861
$Rating_j$	22.630	5.809	1.000	28.900	1861
$Revision_j$	0.258	0.438	0.000	1.000	1861
Log($Distance_{ij}$)	8.006	1.010	5.159	9.809	1861
Log($RelSize_{ij}$)	0.826	0.824	0.013	4.281	1861
Log($GovDebt_j$)	1.003	0.895	0.179	3.510	1861
Log($PortInv_{ij}$)	6.314	1.439	0.912	9.205	1436

Appendix A.4: Sector and size-group observations according to total assets

	Small		*Medium*		*Large*		*Total*	
Private banks	283	41.1%	262	38.0%	144	20.9%	689	100.0%
	4.2%		5.2%		24.9%			
Cooperative banks	5,932	74.3%	1,987	24.9%	65	0.8%	7,984	100.0%
	87.4%		39.3%		11.2%			
Savings banks	569	15.2%	2,813	75.0%	369	9.8%	3,751	100.0%
	8.4%		55.6%		63.8%			
Total	6,784	54.6%	5,062	40.7%	578	4.7%	12,424	100.0%
	100.0%		100.0%		100.0%			

Appendix A.5: Estimated factor price elasticities for the pre-crisis and crisis period

	Funds	Labour	Physical Capital	Equity
Overall Sample				
2001-2006 (β_1)	0.477***	0.068**	0.022	0.001
	(0.048)	(0.030)	(0.013)	(0.004)
2007-2009 (β_2)	0.522***	0.131***	0.035***	0.030***
	(0.066)	(0.040)	(0.011)	(0.005)
H_0: $\beta_1 = \beta_2$ p (F-test)	0.3359	0.0187	0.1793	0.0001
Private banks				
2001-2006 (β_1)	0.604***	0.341***	0.051	0.038**
	(0.070)	(0.085)	(0.047)	(0.017)
2007-2009 (β_2)	0.592***	0.358***	0.132***	0.032*
	(0.081)	(0.079)	(0.042)	(0.018)
H_0: $\beta_1 = \beta_2$ p (F-test)	0.8853	0.8188	0.0180	0.7644
Cooperative banks				
2001-2006 (β_1)	0.336***	0.030	0.032**	-0.018***
	(0.037)	(0.023)	(0.013)	(0.005)
2007-2009 (β_2)	0.342***	0.040**	0.017	0.023***
	(0.033)	(0.020)	(0.012)	(0.006)
H_0: $\beta_1 = \beta_2$ p (F-test)	0.8790	0.6450	0.0586	0.0000
Savings banks				
2001-2006 (β_1)	0.376***	0.112***	0.000	0.005
	(0.068)	(0.040)	(0.031)	(0.009)
2007-2009 (β_2)	0.258***	0.067*	0.007	0.005
	(0.061)	(0.040)	(0.023)	(0.007)
H_0: $\beta_1 = \beta_2$ p (F-test)	0.1478	0.1808	0.6194	0.9837
Small banks				
2001-2006 (β_1)	0.401***	0.027	0.021	-0.010*
	(0.072)	(0.024)	(0.013)	(0.001)
2007-2009 (β_2)	0.446***	0.047**	0.029**	0.035***
	(0.054)	(0.022)	(0.015)	(0.006)
H_0: $\beta_1 = \beta_2$ p (F-test)	0.3131	0.3715	0.4833	0.0000
Medium banks				
2001-2006 (β_1)	0.454***	0.067*	0.003	0.002
	(0.060)	(0.039)	(0.020)	(0.008)
2007-2009 (β_2)	0.365***	0.161***	0.034*	0.014*
	(0.055)	(0.039)	(0.020)	(0.007)
H_0: $\beta_1 = \beta_2$ p (F-test)	0.1718	0.0152	0.0325	0.2832
Large banks				
2001-2006 (β_1)	0.692***	0.026	0.084*	0.012
	(0.085)	(0.059)	(0.045)	(0.012)
2007-2009 (β_2)	0.809***	0.167**	0.050	0.043***
	(0.095)	(0.079)	(0.034)	(0.011)
H_0: $\beta_1 = \beta_2$ p (F-test)	0.3009	0.0338	0.2146	0.0644

Notes: Fixed effects regression with heteroscedasticity-robust standard errors (White, 1980) in parentheses; *** = $p < 0.01$, ** $p < 0.05$, * = $p < 0.1$.

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