Essays on the Stability and Regulation of International Financial Markets

Dissertation
zur Erlangung des Doktorgrades
der Wirtschafts- und Sozialwissenschaftlichen Fakultät
der Eberhard Karls Universität Tübingen

vorgelegt von

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Tübingen

2016

Tag der mündlichen Prüfung:	14.10.2016
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Acknowledgements

First of all, I would like to express my deepest gratitude to my supervisor Claudia Buch. Her guidance, encouragement, and invaluable support made the completion of this thesis possible in the first place. Her valuable criticism and comments benefited both my research and me personally. I also want to thank her for coauthoring the project on uncertainty and bank lending and the project on liquidity provision and internal adjustment. I am very grateful to my second supervisor Wilhelm Kohler for becoming a member of my thesis committee and for his useful suggestions on my work.

To Lena Tonzer I am grateful for jointly writing the paper on sovereign credit risk co-movements and the work on uncertainty and bank lending. It was a great and instructive experience working together and exchanging so many ideas. I would also like to thank Alexander Lipponer and Esteban Prieto for coauthoring the work on liquidity provision and internal adjustment.

Furthermore, I would like to thank a number of colleagues at the Halle Institute for Economic Research (IWH) at which I spent most of my time working on my thesis. I am indebted to my colleagues at the department of financial markets Michael Koetter, Felix Noth, and Stefan Eichler for their support and guidance. Special thanks also go to my fellow Ph.D. students Konstantin Kiesel, Thomas Krause, and Matias Ossandon Busch as well as to Chris Jürschik, Helge Littke, Carola Müller, Oliver Rehbein, Vahid Saadi, and Kirsten Schmidt for useful comments on my work, helpful suggestions in brownbag seminars, and many interesting conversations – not exclusively on economic issues – during our enjoyable lunch and coffee breaks. I would also like to thank my colleagues Stefano Colonnello, Frieder Kropfhäußer, Axel Lindner, Jan-Christopher Scherer, and Gregor von Schweinitz for useful comments. I gratefully acknowledge all researchers of the research department at the Bank of Estonia (Eesti Pank) for their valuable suggestions and discussions on my work during my stay as a visiting researcher in the summer of 2015. Thanks also to all participants at seminars, workshops, and conferences that commented on my work. I am thankful to the Bank for International Settlements for kindly providing data for the project on credit risk co-movements and the project on uncertainty and bank lending, and to the Deutsche Bundesbank for guaranteeing data access during my stays as a guest researcher.

Finally, I would like to express my deep gratitude to my parents for their great support, which made my university education possible in the first place. I am also grateful to my brother Björn, my sister-in-law Anke and my nephews Raphael and Tobias, and to my sister Patricia for their presence in my life and their support.

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Introduction

The global financial crisis of 2007-08 and its adverse effects on economic activity have put financial stability back on the agenda of both researchers and policymakers. In immediate response to the crisis, central banks across the world provided liquidity to the financial sector on an unprecedented scale. In addition, governments of many countries supported their financial institutions through capital injections and debt guarantee programs. These emergency measures certainly helped prevent financial stress from doing further harm to the real economy. However, it is evident that they did not address the underlying causes of the crisis and might have led to distortions and other unintended consequences.

Against this backdrop, the regulatory debate has since then revolved around the question which reforms are needed to effectively reduce the likelihood and costs of future systemic financial crises. By now, the debate has led to an update of regulatory frameworks on the national, European, and global level. Key reforms in this respect include the use of macroprudential policy instruments, the implementation of new capital and liquidity requirements for banks under the Basel III accord, and the creation of a supranational bank supervisory system and of new rules for bank resolution in Europe.

Designing an appropriate and comprehensive framework of financial regulation is challenging. Such a framework is supposed to foster prudent bank behavior, to reduce bailout expectations, and to minimize systemic risks which might threaten the stability of the financial system and might have negative repercussions on the overall economy. However, it should be designed in a way such that the financial system can still provide its intermediary functions and efficiently allocate funds to productive investments in the real economy. In the face of this challenge, key insights from the crisis can provide helpful guidance for the process of regulatory reform (Beck et al., 2016).

The global financial crisis should be seen in the light of the substantial change the financial system has undergone over the past decades and in particular since the 2000s (Claessens et al., 2010). One fundamental change in the wake of financial globalization was that banks increasingly made use of short-term maturity funding, for instance through global interbank markets, and heavily relied on financial innovations such as securitization of their assets (Brunnermeier, 2009; Keys et al., 2010). Another distinct feature relates to a high level of interconnectedness among market participants such as banks, non-bank financial institutions, and sovereigns – both within and across national borders (Acharya et al., 2014; Allen and Gale, 2000; Bolton and Jeanne, 2011). Taken together, these factors arguably enhanced diversification and improved risk-sharing possibilities. However, they also gave rise to the emergence of systemic risks, for instance, through the external cost that the failure of one individual entity or stress in one market segment might exert on the entire system. Such risks are particularly prevalent if the loss-absorbing capacity of financial institutions is low due to insufficient capital buffers (Acharya et al., 2016; Acharya and Thakor, 2016). In conclusion, externalities due to systemic risks, which are likely to arise in interdependent economies and financial markets, provide a rationale for financial regulation.

Financial globalization appears also to be connected to the build-up of global and macroeconomic imbalances (Mendoza et al., 2009; Obstfeld and Rogoff, 2009). Regarding European crisis countries, there is evidence that increasing financial integration contributed to large and persistent current account deficits (Kang and Shambaugh, 2013; Schmitz and Von Hagen, 2011) and high levels of private or public debt (Lane and McQuade, 2014). Research points towards imbalances in global lending and borrowing being a key factor behind the financial crisis (Gourinchas, 2012; Obstfeld, 2012). In addition, if macroeconomic imbalances reflect weak economic fundamentals, they are likely to increase the vulnerability to sudden shifts in investors' risk perception, which in turn can trigger financial turmoil (Bacchetta et al., 2012; De Grauwe and Ji, 2013). In sum, this indicates that macroeconomic imbalances should be considered in any comprehensive assessment of risks to financial stability.

This thesis contributes to the research on the risks to financial stability and to the debate on the regulation of international financial markets. It builds on some of the key insights from the recent global financial crisis and the respective policy responses. In particular, it analyzes the reasons behind the strong co-movements of credit risk in sovereign bond markets during the financial crisis and the subsequent euro area debt crisis (Chapter 1). Furthermore, it investigates how uncertainty in banking affects banks' loan supply, and it analyzes if the lending behavior is heterogeneous across different types of banks, also differentiating between domestic and foreign-owned banks (Chapter 2). Turning to the analysis of actual policies, it studies the effect of liquidity provided by the Eurosystem on macroeconomic adjustment in European crisis countries (Chapter 3). Finally, it assesses the effectiveness of a macroprudential policy instrument, caps on banks' leverage, in stabilizing credit growth during financial downturns (Chapter 4). The remainder of the introduction will give a more detailed outline of the contents of the thesis.

In Chapter 1, we study credit risk co-movements in sovereign bond markets during the global financial crisis and the subsequent euro area sovereign debt crisis.[1] The study starts from the observation that sovereign credit risk exhibits a pattern of high co-movement across euro area countries. This holds true irrespective of the fact that there was a considerable divergence in the levels of credit spreads across countries: In the course of the debt crisis, credit spreads surged in countries such as Greece, Ireland, Portugal, Spain, and Italy, but they remained at low levels in countries such as France and Germany. Based on these observations, we empirically explore the factors behind credit risk co-movements and ask to what extent they might be the outcome of contagion. In addition, we disentangle different channels through which contagion might occur.

Our empirical analysis is based on a sample of 17 euro area and non-euro area countries and comprises three steps. First, we apply the dynamic conditional correlation (DCC) model by Engle (2002) to daily sovereign CDS spreads and compute volatility-adjusted correlations of sovereign credit risk spreads on a bilateral basis. This allows us to analyze the pattern of co-movements over time and across country pairs. Second, we follow Forbes and Rigobon (2002) and label periods as contagious if we observe a significant increase in the co-movements measure at a given point in time. Third, we can build on the previous steps to separate interdependence, that is, the factors that drive co-movements during tranquil times, from the channels of contagion, that is, from the factors that affect co-movement differently given that the period is contagious. Specifically, we investigate the impact of global factors (implied volatility index and a measure for liquidity risk), common economic fundamentals (based, for example, on GDP, public debt, foreign reserves, or banking system size), cross-border linkages in trade and banking, and a proxy for common market sentiment (weighted stock market volatility). This allows us to differentiate between wake-up call, fundamentals based, and non-fundamentals based contagion.

Our empirical results show that sovereign credit risk co-moves considerably, in particular among euro area countries and during the sovereign debt crisis. Furthermore, we find evidence of contagion in sovereign debt markets at different points in time and for different country pairs. Contagion is mainly channeled through similarity in

[1] Chapter 1 is based on the published article Buchholz, M. and Tonzer, L. (2016). Sovereign credit risk co-movements in the eurozone: Simple interdependence or contagion? *International Finance*, 19(3):246-268 (Buchholz and Tonzer, 2016). The copyright of the original article is with the International Finance, John Wiley & Sons.

fundamentals, cross-country linkages in banking, and common market sentiment. This implies that all three types of contagion – wake-up call, fundamentals based, and non-fundamentals based contagion – played a role in transmitting shocks during the sovereign debt crisis.

In sum, the findings of Chapter 1 suggest that policies targeting weak economic fundamentals such as a high level of public debt relative to GDP might be effective in mitigating the adverse effects of fundamentals based contagion. In addition, the evidence for non-fundamentals based contagion, which might root in sudden shifts in market sentiment or risk panics, potentially provides a rationale for policy measures during a crisis that affect investors' expectations or reduce uncertainty.

In Chapter 2, we analyze how uncertainty affects bank lending to the real economy. We also investigate how this effect depends on bank-level heterogeneity relating to capital and liquidity holdings of banks, and their ownership status (domestic *versus* foreign-owned).[2] The analysis is motivated by the observation that since the outbreak of the financial crisis, many countries have experienced stagnating or even declining levels of bank lending. Banks have also withdrawn from international markets on a large scale. We analyze the role played by increased uncertainty in the banking sector regarding the decline in bank lending. In the presence of uncertainty, that is, in a situation when future outcomes become less predictable (Jurado et al., 2015), it might be beneficial to a bank to postpone the loan decision.

We apply the dispersion measure proposed by Bloom et al. (2012) to banking. From the perspective of an economic agent such as a bank, weaker predictability due to higher uncertainty is reflected by a wider distribution of shocks to key bank-level variables. Therefore, we measure uncertainty in banking as the cross-sectional dispersion of shocks to total asset growth, short-term funding, productivity, and profitability. We then empirically analyze the impact of uncertainty on bank lending. Methodologically, we closely follow Cornett et al. (2011), who measure the impact of funding shocks on bank lending and allow for heterogeneous effects along various banking characteristics such as banks' capital and liquidity holdings.

Our main finding is that higher uncertainty in banking, that is, a higher cross-sectional dispersion of bank-level shocks, has negative effects on bank lending. The effect is heterogeneous across banks: lending by banks which are better capitalized and which have higher liquidity buffers is affected less. Also, the degree of international-

[2] Chapter 2 is based on the published article Buch, C. M., Buchholz, M., and Tonzer, L. (2015). Uncertainty, Bank Lending, and Bank-Level Heterogeneity. *IMF Economic Review*, 63(4):919-954 (Buch et al., 2015). The copyright of the original article is with the IMF Economic Review, Palgrave Macmillan.

ization matters, as loan supply by banks in financially open countries is affected less by uncertainty. In contrast, the impact of the ownership status of the individual bank is less important.

In sum, the results of Chapter 2 suggest that uncertainty was an important explanation behind the decline in bank lending during the crisis and that capital and liquidity buffers tend to stabilize bank lending in the presence of uncertainty. In particular the latter result might provide useful guidance for regulation.

Chapter 3 turns to the analysis of actual policies. In particular, we investigate how liquidity provided by the Eurosystem has affected internal adjustment in European periphery countries after the crisis.[3] European periphery countries faced a massive capital flight during the recent crisis. Because of euro area membership or the commitment to defend the peg to the euro, the necessary adjustment to the crisis had to take place internally, for instance, through prices or labor costs. However, only members of the euro area could access liquidity provided by the Eurosystem. This might lead to different adjustment processes in euro area GIIPS countries than in Eastern European BELL countries.[4]

We draw on cross-sector, cross-country panel data to identify the impact of Eurosystem liquidity provision on the internal adjustment following the liquidity shock that was induced by the sudden stop in private capital flows. Our main hypothesis is that adjustment pressure due to this liquidity shock is higher in more financially vulnerable sectors. As a consequence, liquidity provided by the Eurosystem – mitigating the liquidity shock – could affect the path of internal adjustment differently across this sectoral dimension. More specifically, we focus on identifying the interaction of liquidity support by the Eurosystem with a measure of financial vulnerability in panel regressions explaining internal adjustment. Using sectoral data and focusing on this interaction effect enables us to disentangle the effect of liquidity provision on adjustment to the liquidity shock from other common omitted variables by including time-varying country-specific and time-varying sector-specific fixed effects. Hence, concerns about potential omitted variables constituting conflicting alternative explanations are minimized.

We measure internal adjustment based on the time pattern of sectoral nominal and real unit labor costs since the sudden stop. In addition, we analyze adjustment in real and nominal wages, labor productivity, prices, and employment. Liquidity provision

[3] Chapter 3 is based on joint work with Claudia M. Buch, Alexander Lipponer, and Esteban Prieto.

[4] The countries in our sample comprise the euro area GIIPS countries (Greece, Ireland, Italy, Portugal, Spain) and the Eastern European BELL countries (Bulgaria, Estonia, Latvia, Lithuania). Estonia, Latvia, and Lithuania were not yet members of the euro area at the time when the sudden stop in capital inflows occurred but had pegged their currency to the euro.

by the Eurosystem is measured as TARGET2 net liabilities (relative to 2007 GDP). TARGET2 net liabilities provide a measure of when and to what extent euro area crisis countries substituted central bank funding for dried-up private capital inflows (Cour-Thimann, 2013). Our measure of financial vulnerability is based on sectoral pre-crisis credit growth rates. It varies across sectors but not across countries and is therefore related to the seminal measure of financial dependence by Rajan and Zingales (1998).

Four key results emerge from our analysis. First, Eurosystem liquidity provision lowered the adjustment in real unit labor costs and real wages in sectors that are more financially vulnerable. Second, conditional on financial vulnerability, higher liquidity provision leads to lower price increases. Third, there is no evidence for differential adjustment due to liquidity provision in nominal unit labor costs, nominal wages or labor productivity. Finally, more financially vulnerable sectors reduce employment more strongly, the higher the liquidity provision by the Eurosystem.

Our finding that liquidity provision by the Eurosystem affects adjustment by reducing price increases in financially vulnerable sectors relates to recent theoretical work analyzing the effects of liquidity shocks in models featuring financial frictions. Christiano et al. (2015) show that firms pass on jumps in financing costs to consumers and increase their prices. We conjecture that the more financially vulnerable the sector, the stronger this channel should be. Similarly, Gilchrist et al. (2015) develop a menu-cost model with heterogeneous firms, in which firms with limited access to external liquidity have an incentive to increase prices in response to adverse financial shocks compared to firms with better access to liquidity. The result that higher liquidity provision leads to stronger reduction in employment in financially vulnerable sectors is in line with Schmitt-Grohé and Uribe (2016). According to their study, the lower reduction in real wages over the adjustment period should lead to a higher reduction in employment (that is, higher unemployment), which is exactly what we find.

The findings of Chapter 3 suggest that central bank liquidity has an effect on macroeconomic adjustment after a liquidity shock induced by a sudden stop in capital flows. More generally, the results point towards a trade-off between mitigating the impact of negative (liquidity) shocks and delaying adjustment. Therefore, they contribute to our understanding of the macroeconomic consequences of non-standard monetary policy measures in response to crises.

In Chapter 4, I assess if a macroprudential policy instrument, caps on banks' leverage, stabilizes bank lending during financial downturns.[5] The study is motivated by recent empirical studies suggesting that macroprudential policy is effective in damp-

[5] Chapter 4 is based on Buchholz (2015).

ening the credit cycle and reducing the build-up of systemic risk (Cerutti et al., 2016; Claessens et al., 2013). This is important because excessive credit booms might lead to systemic financial crises and thus to large economic costs in terms of output losses (Jordà et al., 2013; Schularick and Taylor, 2012). However, there is a second dimension to countercyclical macroprudential policy, which is that it should not only reduce the probability of a crisis occurring but also stabilize the provision of credit during financial downturns. Less is known about how macroprudential policy contributes to stabilizing financial markets and the real economy during such periods. The aim of the study is to fill this gap.

The chapter focuses on one particular macroprudential policy instrument: caps on banks' leverage. This instrument, which is often referred to simply as the leverage ratio, is an example of a measure which might potentially stabilize the lending of banks during financial downturns. Technically, a cap on the leverage of a bank means that it has to hold a minimum amount of equity capital relative to its total assets. Through this, the instrument can increase loss-absorbing capacity and thus make banks more resilient in the face of adverse shocks.

The empirical analysis is based on a sample of 69 advanced and emerging countries during 2002-14, of which eight had introduced the leverage cap before the crisis. The study analyzes the effect of the leverage cap on bank credit to the domestic private sector. Methodologically, I apply a difference-in-differences approach. This means that the difference in real credit growth rates in the post-crisis period of 2009-14 and the pre-crisis period of 2002-08 is compared for those countries that implemented a leverage cap prior to the crisis and those that did not. Under the assumption that real credit growth rates would have continued to develop similarly in both groups of countries if the crisis had not occurred, this differential effect can then be attributed to the implementation of the leverage cap prior to the crisis.

The main finding of the study is that caps on banks' leverage indeed have a stabilizing effect on real credit growth during financial downturns. Additional evidence suggests that the channel through which this stabilizing effect works is that banks build up higher capital buffers before the crisis and can then draw on them afterwards to stabilize lending to the private sector.

The implication of the results of Chapter 4 is that any comprehensive cost-benefit analysis of macroprudential policy should incorporate the potentially stabilizing effect of the chosen policy instruments during crisis times. This is particularly important because even if macroprudential policy might not be able to prevent financial crises from happening at all, it might still be effective in stabilizing the economy in their aftermath.

In sum, this thesis provides a number of insights on the risks to financial stability that can inform the debate on regulatory reform. One general conclusion is that systemic risks in financial markets provide a rationale for a sustainable regulatory framework which aims at reducing the likelihood and costs of future financial crises. Regulation of bank capital and liquidity as well as the use of macroprudential policy instruments might make a valuable contribution to achieve this goal. At the same time, the findings of this thesis point towards a major role for short-term policy measures which help mitigate the immediate and severe impact of a financial crisis.

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Chapter 1

Sovereign Credit Risk Co-movements in the Eurozone: Simple Interdependence or Contagion?

1.1 Motivation

Diverging sovereign credit risk in Europe has received increasing attention in recent times. While sovereign spreads surged in countries such as Greece, Ireland, Portugal, Spain and Italy during 2010-11, they have remained at low levels in countries such as France and Germany. Despite this divergence, the Eurozone as a whole entered the recent global financial crisis as a highly interdependent region characterized by a considerable degree of financial and trade integration fostered by a common currency. While such interdependencies play an important role in international risk sharing in normal times, they also facilitate the transmission of distress in sovereign debt markets across national borders in times of crisis. In this respect, Figure 1.1 presents a primary indication that sovereign credit risk (as measured by CDS spreads) has shown a common pattern across core and periphery Eurozone countries for the period of 2008-12.[1]

Thus, in this study, our interest is not in the reasons for which sovereign credit risk has diverged but in co-movements of credit risk in integrated markets like the one of the Eurozone. We ask two research questions: First, do co-movements in sovereign markets arise due to simple interdependence or contagion? Second, if we find evidence for contagion, which are the channels through which contagion occurs? Thereby, we

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distinguish between "wake-up call contagion" going back to similarities in economic fundamentals, fundamentals based contagion arising due to direct links between countries, and non-fundamentals based contagion, which can be associated with the idea of sudden changes in market sentiments.

The contribution of our empirical study is threefold. First, we begin by taking a closer look at the pattern of sovereign credit risk co-movements in a sample of 17 Eurozone and non-Eurozone countries for the period 2008-12. We apply the dynamic conditional correlation (DCC) model developed by Engle (2002) to daily sovereign CDS spreads and compute volatility-adjusted correlations of sovereign credit risk spreads on a bilateral basis. Using these time-varying measures of co-movement, we can analyze the pattern of sovereign credit risk co-movements over time and across country pairs.

Second, we investigate whether and at what time contagion prevailed in sovereign debt markets: For each country pair, we check whether at any point in time sovereign credit risk co-movements increase significantly. To do so, we run sequential time-series regression of the co-movements on dummies that take a value of one for each period and check their impact. We follow Forbes and Rigobon (2002) in that we interpret a significant increase in volatility-adjusted co-movements as contagion. Our specification is flexible enough such that we do not need to make assumptions about breakpoints between tranquil and turbulent periods.[2]

Third, we apply panel regressions to separate interdependence from channels of contagion. We investigate the impact of global factors, common fundamentals, cross-border linkages in trade and banking, and a proxy for common market sentiment on sovereign credit risk co-movements. By including cross-border linkages in banking, we take the sovereign-bank risk nexus and the related two-way feedback into account (Acharya et al., 2014; Alter and Beyer, 2014; Alter and Schüler, 2012; König et al., 2014). We interact selected variables with the contagion indicator to assess whether they affect co-movements differently conditional on the occurrence of contagion. If this is the case, these variables constitute channels of contagion. This approach allows the empirical differentiation between "wake-up call" contagion, fundamentals based, and non-fundamentals based contagion. The differentiation between fundamentals based and non-fundamentals based contagion is motivated by, for example, the finding of Dewachter et al. (2015) that during the height of the sovereign debt crisis both economic fundamentals and non-fundamental risks like policy uncertainty influenced Eurozone sovereign bond yield spreads. In contrast to our paper, they analyze sovereign

[2] We distinguish "tranquil" from "turbulent" periods rather than "pre-crisis" from "crisis" periods to account for the fact that our full sample spans a period of crisis. We are thus comparing "bad times" to "really bad times" (see also Caporin et al., 2013).

credit risk spreads whereas our focus is on co-movements in sovereign debt markets.

Our empirical findings suggest that despite the divergence in its levels, sovereign credit risk co-moves considerably. This holds particularly among Eurozone countries and during the sovereign debt crisis. Furthermore, we find evidence of contagion in sovereign debt markets at different points in time and for different country pairs. In a related paper, Claeys and Vašíček (2014) apply multivariate structural break tests in a FAVAR model to detect spillovers in EU sovereign bond markets. In line with our results, they find that spillovers increase during the sovereign debt crisis. Finally, contagion is channeled mainly through similarity in fundamentals, cross-country linkages in banking, and common market sentiment.

Our study relates to three main strands of literature. The first strand is the extensive body of literature on the determinants of sovereign credit risk during the Eurozone sovereign debt crisis. One of the main findings is that with the onset of the financial crisis, common risk factors, deteriorating debt positions, and high expected fiscal deficits have become the main drivers of sovereign credit risk spreads (Attinasi et al., 2010; Aizenman et al., 2013; Beirne and Fratzscher, 2013). We build on the insights of this literature when analyzing the determinants of sovereign credit-risk co-movements.

The second strand deals with the strengthened interdependence between bank fragility and sovereign credit risk, which gives rise to a reinforcing negative feedback loop between banks and sovereigns (Acharya et al., 2014; Alter and Schüler, 2012; Ejsing and Lemke, 2011). These studies find, for example, that sovereign credit risk is sensitive to the state of the financial sector (Dieckmann and Plank, 2012). For a sample of European banks, Mink and De Haan (2013) show that banks' stock prices are negatively affected by news about a Greek bailout. This indicates that investors price in potential future bailout costs and banks' losses due to sovereign debt holdings. De Bruyckere et al. (2013) study spillovers among sovereigns and banks and find significant evidence for contagion which is defined as excess correlations. Based on these findings, our analysis incorporates variables related to the banking sector and takes the sovereign-bank risk nexus into account. However, we do not assess the bank-sovereign nexus within one country but analyze cross-country correlations in sovereign credit risk and the underlying determinants.

Third, a number of studies analyze the feedback between bank and sovereign credit risk across national borders and contagion in sovereign debt markets during the Eurozone sovereign debt crisis. In a theoretical contribution, Bolton and Jeanne (2011) show that international contagion in sovereign debt markets is facilitated by the exposure of banks to foreign sovereign debt. Forbes (2012) shows empirically that countries with leveraged banking systems, greater trade exposure, weak economic fundamentals, and higher external debt positions are more vulnerable to contagion. Gorea and Radev (2014) analyze the joint probability of default of sovereigns in the Eurozone and find that financial linkages are only a transmission channel of contagion among Eurozone periphery countries. Beirne and Fratzscher (2013) report evidence for "herding contagion" during the Eurozone sovereign debt crisis. Caporin et al. (2013) use quantile regressions to analyze contagion in the Eurozone and find only limited evidence for spillovers. In contrast to these papers, our focus is on sovereign credit risk co-movements. Based on these co-movements, we can detect episodes in which sovereign debt markets were subject to contagion. At the same time, they provide valuable information on how shocks were transmitted internationally.

The detection of contagion and understanding through which channels it spreads is by no means only an academic exercise. The reason is that the effectiveness of policy responses might depend on the underlying contagion channel. If contagion was found to be associated with non-fundamentals such as shifts in market sentiment or risk panics, policy measures that affect investors' expectations or reduce uncertainty might prove more useful than those that aim at influencing financial cross-border exposures (Forbes, 2012). Interestingly, events in markets during the crisis were understood as evidence for contagion by policymakers and market participants.[3] Rescue measures in Greece, Ireland, and Portugal were justified by the fear that a default might be contagious and spill over to other highly indebted Eurozone countries with fragile banking systems, causing adverse effects for the Eurozone as a whole.

The remainder of the chapter is structured as follows. Section 1.2 describes the sample and the properties of the CDS data used for the analysis. Section 1.3 outlines the empirical methodology. Section 1.4 presents the empirical results and robustness analyses. Section 1.5 concludes the chapter.

1.2 Data Description

1.2.1 CDS Data Description

The analysis is based on daily data on five-year sovereign credit default swap (CDS) spreads as a measure of credit risk in sovereign debt markets. The sample covers 17 countries, of which 11 are Eurozone member countries, and the period spans January

[3] E.g., Mario Monti – then prime minister of Italy – stated on July 10, 2012: "It's difficult to say to what extent the contagion comes or came from Greece or from Portugal or from Ireland or from the situation of the Spanish banks. (...) The contagion is that unease hitting through the markets in terms of bigger uncertainty, lower confidence towards the euro's integrity, higher interest rates."

2008 to September 2012.[4] We include non-Eurozone countries mainly to obtain a clear picture of how co-movement patterns in the Eurozone differ from those of non-Eurozone countries. We conduct the estimations for the period starting in 2008. This is because before 2007, the volume of CDS markets was relatively small and trading occurred infrequently. However, the volume has steadily increased over recent years, reaching an amount outstanding of almost 3,000 billion USD (approximately four percent of 2012 world nominal GDP) in 2012.[5] This ensures that CDS markets are sufficiently active such that CDS spreads represent a timely measure of (perceived) credit risk.

Data on CDS spreads are obtained from Datastream, which relies on two sources: CMA and Thomson Reuters. To obtain long time series, we append data from the two sources.[6] If available, we used data for which the underlying sovereign CDS contract is denominated in US dollars. If not, the contract is specified in euro. Because CDS spreads are measured in basis points and are therefore free of units, currency differences are of minor concern (Ang and Longstaff, 2013; Longstaff et al., 2011).

Compared to yield spreads on sovereign bonds, CDS data have the advantage that they already represent a risk premium and therefore, we do not need to omit, e.g., Germany from the sample by computing yield spreads relative to German bund yields. This would require the strong assumption that German bund yields represent a risk-less benchmark. Additionally, as opposed to bond yields, CDS spreads lead price discovery (Palladini and Portes, 2011), and no premia compensating for inflation or devaluation risk are included in the data because a CDS contract primarily insures against credit risk.

Figure 1.1 shows that most of the series have an upward-moving behavior in the second half of 2008 and at the beginning of 2010 when the sovereign debt crisis started. Because we are interested in co-movements, it must be noted that the time series of various countries show common patterns. This holds for core Eurozone countries, e.g., Germany and France, and periphery Eurozone countries, such as Italy and Spain. In contrast, the range of CDS spreads varies across the different country groups. While non-Eurozone countries' spreads tend to remain below 150 basis points, Eurozone CDS spreads can lie above 200 basis points for core-Eurozone countries and considerably higher for periphery states.

[4] Finland is the only country for which we did not obtain data before mid-2008. Data entries for Greek CDS spreads increase suddenly and dramatically after February 2012 and remain constant. These observation points are excluded from the analysis.

[5] See BIS Derivatives Statistics, http://www.bis.org/statistics/derstats.htm.

[6] See the Datastream Extranet website for information on how to merge the two series: http://extranet.datastream.com/data/CDS/Index.htm.

1.2.2 CDS Time Series Properties

Visual inspection (Figure 1.1) and augmented Dickey Fuller tests show that the data are clearly not stationary. We thus take the first difference of the natural log of the series. This data transformation is comparable to studies applying DCC models to financial asset returns and was also used in related work in which dynamic correlations for CDS spreads have been of interest (Chiang et al., 2007; Coudert and Gex, 2010). Summary statistics of the log-differenced series are provided in Table 1.1.

One noteworthy feature is that the data are found to have a negative skewness and high values for the kurtosis. This suggests that the series do not follow a normal distribution but show extreme events, which is supported by the Jarque-Bera test statistic. An analysis of the squared series reveals a significant first-order autocorrelation based on the Portmanteau (or Q) test statistic with up to 10 lags for most countries. For the residuals of the mean equation, non-reported ARCH-LM tests broadly reject the null of no autocorrelation. This, together with signs of persistence in the log-differenced time series depicted in Figure 1.2, gives evidence of volatility clustering. In sum, the daily log-differenced CDS data show signs of non-normality, autocorrelation and volatility clustering. This supports the computation of conditional correlations based on a GARCH model, which accounts for these data properties.

Simple pairwise correlations are given in Table 1.2. To obtain a better picture of the ongoing dynamics in co-movements in sovereign credit risk, we investigate the correlation coefficients during the financial crisis as well as after the start of the sovereign debt crisis. For the latter, we choose as a starting date the Greek announcement of the fiscal deficit being twice as large as expected in November 2009. Comparing correlation coefficients across sovereign CDS markets for the different time periods shows that correlations increase for Eurozone countries and particularly for the periphery during the sovereign debt crisis. This does not hold for Greece, potentially revealing the special role it played during the start of the sovereign debt crisis. However, it should be noted that this still does not provide any evidence of contagion because an increase in these unconditional correlation coefficients might simply be driven by an increase in volatility during turbulent times (Forbes and Rigobon, 2002).

Nevertheless, the correlation matrices reveal interesting patterns for different country pairs. Within the group of Eurozone countries, there is strong evidence of common patterns as correlation coefficients tend to be higher than 0.5 from 2007 on. Interestingly, this also holds for periphery-core country pairs, e.g., Germany and Portugal. Not surprisingly, co-movements are more pronounced if both countries belong to the periphery crisis countries, e.g., Ireland or Greece. For the sovereign debt crisis period, the correlations reveal strong interdependencies for Italy, Portugal and Spain. The non-Eurozone countries show small correlations with the remaining countries. This provides primary evidence that developments in Eurozone sovereign debt markets are affected by membership in the currency union. Whether this result continues to hold for volatility-adjusted conditional correlations is part of the following analysis.

1.3 Empirical Methodology

The empirical estimation strategy consists of three steps. First, we apply dynamic conditional correlations from a bivariate GARCH model to sovereign CDS spreads of 17 countries over the period of 2008 to 2012. Second, we separate periods of simple interdependence from contagion. Third, we analyze the determinants behind interdependent credit risk co-movements and the role of contagion using a regression analysis.

1.3.1 Correlation Analysis

We estimate dynamic conditional correlations (DCC) to obtain an indicator for the time-varying pattern of co-movements in sovereign credit risk spreads. The DCC series are obtained from a bivariate GARCH model as proposed by Engle (2002) and have been applied by e.g., Chiang et al. (2007) to study contagion in stock markets during the Asian crisis.[7] See the Appendix for a more detailed description of the model.

Similar to Engle (2002) or Chiang et al. (2007), the estimation of the DCC model evolves in two steps. First, univariate GARCH models are estimated for each demeaned time series of returns (or in our case, risk spreads). Thereby, time-varying standard deviations $\sqrt{h_{i,t}}$ are obtained. Second, these standard deviations are used to adjust the residuals $\xi_{i,t}$ corresponding to the time series under consideration, i.e., $v_{i,t} = \frac{\xi_{i,t}}{\sqrt{h_{i,t}}}$. From the standardized residuals, one can derive the conditional correlations. The DCC model is estimated by maximum likelihood in a two-stage procedure (see Engle, 2002). In contrast to Chiang et al. (2007), we do not specify a source country but estimate bivariate DCC GARCH models to obtain conditional correlations for each possible country pair separately. This accounts for the heterogeneity in the parameters that characterize the underlying correlation process.

[7] Coudert and Gex (2010) apply GARCH DCCs to study contagion among firms in the CDS market during the GM and Ford crisis. Wang and Moore (2012) use a DCC model to study co-movements in the sovereign CDS market during the subprime crisis. Missio and Watzka (2011) find evidence of contagion during the sovereign debt crisis based on conditional correlations but focus on yield spreads for the period 2008-2010 and rating announcements as the main determinants of contagious effects.

The dynamic conditional correlation framework provides us with estimates of volatility-adjusted co-movements of credit risk spreads between countries. This methodology has various advantages compared to alternative correlation measures. First, as in the study by Forbes and Rigobon (2002), the measure controls for heteroscedasticity. This is important because given that in turbulent times volatility increases, the correlation increases by statistical definition. This occurs even if fundamental cross-country linkages do not change. Only a significant change in volatility-adjusted correlations can thus be labeled as contagion.

Second, and in contrast to Forbes and Rigobon (2002), who rely on static correlations for the identification of contagion, our approach provides us with dynamic correlations. By obtaining time-varying correlation coefficients, we can, e.g., trace out the effects of changes in investors' behavior in response to market developments on cross-country co-movements.

Based on Forbes and Rigobon (2002), we interpret a significant increase in the estimated correlations between two countries' credit risk spreads as an indicator of contagion. This definition of contagion implies that a necessary condition to find evidence of contagion is the rejection of constant conditional correlations. If this is the case, the next step requires the measurement of significant increases in the DCCs. Once contagious episodes have been found, the results can be used to analyze the determinants of credit risk co-movements in sovereign debt markets and their role in channeling contagion. The empirical implementation to achieve this is presented in the following two sections.

1.3.2 Measurement of Contagion

Contagion is a term commonly used at least since the Russian and Asian crises. However, a common agreement on what constitutes contagion and how to measure it is lacking.[8] In this paper, we *define* an episode as contagious only if we find a significant increase in volatility-adjusted correlations (Boyer et al., 2006; Caporin et al., 2013; Forbes and Rigobon, 2002). The literature uses different methods to *measure* a contagious episode: if a threshold is exceeded, i.e., if the correlation falls outside of a certain confidence interval, if mean difference tests between tranquil and turbulent periods deliver significant results, or if time dummies capturing the turbulent periods have a significant impact on co-movements (Chiang et al., 2007; Caporale et al., 2005). Based on the third method, we take the weekly average of the dynamic conditional

[8] For further discussions see, e.g., Dornbusch et al. (2000), Kaminsky et al. (2003), Pericoli and Sbracia (2003) or Forbes (2012). Corsetti et al. (2005), Dungey et al. (2005), and Pesaran and Pick (2007) discuss empirical methods to measure contagion.

correlation ρ_{ijt} and test for contagion as follows:

$$\rho_{ijw} = d_0 + \sum_{k=1}^{K} d_k \rho_{ijw-k} + q_w dummy_w + \epsilon_{ijw}, \tag{1.1}$$

where ρ_{ijw} is the weekly average of the dynamic conditional correlation of country pair ij and $dummy_w$ is an indicator variable taking a value of one for a given week w and zero otherwise. If q_w shows a positive sign and is significantly different from zero at the 10 percent significance level, we interpret the episode corresponding to the dummy variable $dummy_w$ as contagious. The regressions are conducted for each country pair separately and in a sequential way, i.e. in the first set of regressions the dummy is one in week one and zero otherwise, in the second set of regressions the dummy is one in week two and zero otherwise, and so on.

It is important to note that we deviate from previous studies in various ways. First, we do not specify periods related to tranquil and turbulent times ex-ante as in Forbes and Rigobon (2002) or Chiang et al. (2007) in order to test whether correlations behave differently across periods. Instead, we take an agnostic and data driven approach in that we aggregate the data to weekly frequency, construct dummies for each week of the estimation period and test their significance sequentially. Aggregating to a lower frequency serves to eliminate possible short-run (over-)reactions in investors' perceptions. Constructing weekly dummies has the advantage that we do not impose strong assumptions about cut-off points. Focusing on the whole sample avoids a selection bias arising from an arbitrary division into subsamples with a usually large "non-crisis" sample and small "crisis" sample.[9]

Second, we do not specify a source crisis country but conduct the regression to measure contagion for each country pair in our sample separately. This allows us to obtain contagion indicators that vary across two dimensions: (i) over time and (ii) across country pairs. The contagion indicator can be exploited in the subsequent regression analysis and delivers a refined measure of contagion. Because the regression analysis is based on monthly data, the country pair specific contagion indicator is aggregated to monthly frequency and takes a value of one if at least one of the weekly dummies showed evidence of contagion and zero otherwise.

Third, in contrast to e.g., Caporin et al. (2013), we do not limit the analysis to the detection of contagion but seek to find out through which channels it affects credit risk co-movements. Because we obtain correlations for the whole period, this does not limit

[9] In a similar vein, and in order to circumvent this shortcoming, Caporale et al. (2005) select breakpoints endogenously to analyze contagion during the Asian crisis. Claeys and Vašíček (2014) use multivariate structural break tests in a FAVAR model to identify contagion.

our analysis to extreme events as in the studies by Bae et al. (2003) or Forbes (2012), and discrepancies in the transmission channels during tranquil and turbulent times can be separated. We can compare the determinants of significant increases in correlations with those causing cross-country correlations in tranquil times. In addition, by not imposing restrictions on the transmission channels of contagion ex ante, we can consider both the possibility of fundamentals based and non-fundamentals based contagion. A more detailed discussion of possible contagion channels can be found in Section 1.3.3.

In sum, our approach allows us to make use of the time series of volatility-adjusted correlations to analyze when significant increases in cross-country correlations, i.e., contagion, took place without being forced to make assumptions about break points, facing restrictions by observation windows of different length, or focusing only on one source country or contagion channel.

1.3.3 Separating Interdependence from Channels of Contagion

Empirical Specification

We now analyze which economic variables explain the observed pattern of sovereign credit risk co-movements. Thereby, our approach allows us to separate interdependence from channels of contagion. The dynamic conditional correlation framework outlined in Section 1.3.1 provides us with estimates of daily credit risk co-movements (ρ_{ijt}), which we aggregate to monthly averages denoted by ρ_{ijm}. Monthly data still capture short-run variation in co-movements but smooth out high-frequency noise. This approach is also in line with data availability regarding the explanatory variables (Table 1.3).

To investigate the determinants of credit risk co-movements, we use the DCCs as dependent variable in the following regression model (**specification (I)**):[10]

$$\rho_{ijm} = \mathbf{x}'_{ijm}\,\boldsymbol{\beta}_I + u_{ijm}, \tag{1.2}$$

where $\mathbf{x}_{ijm}$ denotes a vector containing the elements for all K explanatory variables ("determinants") for a certain country pair (ij) and time period (m), β_I is a vector containing the parameters, and u_{ijm} is the error term.

While this specification allows us to empirically assess the impact of global variables on sovereign credit risk co-movements, it controls neither for the full set of arbitrary

[10] Flavin et al. (2002) and Beine and Candelon (2011) use similar regression models applied to stock market correlations.

global shocks nor for unobserved heterogeneity across country pairs. To overcome this shortcoming, country pair and time fixed effects are included in **specification (II)**:

$$\rho_{ijm} = \boldsymbol{z}'_{ijm} \boldsymbol{\beta}_{II} + \lambda_{ij} + \gamma_m + v_{ijm}, \tag{1.3}$$

where $\boldsymbol{z}_{ijm}$ is a subset of $\mathbf{x}_{ijm}$ that contains the explanatory variables that vary across time and country pairs, λ_{ij} denotes country pair specific effects, and γ_m denotes time fixed effects.

The contagion indicator described in section 1.3.2 carries information about whether a country pair experienced a contagious episode at a certain point in time. Based on our definition, contagion means that shocks are transmitted more intensely than they are in tranquil times, leading to a significant increase in co-movements. Consequently, we call the channels through which this shock transmission occurs *channels of contagion*. These channels of contagion might be linkages that exist in tranquil times but abruptly change their strength or their role (or both) in turbulent times. Furthermore, they might be new channels that emerge in turbulent times and can be related to shifts in market sentiment. We refer to the first phenomenon as fundamentals based contagion and to the latter as non-fundamentals based contagion. We separate channels of contagion by adding interaction terms of the explanatory variables and the contagion indicator (**specification (III)**):

$$\rho_{ijm} = \mathbf{x}'_{ijm} \boldsymbol{\beta}_{III} + \tilde{\mathbf{x}}'_{ijm} \boldsymbol{\delta}_{III} \times CI_{ijm} + \phi_{IV}\, CI_{ijm} + u_{ijm} \tag{1.4}$$

where $\tilde{\mathbf{x}}_{ijm}$ is a subset of the explanatory variables $\mathbf{x}_{ijm}$. A variable constitutes a channel of contagion only if it affects the pattern of co-movements differently conditional on the occurrence of contagion, i.e., if the contagion indicator (CI_{ijm}) takes a value of one. In this case, the interaction term will have a significant effect. The equivalent specification including fixed effects is straightforward (**specification (IV)**):

$$\rho_{ijm} = \boldsymbol{z}'_{ijm} \boldsymbol{\beta}_{IV} + \tilde{\boldsymbol{z}}'_{ijm} \boldsymbol{\delta}_{IV} \times CI_{ijm} + \phi_{IV}\, CI_{ijm} + \lambda_{ij} + \gamma_m + v_{ijm} \tag{1.5}$$

Including the contagion indicator as explanatory variable in specifications (III) and (IV) leads to a bias in its coefficient (ϕ). The reason is that according to Section 1.3.2, the contagion indicator is derived endogenously from sovereign credit risk co-movements, which is the dependent variable in both specifications. However, following the identification strategy in Nunn and Qian (2013), interaction terms including one endogenous and one exogenous variable can be considered as exogenous.[11] Therefore estimation of the empirical specifications can yield insightful results on the channels of contagion. Clearly, the assumption of exogeneity of the explanatory variables entering the interaction term is key for the argument to hold. While exogeneity can be plausibly assumed for rather low-frequency macroeconomic and aggregate balance sheet variables, this might not be the case for high-frequency financial variables.

Choice of Explanatory Variables

We divide the explanatory variables into three groups based on their economic interpretation and theoretical considerations: (i) global controls, (ii) similarity in economic fundamentals, and (iii) direct and indirect linkages between countries. Table 1.3 shows the list of explanatory variables and their classifications.

(i) Global controls: Common macroeconomic shocks that affect all countries at the same time, such as changes in risk aversion or liquidity risk, are likely to affect the structure of credit risk co-movements in sovereign debt markets. We control for these global factors by including the VDAX implied volatility index and the Euribor-Eonia spread in specifications (I) and (III).[12] We expect increases in risk aversion and decreases in liquidity risk to lead to stronger credit risk co-movements. Macro shocks of any kind are implicitly controlled for by the time fixed effects in specifications (II) and (IV).

(ii) Similarity in economic fundamentals: Because the creditworthiness of a sovereign is connected to economic fundamentals, two countries with similar economic fundamentals should exhibit a higher degree of credit risk co-movement. This justifies the inclusion of similarity measures based on GDP growth, public debt, and foreign reserves held by the (national) central bank. We also include similarities in the size of the banking system and common portfolio exposure, where the first is proxied by banks' total assets and the latter by the correlation of bank equity prices. The rationale behind the inclusion of these banking sector-related variables is to capture the interdependence between sovereign and bank credit risk as an important feature of the Eurozone debt crisis. Such interdependence might arise through risk transfers from banks to sovereigns and the impact of sovereign credit risk on banks' holdings of sovereign debt (Acharya et al., 2014). We expect sovereign credit risk to co-move more strongly for two countries that

[11] In their 2012 working paper version (Nunn and Qian, 2012), the authors write: "Our instrument, which is constructed by interacting an arguably exogenous term (...) with one that is potentially endogenous (...), can be interpreted as exogenous since we directly control for the main effect of the endogenous variable (...)."

[12] We use the VDAX implied volatility index rather than the VIX because we consider it to be the more relevant measure in our analysis which focuses on the Eurozone.

are more similar to each other in specifications (I) and (II). By interacting the similarity measures with the contagion indicator in specifications (II) and (III), we can test for the presence of "wake-up call" contagion. This might arise if weak fundamentals in one country make investors aware of (similar) structural problems in other countries. In such a case, similarities in economic fundamentals constitute a channel of contagion.

(iii) Direct and indirect linkages: Variables related to direct linkages between countries account for simple interdependence in specifications (I) and (II). They comprise linkages associated with the real and financial sector. The real linkage is captured by bilateral trade flows. As banks hold sovereign debt on their balance sheets, they are likely to play a critical role in the transmission of shocks related to sovereign debt markets. We thus compute the financial linkage using bilateral data on banks' foreign claims from the Bank for International Settlements. In tranquil times, the financial linkage is assumed to improve international risk sharing and thus to reduce co-movements in sovereign credit risk (Kalemli-Ozcan et al., 2013). However, direct real and financial linkages might constitute channels of contagion in two respects. First, the *strength* of the linkages can fluctuate if trade flows collapse, banks rebalance their portfolios via asset sales, international interbank markets freeze, and bailouts take place. Second, the *role* of the linkages can change. While the linkages can enhance risk sharing and financial stability in tranquil times, it can foster the transmission of shocks and thus channel contagion in turbulent times. In both cases, we would expect an increase in credit risk co-movements. Bolton and Jeanne (2011) provide a theoretical framework for this state-dependent role of financial (or banking sector) integration in the transmission of shocks in sovereign debt markets.[13] By interacting both linkages with the contagion indicator in specifications (III) and (IV), we can test for this channel of contagion, which we call *fundamentals based contagion.*

In addition to direct linkages, sovereign debt markets might also be connected via more indirect or non-fundamental linkages. These linkages are often not prevalent in tranquil times but emerge in turbulent times. From a theoretical point of view, they can be related to concepts such as herding behavior, changes in market sentiment and the occurrence of "bad equilibria" or "risk panics" (Bacchetta et al., 2012; Masson, 1999). Even though non-fundamentals are generally not observable, proxies do exist. We choose the GDP weighted stock market volatility as a measure of common market sentiment for a given country pair. We do not expect the non-fundamental linkage to have a strong impact on credit risk co-movement in tranquil times. A significant

[13] The relation between the degree of market integration in general and the vulnerability to transmission of shocks and/or contagion is addressed in many papers and usually found to be non-monotonic. While a comprehensive literature review is out of scope of this paper, we refer to Allen and Gale (2000) as the seminal paper in this strand of literature.

impact of this variable when interacted with the contagion indicator in specifications (III) and (IV), however, would be a strong indication that sovereign debt markets have been subject to *non-fundamentals based contagion*.

1.4 Empirical Results

1.4.1 Dynamic Conditional Correlations

For all country pairs, we conduct bivariate DCC estimations with standard errors robust to non-normality. The DCC estimations deliver parameter estimates for the mean, conditional variance and correlation equation for $17 \times 16/2$ country pairs. These are reported in Table 1.4. In general, the AR(1) term in the mean equation is positive and significant. This can be explained by, for example, delayed adjustments in CDS prices (Duffie, 2011). The conditional variance equation shows mostly significant coefficients both for the lagged variance and the squared error term. This justifies the use of a time-varying volatility model. Because the coefficients a and b of the conditional variance equation almost sum up to one, this points towards a high persistence in volatility. The coefficients α and β, which characterize the time-varying correlation process, are highly significant for most country pairs.

Based on the coefficients of the correlation equation, we test if our assumption of a dynamic instead of a static model is reasonable. Except for three country pairs, we reject the null of static correlations at a significance level of 5 percent. This is a necessary pre-condition to not rule out the possibility of contagion, i.e., significant increases in volatility-adjusted correlations. To see whether our model fits the data in an acceptable way, we test the estimated standardized residuals for remaining ARCH effects. Following ARCH-LM tests, we cannot reject the null of no second order autocorrelation for the majority of cases. This reduces the concerns of model misspecification and is in line with the common finding that it is often hard to improve on a GARCH(1,1) model.[14]

Pairwise dynamic conditional correlations averaged across country pairs are shown in Figure 1.3. Countries are classified into four groups: Eurozone core countries, Eurozone periphery (GIIPS) countries, countries belonging to the EU but not the Eurozone, and countries outside of the EU (Table 1.5). From Figure 1.3, it becomes obvious that co-movements in sovereign CDS spreads increase after September 2008. The increase is highest for country pairs with both countries belonging to the Eurozone periphery and points towards the importance of weak economic fundamentals and common structural

[14]For brevity, post-estimation tests are not reported but can be obtained from the authors on request.

problems. Not surprisingly, the averaged dynamic conditional correlation series for this country group remains at high levels in the time following.

Nevertheless, crucial events leave their mark. For example, after the announcement that the expected Greek deficit was twice as large as expected in November 2009, the correlations for the periphery countries increase to 0.8. The following decline can be associated with the announcement of rescue packages in April 2010. However, the effect of these policy measures seems to be rather short-run. Another peak takes place during October 2011, which refers to a month with a great deal of uncertainty stemming from the failure of Dexia and negotiations about private sector involvement regarding Greek sovereign bonds. Co-movements again reach a lower level of approximately 0.6 in November 2011, most likely in response to ECB interventions in sovereign debt markets. In sharp contrast, correlation series referring to countries belonging to the EU and non EU countries tend to persist at low levels.

For the remaining three groups of country pairs, sovereign CDS spreads show similar co-movement patterns during the financial crisis. For example, correlations among core Eurozone country pairs behave very similarly to Eurozone and EU/non-Eurozone country pairs. However, while the latter decline with the start of the sovereign debt crisis, this decline does not take place for Eurozone country pairs. The importance of being a member in the Eurozone is also reflected in the fact that risk spreads of Eurozone country pairs show stronger co-movements on average than correlation series for combinations of Eurozone countries and EU countries outside the Eurozone.[15] In this regard, the sovereign debt crisis seems to keep common dynamics at a higher level within Eurozone countries, whereas rescue packages predominantly lower co-movements between GIIPS countries as well as among EU countries inside and outside the Eurozone. Summary statistics of the DCC series averaged per country group and for different sub-periods confirm the findings above (Table 1.6).

1.4.2 Measurement of Contagion

As outlined in Section 1.3.2, the regression model to measure contagion as a significant increase in DCC series is given by:

$$\rho_{ijw} = d_0 + d_1\rho_{ijw-1} + d_2\rho_{ijw-2} + q_w dummy_w + \epsilon_{ijw}, \tag{1.6}$$

[15] Similarly, using a multifactor model, Ang and Longstaff (2013) find high levels of systemic risk among Eurozone sovereigns compared to US states whereby the latter share not only a common currency but also a political union.

where ρ_{ijw} is the dynamic correlation of country pair ij and $dummy_w$ is an indicator variable taking a value of one for a given week w and zero otherwise. We choose an AR(2) model following the general tendency suggested by conventional model selection criteria. The number of measured contagious episodes, i.e., the number of q_w that are positive and significant, summed up across country pairs for each week of the estimation period is shown in Figure 1.4.

Both the total number as well as the number of contagious episodes per country group can be observed, and the result confirms our strategy to test for contagion by country pair and across time. Without doubt, there are common patterns across country groups, such as a high number of significant increases in correlations after the failure of Lehman Brothers. However, there are also discrepancies: Looking at the period between the announcement of the unexpectedly high Greek deficit in November 2009 and the Greek bailout combined with ECB interventions in securities markets in May 2010, it becomes obvious that contagion occurs more frequently in periphery Eurozone than in core Eurozone countries. This indicates that uncertainty about the sustainability of Greek government finances particularly affected countries assumed to have economic fundamentals and structural problems similar to Greece. Trying to measure contagion by imposing a single dummy variable for e.g., a crisis period that is in continuation held constant across all country pairs would miss this variation. Our results are also in line with Alter and Beyer (2014) who study spillovers among banks and sovereigns in the Eurozone. The authors derive a contagion index from generalized impulse response functions in a standard VAR analysis. They find that the contagion index fluctuates, whereas high values can be associated with policy events. However, their index relates to bank-sovereign contagion not sovereign-sovereign contagion.

1.4.3 Separating Interdependence from Channels of Contagion

The estimation results of the regression analysis are shown in Table 1.7. The estimation period runs from January 2008 to March 2012.[16] The column numbers correspond to the numbers of the empirical specifications presented in section 1.3.3. Accordingly, estimation results given in columns (I) and (II) – the latter based on the specification with fixed effects – shed light on the factors that explain the general pattern of sovereign credit risk co-movements. The VDAX volatility index and the Euribor-Eonia spread were chosen as global controls that measure the degree of risk aversion and overall liquidity risk, respectively. The results suggest that increasing risk aversion and higher

[16] March 2012 being the last period is due to availability of data from the BIS Consolidated Banking Statistics.

liquidity risk in financial markets are associated with higher credit risk co-movements. These results are in line with the literature on the determinants of sovereign credit risk spreads (Manganelli and Wolswijk, 2009; Aizenman et al., 2013).

Furthermore, sovereign credit risk co-moves more strongly for two countries that are more similar with respect to GDP growth, the size of their banking systems, and common portfolio exposures of banks proxied by the correlation in bank equity prices. The significant impact of the two banking sector-related variables reflects the interconnection between the financial and the public sectors (Acharya et al., 2014). In contrast, neither similarities in foreign reserves (only weakly significant in (II)) nor similarities in public debt seem to play a role in sovereign credit risk co-movements. The results for the variables capturing cross-country linkages suggest that stronger financial linkages, as measured by banks' foreign claims, tend to reduce co-movements (in (I) only), while the real linkage, as measured by bilateral trade flows, does not seem to have an effect. Adverse shifts in common market sentiment, as measured by an increase in GDP-weighted stock market volatilities, are associated with higher co-movements.

Columns (III) and (IV) show the estimation results of the two corresponding specifications, which include the interaction terms of selected explanatory variables and the contagion indicator to separate the different channels of contagion. As outlined in Section 1.3.3, the idea behind this approach is that an explanatory variable constitutes a channel of contagion if it affects the pattern of co-movements differently conditional on the occurrence of contagion. The results in the upper portions of the table show that for all three groups of variables, the direct impact (without interaction) does not change much compared to the previous two columns. This confirms the roles of these variables as determinants of sovereign credit risk co-movements in tranquil times that constitute the underlying interdependence structure. The picture changes, however, as soon as not only simple interdependence but also contagious episodes are accounted for. Not surprisingly, the contagion indicator itself (CI) is highly significant and positively correlated with sovereign credit risk co-movements. While this is a result of the contagion indicator being derived endogenously from the co-movements, its interactions with other variables is still informative as pointed out in Section 1.3.3. The interaction terms are shown in the lower part of the table. Their effects on the pattern of sovereign credit risk co-movements can be attributed to either "wake-up call", fundamentals based or non-fundamentals based contagion.

First, we find evidence of *"wake-up call" contagion*: Conditional on the occurrence of contagion, the effect of similarity in public debt on sovereign credit risk co-movements is positive and statistically significant (in (IV) only). This finding indicates that contagion is related to the re-assessment of public sector debt as an important determinant of credit risk. In contrast, we do not find such a significant re-assessment regarding banks' common portfolio exposures proxied by the correlation in bank equity prices.

Second, the empirical findings point to *fundamentals based contagion*: In tranquil times, sovereign credit risk in two countries that are more financially integrated in terms of their banks' foreign claims seems to be unaffected (column (IV)) or tends to co-move less (column (III)). This supports the notion that this type of financial linkage enhances risk diversification (Kalemli-Ozcan et al., 2013). Conditional on the occurrence of contagion, however, a stronger linkage is associated with stronger co-movement in sovereign credit risk (column (IV) only). The role of the financial linkage changes from being a tool for risk diversification to a channel of contagion. The result provides evidence of the state-dependent role of banking sector integration as outlined by Bolton and Jeanne (2011) and thus what we call fundamentals based contagion. As regards the impact of trade ("real linkage"), it seems to increase co-movements in tranquil times but decrease them during contagious episodes. An interpretation might be that risk diversification via bilateral trade was still possible.

Finally, *non-fundamentals based contagion* is also present in sovereign debt markets: We find a positive and significant relationship between adverse shifts in common market sentiment, i.e., higher GDP-weighted stock market volatility and credit risk co-movements. Consequently, part of the pattern of credit risk co-movements can be attributed to non-fundamentals based contagion. This result is in line with recent findings by Beirne and Fratzscher (2013). The authors report evidence for "herding contagion", which corresponds closely to our definition of non-fundamentals based contagion. It is also in line with the results of Aizenman et al. (2013) and De Grauwe and Ji (2012), who see "bad" or "pessimistic equilibria" as a possible explanation for their empirical findings of the higher pricing of sovereign risk.

1.4.4 Robustness Analyses

Table 1.8 shows that the results are robust to a number of alternative specifications. In column (A-I), we apply the Fisher z-transformation to the dependent variable. The Fisher z-transformation mitigates a potentially skewed distribution in correlation coefficients, which could lead to incorrect inference. While the point estimates differ in size due to the transformation, there are no major changes in their statistical significance. In column (A-II) all explanatory variables are lagged by one period. This mitigates potential concerns related to simultaneity. We still find evidence for fundamentals based contagion channeled through the financial linkage. The interaction term of banks' foreign claims and the contagion indicator remains significant at the 5 percent level. The same holds true for "wake-up call" contagion, albeit at a higher significance level of

10 percent. In contrast, the specification does not point to non-fundamentals based contagion. An explanation is that common market sentiment channels contagion right at the instant it occurs, which is better captured by the contemporaneous rather than the lagged stock market volatility. Column (A-III) shows that the main results remain unaltered if the contagion indicator is based on a lower significance level of 5 percent. This does not hold true for "wake-up call" contagion, however, as the interaction term with public debt now becomes insignificant. Column (A-IV) shows that the results with respect to "wake-up call" contagion are robust for the time span starting from the onset of the sovereign debt crisis (November 2009). However, nothing can be said about fundamentals based and non-fundamentals based contagion during this time period.

The results in Table 1.9 are based on a subsample of Eurozone countries. Columns (B-I) and (B-II) are equivalent to specifications (III) and (IV) and confirm the results regarding fundamentals based contagion (for the financial linkage only in (B-II)). Column (B-II) shows that while the financial linkage is associated with lower co-movements in tranquil times, it is related to higher co-movements in turbulent times. As pointed out in Section 1.4.3, this finding is in line with Bolton and Jeanne (2011) and Kalemli-Ozcan et al. (2013). However, the finding of "wake-up call" and non-fundamentals based contagion is not robust to the smaller sample of Eurozone countries. Specification (B-III) additionally includes the euro exchange rate (EUR/USD) as global control, which turns out to have a large and significant effect on credit risk co-movements. Including the euro exchange rate renders the impact of global risk aversion insignificant. While risk aversion was found to be a key driver of sovereign credit risk spreads, it seems to be dominated by a common regional factor among Eurozone countries. This suggests that Eurozone countries are tied together, and by no means do only national factors play a role in shaping credit risk movements.

1.5 Conclusions

This study investigates credit risk co-movements and contagion in sovereign debt markets for the period 2008-12. We first apply a DCC GARCH model to the sovereign CDS spreads of 17 industrialized countries. In this way, we obtain time-varying correlations for each country pair. Because our sample includes both countries within and outside the Eurozone, this sheds light on the role of the common currency in sovereign credit risk co-movements. Second, we detect contagious episodes, i.e., periods in which co-movements increase significantly, separately for each country pair. We collect the information in a contagion indicator, which varies across time and countries. Third, we assess which variables determine the overall pattern of co-movement and account for interdependence. The contagion indicator is used to analyze whether certain variables affect the pattern of sovereign credit risk co-movement differently conditional on the occurrence of contagion. This approach allows the identification of the channels of contagion.

Our main results are as follows. First, the correlation analysis shows that sovereign markets in the Eurozone are strongly interconnected and co-move on a higher level than non-Eurozone countries. This holds for both periphery and core Eurozone countries and is in contrast to the vastly documented divergence in individual countries' credit risks. We document that contagion cannot be attributed to one moment in time but shows a large variation both across time and countries. The contagious episodes we detect match well with key events in the crisis. Finally, our results suggest that similarities in economic fundamentals, cross-country linkages in banking, and common market sentiment constitute the channels through which contagion occurs.

Several policy implications can be drawn from our findings. Given that contagion occurs at different points in time, there is a need for timely intervention measures. The evidence of "wake-up call" contagion suggests that fundamental reforms targeted at reducing unsustainable debt levels, for instance, will reduce vulnerabilities to contagious episodes. The role of financial and trade linkages in transmitting or absorbing shocks is double-edged. Even during crises, these linkages might serve risk-sharing purposes but can instantly become a channel of contagion. In line with Forbes (2012), policies that aim to reduce international linkages would need to consider this trade-off. Regarding non-fundamentals based contagion, policy measures that influence expectations of market participants might prove most effective in reducing uncertainty. Our finding of a strong "Eurozone effect" points towards the need for Eurozone-wide policy measures. The creation of the European Stability Mechanism (ESM) and unconventional monetary policy measures conducted by the ECB might be considered in this light.

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Appendix to Chapter 1

1.A GARCH DCC model

The estimation of a GARCH DCC model requires time series with mean zero (Engle and Sheppard, 2001). Thus, to start with, we have to apply a demeaning process to the credit risk spreads in order to obtain appropriate residual series. The mean equation for each 2×1 vector of daily CDS spreads $y_t = (y_{1,t}, y_{2,t})'$ is specified as

$$y_t = \gamma_0 + \gamma_1 y_{t-1} + \xi_t \tag{1.7}$$

where $y_{i,t}$ is the log first difference of the CDS spreads, i.e. $log(CDS_{i,t}) - log(CDS_{i,t-1})$, and $\xi_t = (\xi_{1,t}, \xi_{2,t})'$ is a 2×1 vector of residual terms. Conditional on time $t-1$ information Ω_{t-1}, the residuals are assumed to be multivariate normally distributed with mean zero and variance-covariance matrix H_t such that $\xi_t|\Omega_{t-1} \sim N(0, H_t)$. The method exploits the fact that the variance-covariance matrix can be written as

$$H_t = D_t R_t D_t \tag{1.8}$$

where R_t is a 2×2 matrix of time-varying conditional correlations and D_t is a 2×2 diagonal matrix of time-varying standard deviations with $\sqrt{h_{i,t}}$ on the $i-$th diagonal. The elements of D_t are assumed to follow a univariate GARCH (1,1) process given by:

$$h_{i,t} = \omega_i + a_i \xi_{i,t-1}^2 + b_i h_{i,t-1} \tag{1.9}$$

with a constant ω_i and the parameters a_i and b_i accounting for the effect of past innovations, respectively capturing the persistence in volatility. In the first stage, univariate GARCH models for $h_{i,t}$ are estimated and the estimates for the standard deviations are used to standardize the residuals, i.e. $v_{i,t} = \frac{\xi_{i,t}}{\sqrt{h_{i,t}}}$.

The second stage makes use of the standardized residuals in order to estimate the time-varying correlation of the DCC (1,1) process which can be expressed as follows:

$$Q_t = (1 - \alpha - \beta)\bar{Q} + \alpha v_{t-1} v_{t-1}' + \beta Q_{t-1} \tag{1.10}$$

where $\bar{Q}$ is the 2×2 unconditional time-invariant covariance matrix while Q_t with elements $q_{ij,t}$ is the 2×2 time-varying variance-covariance matrix of the standardized residuals v_t. The parameters α and β are non-negative and restricted to $\alpha + \beta < 1$.

The final correlation matrix R_t is then given by

$$R_t = (diag(Q_t))^{-1/2} Q_t (diag(Q_t))^{-1/2}. \tag{1.11}$$

The scaling of Q_t ensures to obtain a correlation matrix with ones on the diagonal and elements $\in [-1, 1]$ otherwise. Individual off-diagonal elements of R_t provide information on the correlation between CDS spreads in country i and j and can be written as $\rho_{ij,t} = q_{ij,t}/\sqrt{q_{ii,t}q_{jj,t}}$ for $i \neq j$.

Following Engle (2002), the GARCH DCC model is estimated by maximum likelihood in two steps. The log likelihood function is given below:

$$\ell = -1/2 \sum_{t=1}^{T} (2log(2\pi) + log|H_t| + \xi_t' H_t^{-1} \xi_t) \tag{1.12}$$

and can be decomposed in a volatility part being the sum of the individual GARCH likelihoods and a correlation component such that we can write $\ell(\theta, \phi) = \ell_v(\theta) + \ell_c(\theta, \phi)$ where $\ell_v(\theta) = -1/2 \sum_{t=1}^{T} (2log(2\pi) + 2log|D_t| + \xi_t' D_t^{-1} D_t^{-1} \xi_t)$ and $\ell_c(\theta, \phi) = -1/2 \sum_{t=1}^{T} (log|R_t| + v_t' R_t v_t - v_t' v_t)$. Thereby, $\theta = (\omega_i, a_i, b_i)$ denotes the parameters belonging to D_t and $\phi = (\alpha, \beta)$ contains the remaining parameters in R_t. In a first step, the log likelihood $\ell_v(\theta)$ is maximized yielding estimates for θ. The following estimation step conditions on these estimates $\hat{\theta}$ and maximizes $\ell_c(\hat{\theta}, \phi)$ with respect to the correlation coefficients in ϕ. Under a set of regularity conditions the parameter estimates are consistent and asymptotically normal (Engle and Sheppard, 2001).

1.B Figures and Tables

Figure 1.1: **Credit risk in sovereign debt markets (CDS, basis points)**
The graph plots sovereign CDS premia in basis points for the period January 2008 to September 2012. The series for six selected Eurozone countries (France, Germany, Ireland, Italy, Portugal and Spain) are depicted in the upper left. The series for the group of periphery Eurozone countries (Ireland, Italy, Portugal, Spain and Greece) are shown in the upper right. The lower left refers to core Eurozone countries (Austria, Belgium, Finland, France, Germany and the Netherlands) and the lower right to non-Eurozone countries (Denmark, Japan, Norway, Sweden, United Kingdom and United States). Data source: Datastream.

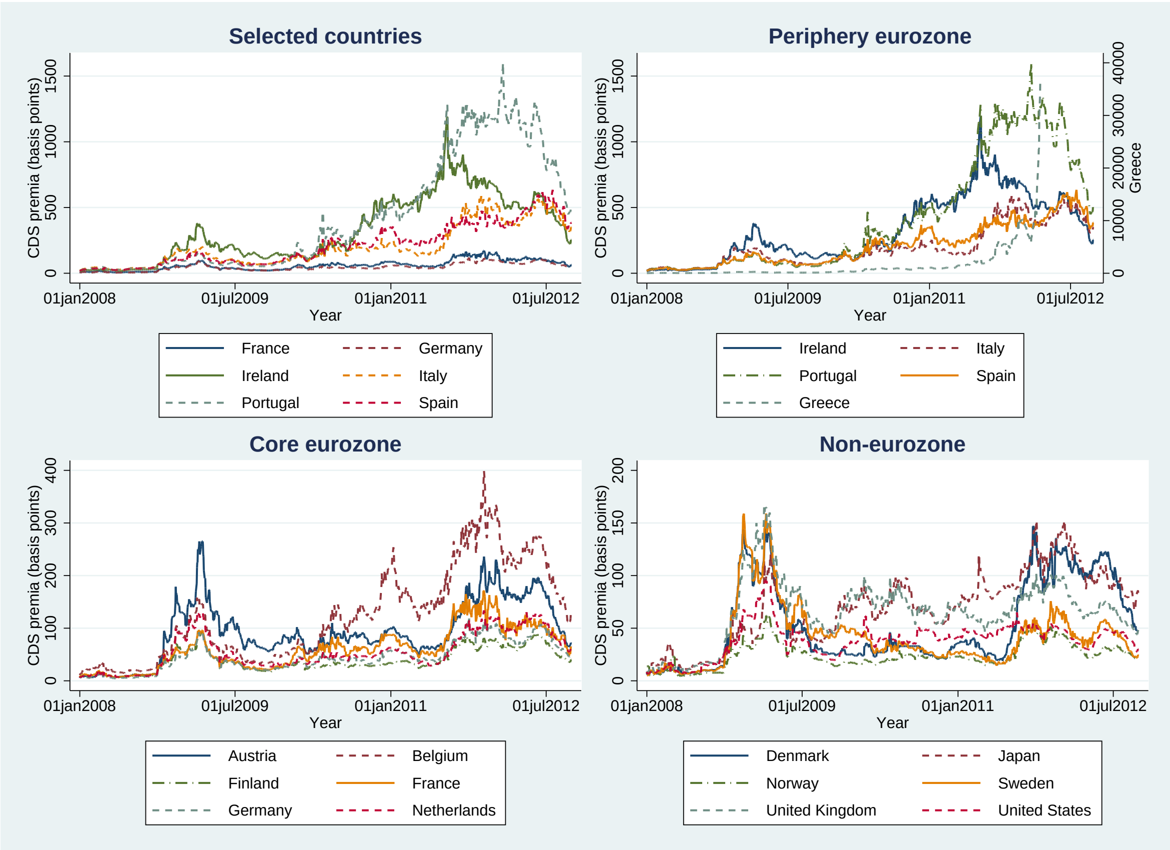

Figure 1.2: **Credit risk in sovereign debt markets (CDS, log difference)**
The graph plots the log differenced series of sovereign CDS premia for the 17 countries in the sample over the period from January 2008 to September 2012. Data source: Datastream, own calculations.

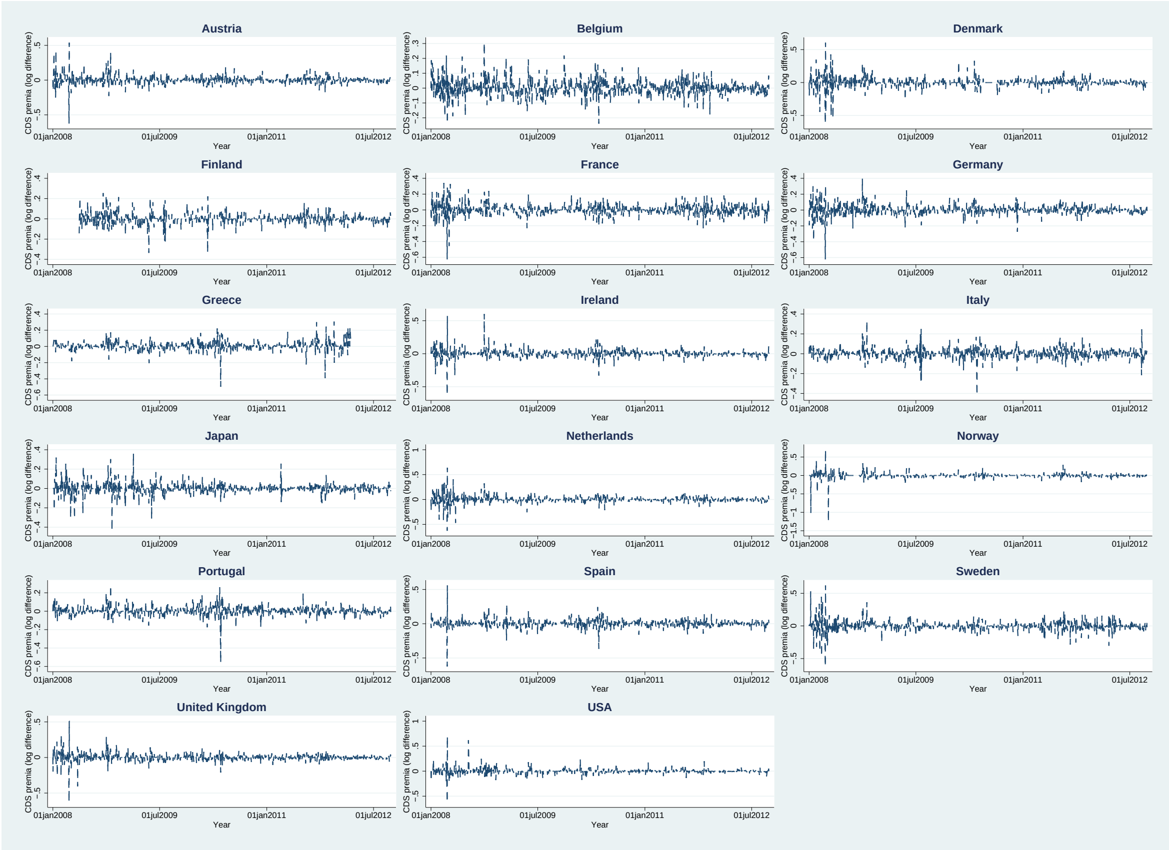

Figure 1.3: **Dynamic conditional correlations by country group**
The graph shows dynamic conditional correlations by country groups for the estimation period from January 2008 to September 2012. The individual series are averaged across countries belonging to one country group. All series are depicted in the upper left panel followed by the averaged series across core Eurozone country pairs (EZ: Core-core), periphery Eurozone country pairs (EZ: Periphery-periphery), core and periphery Eurozone country pairs (EZ: Core-periphery), Eurozone and non Eurozone country pairs belonging to the EU (EU: EZ-non EZ), EU and non EU country pairs (Other: EU-non EU). Key events are marked by a vertical line, e.g. 1 corresponds to the failure of Lehman Brothers in September 2008.

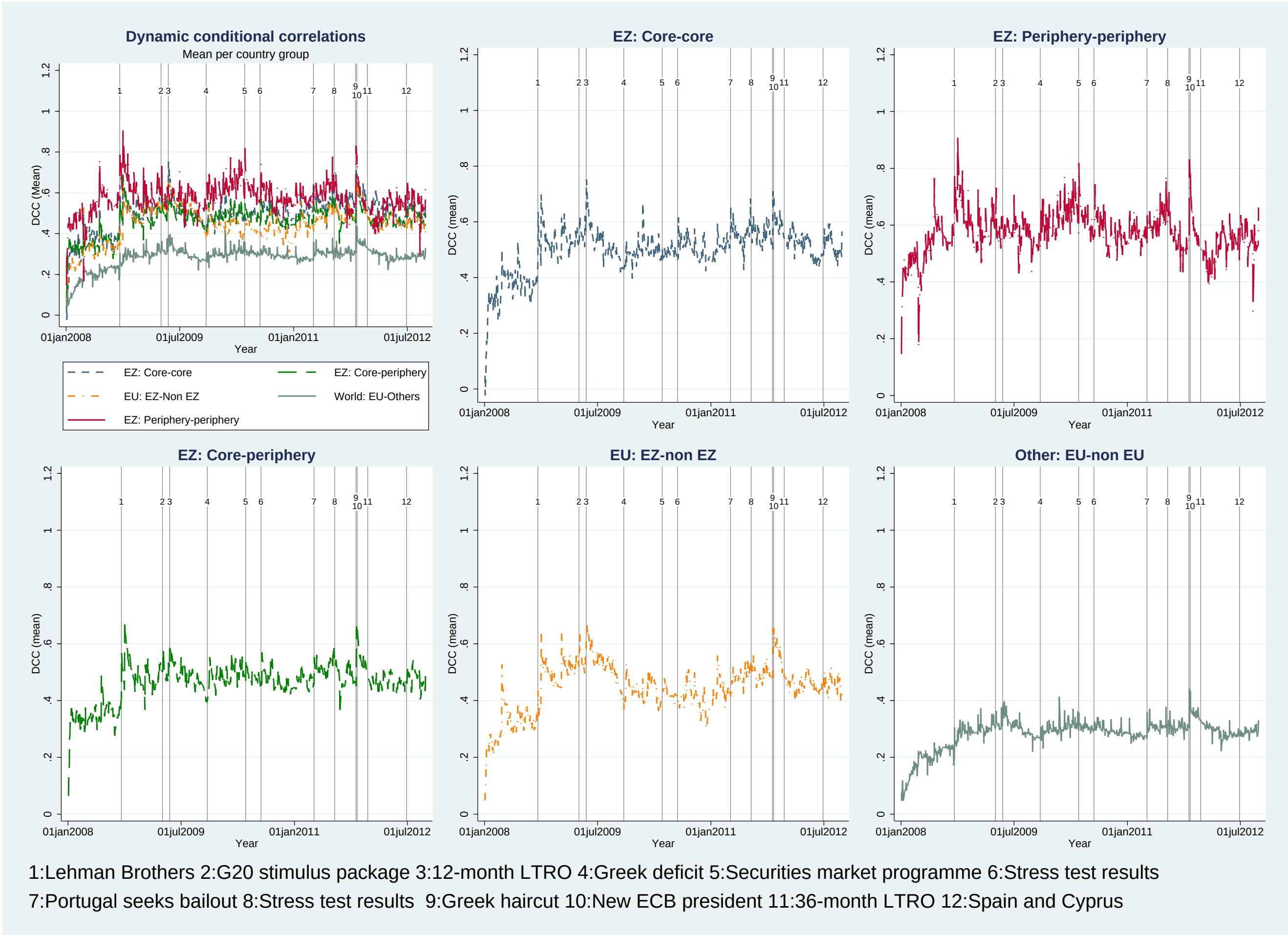

Figure 1.4: **Contagious episodes**
The graph shows the number of measured contagious episodes, i.e. the number of q_w being positive and significant, summed up across country pairs for each week of the estimation period from January 2008 to September 2012. The total sum across all country pairs is depicted in the upper left panel followed by the partial sums over core Eurozone country pairs (EZ: Core-core), periphery Eurozone country pairs (EZ: Periphery-periphery), core and periphery Eurozone country pairs (EZ: Core-periphery), Eurozone and non Eurozone country pairs belonging to the EU (EU: EZ-non EZ), EU and non EU country pairs (Other: EU-non EU). Key events are marked by a vertical line, e.g. 1 corresponds to the failure of Lehman Brothers in September 2008.

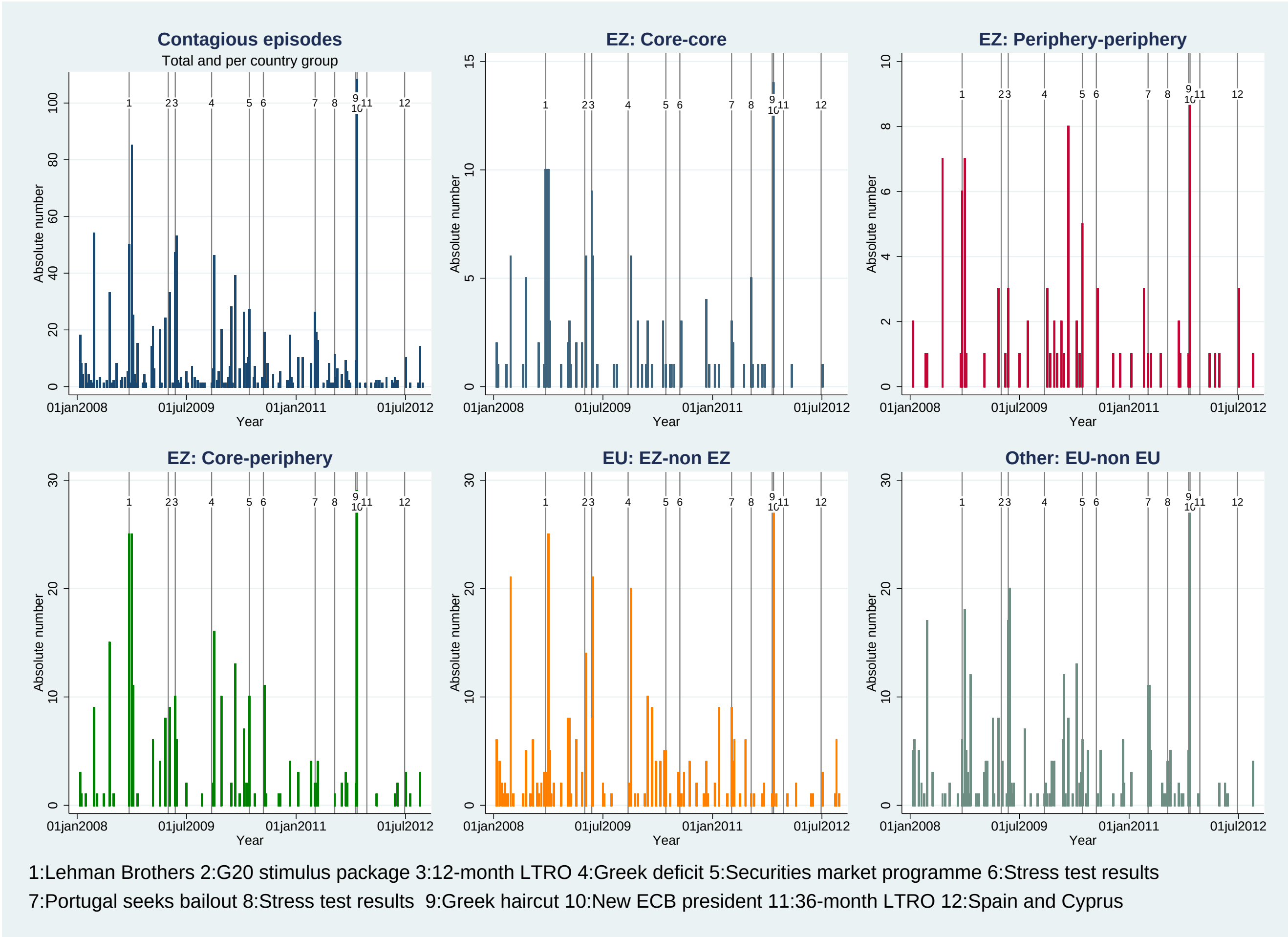

Table 1.1: **Summary statistics: daily 5-year CDS premia (log difference)**
The table shows summary statistics for the daily series of 5-year sovereign CDS premia in log differences. The period starts in January 2008 and ends in September 2012. The table gives the minimum, maximum, mean, standard deviation, skewness, kurtosis, the augmented Dickey Fuller tests with lag order 10 to test for a unit root, the Jarque Bera test statistic to test for normality, and the Q-statistic with lag order 10 to test for serial correlation in the squared series.

Country	Min	Max	Mean	Std.Dev.	Skewness	Kurtosis	ADF lag(10)	Jarque-Bera	Q-statistic lag (10)
Austria	-0.627	0.539	0.002	0.058	0.69	26.43	-9.71	28000	191
Belgium	-0.239	0.306	0.002	0.050	0.45	7.28	-10.93	986	100
Denmark	-0.624	0.606	0.002	0.069	-0.54	24.86	-10.26	25000	302
Finland	-0.337	0.255	0.002	0.048	-0.03	11.75	-10.14	3638	190
France	-0.626	0.343	0.002	0.065	-0.50	14.56	-10.96	6942	268
Germany	-0.622	0.398	0.002	0.060	-0.59	18.73	-11.06	13000	115
Greece	-0.497	0.307	0.007	0.052	-0.53	18.15	-8.32	10000	54
Ireland	-0.626	0.601	0.002	0.057	0.61	35.56	-11.33	55000	120
Italy	-0.416	0.331	0.002	0.049	-0.28	12.82	-11.69	4993	164
Japan	-0.437	0.363	0.002	0.053	-0.10	16.35	-10.00	9191	97
Netherlands	-0.628	0.640	0.002	0.065	-0.10	26.42	-11.22	28000	320
Norway	-1.259	0.699	0.000	0.071	-5.77	125.30	-13.07	780000	1
Portugal	-0.560	0.280	0.003	0.048	-0.88	21.91	-10.90	19000	122
Spain	-0.624	0.559	0.003	0.053	-0.34	31.07	-11.92	41000	220
Sweden	-0.621	0.621	0.001	0.072	0.26	19.77	-11.13	15000	265
United Kingdom	-0.628	0.511	0.001	0.051	-0.84	37.07	-10.69	60000	195
United States	-0.620	0.699	0.001	0.054	1.88	53.87	-9.89	130000	158

Table 1.2: **Correlation matrix: daily 5-year CDS premia (log difference)**
The table shows the correlation matrix for the daily series of 5-year sovereign CDS premia in log differences. The upper part is based on the period January 2008 to October 2009. The lower part is based on the period November 2009 to September 2012.

	AU	BE	DK	FI	FR	DE	GR	IE	IT	JP	NL	NO	PT	ES	SE	UK	USA
January 2008 - October 2009																	
Austria	1.00																
Belgium	0.66	1.00															
Denmark	0.63	0.62	1.00														
Finland	0.51	0.52	0.59	1.00													
France	0.64	0.64	0.60	0.52	1.00												
Germany	0.51	0.53	0.50	0.50	0.63	1.00											
Greece	0.69	0.61	0.65	0.51	0.62	0.53	1.00										
Ireland	0.65	0.63	0.54	0.41	0.61	0.55	0.67	1.00									
Italy	0.65	0.57	0.53	0.44	0.56	0.53	0.69	0.57	1.00								
Japan	0.35	0.28	0.26	0.20	0.25	0.17	0.19	0.25	0.28	1.00							
Netherlands	0.68	0.62	0.61	0.58	0.62	0.63	0.58	0.56	0.54	0.22	1.00						
Norway	0.55	0.53	0.46	0.40	0.51	0.45	0.50	0.50	0.47	0.15	0.49	1.00					
Portugal	0.72	0.62	0.55	0.47	0.61	0.51	0.66	0.68	0.69	0.31	0.59	0.50	1.00				
Spain	0.70	0.64	0.59	0.53	0.66	0.53	0.69	0.63	0.65	0.28	0.58	0.49	0.73	1.00			
Sweden	0.60	0.52	0.60	0.51	0.58	0.50	0.63	0.53	0.53	0.26	0.57	0.47	0.57	0.57	1.00		
United Kingdom	0.55	0.59	0.55	0.48	0.62	0.44	0.56	0.46	0.50	0.18	0.52	0.43	0.53	0.60	0.50	1.00	
United States	0.29	0.33	0.33	0.31	0.47	0.36	0.34	0.26	0.36	0.13	0.36	0.24	0.32	0.36	0.24	0.46	1.00
November 2009 - September 2012																	
Austria	1.00																
Belgium	0.70	1.00															
Denmark	0.50	0.48	1.00														
Finland	0.54	0.47	0.43	1.00													
France	0.64	0.66	0.43	0.46	1.00												
Germany	0.64	0.64	0.53	0.45	0.66	1.00											
Greece	0.41	0.50	0.31	0.32	0.44	0.41	1.00										
Ireland	0.53	0.63	0.41	0.39	0.54	0.52	0.52	1.00									
Italy	0.64	0.78	0.48	0.47	0.65	0.62	0.54	0.69	1.00								
Japan	0.21	0.21	0.20	0.21	0.22	0.24	0.18	0.20	0.23	1.00							
Netherlands	0.68	0.65	0.52	0.52	0.59	0.66	0.36	0.46	0.59	0.22	1.00						
Norway	0.60	0.50	0.44	0.51	0.48	0.56	0.34	0.42	0.46	0.18	0.56	1.00					
Portugal	0.55	0.66	0.39	0.39	0.55	0.60	0.57	0.74	0.76	0.18	0.46	0.43	1.00				
Spain	0.62	0.76	0.50	0.44	0.65	0.63	0.56	0.72	0.88	0.17	0.54	0.46	0.80	1.00			
Sweden	0.44	0.39	0.39	0.42	0.36	0.41	0.30	0.30	0.37	0.12	0.46	0.42	0.30	0.37	1.00		
United Kingdom	0.65	0.68	0.43	0.45	0.62	0.65	0.44	0.59	0.71	0.21	0.58	0.48	0.62	0.68	0.38	1.00	
United States	0.44	0.48	0.32	0.38	0.40	0.44	0.30	0.36	0.48	0.20	0.40	0.38	0.43	0.44	0.25	0.51	1.00

Table 1.3: **Explanatory variables descriptions and sources: regression analysis**

Classification	Variable	Description	Frequency	Source
Global controls (m)	%ΔVDAX volatility	pct. change of DAX implied volatility	monthly	Datastream
	%ΔEuribor - Eonia	pct. change in spread	monthly	Datastream
	%ΔEUR/USD	pct. change in exchange rate (Euro/USD)	monthly	Datastream
Similarity in economic fundamentals (ij)	ΔGDP	Q/Q change in sum of log GDP (times 100)	quarterly	Datastream
	Public debt	$-\lvert X_i - X_j \rvert \times 100$ with $X_i = \frac{\text{Public debt}_i}{\text{GDP}_i}$ (percent)	quarterly	BIS
	Foreign reserves	$-\lvert X_i - X_j \rvert \times 100$ with $X_i = \frac{\text{Foreign reserves}_i}{\text{GDP}_i}$ (percent)	monthly	Datastream
	Banking system size	$-\lvert X_i - X_j \rvert \times 100$ with $X_i = \frac{\text{Bank assets}_i}{\text{GDP}_i}$ (percent)	monthly	ECB
	Bank equity corr.	Monthly correlation of bank stock price index (percent)	monthly	Datastream
Linkages (ij)	Banks' foreign claims	sum of bilateral claims over sum of GDP (percent)[a]	quarterly	BIS Consolidated Banking Statistics
	Trade	sum of exports over sum of GDP (percent)	monthly	IMF DOTS
	Stock market volatility	GDP weighted average of countries' stock market volatilities	monthly	Datastream

[a] Bilateral claims are banks' total foreign claims reported on *ultimate risk basis* (URB). If data on URB was not available, data reported on *intermediate borrower basis* (IBB) were used instead.

Table 1.4: **DCC GARCH model: estimation results**
The table reports estimation results of bivariate DCC-GARCH models. The return equation is given by: $y_t = \gamma_0 + \gamma_1 y_{t-1} + \xi_t$. The variance equations is: $h_{i,t} = \omega_i + a_i \xi^2_{i,t-1} + b_i h_{i,t-1}$. The coefficients of the correlation process are given by: α and β. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively. Standard errors (SE) are robust to non-normality.

Country pair ij		Mean equation								Variance equation												Covariance equation			
i	j	γ_{0i}	SE	γ_{1i}	SE	γ_{0j}	SE	γ_{1j}	SE	ω_{0i}	SE	a_i	SE	b_i	SE	ω_{0j}	SE	a_j	SE	b_j	SE	α	SE	β	SE
1) AU	Belgium	-0.001	0.001	0.124 ***	0.027	0.000	0.001	0.090 ***	0.028	0.000 ***	0.000	0.072 ***	0.008	0.932 ***	0.006	0.000 ***	0.000	0.116 ***	0.019	0.865 ***	0.023	0.076 ***	0.011	0.859 ***	0.015
	Denmark	-0.001	0.001	0.099 ***	0.028	0.000	0.001	0.072 **	0.030	0.000 ***	0.000	0.053 ***	0.007	0.943 ***	0.006	0.000 ***	0.000	0.061 ***	0.009	0.911 ***	0.013	0.149 ***	0.026	0.463 ***	0.092
	Finland	-0.001	0.001	0.110 ***	0.029	0.000	0.001	0.078 **	0.035	0.000 ***	0.000	0.067 ***	0.010	0.923 ***	0.010	0.000 ***	0.000	0.185 ***	0.030	0.722 ***	0.043	0.003	0.002	0.991 ***	0.002
	France	-0.001	0.001	0.064 **	0.028	0.000	0.001	0.021	0.029	0.000 ***	0.000	0.058 ***	0.007	0.941 ***	0.005	0.000 ***	0.000	0.102 ***	0.018	0.882 ***	0.019	0.026 ***	0.006	0.958 ***	0.009
	Germany	-0.001	0.001	0.083 ***	0.028	0.000	0.001	0.033	0.030	0.000 **	0.000	0.070 ***	0.008	0.935 ***	0.006	0.000 ***	0.000	0.099 ***	0.014	0.898 ***	0.013	0.042 ***	0.008	0.900 ***	0.022
	Greece	-0.001	0.001	0.138 ***	0.029	0.002 **	0.001	0.114 ***	0.032	0.000 **	0.000	0.057 ***	0.007	0.943 ***	0.006	0.000 ***	0.000	0.074 ***	0.008	0.929 ***	0.006	0.053 ***	0.011	0.878 ***	0.020
	Ireland	-0.002	0.001	0.147 ***	0.028	0.000	0.001	0.194 ***	0.030	0.000 ***	0.000	0.063 ***	0.009	0.934 ***	0.006	0.000 ***	0.000	0.176 ***	0.020	0.863 ***	0.010	0.028	0.017	0.272	0.189
	Italy	-0.002	0.001	0.133 ***	0.027	0.000	0.001	0.088 ***	0.029	0.000 **	0.000	0.059 ***	0.007	0.942 ***	0.005	0.000 ***	0.000	0.168 ***	0.021	0.793 ***	0.024	0.064 ***	0.014	0.845 ***	0.027
	Japan	-0.002	0.001	0.141 ***	0.032	0.000	0.001	0.064 *	0.033	0.000 **	0.000	0.061 ***	0.008	0.939 ***	0.006	0.000 ***	0.000	0.089 ***	0.011	0.908 ***	0.009	0.006	0.006	0.958 ***	0.025
	Netherlands	-0.001	0.001	0.101 ***	0.027	-0.001	0.001	0.082 ***	0.028	0.000 **	0.000	0.057 ***	0.007	0.945 ***	0.005	0.000 ***	0.000	0.081 ***	0.013	0.917 ***	0.012	0.007 *	0.004	0.972 ***	0.007
	Norway	-0.002	0.001	0.133 ***	0.029	-0.002 *	0.001	0.054	0.034	0.000 **	0.000	0.052 ***	0.007	0.948 ***	0.005	0.000 ***	0.000	0.050 ***	0.007	0.943 ***	0.007	0.012 **	0.005	0.968 ***	0.005
	Portugal	-0.001	0.001	0.158 ***	0.028	0.001	0.001	0.153 ***	0.029	0.000 ***	0.000	0.059 ***	0.007	0.941 ***	0.005	0.000 ***	0.000	0.104 ***	0.016	0.863 ***	0.021	0.066 ***	0.012	0.868 ***	0.015
	Spain	-0.002	0.001	0.122 ***	0.027	0.001	0.001	0.029	0.030	0.000 ***	0.000	0.081 ***	0.010	0.921 ***	0.007	0.000 ***	0.000	0.132 ***	0.018	0.854 ***	0.017	0.031 ***	0.012	0.869 ***	0.050
	Sweden	-0.001	0.001	0.085 ***	0.029	-0.003 **	0.001	-0.053 *	0.030	0.000 ***	0.000	0.060 ***	0.008	0.940 ***	0.006	0.000 ***	0.000	0.061 ***	0.007	0.930 ***	0.008	0.050 ***	0.010	0.894 ***	0.023
	UK	-0.002	0.001	0.110 ***	0.027	-0.001	0.001	0.016	0.027	0.000 ***	0.000	0.066 ***	0.008	0.936 ***	0.006	0.000 ***	0.000	0.057 ***	0.009	0.940 ***	0.008	0.084 ***	0.013	0.810 ***	0.023
	USA	-0.002 **	0.001	0.151 ***	0.029	-0.002 *	0.001	0.023	0.040	0.000 ***	0.000	0.058 ***	0.008	0.942 ***	0.006	0.000 ***	0.000	0.305 ***	0.044	0.705 ***	0.033	0.002	0.004	0.992 ***	0.003
2) BE	Denmark	0.001	0.001	0.078 **	0.035	0.001	0.001	0.084 **	0.039	0.000	0.000	0.071 **	0.034	0.905 ***	0.057	0.000	0.000	0.063 **	0.026	0.920 ***	0.040	0.025 ***	0.008	0.974 ***	0.007
	Finland	0.001	0.001	0.118 ***	0.038	0.000	0.001	0.104 **	0.042	0.000	0.000	0.088 ***	0.029	0.872 ***	0.059	0.000 *	0.000	0.185 **	0.078	0.725 ***	0.109	0.044 *	0.026	0.777 ***	0.066
	France	0.001	0.001	0.061	0.038	0.000	0.001	0.087 **	0.037	0.000	0.000	0.078 **	0.031	0.891 ***	0.057	0.000	0.000	0.108 ***	0.036	0.879 ***	0.040	0.103 ***	0.034	0.697 ***	0.083
	Greece	0.001	0.001	0.100 ***	0.034	0.003 **	0.001	0.126 ***	0.037	0.000	0.000	0.071 *	0.041	0.881 ***	0.087	0.000	0.000	0.074 ***	0.021	0.929 ***	0.021	0.017 ***	0.005	0.974 ***	0.004
	Ireland	0.000	0.001	0.105 ***	0.038	0.000	0.001	0.213 ***	0.075	0.000	0.000	0.053	0.036	0.932 ***	0.053	0.000	0.000	0.165 *	0.087	0.876 ***	0.041	0.076 ***	0.025	0.683 ***	0.124
	Italy	0.000	0.001	0.124 ***	0.036	0.000	0.001	0.079 **	0.036	0.000	0.000	0.093 ***	0.029	0.893 ***	0.040	0.000 **	0.000	0.146 ***	0.029	0.823 ***	0.039	0.059	0.079	0.906 ***	0.160
	Netherlands	0.000	0.001	0.055	0.038	0.000	0.001	0.104 ***	0.035	0.000	0.000	0.072 **	0.031	0.914 ***	0.044	0.000 *	0.000	0.105 ***	0.031	0.896 ***	0.028	0.053 ***	0.014	0.874 ***	0.017
	Norway	0.000	0.001	0.120 ***	0.041	-0.002	0.001	0.082	0.050	0.000	0.000	0.075 **	0.036	0.896 ***	0.060	0.000	0.000	0.055 *	0.032	0.939 ***	0.028	0.003	0.002	0.972 ***	0.009
	Portugal	0.001	0.001	0.114 ***	0.033	0.002	0.001	0.168 ***	0.033	0.000	0.000	0.065 **	0.032	0.902 ***	0.059	0.000 **	0.000	0.105 ***	0.026	0.854 ***	0.033	0.054	0.034	0.774 ***	0.112
	Spain	0.000	0.001	0.119 ***	0.034	0.002 *	0.001	0.087 **	0.037	0.000	0.000	0.094 ***	0.032	0.887 ***	0.043	0.000 **	0.000	0.156 ***	0.040	0.834 ***	0.025	0.114 ***	0.025	0.850 ***	0.019
	Sweden	0.000	0.001	0.086 **	0.035	-0.003 *	0.002	-0.033	0.039	0.000	0.000	0.094 **	0.045	0.871 ***	0.080	0.000 *	0.000	0.067 ***	0.019	0.927 ***	0.020	0.050 **	0.021	0.886 ***	0.030
	UK	0.000	0.001	0.097 ***	0.037	-0.001	0.001	0.038	0.037	0.000	0.000	0.073 **	0.031	0.913 ***	0.042	0.000	0.000	0.063 ***	0.018	0.939 ***	0.019	0.019 ***	0.007	0.971 ***	0.005
	USA	0.000	0.001	0.147 ***	0.039	-0.002	0.001	0.083 *	0.048	0.000	0.000	0.100 **	0.046	0.869 ***	0.073	0.000 *	0.000	0.272	0.195	0.729 ***	0.124	0.164 **	0.079	0.019	0.016
3) DK	Finland	0.001	0.001	0.057	0.039	0.000	0.001	0.041	0.041	0.000	0.000	0.035 **	0.017	0.937 ***	0.049	0.000 **	0.000	0.169 ***	0.058	0.730 ***	0.083	0.019 ***	0.004	0.979 ***	0.004
	France	0.001	0.002	0.028	0.051	0.001	0.002	0.074 **	0.032	0.000	0.000	0.102	0.115	0.860 ***	0.162	0.000	0.000	0.100 *	0.051	0.879 ***	0.066	0.138 **	0.065	0.663 ***	0.102
	Germany	0.000	0.002	0.066 *	0.037	0.001	0.001	0.044	0.033	0.000	0.000	0.077 *	0.041	0.900 ***	0.056	0.000 *	0.000	0.092 ***	0.024	0.902 ***	0.026	0.044 **	0.019	0.926 ***	0.025
	Greece	0.001	0.002	0.086 **	0.042	0.003 ***	0.001	0.131 ***	0.036	0.000	0.000	0.066 **	0.032	0.899 ***	0.048	0.000	0.000	0.075 ***	0.022	0.928 ***	0.022	0.034 ***	0.006	0.960 ***	0.005
	Ireland	0.000	0.002	0.099 **	0.039	0.000	0.001	0.200 ***	0.073	0.000	0.000	0.070 **	0.033	0.898 ***	0.048	0.000 *	0.000	0.153 *	0.084	0.876 ***	0.040	0.017 **	0.008	0.979 ***	0.010
	Italy	0.000	0.002	0.094 **	0.040	0.000	0.001	0.093 **	0.036	0.000	0.000	0.065 *	0.033	0.906 ***	0.051	0.000 **	0.000	0.153 ***	0.035	0.797 ***	0.051	0.064 ***	0.017	0.862 ***	0.027
	Japan	0.000	0.001	0.095 **	0.043	0.000	0.001	0.065	0.041	0.000	0.000	0.063 **	0.031	0.910 ***	0.047	0.000	0.000	0.091 ***	0.031	0.907 ***	0.028	0.003	0.004	0.995 ***	0.001
	Netherlands	0.000	0.002	0.050	0.039	-0.001	0.001	0.063 *	0.034	0.000	0.000	0.074 **	0.035	0.901 ***	0.053	0.000 **	0.000	0.068 ***	0.017	0.925 ***	0.018	0.099 ***	0.025	0.801 ***	0.055
	Norway	0.000	0.001	0.085 **	0.041	-0.002	0.001	0.044	0.052	0.000	0.000	0.055 **	0.026	0.917 ***	0.042	0.000	0.000	0.050	0.032	0.942 ***	0.030	0.004	0.004	0.991 ***	0.001
	Portugal	0.000	0.002	0.114 ***	0.040	0.001	0.001	0.160 ***	0.034	0.000	0.000	0.067 *	0.036	0.903 ***	0.056	0.000 **	0.000	0.111 ***	0.031	0.852 ***	0.037	0.052	0.034	0.858 ***	0.087
	Spain	0.001	0.002	0.136 ***	0.037	0.002	0.001	0.090 **	0.042	0.000	0.000	0.083 **	0.039	0.884 ***	0.053	0.000 **	0.000	0.140 ***	0.040	0.836 ***	0.026	0.081 ***	0.030	0.756 ***	0.057
	Sweden	0.001	0.002	0.037	0.039	-0.002	0.002	-0.058	0.035	0.000	0.000	0.076 **	0.036	0.891 ***	0.053	0.000 **	0.000	0.064 ***	0.018	0.921 ***	0.022	0.149 ***	0.044	0.300 **	0.121
	UK	0.000	0.002	0.060	0.038	-0.001	0.001	-0.002	0.035	0.000	0.000	0.060 **	0.027	0.915 ***	0.039	0.000	0.000	0.056 ***	0.017	0.941 ***	0.018	0.027 ***	0.005	0.972 ***	0.003
	USA	-0.001	0.002	0.103 **	0.042	-0.002	0.001	0.014	0.045	0.000	0.000	0.060 **	0.025	0.916 ***	0.041	0.000 *	0.000	0.314	0.232	0.687 ***	0.142	0.008	0.006	0.990 ***	0.002
4) FI	France	0.000	0.001	0.080 **	0.041	0.001	0.001	0.081 **	0.034	0.000 **	0.000	0.164 ***	0.060	0.741 ***	0.087	0.000	0.000	0.110 ***	0.037	0.857 ***	0.053	0.077 **	0.033	0.304	0.266
	Germany	0.001	0.001	0.048	0.042	0.001	0.001	0.061 *	0.036	0.000	0.000	0.215 **	0.108	0.704 ***	0.131	0.000	0.000	0.104 **	0.050	0.872 ***	0.079	0.043 ***	0.016	0.890 ***	0.025
	Greece	0.001	0.001	0.124 ***	0.047	0.003 **	0.001	0.139 ***	0.038	0.000 *	0.000	0.176 ***	0.068	0.738 ***	0.089	0.000	0.000	0.072 ***	0.019	0.933 ***	0.019	0.014	0.013	0.914 ***	0.019
	Ireland	0.000	0.001	0.128 **	0.054	0.000	0.001	0.207 ***	0.067	0.000	0.000	0.222 **	0.111	0.670 ***	0.155	0.000 **	0.000	0.223 *	0.122	0.815 ***	0.049	0.002	0.001	0.992 ***	0.001
	Italy	0.000	0.001	0.115 ***	0.043	0.000	0.001	0.075 **	0.037	0.000 *	0.000	0.188 ***	0.073	0.725 ***	0.095	0.000 **	0.000	0.196 ***	0.043	0.765 ***	0.051	0.004	0.004	0.989 ***	0.002
	Netherlands	0.000	0.001	0.062	0.040	0.000	0.001	0.111 ***	0.035	0.000 *	0.000	0.187 ***	0.071	0.727 ***	0.096	0.000	0.000	0.109 **	0.048	0.871 ***	0.060	0.105 ***	0.038	0.674 ***	0.134
	Norway	0.000	0.001	0.074	0.048	-0.001	0.001	0.021	0.038	0.000 **	0.000	0.187 **	0.076	0.724 ***	0.094	0.000 *	0.000	0.106 **	0.046	0.833 ***	0.068	0.082	0.051	0.650 ***	0.075
	Portugal	0.000	0.001	0.140 ***	0.046	0.002	0.001	0.172 ***	0.035	0.000 **	0.000	0.171 ***	0.059	0.752 ***	0.068	0.000 **	0.000	0.126 ***	0.032	0.844 ***	0.031	0.007	0.009	0.987 ***	0.006
	Spain	0.000	0.001	0.145 ***	0.044	0.002	0.001	0.073 **	0.033	0.000 *	0.000	0.183 **	0.073	0.720 ***	0.103	0.000 *	0.000	0.135 ***	0.035	0.833 ***	0.047	0.002	0.002	0.992 ***	0.002
	Sweden	0.000	0.001	0.049	0.042	-0.002	0.002	-0.039	0.036	0.000 **	0.000	0.165 ***	0.060	0.746 ***	0.082	0.000	0.000	0.071 **	0.030	0.913 ***	0.044	0.027	0.020	0.802 ***	0.118
	UK	0.000	0.001	0.081 *	0.047	-0.001	0.001	-0.003	0.040	0.000 *	0.000	0.197 **	0.083	0.710 ***	0.113	0.000 ***	0.000	0.195 ***	0.071	0.653 ***	0.089	0.023 ***	0.008	0.972 ***	0.008
5) FR	Germany	0.000	0.001	0.046	0.032	0.000	0.001	-0.009	0.033	0.000 **	0.000	0.121 ***	0.032	0.870 ***	0.034	0.000 **	0.000	0.091 ***	0.022	0.903 ***	0.023	0.110 ***	0.027	0.670 ***	0.066
	Greece	0.001	0.001	0.142 ***	0.036	0.003 **	0.001	0.093 **	0.038	0.000 *	0.000	0.143 ***	0.049	0.850 ***	0.049	0.000	0.000	0.073 ***	0.020	0.928 ***	0.020	0.039 ***	0.014	0.887 ***	0.028
	Ireland	0.000	0.001	0.150 ***	0.042	0.000	0.001	0.177 **	0.083	0.000 **	0.000	0.144 ***	0.047	0.835 ***	0.052	0.000	0.000	0.166 *	0.086	0.872 ***	0.039	0.065 *	0.038	0.692 ***	0.069
	Italy	0.000	0.001	0.077 **	0.031	0.000	0.001	0.061 *	0.032	0.000 *	0.000	0.126 ***	0.044	0.850 ***	0.054	0.000 **	0.000	0.149 ***	0.032	0.804 ***	0.041	0.054 ***	0.014	0.862 ***	0.015
	Japan	0.000	0.001	0.106 ***	0.034	0.000	0.001	0.058	0.040	0.000 *	0.000	0.117 ***	0.039	0.860 ***	0.047	0.000	0.000	0.093 ***	0.033	0.904 ***	0.030	0.004 **	0.002	0.996 ***	0.001
	Netherlands	0.000	0.001	0.048	0.031	0.000	0.001	0.050	0.033	0.000	0.000	0.111 ***	0.037	0.876 ***	0.044	0.000 **	0.000	0.085 ***	0.020	0.910 ***	0.019	0.034 ***	0.009	0.940 ***	0.009
	Norway	0.000	0.001	0.105 ***	0.038	-0.002	0.001	0.032	0.048	0.000	0.000	0.119 **	0.047	0.862 ***	0.053	0.000	0.000	0.049	0.037	0.943 ***	0.037	0.016 *	0.008	0.965 ***	0.007
	Portugal	0.000	0.001	0.113 ***	0.034	0.002	0.001	0.126 ***	0.033	0.000 *	0.000	0.132 ***	0.043	0.855 ***	0.048	0.000 **	0.000	0.109 ***	0.029	0.864 ***	0.036	0.023 ***	0.007	0.956 ***	0.008
	Spain	0.001	0.001	0.115 ***	0.035	0.002 *	0.001	0.037	0.043	0.000 **	0.000	0.124 ***	0.035	0.861 ***	0.037	0.000 **	0.000	0.165 ***	0.044	0.828 ***	0.026	0.100 ***	0.036	0.714 ***	0.077
	Sweden	0.000	0.001	0.077 **	0.034	-0.003 *	0.002	-0.057	0.038	0.000 *	0.000	0.127 ***	0.045	0.855 ***	0.051	0.000 *	0.000	0.062 ***	0.016	0.930 ***	0.018	0.030 ***	0.009	0.956 ***	0.017
	UK	0.000	0.001	0.062 **	0.030	-0.001	0.001	-0.002	0.033	0.000	0.000	0.089 ***	0.031	0.900 ***	0.036	0.000	0.000	0.064 ***	0.017	0.937 ***	0.017	0.041 ***	0.013	0.936 ***	0.019
	USA	0.000	0.001	0.095 ***	0.033	-0.002	0.001	0.027	0.041	0.000 *	0.000	0.132 ***	0.042	0.846 ***	0.048	0.000 **	0.000	0.341	0.210	0.662 ***	0.127	0.019 **	0.009	0.967 ***	0.009

Table 1.4 ***Continued***

Country pair ij		Mean equation								Variance equation												Covariance equation			
i	j	γ_{0i}	SE	γ_{1i}	SE	γ_{0j}	SE	γ_{1j}	SE	ω_{0i}	SE	a_i	SE	b_i	SE	ω_{0j}	SE	a_j	SE	b_j	SE	α	SE	β	SE
6) DE	Greece	0.000	0.001	0.080 **	0.037	0.003 **	0.001	0.105 ***	0.038	0.000	0.000	0.102 ***	0.034	0.888 ***	0.038	0.000	0.000	0.075 ***	0.020	0.929 ***	0.020	0.032 **	0.014	0.870 ***	0.032
	Ireland	0.000	0.001	0.138 ***	0.034	-0.001	0.001	0.165 **	0.066	0.000 **	0.000	0.131 ***	0.041	0.861 ***	0.040	0.000 *	0.000	0.159 **	0.078	0.877 ***	0.035	0.036 ***	0.010	0.843 ***	0.031
	Italy	0.000	0.001	0.080 **	0.032	0.001	0.001	0.061 *	0.035	0.000 *	0.000	0.102 ***	0.027	0.895 ***	0.027	0.000 **	0.000	0.147 ***	0.030	0.818 ***	0.039	0.066 ***	0.022	0.820 ***	0.047
	Netherlands	0.000	0.001	0.037	0.030	-0.001	0.001	0.068 **	0.032	0.000 *	0.000	0.086 ***	0.019	0.910 ***	0.020	0.000 *	0.000	0.090 ***	0.025	0.909 ***	0.024	0.066 ***	0.023	0.798 ***	0.095
	Norway	0.000	0.001	0.077 *	0.043	-0.002	0.001	0.031	0.050	0.000 *	0.000	0.086 ***	0.027	0.907 ***	0.028	0.000	0.000	0.052	0.035	0.942 ***	0.033	0.003	0.004	0.977 ***	0.008
	Portugal	0.000	0.001	0.114 ***	0.034	0.002	0.001	0.144 ***	0.033	0.000	0.000	0.111 ***	0.031	0.887 ***	0.031	0.000 **	0.000	0.128 ***	0.034	0.838 ***	0.037	0.008	0.005	0.984 ***	0.004
	Spain	0.001	0.001	0.125 ***	0.033	0.002 *	0.001	0.066	0.042	0.000 **	0.000	0.107 ***	0.028	0.884 ***	0.028	0.000 **	0.000	0.175 ***	0.043	0.824 ***	0.029	0.073 ***	0.019	0.790 ***	0.043
	Sweden	0.000	0.001	0.032	0.033	-0.003 *	0.002	-0.061	0.039	0.000 *	0.000	0.087 ***	0.027	0.901 ***	0.029	0.000 *	0.000	0.061 ***	0.018	0.930 ***	0.020	0.064 **	0.029	0.253	0.183
	UK	0.000	0.001	0.022	0.033	-0.001	0.001	-0.010	0.034	0.000 **	0.000	0.081 ***	0.023	0.910 ***	0.024	0.000	0.000	0.062 ***	0.017	0.938 ***	0.018	0.036 ***	0.007	0.951 ***	0.008
	USA	-0.001	0.001	0.077 **	0.032	-0.002	0.001	0.034	0.043	0.000 *	0.000	0.093 ***	0.027	0.896 ***	0.030	0.000 **	0.000	0.302	0.186	0.698 ***	0.114	0.125 ***	0.047	0.171	0.154
7) GR	Ireland	0.002	0.001	0.154 ***	0.049	0.000	0.001	0.208 **	0.084	0.000	0.000	0.079 ***	0.021	0.930 ***	0.020	0.000	0.000	0.148 *	0.079	0.885 ***	0.037	0.193 **	0.077	0.408	0.285
	Italy	0.002 *	0.001	0.115 ***	0.036	0.000	0.001	0.152 ***	0.034	0.000	0.000	0.072 ***	0.021	0.928 ***	0.023	0.000 **	0.000	0.145 ***	0.026	0.836 ***	0.031	0.029 ***	0.011	0.939 ***	0.016
	Netherlands	0.002 **	0.001	0.112 ***	0.038	-0.001	0.001	0.125 ***	0.037	0.000	0.000	0.074 ***	0.021	0.930 ***	0.021	0.000	0.000	0.090 ***	0.033	0.908 ***	0.030	0.013 *	0.007	0.961 ***	0.014
	Norway	0.002 **	0.001	0.168 ***	0.041	-0.002	0.001	0.111 **	0.055	0.000	0.000	0.071 ***	0.020	0.930 ***	0.020	0.000	0.000	0.052	0.037	0.941 ***	0.035	0.017	0.031	0.914 ***	0.061
	Portugal	0.003 **	0.001	0.088 **	0.036	0.002 **	0.001	0.123 ***	0.034	0.000	0.000	0.075 ***	0.020	0.926 ***	0.023	0.000	0.000	0.111 ***	0.029	0.875 ***	0.035	0.068 ***	0.015	0.892 ***	0.016
	Spain	0.003 **	0.001	0.122 ***	0.037	0.001	0.001	0.094 *	0.049	0.000	0.000	0.081 ***	0.024	0.926 ***	0.021	0.000	0.000	0.183 ***	0.063	0.824 ***	0.028	0.088 **	0.035	0.822 ***	0.038
	Sweden	0.002 *	0.001	0.090 **	0.037	-0.002	0.002	-0.005	0.041	0.000	0.000	0.073 ***	0.020	0.930 ***	0.021	0.000	0.000	0.058 ***	0.014	0.937 ***	0.015	0.044	0.033	0.941 ***	0.059
	UK	0.003 **	0.001	0.105 ***	0.040	-0.001	0.001	0.070 *	0.039	0.000	0.000	0.071 ***	0.019	0.932 ***	0.021	0.000	0.000	0.061 ***	0.017	0.941 ***	0.019	0.026 ***	0.007	0.969 ***	0.005
	USA	0.002 *	0.001	0.147 ***	0.038	-0.002	0.002	0.056	0.047	0.000	0.000	0.071 ***	0.020	0.932 ***	0.020	0.000	0.000	0.326	0.293	0.666 ***	0.204	0.012	0.010	0.973 ***	0.007
8) IE	Italy	-0.001	0.001	0.211 ***	0.077	0.000	0.001	0.157 ***	0.048	0.000	0.000	0.151 *	0.080	0.881 ***	0.041	0.000 **	0.000	0.209 ***	0.040	0.763 ***	0.042	0.063	0.058	0.788 ***	0.246
	Japan	-0.001	0.001	0.231 ***	0.083	0.000	0.001	0.066	0.040	0.000	0.000	0.167 *	0.092	0.874 ***	0.042	0.000	0.000	0.091 ***	0.032	0.907 ***	0.029	0.000	0.000	0.990 ***	0.011
	Netherlands	-0.001	0.001	0.194 **	0.076	-0.001	0.001	0.149 ***	0.038	0.000 *	0.000	0.151 *	0.080	0.879 ***	0.039	0.000	0.000	0.111 **	0.049	0.881 ***	0.048	0.064 **	0.027	0.732 ***	0.083
	Norway	-0.001	0.001	0.218 ***	0.080	-0.002 *	0.001	0.077	0.053	0.000	0.000	0.154 *	0.088	0.881 ***	0.042	0.000	0.000	0.053 *	0.032	0.940 ***	0.029	0.006	0.007	0.976 ***	0.005
	Portugal	-0.001	0.001	0.181 **	0.077	0.001	0.001	0.190 ***	0.052	0.000	0.000	0.157 **	0.078	0.880 ***	0.037	0.000 **	0.000	0.184 ***	0.055	0.794 ***	0.051	0.081	0.064	0.752 ***	0.286
	Spain	0.000	0.001	0.170 **	0.079	0.001	0.001	0.084 *	0.048	0.000 **	0.000	0.220 **	0.102	0.829 ***	0.039	0.000 **	0.000	0.192 ***	0.045	0.807 ***	0.040	0.077 ***	0.028	0.574 ***	0.117
	Sweden	-0.001	0.001	0.187 **	0.078	-0.003 *	0.001	-0.031	0.040	0.000	0.000	0.171 *	0.096	0.872 ***	0.043	0.000 *	0.000	0.059 ***	0.016	0.933 ***	0.018	0.020 ***	0.006	0.970 ***	0.004
	UK	-0.001	0.001	0.163 **	0.078	-0.002	0.001	0.045	0.037	0.000 *	0.000	0.159 *	0.087	0.876 ***	0.037	0.000	0.000	0.076 ***	0.022	0.926 ***	0.020	0.063 ***	0.015	0.884 ***	0.028
	USA	-0.001	0.001	0.223 ***	0.082	-0.002	0.001	0.065	0.046	0.000	0.000	0.171 *	0.098	0.871 ***	0.043	0.000 *	0.000	0.309	0.223	0.694 ***	0.135	0.004	0.003	0.990 ***	0.002
9) IT	Netherlands	0.000	0.001	0.073 **	0.034	-0.001	0.001	0.123 ***	0.035	0.000 **	0.000	0.179 ***	0.037	0.783 ***	0.044	0.000 *	0.000	0.125 **	0.051	0.875 ***	0.044	0.057 ***	0.018	0.864 ***	0.018
	Norway	0.000	0.001	0.140 ***	0.045	-0.002 *	0.001	0.070	0.049	0.000 **	0.000	0.186 ***	0.041	0.766 ***	0.049	0.000	0.000	0.049	0.037	0.943 ***	0.036	0.004	0.004	0.973 ***	0.007
	Portugal	0.000	0.001	0.119 ***	0.029	0.001	0.001	0.142 ***	0.031	0.000 **	0.000	0.137 ***	0.024	0.809 ***	0.041	0.000 **	0.000	0.115 ***	0.026	0.829 ***	0.036	0.019 **	0.009	0.970 ***	0.020
	Spain	-0.003	0.003	0.170 *	0.089	-0.001	0.002	0.111	0.085	0.000 *	0.000	0.176 ***	0.055	0.747 ***	0.075	0.000 *	0.000	0.170 ***	0.047	0.790 ***	0.038	0.349	0.226	0.307 ***	0.098
	Sweden	0.000	0.001	0.101 ***	0.035	-0.003 **	0.001	-0.028	0.038	0.000 **	0.000	0.184 ***	0.038	0.764 ***	0.047	0.000 *	0.000	0.064 ***	0.017	0.929 ***	0.019	0.066 ***	0.015	0.870 ***	0.019
	UK	0.000	0.001	0.076 **	0.036	-0.001	0.001	0.035	0.038	0.000 **	0.000	0.139 ***	0.029	0.817 ***	0.044	0.000	0.000	0.057 ***	0.017	0.944 ***	0.018	0.044 ***	0.015	0.896 ***	0.027
	USA	0.000	0.001	0.143 ***	0.036	-0.002	0.001	0.068	0.048	0.000 **	0.000	0.167 ***	0.036	0.781 ***	0.048	0.000 *	0.000	0.296	0.192	0.711 ***	0.116	0.110 *	0.061	0.325	0.395
10) JP	Norway	0.000	0.001	0.087 **	0.042	-0.002	0.001	0.065	0.044	0.000	0.000	0.085 **	0.033	0.913 ***	0.029	0.000	0.000	0.066 ***	0.021	0.931 ***	0.016	0.000	0.001	0.995 ***	0.002
	Portugal	0.000	0.001	0.069 *	0.040	0.001	0.001	0.199 ***	0.035	0.000	0.000	0.087 ***	0.032	0.908 ***	0.030	0.000 **	0.000	0.114 ***	0.032	0.846 ***	0.036	0.007	0.010	0.900 ***	0.054
	Spain	0.000	0.001	0.072 *	0.040	0.001	0.001	0.167 **	0.071	0.000	0.000	0.087 ***	0.031	0.908 ***	0.029	0.000	0.000	0.185 ***	0.064	0.809 ***	0.031	0.010	0.013	0.772 ***	0.111
11) NL	Norway	-0.001	0.001	0.128 ***	0.045	-0.002 *	0.001	0.040	0.048	0.000 *	0.000	0.069 ***	0.022	0.924 ***	0.022	0.000	0.000	0.047	0.037	0.945 ***	0.038	0.004	0.006	0.974 ***	0.007
	Portugal	-0.001	0.001	0.142 ***	0.035	0.001	0.001	0.150 ***	0.032	0.000 *	0.000	0.123 **	0.050	0.874 ***	0.044	0.000 **	0.000	0.125 ***	0.035	0.838 ***	0.041	0.026	0.022	0.899 ***	0.042
	Spain	0.000	0.001	0.147 ***	0.033	0.002	0.001	0.064	0.040	0.000 *	0.000	0.099 ***	0.032	0.898 ***	0.031	0.000 **	0.000	0.167 ***	0.042	0.826 ***	0.026	0.086 ***	0.025	0.795 ***	0.053
	Sweden	-0.001	0.001	0.084 **	0.034	-0.003 *	0.002	-0.051	0.038	0.000 *	0.000	0.081 ***	0.025	0.912 ***	0.025	0.000 *	0.000	0.061 ***	0.018	0.931 ***	0.020	0.053 **	0.022	0.855 ***	0.102
	UK	-0.001	0.001	0.093 ***	0.034	-0.001	0.001	0.016	0.033	0.000 *	0.000	0.078 ***	0.019	0.919 ***	0.018	0.000	0.000	0.056 ***	0.016	0.943 ***	0.016	0.034 ***	0.009	0.945 ***	0.010
	USA	-0.001	0.001	0.153 ***	0.036	-0.002	0.001	0.055	0.044	0.000 *	0.000	0.091 ***	0.029	0.903 ***	0.028	0.000 *	0.000	0.271	0.194	0.723 ***	0.125	0.132 *	0.071	0.104	0.247
12) NO	Portugal	-0.002	0.001	0.095 **	0.042	0.001	0.001	0.188 ***	0.033	0.000 **	0.000	0.098 ***	0.028	0.905 ***	0.021	0.000 **	0.000	0.115 ***	0.036	0.851 ***	0.038	0.012	0.011	0.970 ***	0.004
	Spain	0.001	0.002	0.044	0.034	0.002 *	0.001	0.093 **	0.037	0.009 ***	0.003	0.003 **	0.001	-0.954 ***	0.020	0.000 **	0.000	0.207 ***	0.067	0.799 ***	0.029	0.005	0.003	0.976 ***	0.004
	Sweden	-0.002	0.001	0.014	0.046	-0.003 *	0.002	-0.031	0.040	0.000	0.000	0.047	0.029	0.943 ***	0.028	0.000 *	0.000	0.057 ***	0.016	0.931 ***	0.019	0.052 ***	0.019	0.255	0.226
	UK	-0.002 *	0.001	0.045	0.053	-0.002 *	0.001	0.038	0.049	0.000	0.000	0.052	0.035	0.941 ***	0.033	0.000	0.000	0.058 ***	0.019	0.942 ***	0.019	0.017	0.011	0.966 ***	0.007
	USA	-0.002 *	0.001	0.055	0.050	-0.002	0.001	0.040	0.050	0.000	0.000	0.051	0.035	0.941 ***	0.033	0.000 *	0.000	0.303	0.216	0.700 ***	0.133	0.002	0.004	0.990 ***	0.004
13) PT	Spain	0.001	0.001	0.198 ***	0.061	0.001	0.001	0.100	0.075	0.000 **	0.000	0.136 ***	0.035	0.808 ***	0.042	0.000	0.000	0.152 ***	0.058	0.817 ***	0.029	0.172	0.117	0.263 ***	0.095
	UK	0.001	0.001	0.137 ***	0.035	-0.002 *	0.001	0.063 *	0.038	0.000 *	0.000	0.105 ***	0.029	0.868 ***	0.036	0.000	0.000	0.064 ***	0.018	0.938 ***	0.019	0.022 ***	0.008	0.963 ***	0.008
	USA	0.001	0.001	0.171 ***	0.035	-0.002	0.001	0.075	0.047	0.000 **	0.000	0.122 ***	0.034	0.837 ***	0.039	0.000 **	0.000	0.307	0.203	0.705 ***	0.118	0.160 *	0.084	0.022	0.032
14) ES	Sweden	0.001	0.001	0.084 *	0.048	-0.002	0.002	-0.012	0.039	0.000 *	0.000	0.168 ***	0.052	0.820 ***	0.027	0.000 *	0.000	0.062 ***	0.019	0.927 ***	0.022	0.053 ***	0.014	0.865 ***	0.019
	UK	0.001	0.001	0.034	0.036	-0.001	0.001	0.043	0.030	0.000 **	0.000	0.117 ***	0.031	0.860 ***	0.026	0.000 *	0.000	0.074 ***	0.023	0.919 ***	0.024	0.057 **	0.022	0.840 ***	0.091
	USA	0.001	0.001	0.128 **	0.053	-0.002	0.001	0.074	0.048	0.000 *	0.000	0.170 ***	0.054	0.825 ***	0.024	0.000	0.000	0.241	0.192	0.747 ***	0.130	0.053 ***	0.017	0.906 ***	0.021
15) SE	UK	-0.003 **	0.002	-0.053	0.039	-0.002	0.001	0.012	0.036	0.000 *	0.000	0.061 ***	0.017	0.930 ***	0.019	0.000	0.000	0.063 ***	0.020	0.938 ***	0.020	0.039 **	0.016	0.866 ***	0.051
	USA	-0.004 **	0.002	-0.045	0.041	-0.002	0.001	0.027	0.046	0.000 *	0.000	0.063 ***	0.018	0.928 ***	0.021	0.000 *	0.000	0.286	0.194	0.710 ***	0.120	0.029 ***	0.011	0.917 ***	0.024
16) UK	USA	-0.002 *	0.001	0.041	0.038	-0.002	0.001	0.057	0.045	0.000	0.000	0.077 ***	0.025	0.923 ***	0.025	0.000	0.000	0.218	0.170	0.761 ***	0.124	0.180 ***	0.067	0.273	0.265

Table 1.5: **Sample countries: classification into country groups**
The table shows the 17 sample countries classified into country groups: Core Eurozone; periphery Eurozone; EU but non Eurozone; non EU countries.

Core Eurozone	Periphery Eurozone	EU, non-Eurozone	Non EU
AU: Austria	GR: Greece	DK: Denmark	JP: Japan
BE: Belgium	IE: Ireland	SE: Sweden	NO: Norway
FI: Finland	IT: Italy	UK: United Kingdom	USA: United States
FR: France	PT: Portugal		
DE: Germany	ES: Spain		
NL: Netherlands			

Table 1.6: **Summary statistics: DCC time series**
The table shows summary statistics (minimum, maximum, mean and standard deviation) for the estimated dynamic conditional correlation (DCC) series. The statistics are reported for different time periods (January 2008-September 2012; January 2008-mid September 2008; mid September 2008-October 2009; November 2009-September 2012) and for different groups of country pairs (core Eurozone country pairs (EZ: Core-core), periphery Eurozone country pairs (EZ: Periphery-periphery), core and periphery Eurozone country pairs (EZ: Core-periphery), Eurozone and non Eurozone country pairs belonging to the EU (EU: EZ-non EZ), the EU and non EU country pairs (Other: EU-non EU).

Country group	Min	Max	Mean	Std.Dev.
(2008-2012)				
EZ: Core-core	-0.38	0.91	0.50	0.12
EZ: Periphery-periphery	-0.48	0.98	0.57	0.14
EZ: Core-periphery	-0.24	0.92	0.47	0.14
EU: EZ-non EZ	-0.51	0.95	0.44	0.16
Other: EU-non EU	-0.67	0.93	0.29	0.13
Total	-0.67	0.98	0.42	0.17
(January 2008-mid September 2008)				
EZ: Core-core	-0.38	0.91	0.36	0.17
EZ: Periphery-periphery	-0.37	0.97	0.51	0.16
EZ: Core-periphery	-0.24	0.92	0.34	0.17
EU: EZ-non EZ	-0.38	0.95	0.31	0.17
Other: EU-non EU	-0.67	0.93	0.19	0.14
Total	-0.67	0.97	0.30	0.19
(mid September 2008-October 2009)				
EZ: Core-core	-0.02	0.91	0.53	0.10
EZ: Periphery-periphery	-0.20	0.98	0.59	0.13
EZ: Core-periphery	-0.12	0.88	0.49	0.12
EU: EZ-non EZ	-0.24	0.93	0.51	0.12
Other: EU-non EU	-0.32	0.87	0.30	0.12
Total	-0.32	0.98	0.46	0.15
(November 2009-September 2012)				
EZ: Core-core	-0.01	0.89	0.52	0.09
EZ: Periphery-periphery	-0.48	0.97	0.58	0.14
EZ: Core-periphery	-0.15	0.91	0.48	0.12
EU: EZ-non EZ	-0.51	0.86	0.45	0.14
Other: EU-non EU	-0.30	0.91	0.30	0.12
Total	-0.51	0.97	0.43	0.15

Table 1.7: **Regression analysis: estimation results**
The dependent variable is the measure for sovereign credit risk co-movements adjusted for volatility (ρ_{ijm}) in percent. The estimation period runs from January 2008 to March 2012 on a monthly basis. Quarterly data is (linearly) interpolated to monthly frequency. Specifications (II) and (IV) report the estimated coefficients of the panel data model including country pair as well as time fixed effects. Specifications (III) and (IV) include interaction terms of the (0/1)-contagion indicator (CI) with public debt, bank equity, the financial linkage (banks' foreign claims), the real linkage (trade), and the proxy for common market sentiment (GDP weighted stock market volatilities). Continuous variables entering the interaction terms are centered around their mean to facilitate interpretation. Standard errors are clustered by country pair. The reported R^2 is the R^2 within. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

			(I)	(II)	(III)	(IV)
			No FE	$ij + m$ FE	No FE	$ij + m$ FE
Global controls		%ΔVDAX volatility	0.0165***		0.0210***	
			(0.0048)		(0.0047)	
		%ΔEuribor-Eonia	0.0044***		0.0033***	
			(0.0008)		(0.0008)	
Similarity in economic fundamentals		ΔGDP	0.1152***	0.1748***	0.1166***	0.1587***
			(0.0139)	(0.0413)	(0.0130)	(0.0390)
		Foreign reserves	-0.0220	-0.0312*	-0.0253	-0.0330*
			(0.0164)	(0.0186)	(0.0169)	(0.0187)
		Banking system size	0.0002***	0.0001*	0.0002***	0.0001
			(0.0000)	(0.0001)	(0.0000)	(0.0001)
		Public debt	-0.0058	-0.0128	-0.0079	-0.0153*
			(0.0068)	(0.0081)	(0.0070)	(0.0083)
		Bank equity corr.	0.0051**	0.0113***	0.0092***	0.0134***
			(0.0026)	(0.0031)	(0.0033)	(0.0034)
Linkages	financial	Banks' foreign claims	-0.0918**	-0.0526	-0.0920*	-0.0684
			(0.0463)	(0.0496)	(0.0522)	(0.0511)
	real	Trade	-0.0132	0.0284	-0.0019	0.0446*
			(0.0126)	(0.0253)	(0.0133)	(0.0265)
	non-fundamental	Stock market volatility	0.0459***	0.0204**	0.0106	-0.0010
			(0.0087)	(0.0099)	(0.0088)	(0.0095)
		CI			4.6056***	3.0639***
					(0.3480)	(0.3542)
Interaction (× CI)		Public debt			0.0134	0.0182**
					(0.0088)	(0.0088)
		Bank equity corr.			-0.0174	-0.0140
					(0.0111)	(0.0088)
		Banks' foreign claims			-0.0490	0.1563**
					(0.0685)	(0.0736)
		Trade			-0.1112***	-0.0563**
					(0.0272)	(0.0246)
		Stock market volatility			0.0669***	0.0794***
					(0.0150)	(0.0192)
Observations			5,677	5,677	5,677	5,677
Country pairs			107	107	107	107
R^2			0.05	0.27	0.09	0.29

Table 1.8: **Regression analysis: robustness A**
The table presents various robustness checks based on the preferred specification (IV) of Table 1.7. Specification (A-I) applies the Fisher z-transformation to the measure for sovereign credit risk co-movements in percent ($\tilde{\rho}_{ijm} = \log(1+\rho_{ijm})/(1-\rho_{ijm})$). The transformed variable is used as dependent variable to mitigate the potentially skewed distribution of correlation coefficients. In specification (A-II) all explanatory variables are lagged by one period. In (A-III), computation of the contagion indicator (CI) is based on lower significance levels of 5%. Specification (A-IV) is based on a sample split considering only observations from November 2009 capturing the onset of the sovereign debt crisis in the Eurozone. Standard errors are clustered by country pair. The reported R^2 is the R^2 within. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

			(A-I)	(A-II)	(A-III)	(A-IV)
			Fisher Z	Lagged RHS	CI (5%)	Debt Crisis
Similarity in economic		ΔGDP	0.4205***	0.1023***	0.1616***	0.1189***
fundamentals			(0.1070)	(0.0363)	(0.0389)	(0.0411)
		Foreign reserves	-0.0785	-0.0103	-0.0333*	-0.0144
			(0.0481)	(0.0189)	(0.0186)	(0.0241)
		Banking system size	0.0002	0.0000	0.0001	0.0001**
			(0.0002)	(0.0001)	(0.0001)	(0.0000)
		Public debt	-0.0360*	-0.0201**	-0.0145*	-0.0274***
			(0.0210)	(0.0088)	(0.0084)	(0.0091)
		Bank equity corr.	0.0321***	0.0069**	0.0129***	0.0147***
			(0.0082)	(0.0035)	(0.0032)	(0.0037)
Linkages	financial	Banks' foreign claims	-0.1994*	-0.0538	-0.0677	0.1530**
			(0.1212)	(0.0434)	(0.0505)	(0.0763)
	real	Trade	0.1186*	0.0141	0.0425	0.0728***
			(0.0672)	(0.0202)	(0.0278)	(0.0273)
	non-fundamental	Stock market volatility	-0.0073	0.0311**	0.0093	-0.0039
			(0.0257)	(0.0125)	(0.0129)	(0.0123)
		CI	7.8891***	3.3189***	3.2102***	2.9011***
			(0.9123)	(0.3449)	(0.4396)	(0.4265)
Interaction (× CI)		Public debt	0.0433*	0.0192*	0.0142	0.0275**
			(0.0231)	(0.0104)	(0.0098)	(0.0111)
		Bank equity corr.	-0.0341	0.0094	-0.0174*	-0.0180*
			(0.0229)	(0.0090)	(0.0103)	(0.0095)
		Banks' foreign claims	0.4062**	0.1534**	0.2715***	0.0715
			(0.2015)	(0.0646)	(0.1017)	(0.0899)
		Trade	-0.1866***	0.0020	-0.0737**	-0.0388
			(0.0682)	(0.0290)	(0.0358)	(0.0501)
		Stock market volatility	0.2059***	0.0091	0.0605***	0.0034
			(0.0512)	(0.0208)	(0.0218)	(0.0453)
Observations			5,677	5,582	5,677	3,551
Country pairs			107	107	107	107
R^2			0.28	0.28	0.28	0.19

Table 1.9: **Regression analysis: robustness B (Eurozone only)**
The table presents robustness checks excluding non-Eurozone countries. Based on the smaller sample of Eurozone countries, specifications (B-I) and (B-II) are equivalent to specifications (III) and (IV) of Table 1.7. Specification (B-III) additionally includes the exchange rate (EUR/USD). Standard errors are clustered by country pair. The reported R^2 is the R^2 within. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

			(B-I) EZ	(B-II) EZ	(B-III) EZ
Global controls		%ΔVDAX volatility	0.0223***		0.0050
			(0.0079)		(0.0067)
		%ΔEuribor-Eonia	0.0048***		0.0059***
			(0.0010)		(0.0010)
		%ΔEUR/USD			-24.7486***
					(3.3735)
Similarity in economic fundamentals		ΔGDP	0.0948***	0.2990*	0.0666***
			(0.0135)	(0.1674)	(0.0113)
		Foreign reserves	-0.2828**	-0.1225	-0.0536
			(0.1270)	(0.0829)	(0.1269)
		Banking system size	0.0047***	0.0016	0.0030**
			(0.0013)	(0.0011)	(0.0012)
		Public debt	-0.0128	-0.0388***	-0.0149
			(0.0103)	(0.0139)	(0.0107)
		Bank equity corr.	-0.0006	0.0050	0.0042
			(0.0054)	(0.0050)	(0.0049)
Linkages	financial	Banks' foreign claims	-0.2435***	-0.1137**	-0.1985***
			(0.0473)	(0.0462)	(0.0416)
	real	Trade	0.0270*	0.0577	0.0402*
			(0.0163)	(0.0374)	(0.0231)
	non-fundamental	Stock market volatility	0.0871***	0.0761**	0.0892***
			(0.0329)	(0.0387)	(0.0323)
		CI	4.2247***	2.1607***	4.3475***
			(0.4502)	(0.4288)	(0.4318)
Interaction (× CI)		Public debt	0.0187	0.0256	0.0235
			(0.0150)	(0.0158)	(0.0154)
		Bank equity corr.	0.0098	0.0057	0.0032
			(0.0199)	(0.0158)	(0.0189)
		Banks' foreign claims	0.0481	0.1918**	0.0329
			(0.0694)	(0.0861)	(0.0603)
		Trade	-0.1239***	-0.1137***	-0.1164***
			(0.0296)	(0.0372)	(0.0276)
		Stock market volatility	-0.0264	0.0316	-0.0101
			(0.0338)	(0.0366)	(0.0326)
Observations			2,311	2,311	2,311
Country pairs			44	44	44
R^2			0.11	0.39	0.16

Chapter 2

Uncertainty, Bank Lending, and Bank-Level Heterogeneity

2.1 Motivation

Since the outbreak of the financial crisis, many countries have experienced stagnating or even declining levels of bank lending. Banks have also withdrawn from international markets on a large scale. In this paper, we analyze the role played by increased uncertainty in the banking sector regarding the decline in bank lending. We develop a new measure for uncertainty that exploits bank-level information, and we explore whether the impact of uncertainty in banking on the lending behavior is heterogeneous across different types of banks, differentiating also between domestic and foreign-owned banks.[1]

By analyzing the link between bank lending and uncertainty, this paper contributes to a large body of research documenting the impact of uncertainty on investment. In a recent survey, Bloom (2014) shows that uncertainty increases in recessions and that it has a negative impact on short-run hiring and investment in the manufacturing sector. Moreover, measures of uncertainty based on firm-level micro-data are strongly countercyclical and negatively correlated with economic growth. A channel for the weakening effect of increased uncertainty on investment and consequently economic growth is that firms might exercise an "option value of waiting": the higher the degree of uncertainty, the more firms benefit from postponing investment projects, in particular if investments are irreversible (Bloom et al., 2007).

Similar to an investment by a nonfinancial firm, bank lending is a longer-term con-

[1] This chapter is based on the published article Buch, C. M., Buchholz, M., and Tonzer, L. (2015). Uncertainty, Bank Lending, and Bank-Level Heterogeneity. *IMF Economic Review*, 63(4):919-954. The copyright of the original article is with the IMF Economic Review, Palgrave Macmillan.

tractual arrangement. Consequently, it might be beneficial to postpone the loan decision in the presence of uncertainty. Uncertainty can thus affect bank lending through various channels. First, banks intermediate short-term funds into long-term loans. This exposes them to liquidity risk and maturity mismatch. In uncertain times, refinancing in interbank markets might become more difficult, leading banks to restrain loan supply. Second, intermediation through banks reduces information asymmetries and facilitates access to credit. In an environment characterized by higher uncertainty, credit risk increases, and banks may restrict lending. Third, the probability that banks are hit by large shocks increases in uncertain times such that investors demand a higher funding premium. Hence, banks might face tightened external financing constraints which restrict the ability to provide loans (Valencia, 2013).

Higher uncertainty in banking can thus be considered a key factor behind the decline in loan supply during the crisis. However, there are few applications of the literature on firm-level uncertainty for banks. In this paper, we construct a measure of uncertainty based on bank-level data, and we analyze its impact on bank lending. Our data are taken from Bankscope. We add information on the ownership status of banks provided by Claessens and Van Horen (2014) and the degree of financial integration using data from the Bank for International Settlements. The combined data are used to generate measures of uncertainty in banking derived from bank-level data and to capture the degree of internationalization of banks.

With these data at hand, we ask two questions. First, how can we measure uncertainty in banking, and what have been patterns of uncertainty in banking during the crisis? Uncertainty is often measured through the volatility of high-frequency time series such as (bank) stock prices. The advantage of this method is that it allows analyzing short-run changes in uncertainty. The disadvantage is that it is applicable to listed banks only. In Europe though, smaller banks accounting for a significant fraction of the market are not covered. Not only are market data unavailable for these banks, relevant time series data are also available at a low (annual) frequency only. We thus use the cross-sectional dispersion of bank-level shocks to growth rates in total assets, short-term funding, productivity, and profitability as measures for uncertainty in banking. Descriptive statistics show that the dispersion of bank-level shocks has increased during the crisis, which we interpret as higher uncertainty. This pattern is in line with alternative measures of uncertainty which are positively correlated with our measure of uncertainty in banking.

Second, how does uncertainty affect bank lending, and is the effect heterogeneous across different types of banks? We closely follow previous literature analyzing the impact of funding shocks on banks' investment patterns. Cornett et al. (2011) analyze the impact of funding shocks on the lending behavior of banks.[2] They find that, during liquidity crises, banks with a relatively large share of illiquid assets reduce lending by more.Valencia (2013) analyzes the relationship between loan supply and uncertainty for a sample of US commercial banks and the period 1984-2010. Uncertainty is measured as the dispersion of professional forecasts or stock market volatility. Valencia shows that banks with relatively low levels of capitalization decrease lending more if uncertainty increases. We find that higher uncertainty in banking, i.e. a higher cross-sectional dispersion of bank-level shocks, has negative effects on bank lending. The effect is heterogeneous across banks: lending by banks which are better capitalized and which have higher liquidity buffers is affected less. These results are essentially in line with those by Valencia (2013).

One additional aspect of heterogeneity that we are interested in is the degree of internationalization. Previous literature shows that internationally active or foreign-owned banks decreased their loan supply more than domestic and locally funded banks (Haas and Lelyveld, 2014; Ongena et al., 2015). This retrenchment of international lending can be attributed to a flight home effect (Giannetti and Laeven, 2012), and it depends on the geographical distance of the foreign market (De Haas and Van Horen, 2013). We contribute to this literature by asking whether the ownership structure of the individual bank or the degree of financial openness of a country matter for the response of individual banks to uncertainty. We find weak evidence that foreign-owned banks react to a minor extent to uncertainty in the host country compared to domestic banks. Focusing instead on the degree of integration of the banking system as a whole, we find that the negative effect of uncertainty is less pronounced for banks in financially more open countries.

In Section 2.2, we present a stylized model to illustrate the concept of uncertainty in banking and its effect on bank lending. In Section 2.3, we describe the data that we use and discuss how we measure uncertainty in banking. In Section 2.4, we show the evolution of uncertainty in banking across countries and time, and we relate uncertainty in banking derived from bank-level data to alternative measures of uncertainty. In Section 2.5, we analyze the link between uncertainty and bank lending empirically taking bank-level heterogeneity into account. In Section 2.6, we conclude.

[2] For research on the transmission of shocks across countries through internationally active banks, see the work by Cetorelli and Goldberg (2011, 2012).

2.2 Uncertainty and Bank Lending: A Stylized Model

To illustrate the concept of uncertainty which underlies this paper, we present a stylized model. Based on the model by Shin (2010), we can assess the impact of higher uncertainty in banking on banks' loan supply. Assume that at time t, the balance sheet of the bank looks as follows:

Assets		Liabilities	
Loans	l_t	Deposits	d_t
Cash and liquid assets	c_t	Equity	e_t

The bank makes loans l_t at time t and receives an interest rate on loans at time $t+1$ of $\tilde{r}_{t+1}$: The loan rate $\tilde{r}_{t+1}$ is uncertain, as borrowers might not pay back the full loan but larger than zero in expectation ($E[\tilde{r}_{t+1}] > 0$). The deposit rate and the return on liquid assets are assumed to be risk-free and equal to zero.

The value of equity at time $t+1$ is then given by:

$$e_{t+1} = l_t\left(1 + \tilde{r}_{t+1}\right) + c_t - d_t = e_t + \tilde{r}_{t+1} l_t \tag{2.1}$$

The bank defaults in $t+1$ if the value of the equity is negative ($e_{t+1} < 0$), that is, if the return on loans is smaller than the amount of equity per unit of loans available to cover potential losses:

$$\tilde{r}_{t+1} < -\frac{e_t}{l_t} \tag{2.2}$$

The VaR Constraint

We assume that the bank is risk-neutral but operates under a value at risk (VaR) constraint which is given by:

$$Prob\left(\tilde{r}_{t+1} < -\frac{e_t}{l_t}\right) \leq 1 - \alpha \tag{2.3}$$

The VaR is defined as the loss not to be exceeded with probability $1 - \alpha$, that is, $VaR_\alpha = e_t/l_t$. We can think of the VaR constraint as reflecting how the bank manages its risk. A minimum capital requirement imposed by the regulator would have the same effect as a VaR constraint because any violation of the capital requirement would trigger regulatory interventions. The VaR constraint can also be defined as a deviation from the mean measured in terms of its standard deviation σ_t, which is assumed to be known at time t, that is

$$Prob\left(\tilde{r}_{t+1} < \mu - \phi\sigma_t\right) \leq 1 - \alpha \tag{2.4}$$

where ϕ is some constant.

We assume that the bank maximizes its shareholder value e_{t+1} at time $t+1$. In the absence of the VaR constraint, the risk-neutral bank would give out as many loans as possible. The reason for this is that the expected return is larger than zero. In principle, the size of the balance sheet would thus be indeterminate. However, the VaR constraint under which the bank operates determines the size of the loan portfolio. This can be seen by combining Equations (2.3) and (2.4):

$$l_t = \frac{e_t}{\phi\sigma_t - \mu} \tag{2.5}$$

Uncertainty in Banking and Loan Rates

We assume that loan rates of bank i follow a stochastic process with time-varying volatility:

$$\tilde{r}_{it+1} = \mu_i + \sigma_t \varepsilon_{it+1} \tag{2.6}$$

where $E[\varepsilon_{it}] = 0$ and $\varepsilon_{it} \sim N(0,1)$, which implies that the mean of the loan rate conditional on time t information (I_{it}) is constant, so $E[\tilde{r}_{it+1}|I_{it}] = \mu_i$. Although the assumption of μ_i being constant might appear too restrictive, its interpretation can easily be generalized to the predicted value of the loan rate at time t without making a specific assumption on the underlying prediction model. Therefore, we can simply refer to μ_i as the predicted portion of the loan rate and to $\sigma_t\varepsilon_{it+1}$ as the unpredicted portion for each bank i.

The volatility of the bank-specific shock ε_{it+1} to the loan rate is time-varying. Regarding the timing convention, we follow Bloom et al. (2012) and assume that banks know in advance about any potential change in business conditions. This would be reflected in a change in the distribution of shocks and thus the volatility σ_t. A higher σ_t can be interpreted as higher uncertainty because it widens the distribution of $\tilde{r}_{it+1}$. Hence, it constitutes a measure of *uncertainty in banking*. More specifically, we assume that in t, the bank can condition its portfolio decision on the level of uncertainty σ_t. Although the bank knows that the distribution of shocks has widened, the bank does not learn about the realization of the loan rate $\tilde{r}_{it+1}$ before $t+1$.

Uncertainty in Banking and Loan Supply

We now show how higher uncertainty in banking affects the structure of banks' assets and induces the banks to shift from risky to safe assets. Starting from the optimal size of loans on the asset side given by Equation (2.5) which is assumed to hold in all periods, we can derive the change in loans from $t-1$ to t relative to total assets at time $t-1$ ($ta_{t-1} = e_{t-1} + d_{t-1}$).[3] This will constitute the dependent variable in the empirical analysis below:

$$\frac{\Delta l_t}{ta_{t-1}} = \frac{l_t - l_{t-1}}{ta_{t-1}} = \frac{\frac{e_{t-1}}{ta_{t-1}}\left(1 + \frac{r_t}{\phi\sigma_{t-1}-\mu}\right)}{\phi\sigma_t - \mu} - \frac{\frac{e_{t-1}}{ta_{t-1}}}{\phi\sigma_{t-1} - \mu} \tag{2.7}$$

We assume that, at time t, the bank learns about changes in uncertainty in banking and can incorporate this information into its loan supply decision. The effect of higher uncertainty on the change in loans relative to total assets in $t-1$ is given by the first partial derivative of Equation (2.7) with respect to uncertainty σ_t:

$$\frac{\partial\left(\frac{\Delta l_t}{ta_{t-1}}\right)}{\partial\sigma_t} = \frac{-\frac{\phi e_{t-1}}{ta_{t-1}}\left(1 + \frac{r_t}{\phi\sigma_{t-1}-\mu}\right)}{(\phi\sigma_t - \mu)^2} < 0 \tag{2.8}$$

The bank reduces the volume of loans on its balance sheet, that is, it supplies fewer loans, if uncertainty in banking increases. The inequality holds as long as $r_t > \mu - \phi\sigma_{t-1}$, which implies that the bank is solvent in t (see Equation (2.2) combined with Equation (2.5)).

The Role of the Capital Buffer

In the empirical analysis, we will investigate how the response of banks to uncertainty depends on bank-level characteristics. One of these characteristics is the capital buffer that a bank holds. A bank might voluntarily choose to hold capital above the regulatory requirement to shield itself against unexpected losses. The probability to incur such an unexpected loss, in turn, depends on the bank's capital buffer. A bank with a capital buffer is subject to a more stringent (but voluntarily chosen) VaR constraint at time $t-1$ which can be relaxed at time t ($\phi_{t-1} > \phi_t$). In the Appendix, we show that a bank holding a capital buffer reduces the loan volume by less as long as it still receives a positive return on its loans ($r_t > 0$).

Empirical Implications

The model illustrates a specific mechanism how uncertainty in banking – modeled as an increase in the standard deviation of loan rates – affects banks' behavior. Under the assumption that loans are the only risky assets of banks, uncertainty in banking directly translates into a higher dispersion of shocks to observable bank-level outcomes such as return on assets or asset growth. We apply this idea to our empirical analysis

[3] For notational convenience, we will skip the bank index i in the following.

and measure uncertainty as the cross-sectional dispersion of bank-specific shocks. In reality, banks have a more general asset and liability structure and thus might be affected by uncertainty through a range of other channels. In addition to dispersion in shocks to asset growth and return on assets, we will thus also account for shocks to bank productivity and to short-term funding. Heterogeneity in banks' responses to these shocks, in turn, will be modeled as a function of their capital buffer, the structure of their assets, and their ownership status (domestic vs. foreign).

2.3 Data and Measurement Issues

In this paper, we ask two questions: How can we measure uncertainty in banking? How does higher uncertainty affect bank lending and is the impact of uncertainty heterogeneous across different types of banks? In this section, we discuss the data sources that we use and other issues related to measurement.

2.3.1 Bank-Level Data

Banks' balance sheet and income statement data are taken from Bankscope. Our sample is based on banks in 48 countries which belong to the OECD, the EU, and/ or the G20. This ensures having a sufficiently homogenous set of industrialized countries while at the same time exploiting a sufficient degree of heterogeneity with regard to uncertainty in banking. We keep only countries with more than 50 bank-year observations and banks with at least five observations. The sample period spans the years 1998-2012.

In addition to bank capital as a key variable in our theoretical model, our explanatory variables include balance sheet strength and banks' liquidity risk management as in previous papers in the field such as Cornett et al. (2011). We construct these variables from Bankscope, and we winsorize them at the top and the bottom percentile. *Liquidity* is measured as the ratio of liquid assets to total assets (in percent). *Capitalization* is measured as the Tier 1 regulatory capital relative to total assets (in percent). We control for *customer deposits* relative to the total size of the balance sheet by including the deposits to assets ratio (in percent). Additionally, we include the log of total assets (in thousand U.S. dollars). We also include the fraction of *committed loans* relative to the sum of committed loans and total assets (in percent). For more information, see the data description in the Appendix and the summary statistics in Table 2.1.

We use standard procedures to correct for outliers and implausible values. First, we exclude observations for which total assets are missing as well as the bottom percentile of total assets. Second, to account for mergers, we drop observations for which the annual change in assets is larger than 40 percent (Cornett et al., 2011). Third, we drop observations if assets, equity, or loans are negative. We do the same if loans to assets, equity to assets, or non-performing loans ratios are larger than one. Fourth, a bank is kept in the sample if it is a bank holding company, a commercial bank, a cooperative bank, or a savings bank.

To account for ownership status and to distinguish domestic from foreign banks, we resort to data compiled by Claessens and Van Horen (2014). Their data set covers 5,324 banks in 137 countries for the period 1995-2009. Countries are included in the sample if they have more than five active banks in 2009. For advanced countries, only the largest 100 banks (based on their assets in the year 2008) are included. Despite these restrictions, 90 percent of a country's banking system's assets are covered.

From this database, we extract information on whether a bank is domestic or foreign-owned. In addition, if a bank is foreign-owned, we know the country of origin of the largest foreign shareholder. We can thus test whether the lending decision of a foreign-owned bank differs from a domestic bank, and we can control for uncertainty in banking in the residence country of the largest foreign shareholder. We match these data to the bank-level data obtained from Bankscope. This implies that subsidiaries are included but not branches. Hence, we can discriminate whether foreign-owned banks, excluding branches, are affected differently by uncertainty in the host country compared with domestic banks.

2.3.2 Uncertainty and Cross-Sectional Dispersion

If uncertainty increases, future outcomes become less predictable. From the perspective of an economic agent such as a bank, weaker predictability due to higher uncertainty is reflected by a wider distribution of shocks to key bank-level variables. In the theoretical model, this was reflected by a widening of the distribution of shocks to the loan rate. This suggests measuring uncertainty in banking as the cross-sectional dispersion of shocks to different bank-level variables.

Empirically, uncertainty is often measured using (lagged) stock price volatility as a measure of historic volatility (Bloom, 2007). This approach is based on high-frequency market data. Similarly, measures of implied volatility draw on market data such as prices of stock options (Stein and Stone, 2013). However, for many applications of interest, such high-frequency market data are not available for all firms. This is the case in banking. Reliable market data on banks' share prices are difficult to obtain for countries in which many banks are not listed and/or in which stock markets are shallow. For this reason, we need a measure of uncertainty which can be computed based on lower frequency balance sheet or profitability data.

As an alternative to measures of uncertainty based on the volatility of high-frequency data, Bloom et al. (2012) suggest using information on the cross-sectional dispersion of (productivity) shocks. Dispersion increases if the distribution of shocks widens: on average across all firms, the future becomes more uncertain. An increase in the cross-sectional dispersion of shocks can thus be interpreted as a higher degree of uncertainty. In their empirical application to U.S. manufacturing firms, Bloom et al. (2012) show that the cross-sectional dispersion derived from firm-level data can be used to explain variations in business cycle movements.

We apply the dispersion measure proposed by Bloom et al. (2012) to banking. In line with our theoretical model, we compute the dispersion of shocks to total asset growth and profitability measured via return on assets. We complement these measures by the dispersions of shocks to productivity and to short-term funding:

- *Dispersion of shocks to profitability (RoA):* One measure of higher uncertainty with regard to loan returns $\tilde{r}_{t+1}$ is a wider dispersion of shocks to bank profitability. During crisis times, adverse shocks become more likely. This can cause the distribution of profitability to widen. These shocks can, for instance, be related to an increase in credit risk. Profitability is proxied by return on assets (RoA) defined as the ratio of operating profits to total assets (in percent).

- *Dispersion of shocks to total asset growth:* Because bank profitability can be driven by many factors other than shocks to loan rates, we additionally use the dispersion of shocks to total asset growth as a proxy for asset-side shocks. These asset-side shocks can be related to loan demand shocks but they can also capture other factors affecting the volume of banks' assets.

- *Dispersion of shocks to productivity growth:* The most straightforward application of Bloom et al. (2012) would be to measure shocks to bank productivity. In banking though, the distinction between inputs and outputs is less clear (Degryse et al., 2009). Deposits may be considered as being an input into the "production" of loans, but overdraft deposits might also turn into loans. Also, banks have to balance the optimal use of inputs and outputs to generate sufficient returns while also managing the risk of their operations. We thus estimate bank productivity using an empirical methodology in the spirit of Levinsohn and Petrin (2003) and applied to banks by Nakane and Weintraub (2005) (see the Appendix for details).

- *Dispersion of shocks to short-term funding growth:* Finally, we account for the fact that uncertainty affects not only asset returns but also funding conditions. In uncertain times, access to funding might differ significantly across banks. Banks which heavily rely on customer deposits may be affected less by a funding shock than banks relying on wholesale funding. As a result, the dispersion of shocks to short-term funding across banks widens. We measure short-term funding as deposits from banks, repos and cash collateral, and other deposits and short-term borrowings.

Uncertainty in banking is measured as the cross-sectional dispersion of shocks. To compute the cross-sectional dispersion of shocks, we proceed in two steps. In a first step, we derive bank-year-specific shocks for each of these four variables from the following regression model:

$$\log X_{ijt} - \log X_{ijt-1} = \Delta \log X_{ijt} = \alpha_i + \alpha_{jt} + \varepsilon_{ijt} \tag{2.9}$$

where $\Delta \log X_{ijt}$ is the growth rate of bank i's assets (short-term funding or productivity) in percent at time t in country j and α_i are bank fixed effects. Because return on assets (RoA) is a flow variable, we estimate this equation for the levels of RoA. Results remain unaffected if we estimate Equation (2.9) separately for all banks in one country. We account for heterogeneous effects of common factors at the country level by including time-varying country fixed effects α_{jt}. The residuals ε_{ijt} are used to calculate the cross-sectional dispersion measures.

Note that we do not aim at setting up a forecasting model for banks. Nevertheless, Equation (2.9) removes the impact of any bank-specific or time-varying country-specific factors on the bank-level variables. The residual from this regression thus provides us with a measure of shocks to these variables at the bank level. If banks have access to the type of information that is captured by bank and country-year fixed effects, and if we assume that they make use of this information, our measure will reflect the uncertainty that is perceived by banks. This perceived uncertainty should then affect banks' lending decisions.[4] From a technical point of view, our approach is similar to De Veirman and Levin (2016) who derive firm-specific volatility measures from residuals of sales or earnings growth regressions of U.S. firms. Also, Jurado et al. (2015) argue that a meaningful measure of uncertainty needs to relate to the unpredicted component of a given variable.

In a second step, we calculate uncertainty in banking as the cross-sectional dispersion across all bank-specific shocks ε_{ijt} per country and year. We compute the cross-sectional dispersion as the standard deviation (SD). This gives the measure for

[4] Measures of perceived uncertainty have also been used by Bachmann et al. (2010) for firms, and by Leduc and Liu (2015) for consumers.

uncertainty in banking derived from bank-level data, which we call $UncBank_{jt}$ for country j at time t:

$$UncBank_{jt} = SD(\varepsilon_{ijt}) \tag{2.10}$$

This is a conditional cross-sectional dispersion measure because it is based on bank-level variables from which all bank-specific and time-varying, country-specific factors have been removed. It is a measure of the second moment of the distribution of shocks to key bank-level variables. Therefore it is conceptually related to uncertainty in the banking sector as a whole. Furthermore, it can be seen as the empirical counterpart of the time-varying volatility σ_t capturing uncertainty in banking in the theoretical part.

Note that we derive a measure of uncertainty that is common to all banks in one country.[5] In our regression analysis, we then allow for heterogeneous responses of banks to uncertainty conditional on their balance sheet strength or liquidity management. Nevertheless, banks might have already perceived uncertainty differently. For example, in response to a common event, one bank might perceive a higher level of uncertainty while, for another bank, perceived uncertainty might have decreased. Deriving a bank-specific measure of uncertainty could thus be an interesting avenue for future research.

The corresponding summary statistics of the dispersion measures are provided in Table 2.1. Note that the values cannot be easily compared across the different measures. The reason is that the summary statistics of the standard deviations depend on the definition and the levels of the underlying variable.

2.3.3 Alternative Measures of Uncertainty

To compare our measures of uncertainty in banking derived from bank-level data to other uncertainty measures, we use the following alternative variables:

First, we compare our cross-sectional measure of uncertainty in banking to measures based on time-series variation in the data. For this purpose, we calculate the volatility of bank stock returns based on weekly bank stock price indices taken from Datastream. To capture uncertainty in overall stock markets, we construct a measure of stock market volatility using monthly stock price indices from Datastream.

[5] For robustness tests, we have changed the level of aggregation for the cross-sectional dispersion measure. Instead of taking the standard deviation across all banks in one country per year, we have aggregated by banks' size, that is, small and large banks, as well as banks' specialization type, that is, commercial banks vs. savings banks and credit unions. Regression results using these uncertainty measures can be found in Section 2.5.6

Second, we compare the measure for uncertainty in banking to measures of uncertainty in the real economy. We use the dispersion in firm returns obtained from Bloom (2014), and we compute the three-year rolling volatility of quarterly (year-over-year) real GDP growth taken from the IMF International Financial Statistics. Figure 2.1 shows the time-series pattern of these four alternative measures.

2.4 What Have Been Patterns of Uncertainty in Banking?

2.4.1 Uncertainty in Banking

In Figure 2.2, we plot the cross-sectional dispersion measures over time. For comparability, we have standardized these uncertainty measures, and we distinguish countries inside and outside the euro area to check whether patterns in the data are affected by the European debt crisis.

Overall, there has been a downward trend in the bank-level dispersion of shocks which has been interrupted by the financial crisis. Although the overall picture is similar for shocks to assets, profitability, and productivity, patterns of the dispersion of shocks to short-term funding are different from this general picture. Dispersion of short-term funding growth increased in the run-up to the crisis, and it has declined subsequently. Overall, interpreting a higher standard deviation as a higher degree of uncertainty, these patterns indicate that uncertainty in banking was transmitted through a wider dispersion of shocks to bank-level variables.

With respect to the pattern of the short-term funding dispersion, it should be noted that our data do not allow distinguishing between private and public sources of short-term funding. Therefore, the decline in the dispersion of funding shocks during the crisis might be related to monetary policy interventions. During the crisis, central banks all over the world immediately provided funding liquidity via their monetary policy operations. The initial shock to short-term funding of banks was thus mitigated. Banks which were hit by a funding shock might have replaced dried-up funding in private interbank markets with central bank liquidity. This might have narrowed down the heterogeneity in shocks to short-term funding across banks and made the peak in the aggregate dispersion measure during the crisis less pronounced, when monetary policy was strongly expansive.

These trends in the data are very similar for countries inside and outside the euro area. The levels of uncertainty differ though between euro area and non-euro area countries. Generally, there is a lower degree of dispersion in the euro area countries compared with the countries outside the euro area.

2.4.2 Do Different Measures of Uncertainty Evolve Similarly?

Figure 2.3 compares the development of the common measures for uncertainty with the standardized dispersion measures derived from bank-level data. Measures based on high-frequency data like bank stock return volatility fluctuate more. Such short-term fluctuations are smoothed out in the dispersion measures derived from annual bank-level data.[6] To test more explicitly whether the cross-sectional dispersion measures differ in their information content compared with the measures based on higher frequency, we conduct a simple regression analysis.

Table 2.2 gives results of univariate panel regressions using the dispersion measures as the dependent and alternative uncertainty measures as the explanatory variables. These regressions include country and year fixed effects. All variables are positively and significantly correlated with bank stock return volatility, except the cross-sectional uncertainty measure based on the dispersion of shocks to productivity (column 1). Hence, our cross-sectional measures for uncertainty in banking behave similarly to commonly used time-series measures for uncertainty in the banking sector.

For the remaining common uncertainty measures, the picture is less clear-cut. Three out of four measures show a positive and significant relation with the volatility of GDP (column 4). This suggests that uncertainty in banking and the real economy are linked. For stock market volatility or firm return dispersion, the relationship with the measures for uncertainty in banking is weak except if the dispersion of shocks to profitability is considered.

In sum, uncertainty in banking is related to alternative uncertainty measures like bank stock return volatility and GDP volatility. Yet, the link with alternative and commonly used measures like stock market volatility or firm return dispersion is rather weak. Hence, the result suggests that our uncertainty measures based on bank-level data contain additional information on uncertainty in the banking sector.

[6] The key advantage of using annual bank-level data is that these data are available for a broad set of banks and not only for stock listed banks. Even if higher frequency balance sheet data were available, we would not expect the cross-sectional measures to vary much more given that balance sheet data move more slowly than stock market data and capture changes in the longer-term business model of banks.

2.5 How does Uncertainty Affect Bank Lending?

To analyze the effect of uncertainty in banking on bank lending, we follow Cornett et al. (2011) and set up the following empirical model:

$$\frac{\Delta Loans_{ijt}}{Assets_{ijt-1}} = v_i + v_t + \alpha_1 X_{jt} + \alpha_2 X_{ijt-1} + \alpha_3 UncBank_{jt} + \alpha_4 UncBank_{jt} \times X_{ijt-1} + \varepsilon_{ijt} \tag{2.11}$$

where $\Delta Loans_{ijt}/Assets_{ijt-1}$ denotes the difference in the loan volume relative to total assets of bank i in country j in $t-1$ (in percent). In line with our theoretical model, we analyze how banks adjust the structure of their assets in response to higher uncertainty. We account for time invariant bank characteristics and common time trends by including the fixed effects v_i and v_t. Uncertainty ($UncBank_{jt}$) is measured through the cross-sectional dispersion across bank-specific shocks. Note that uncertainty varies across countries and time; hence, we cannot include country-year effects in the baseline model if we want to estimate α_3. Below, we will comment on robustness tests including country-year fixed effects.

Macroeconomic factors are captured by X_{jt} which includes the change in the natural logarithm of the GDP deflator ($GDPdeflator_{jt}$) and in real GDP ($realGDP_{jt}$) taken from the IMF World Economic Outlook. X_{ijt-1} are time-varying bank characteristics capturing liquidity, capitalization, the share of customer deposits in total assets, size, and committed loan obligations. Lagging the bank characteristics accounts for simultaneity but not necessarily for endogeneity.

When analyzing the impact of uncertainty on bank lending, we face two identification issues. The first relates to the endogeneity of uncertainty. Uncertainty might drive bank lending, but the dynamics of lending might also affect uncertainty. This endogeneity concern is partly remedied because lending and uncertainty are measured at different levels: our dependent variable is bank-level lending, while uncertainty is measured at the country level. Given that individual banks do not drive aggregate uncertainty, this should be a minor concern.

The second identification issue relates to demand and supply effects. Uncertainty affects banks – the supply of loans – as well as the firms and thus the demand side. We disentangle demand and supply effects by making use of bank-level heterogeneity.

Assuming a differential response conditional on these bank-level variables allows identifying supply-side effect. A similar identification strategy has been applied by Cornett et al. (2011) for the case of funding shocks or Valencia (2013) for aggregate uncertainty. This identification scheme is valid as long as borrowers are not systematically similar in the respective balance sheet characteristic to the banks they borrow from. The measure for uncertainty in banking is interacted with the bank-level explanatory variables $UncBank_{jt} \times X_{ijt-1}$. This allows for different responses of banks to uncertainty depending on their balance sheet strength and liquidity management.

We start from a benchmark regression, including macroeconomic control variables (Table 2.3), distinguishing domestic and foreign banks (Table 2.4) and controlling for the degree of financial integration of a country's banking system as such (Table 2.5). We then perform several robustness tests using stock market volatility or firm return dispersion to measure uncertainty (Table 2.6), we replace the macroeconomic controls by country-year fixed effects (Table 2.7), and we change the construction of the uncertainty measure (Tables 2.8 and 2.9).

2.5.1 Baseline Regression Results

Table 2.3 shows the results for the baseline regressions including macroeconomic controls. The average bank reduces lending in response to higher uncertainty in banking ($UncBank$).[7] This holds for all cross-sectional uncertainty measures derived from bank-level data except the dispersion of shocks to short-term funding. For the latter, the effect is significantly negative only for banks with low liquidity. A one unit increase in uncertainty in banking reduces bank lending on average from 1.3 percentage points in the case of the dispersion of shocks to profitability to 4.3 percentage points in the case of the dispersion of shocks to total assets. Given that we have standardized our uncertainty measures, a one unit increase in UncBank corresponds to one standard deviation.

Note that the negative impact of uncertainty on the loan supply is significant also in regressions not including interaction terms or macroeconomic controls. Also, the effects are not driven by a certain time period or group of countries, as we have restricted estimates to OECD countries and to the crisis period (2008-12).[8]

Based on the estimated coefficients, we can assess the quantitative impact of how uncertainty in banking affects banks' loan supply at the aggregate level. Across all bank-year observations included in the estimations, the change in loans relative to total assets of the previous period amounts to 3.9 percent on average. We do an in-sample prediction which sets uncertainty in banking first to its minimum value as observed in

[7] The bank-level variables entering the interaction terms are demeaned. Therefore, the estimated coefficient of uncertainty in banking ($UncBank$) can be interpreted as the marginal effect of uncertainty in banking on bank lending for the average bank. The average bank is defined as a bank for which all bank-level variables are set to their sample means.

[8] These results are available in the web appendix accompanying the published article.

the sample and then to its maximum value. For the sake of brevity, only the results for the dispersion of shocks to profitability are considered. It turns out that bank lending would have been equal to 5.7 percent, that is, 1.8 percentage points higher, if uncertainty in banking had been at its minimum. Equivalently, bank lending would have been equal to -1.5 percent on average, that is, 5.4 percentage points lower, if uncertainty in banking had been at its maximum.[9]

Regarding the macroeconomic controls, we find that both higher growth and higher inflation increase the loan supply. For a 1 percentage point increase in the inflation rate (measured as GDP deflator), the nominal loan supply increases by 0.34 percentage points. If real GDP growth increases by 1 percentage point, bank lending increases by 0.62 percentage points (column 1).

2.5.2 Is the Effect of Uncertainty Heterogeneous Across Banks?

As regards bank-level determinants, Table 2.3 confirms prior research. Banks have a higher loan supply if they are better capitalized, have a higher deposits-to-assets ratio, and if they hold more liquid assets. To account for the effect of (predetermined) characteristics of banks, we interact *UncBank* with the bank-level variables. These interaction terms show that the effect of uncertainty on bank lending is heterogeneous.

In line with theoretical priors, Table 2.3 shows that higher levels of capital might isolate bank lending against higher uncertainty (columns 1 and 4). Better capitalized banks reduce loans by less relative to their peers if the dispersion of shocks to total assets or profitability increases. This would be in line with regulatory capital requirements becoming increasingly binding in uncertain times. Banks with low capital buffers have to adjust by shifting their portfolio from risky investments such as loans to less risky ones. In contrast, better capitalized banks decrease lending if the dispersion of shocks to short-term funding increases (column 2). Figure 2.4 confirms that the average marginal effect of uncertainty on loan supply is negative, even in the case of short-term funding uncertainty. The negative average marginal effect declines in absolute terms with a higher capital ratio if uncertainty is measured as the dispersion of shocks to total assets or profitability. In the latter case, the marginal effect even turns positive (albeit insignificant) for highly capitalized banks.

In addition to capital, liquidity matters. More liquid banks reduce lending by less given a rise in uncertainty in banking (Table 2.3, columns 1-3). In uncertain times, these banks can draw on their liquidity buffers to stabilize lending. Figure 2.5 shows

[9] For the other three measures for uncertainty in banking, the numbers are as follows: dispersion of asset shocks: 11.2 percent (*UncBank* at minimum) and -14.8 percent (*UncBank* at maximum); short-term funding shocks: 7.4 and 0.5 percent; productivity shocks: 6.5 and -6.9 percent.

average marginal effects of uncertainty in banking on loan supply, conditional on the liquidity ratio of banks. It not only shows the point estimates presented in Table 2.3, but it also varies the liquid asset share from 0 to 80 percent.

For all dispersion measures, the contraction in lending following an increase in uncertainty is smaller the more liquid assets a bank holds. More liquid banks can thus shield their supply of loans against an increase in uncertainty. For banks with sufficiently high liquidity, the marginal effects even turn insignificant. In this case, bank lending is not affected by uncertainty in a significant way. A possible explanation is that in the presence of liquidity freezes, these banks have the option to sell part of their liquid assets and reduce the need for refinancing. An alternative explanation is that liquidity injections from central banks matter, as these banks should have sufficient collateral to refinance via the central bank.

Finally, banks with a higher share of committed credit lines reduce lending by more if they face an increase in uncertainty measured as the dispersion of shocks to short-term funding (column 2). This is plausible as firms tend to draw on their credit lines in uncertain times.[10] Banks compensate for the increase in loan demand by reducing their supply of noncommitted (new) loans accordingly. Cornett et al. (2011) document a similar effect in response to (first-order) liquidity shocks for U.S. banks during the crisis.

2.5.3 Does Heterogeneity with Regard to Internationalization Matter?

The analysis so far has shown that bank lending declines when uncertainty increases, and that this effect can be heterogeneous across banks depending on their balance sheet structure. However, we have not yet accounted for the effect of uncertainty depending on heterogeneity in the degree of internationalization. In recent decades, banking has become more international, and shocks might be transmitted through international activities of banks (Cetorelli and Goldberg, 2011; De Haas and Van Horen, 2012). We contribute to this literature by asking whether foreign-owned banks or banks that are located in more financially integrated countries are affected less by uncertainty because they can diversify shocks across borders.

We measure internationalization at the level of the individual bank (Table 2.4) and at the level of the country (Table 2.5). We begin by exploiting the (foreign) ownership data by Claessens and Van Horen (2014). These data allow analyzing whether

[10] Ivashina and Scharfstein (2010) and Campello et al. (2011) document that private firms drew extensively on committed credit lines during the recent financial crisis.

foreign-owned banks react differently to uncertainty in their host country compared with domestically owned banks while controlling for uncertainty in the residence country of the foreign owner. As the database is limited to the years 1995-2009, we assume that the ownership status of the banks has remained unchanged in the years 2010-12 compared with 2009. The database indicates whether a bank is domestically or foreign-owned. A bank is identified as foreign-owned if foreigners hold 50 percent or more of its shares. In case a bank is foreign-owned, the country of the largest foreign shareholder is indicated.[11]

Using the information on ownership status, we essentially estimate the baseline model except for the interactions with bank-level variables, but we now include a foreign ownership dummy. The measure for uncertainty in banking derived from bank-level data in country j – the host country, if foreign banks are considered – is captured by $UncBank_{jt}$. We interact the uncertainty measure in the country of location with the foreign ownership status $Fown(0/1)$. The dummy takes a value of one if the bank is foreign-owned and zero otherwise. Given that a bank is foreign-owned, we additionally consider the effect of uncertainty in the country of residence of the foreign owner $UncBank_{kt}$. If a bank is domestically owned, we set $UncBank_{kt}$ to zero.

Table 2.4 shows the regression results. Signs and quantities of bank characteristics are comparable with our previous results and, in particular, the effect of uncertainty on bank lending is significantly negative for domestic banks. We only find weak support for the hypothesis that foreign-owned banks are differently affected by host country uncertainty than domestically owned banks. The coefficients on the interaction terms of the uncertainty measure with $Fown(0/1)$ are mostly insignificant. Only in column 3, for the case of the dispersion of shocks to productivity, we find that foreign-owned banks respond differently to uncertainty in the host country than domestically owned banks: the average marginal effects reveal that foreign-owned banks increase their loan supply by 0.6 percent, while domestically owned banks reduce it by 1.1 percent if uncertainty increases by one standard deviation.

We control for the impact of uncertainty in banking in the country of the largest shareholder, as this might impact and presumably reduce the loans supplied by foreign-owned banks. This is indeed the case if we consider the dispersion of shocks to short-term funding (column 2) or productivity (column 3). This arises due to the fact that foreign-owned banks can be affected by developments in the home and the host country.

In Table 2.5, we turn to the question whether it may not be the ownership status

[11]There might be cases in which the bank is identified as foreign-owned, but the largest foreign shareholder does not hold the largest amount of shares. However, we cannot identify such cases from the information in the database.

of individual banks which affects the response to uncertainty but the openness of the financial system. Inter alia, we would expect that lending by banks in financially open countries is affected less by uncertainty because cross-border lending and borrowing can be used to mitigate the impact of uncertainty shocks.

To focus on the question whether banks in more financially integrated countries respond differently to uncertainty, we use data on cross-border activities of a country's banking system of the Bank for International Settlements (BIS). We calculate an openness measure for each country reporting to the Locational Banking Statistics, which is defined as total assets held by the banking system in reporting country j toward the rest of the world relative to nominal GDP in country j (in percent). The standardized variable $Openness_t$ is then interacted with our measure of uncertainty in banking.

Table 2.5 shows the results. Financial openness in and of itself has a negative impact on loan supply. Given that our dependent variable measures changes in bank loans relative to the balance sheet total of banks, this result implies that, in countries that are financially more open, traditional lending business of banks is less important than in financially closed economies. The signs of the remaining variables again remain unchanged. The sign of the interaction term between openness and uncertainty confirms our prior: the significant and positive coefficient of the interaction term indicates that in more financially open countries, the negative effect of uncertainty on loan supply is mitigated. Although the effect of ownership status was rather weak, this suggests that it is the openness of the banking system as such that affects banks' response to uncertainty.

2.5.4 Robustness 1: Alternative Measures of Uncertainty

For comparison, we next consider the effect of the alternative uncertainty measures which are related to the financial and the real sector: bank stock return volatility, stock market volatility, firm return dispersion, and GDP volatility (Table 2.6). In line with our descriptive statistics, volatility of bank stock returns yields results similar to those for the cross-sectional dispersion measures: lending declines as uncertainty increases. Hence, cross-sectional dispersion and time-series volatility measures related to the banking sector capture similar features of uncertainty. Stock market volatility as such has no significant effect.

A higher level of firm return dispersion, which might capture uncertainty in the real sector and borrower default risk, has a negative effect on bank lending. The result for uncertainty stemming from the real sector is supported by the significantly negative effect of GDP volatility on bank lending. The finding is in line with Valencia (2013), who shows that banks reduce lending in times of increased default risk of banks but also of borrowers due to higher uncertainty.

In unreported regressions, we simultaneously include one dispersion measure and its interactions with the bank-level variables and one of the four alternative measures and the interactions with the bank-level variables. This helps ensure that the estimated effect of our dispersion measure on lending is not driven by omitted variables. The effect of our cross-sectional dispersion measures on bank lending remains qualitatively unaltered, except for the case of dispersion of shocks to profitability: the coefficient becomes insignificant if bank stock return volatility is included simultaneously.

2.5.5 Robustness 2: Including Country-Year Fixed Effects

In order to control for macroeconomic conditions affecting all banks in one country, we include country-year fixed effects v_{jt}. Now, the country-level variables – including our measure of uncertainty in banking ($UncBank$) – are omitted, and we focus on the interaction effects. The advantage of this specification is that it controls for a wide range of potentially unobservable factors influencing bank lending. The disadvantage is that it no longer allows assessing the direct impact of uncertainty in banking on bank lending.

Table 2.7 shows the results. The interaction effects, which measure if the effect of uncertainty on bank lending differs between banks with higher and lower values of the respective bank-level variable, are still identified in the regressions. These interaction effects remain robust in most of the cases: in columns 1 and 3, the interaction term of uncertainty in banking with the liquidity ratio remains significant and positive; in columns 1 and 4 the same holds true for the interaction of uncertainty in banking and the capital ratio. The results for uncertainty measured as the dispersion of shocks to short-term funding deviate from the general picture.

2.5.6 Robustness 3: Alternative Aggregation of the Measure of Uncertainty

In order to aggregate bank-specific shocks and to construct our measure of uncertainty, we use the country as the cross-sectional aggregator. This approach is based on the assumption that uncertainty in the country of residence matters for a bank. In most countries, only large banks maintain a wide range of cross-border activities, including foreign affiliates. Because many smaller banks conduct business mostly at home while holding only a small fraction of foreign assets (Buch et al., 2011), aggregating by country seems reasonable. Also, Cetorelli and Goldberg (2014) find that, in most countries, global banks have a large fraction of their affiliates at home.

Nevertheless, as observed in Section 2.5.2, heterogeneity in banks' business models is an important driver of how uncertainty affects banks. This should hold in particular if uncertainty is not driven by country-specific developments. To look in more detail at the possibility that different types of banks are affected differently by uncertainty, we derive the uncertainty measure for subgroups of banks.

The subgroups are defined along the two dimensions size and business model in the following way: (1) Small and large banks. Large banks are defined as banks with total assets above the median of all banks in a given country. (2) Cooperative/ savings banks and commercial banks. Hence, aggregation is not specific to one country but based on certain criteria, for example, the dispersion is computed across the shocks for all small banks and across the shocks of all large banks and then assigned to the respective bank type.

Results in Table 2.8 show that the direct effect of uncertainty remains negative for the dispersion in total assets and return on assets (columns 1 and 4). In Table 2.9, in which subgroups are defined based on the specialization of the bank, the negative effect of uncertainty on loan supply is statistically significant across all specifications. Although the interaction terms partly lose significance, the interaction term with the share of committed loans becomes negative and significant. This might indeed be a result of banks being affected heterogeneously by uncertainty depending on the bank type and related business model.

2.6 Conclusions

During the financial crisis, loan supply by banks has contracted, both domestically and across borders. Lending to the real sector has decreased, and the international banking system has become more fragmented. This paper explores whether the adjustment of banks could be the result of increased uncertainty. The paper uses a measure of uncertainty in banking based on the cross-sectional dispersion of shocks across banks and analyzes the heterogeneous responses of bank loans to uncertainty.

Our measure of uncertainty in banking is constructed from bank-level data. In a first step, we compute bank-level shocks to growth rates of total assets, short-term funding, productivity, and profitability. In a second step, we measure uncertainty in banking as the cross-sectional dispersion of these shocks. A higher cross-sectional dispersion is interpreted as a higher degree of uncertainty in banking.We find that uncertainty in banking fluctuates over time, and that it has increased during the recent crisis.

We then use our uncertainty measure derived from bank-level data to analyze the impact of uncertainty in banking on the loan supply by domestic and foreign-owned banks. Our results show that banks decrease their loan supply during periods of higher uncertainty. This effect is heterogeneous across banks: lending by banks which are better capitalized and have higher liquidity buffers tends to be affected less. We find evidence that the effect of uncertainty on bank lending is mitigated in financially open economies. This effect is driven by the openness of countries as such and not the ownership of specific banks, because there is only weak evidence that foreign-owned and domestic banks react differently to higher uncertainty.

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Appendix to Chapter 2

2.A Extensions

Bank Loan Supply and Capital Buffers

In the following, we show how the response of a bank's loan supply (relative to assets in $t-1$) to higher uncertainty in banking depends on its capital buffer in $t-1$.

If we consider ϕ to be time-varying, we obtain from Equation (2.8):

$$\frac{\partial\left(\frac{\Delta l_t}{ta_{t-1}}\right)}{\partial\sigma_t} = \frac{-\frac{\phi_t e_{t-1}}{ta_{t-1}}\left(1+\frac{r_t}{\phi_{t-1}\sigma_{t-1}-\mu}\right)}{(\phi_t\sigma_t-\mu)^2} < 0$$

The relevant cross derivative is given by:

$$\frac{\partial\left(\frac{\Delta l_t}{ta_{t-1}}\right)}{\partial\sigma_t\partial\phi_{t-1}} = \frac{\frac{\phi_t\sigma_{t-1}e_{t-1}}{ta_{t-1}}r_t}{(\phi_t\sigma_t-\mu)^2(\phi_{t-1}\sigma_{t-1}-\mu)^2}$$

which is > 0 if $r_t > 0$ and < 0 if $r_t < 0$.

Calculating Bank Productivity

We estimate bank productivity using an empirical methodology in the spirit of Levinsohn and Petrin (2003) and applied to banks by Nakane and Weintraub (2005):

$$\log y_{it} = \beta_0 + \beta_l x_{it} + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \eta_{it}$$

Bank output is given by y_{it}, x_{it} denotes the free input variables, k_{it} the fixed input and m_{it} the intermediate input. The error consists of an unobserved productivity term ω_{it} and a random term η_{it}. The approach accounts for simultaneity between productivity and the factor input choices of banks. This is achieved by introducing the intermediate input which correlates with productivity. Productivity shocks thus primarily account for supply-side factors. The output of banks is defined as the total lending volume. We choose two free input variables. The first is total long-term funding. The second accounts for bank staff and is proxied by personnel expenses. Banks have to maintain branches or subsidiaries to provide loans. These cannot be adjusted rapidly and we capture the fixed input by fixed assets. For the intermediate input good, we choose total equity.

2.B Data

The results in this paper are based on various data sources. Data at the bank level are obtained from Bankscope. Information on foreign ownership of banks comes from the database provided by Claessens and Van Horen (2014). Country-level data are obtained from Bloom (2014), Datastream, the International Monetary Fund (IMF), and the Bank for International Settlements (BIS).

List of Countries

	Euro Area	Non-Euro Area
OECD	Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Slovakia, Slovenia, Spain	Australia, Canada, Chile, Czech Republic, Hungary, Iceland, Israel, Japan, Mexico, New Zealand, Norway, Poland, South Korea, Sweden, Switzerland, Turkey, United Kingdom, United States
Non-OECD	Cyprus, Latvia, Malta	Argentina, Brazil, Bulgaria, China, Croatia, India, Indonesia, Lithuania, Romania, Russia, Saudi Arabia, South Africa

Bank-Level Variables

Bank lending: Our measure for bank lending is the difference in total loans relative to total assets in $t-1$ (in percent). The data come from Bankscope and the variable total loans is defined as gross loans minus impaired loans.

Capital/assets: To measure capitalization, we use the Tier 1 regulatory capital relative to total assets (in percent) as obtained from Bankscope.

Committed loans/(committed loans + assets): To control for committed loan obligations, we use committed loans relative to the sum of committed loans and total assets (in percent). Data are provided by Bankscope.

Deposits/assets: The variable deposits/assets denotes the share of customer deposits to balance sheet total (in percent) as obtained from Bankscope.

Liquid assets/assets: The liquidity ratio is defined as the ratio of banks' liquid assets, that is, the sum of trading securities, loans and advances to banks, reverse repos and cash collateral, cash and due from banks minus mandatory reserves included in these positions, relative to total assets (in percent). Data are taken from Bankscope.

Log total assets: To obtain a measure for bank size we use the logarithm of banks' total assets (in thousands of USD) as obtained from Bankscope.

Uncertainty in Banking Measures

Total assets: We use total assets in thousands of USD as provided by Bankscope.

Productivity: Productivity is estimated as proposed by Levinsohn and Petrin (2003). For the free input variables, we choose total long-term funding and personnel expenses. The intermediate input good is proxied by total equity and the fixed input is given by fixed assets. For the output variable, we use total loans defined as gross loans minus impaired loans. Data are in thousands of USD and obtained from Bankscope.

Profitability (RoA): Return on assets (RoA) is the ratio of operating profits to total assets (in percent) and calculated from data available in Bankscope.

Short-term funding: The variable short-term funding (in thousands of USD) is obtained by taking the sum of deposits from banks, repos and cash collateral, and other deposits and short-term borrowings as provided by Bankscope.

Alternative Uncertainty Measures

Bank stock return volatility: To construct a measure for bank stock return volatility, we use weekly bank price indices from Datastream. As they are not available for some countries, we resort to aggregates for the particular region. The measure for bank stock return volatility is computed as the volatility of weekly bank index returns for each year (in percent).

Firm return dispersion: From Bloom (2014), we take a measure to control for uncertainty in the real sector. Data come from the WRDS international equity database and are used to construct the standard deviation of quarterly returns across firms. For our analysis, we use the value for the last quarter of the respective year (in percent).

GDP volatility: GDP volatility is computed as the three-year rolling volatility of quarterly (year-over-year) real GDP growth taken from the IMF International Financial Statistics (in percent).

Stock market volatility: To construct a measure for stock market volatility, we use monthly stock price indices from Datastream. We resort to monthly frequency as this is available for all countries. The stock market volatility measure is computed as the volatility of monthly stock market index returns for each year (in percent).

Internationalization

Foreign ownership: Data on foreign ownership are taken from Claessens and Van Horen (2014) and matched with bank-level information from Bankscope. The data are available for 5,324 banks in 137 countries for the period 1995-2009. We keep all banks which are located in one of our sample countries. For the years 2010-12, we project the ownership status of the year 2009 forward.

Openness: The variable openness is defined as total assets held by the banking system in reporting country j toward the rest of the world relative to nominal GDP in country j (in percent). Data on a country's banking system's cross-border activities come from the Locational Banking Statistics of the BIS.

2.C Figures and Tables

Figure 2.1: **Alternative measures of uncertainty**
The graph shows the evolution of alternative uncertainty measures over time. The variables that proxy uncertainty include *Bank stock return volatility* computed as the volatility of weekly bank index returns for each year, *Stock market volatility* computed as the volatility of monthly stock market index returns for each year, *Firm return dispersion* calculated as the standard deviation of quarterly returns across firms, and *GDP volatility* computed as the three-year rolling volatility of quarterly (year-over-year) real GDP growth. The graphs show the average across all countries in the sample (solid line), the average across euro area countries (dashed line) and the average across non-euro area countries (dotted line) for the period 1998-2012. For better comparison, all variables are standardized (zero sample mean, unit sample standard deviation). Data source: Own calculations based on data taken from Bloom (2014), Datastream, and the IMF.

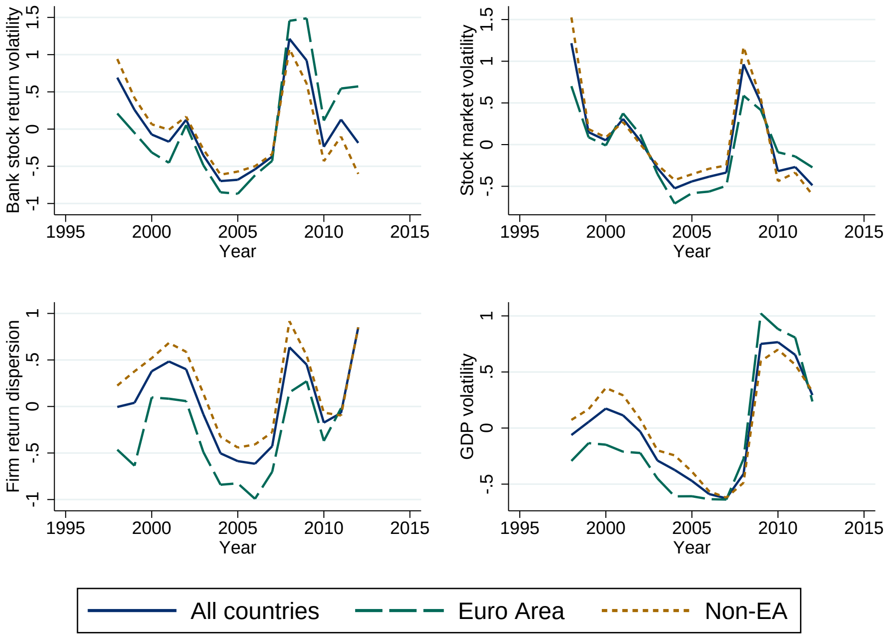

Figure 2.2: **Uncertainty in banking**
The graph shows the evolution of our cross-sectional uncertainty measures derived from bank-level data over time. The measures are based on balance sheet data (total assets/short-term funding), productivity (productivity shock), and profitability (RoA). *Total assets* is in thousands of USD. *Short-term funding* (in thousands of USD) is obtained by taking the sum of deposits from banks, repos and cash collateral, and other deposits and short-term borrowings. *Productivity* is estimated as proposed by Levinsohn and Petrin (2003). *RoA* is the ratio of operating profits to total assets (in %). For each of these variables, we compute in a first step time-varying bank-specific shocks as described in Section 2.3.2. In a second step, we calculate the cross-sectional dispersion per country and year by taking the standard deviation across the shocks of all banks in one country and year. The graphs show the average across all countries in the sample (solid line), the average across euro area countries (dashed line), and the average across non-euro area countries (dotted line). For better comparison, all variables are standardized (zero sample mean, unit sample standard deviation). Data source: Own calculations based on data taken from Bankscope.

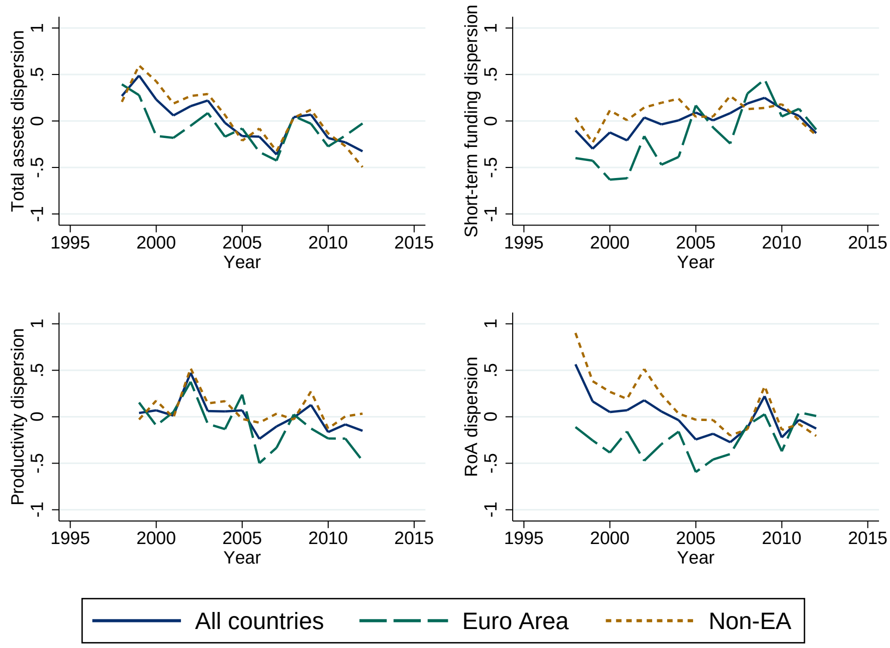

Figure 2.3: **Uncertainty in banking vs. alternative measures of uncertainty**
The graph shows time-series plots of our cross-sectional uncertainty measures derived from banklevel data against alternative measures of uncertainty. The measures for uncertainty in banking are based on (a) *Total assets* in thousands of USD, (b) *Short-term funding* (in thousands of USD) obtained by taking the sum of deposits from banks, repos and cash collateral, and other deposits and short-term borrowings, (c) *Productivity* estimated as proposed by Levinsohn and Petrin (2003), (d) *RoA*, which is the ratio of operating profits to total assets (in %). The variables that proxy uncertainty include *Bank stock return volatility* computed as the volatility of weekly bank index returns for each year, *Stock market volatility* computed as the volatility of monthly stock market index returns for each year, *Firm return dispersion* calculated as the standard deviation of quarterly returns across firms, and *GDP volatility* computed as the three-year rolling volatility of quarterly (year-over-year) real GDP growth. For better comparison, all variables are standardized (zero sample mean, unit sample standard deviation). Data source: Own calculations based on data taken from Bankscope, Bloom (2014), Datastream, and the IMF.

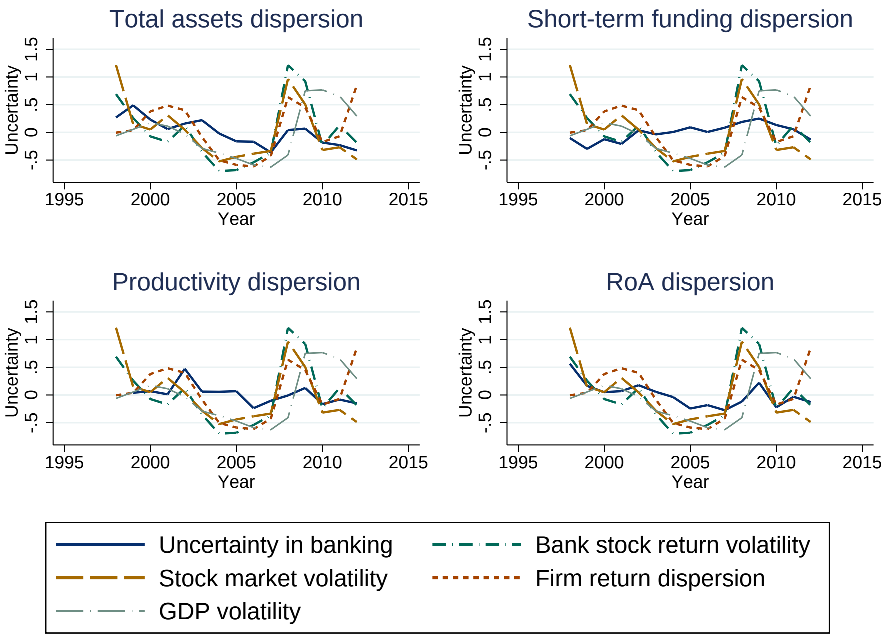

Figure 2.4: **Average marginal effects conditional on the capital ratio**
The graph shows the average marginal effects of our cross-sectional uncertainty measures derived from bank-level data (*UncBank*) on loan supply conditional on the range of values for the *Ratio of Tier 1 regulatory capital to assets* (in %) as observed in the sample. The measures for uncertainty in banking are based on (a) *Total assets* in thousands of USD, (b) *Short-term funding* (in thousands of USD) obtained by taking the sum of deposits from banks, repos and cash collateral, and other deposits and short-term borrowings, (c) *Productivity* estimated as proposed by Levinsohn and Petrin (2003), (d) *RoA*, which is the ratio of operating profits to total assets (in %). The estimated marginal effects are denoted by dots, which are surrounded by 95 percent confidence bands.

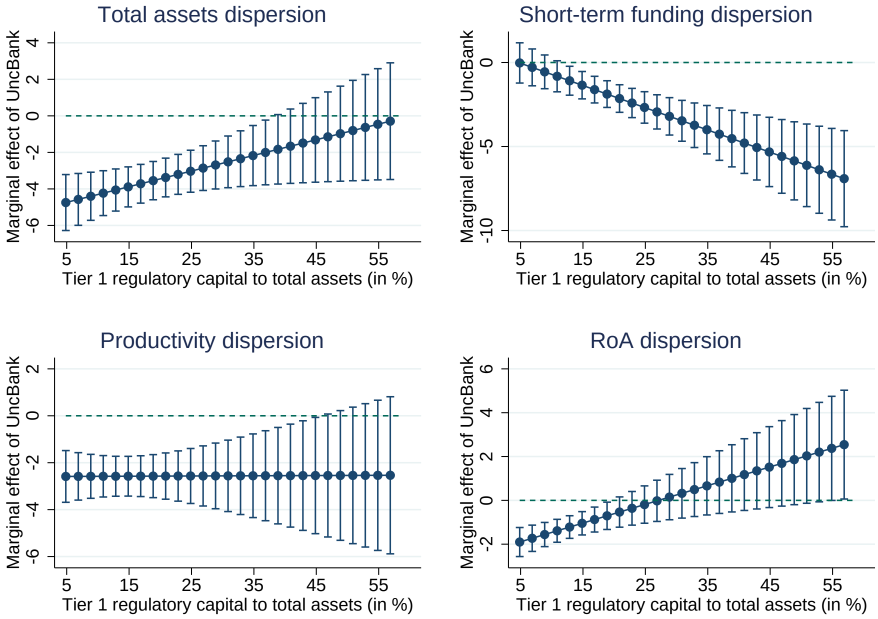

Figure 2.5: **Average marginal effects conditional on the liquidity ratio**
The graph shows the average marginal effects of our cross-sectional uncertainty measures derived from bank-level data (*UncBank*) on loan supply conditional on the range of values for the *Ratio of liquid assets to assets* (in %) as observed in the sample. The measures for uncertainty in banking are based on (a) *Total assets* in thousands of USD, (b) *Short-term funding* (in thousands of USD) obtained by taking the sum of deposits from banks, repos and cash collateral, and other deposits and short-term borrowings, (c) *Productivity* estimated as proposed by Levinsohn and Petrin (2003), (d) *RoA*, which is the ratio of operating profits to total assets (in %). The estimated marginal effects are denoted by dots, which are surrounded by 95 percent confidence bands.

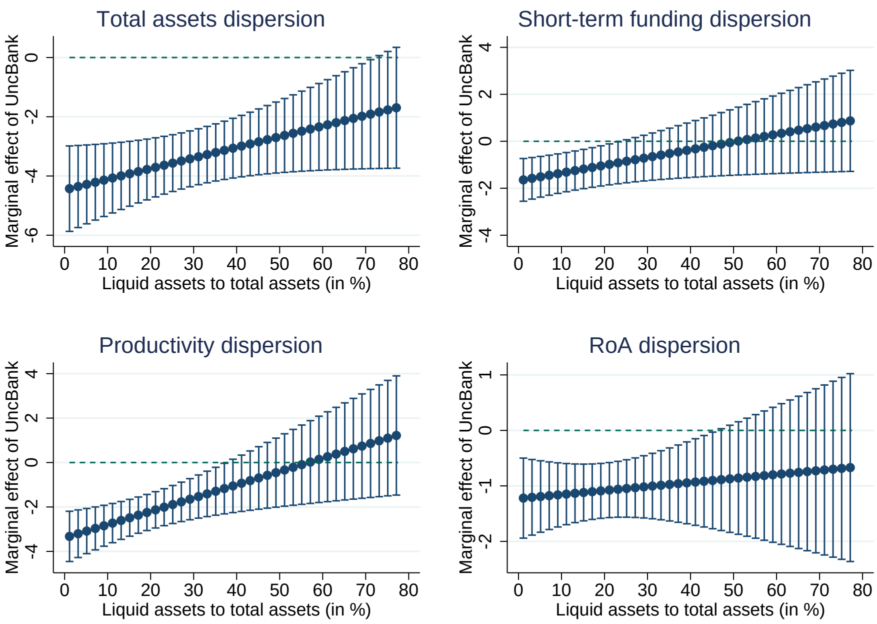

Table 2.1: **Summary statistics**
The table shows summary statistics for the explanatory variables. Panel (a) provides descriptive statistics for the bank-level variables that are based on the banks belonging to one of the sample countries, over the period 1998-2012. *Liquid assets/assets* measures the fraction of the liquidity held by a bank relative to total assets (in %). To measure capitalization we use the *Capital/assets* ratio (in percent). *Deposits/assets* denotes the share of customer deposits to balance sheet total (in percent). *Log total assets* denotes the logarithm of bank assets in thousands of USD. To control for committed loan obligations, we use the ratio *Committed loans/(committed loans + assets)* (in %).
Panel (b) shows summary statistics for the cross-sectional uncertainty measures derived from bank-level data. The measures are based on balance sheet data (*total assets* and *short-term funding*), *productivity*, and *profitability* (RoA). *Total assets* are in thousands of USD. *Short-term funding* (in thousands of USD) is obtained by taking the sum of deposits from banks, repos and cash collateral, and other deposits and shortterm borrowings. *Productivity* is estimated as proposed by Levinsohn and Petrin (2003). *RoA* is the ratio of operating profits to total assets (in %). For each of these variables, we first compute time-varying bank-specific shocks as described in Section 2.3.2. We then calculate the cross-sectional dispersion per country and year by taking the standard deviation across the shocks of all banks in one country and year. For more details, see the description in the Data Appendix.

	Observations	Mean	Standard deviation	Skewness	Kurtosis	Min	Max
			(a) Bank-level variables				
Liquid assets/assets	34,686	17.47	15.85	1.64	5.68	1.14	77.55
Capital/assets	27,762	14.04	8.08	2.92	14.22	4.86	58.74
Deposits/assets	73,683	65.84	22.83	−1.18	3.87	0.58	95.81
Log total assets	74,537	13.81	1.91	0.59	3.49	9.80	19.73
Comm. loans/ (comm. loans + assets)	43,456	5.85	7.37	2.69	11.75	0.00	44.09
			(b) Uncertainty in banking				
Total assets	684	11.64	5.55	0.79	3.78	0.00	36.88
Short-term funding	676	64.98	29.30	0.70	4.71	0.00	223.99
Productivity	536	16.06	13.75	3.27	20.29	0.00	132.06
RoA	683	1.05	0.65	1.66	8.98	0.00	5.95

Table 2.2: **Uncertainty in banking vs. alternative uncertainty measures**
The table shows regressions in which the dependent variables are our uncertainty measures based on (a) total assets, (b) short-term funding, (c) productivity, and (d) return on assets (RoA). The sample covers 48 countries over the period 1998-2012. The explanatory variables that vary across columns are alternative measures of uncertainty and include *Bank stock return volatility* computed as the volatility of weekly bank index returns for each year, *Stock market volatility* computed as the volatility of monthly stock market index returns for each year, *Firm return dispersion* calculated as the standard deviation of quarterly returns across firms, and *GDP volatility* computed as the three-year rolling volatility of quarterly (year-over-year) real GDP growth. All regressions are estimated with a (nonreported) constant and include time fixed effects as well as country fixed effects. For more information on the variables, see the Data Appendix. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1) Bank stock return volatility	(2) Stock market volatility	(3) Firm return dispersion	(4) GDP volatility
Dispersion of shocks to total assets growth	0.332***	0.104	−0.016	0.285*
	(0.121)	(0.108)	(0.067)	(0.168)
Observations	658	647	405	652
R^2	0.11	0.09	0.11	0.09
Number of countries	48	47	31	47
Dispersion of shocks to short-term funding growth	1.861**	0.245	−0.128	1.977**
	(0.843)	(0.771)	(0.252)	(0.949)
Observations	651	639	397	645
R^2	0.06	0.04	0.08	0.05
Number of countries	48	47	31	47
Dispersion of shocks to productivity growth	−0.032	0.310	0.343	−0.121
	(0.430)	(0.329)	(0.237)	(0.187)
Observations	528	517	318	524
R^2	0.03	0.03	0.06	0.04
Number of countries	47	46	30	46
Dispersion of shocks to return on assets (RoA)	0.074***	0.034*	0.022***	0.041**
	(0.022)	(0.018)	(0.006)	(0.019)
Observations	657	646	404	651
R^2	0.16	0.09	0.09	0.10
Number of countries	48	47	31	47

Table 2.3: **Uncertainty and loan supply: baseline regressions**
The table reports fixed effects regressions. The dependent variable is the change in loans divided by total assets of the previous period. The explanatory variables include macro variables, bank-level variables, the cross-sectional uncertainty measures derived from bank-level data (UncBank) (as denoted in columns 1-4), and interactions of the latter with the bank-level variables. All bank-level variables are lagged by one period. The sample comprises yearly data of banks in 48 countries over the time period 1998-2012. The regressions take into account bank and year fixed effects. Standard errors are clustered by individual bank and depicted in parentheses. All variables are centered around their means if they are interacted to facilitate interpretation of estimated coefficients. All measures for uncertainty in banking derived from bank-level data are standardized. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1)	(2)	(3)	(4)
Dependent variable:	*Measure of uncertainty*			
ΔLoans/assets$_{t-1}$	Total assets dispersion	Short-term funding dispersion	Productivity dispersion	RoA dispersion
Macro variables				
ΔLog GDP deflator$_t$	0.341***	0.352***	0.317***	0.322***
	(0.059)	(0.059)	(0.059)	(0.059)
ΔLog real GDP$_t$	0.618***	0.658***	0.563***	0.623***
	(0.083)	(0.088)	(0.084)	(0.083)
Bank-level variables				
Liquid assets/assets$_{t-1}$	0.082***	0.065**	0.082***	0.089***
	(0.022)	(0.029)	(0.023)	(0.022)
Capital/assets$_{t-1}$	0.108*	0.234***	0.152***	0.081
	(0.056)	(0.062)	(0.056)	(0.054)
Deposits/assets$_{t-1}$	0.058*	0.070**	0.069**	0.065**
	(0.032)	(0.032)	(0.031)	(0.031)
Log total assets$_{t-1}$	−3.962***	−3.393***	−3.527***	−3.771***
	(0.924)	(0.913)	(0.906)	(0.869)
Comm. loans/(comm. loans + assets)$_{t-1}$	0.101**	0.180***	0.113**	0.087**
	(0.045)	(0.053)	(0.048)	(0.044)
Uncertainty and interaction terms				
Uncertainty in banking (UncBank$_t$)	−4.309***	−0.355	−2.510***	−1.335***
	(0.674)	(0.504)	(0.512)	(0.339)
Liquid assets/assets$_{t-1}$ × UncBank$_t$	0.036*	0.033**	0.060***	0.007
	(0.019)	(0.016)	(0.022)	(0.014)
Capital/assets$_{t-1}$ × UncBank$_t$	0.086**	−0.132***	0.001	0.085***
	(0.041)	(0.036)	(0.039)	(0.028)
Deposits/assets$_{t-1}$ × UncBank$_t$	−0.001	−0.016	−0.006	−0.027*
	(0.014)	(0.012)	(0.019)	(0.015)
Log total assets$_{t-1}$ × UncBank$_t$	0.720***	−0.248*	0.270	0.130
	(0.175)	(0.146)	(0.185)	(0.127)
Comm. loans/(comm. loans + assets)$_{t-1}$	−0.045	−0.118***	−0.020	0.023
× UncBank$_t$	(0.033)	(0.036)	(0.040)	(0.021)
Observations	10,282	10,282	10,164	10,282
R^2	0.22	0.21	0.21	0.21
Number of banks	2,355	2,355	2,323	2,355

Table 2.4: **Uncertainty and loan supply: foreign ownership status**
The table reports fixed effects regressions. The dependent variable is the change in loans divided by total assets of the previous period. The explanatory variables include macro variables, bank-level variables, the dummy variable Fown(0/1) indicating a bank's foreign ownerships status (0: domestically owned; 1: foreign-owned), the cross-sectional uncertainty measures derived from bank-level data (UncBank) (as denoted in columns 1-4) in the host country j, its interaction with the dummy variable Fown(0/1), and the cross-sectional uncertainty measure derived from bank-level data in the residence country k of the largest shareholder. All bank-level variables are lagged by one period. The sample comprises yearly data of banks in 48 countries over the time period 1998-2012. All banks for which (foreign) ownership status is available in the database by Claessens and Van Horen (2014) are included. The regressions take into account bank and year fixed effects. Standard errors are clustered by individual bank and depicted in parentheses. All variables are centered around their means if they are interacted (except for the dummy variable) to facilitate interpretation of estimated coefficients. All measures for uncertainty in banking derived from bank-level data are standardized. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1)	(2)	(3)	(4)
Dependent variable:	*Measure of uncertainty*			
ΔLoans/assets$_{t-1}$	Total assets dispersion	Short-term funding dispersion	Productivity dispersion	RoA dispersion
Macro variables				
ΔLog GDP deflator$_{jt}$	0.325***	0.343***	0.350***	0.339***
	(0.060)	(0.062)	(0.062)	(0.061)
ΔLog real GDP$_{jt}$	0.862***	0.853***	0.805***	0.786***
	(0.115)	(0.118)	(0.120)	(0.115)
Bank-level variables				
Liquid assets/assets$_{t-1}$	0.096***	0.094**	0.080**	0.088**
	(0.036)	(0.037)	(0.037)	(0.035)
Capital/assets$_{t-1}$	0.223**	0.230**	0.245**	0.231**
	(0.108)	(0.107)	(0.113)	(0.104)
Deposits/assets$_{t-1}$	−0.012	−0.014	0.023	−0.008
	(0.043)	(0.044)	(0.045)	(0.043)
Log total assets$_{t-1}$	−5.396***	−5.385***	−5.389***	−5.685***
	(1.036)	(0.996)	(1.003)	(1.081)
Comm. loans/(comm. loans + assets)$_{t-1}$	0.026	0.027	0.054	−0.001
	(0.065)	(0.072)	(0.060)	(0.065)
Fown(0/1)	2.809	4.669	2.474	1.127
	(4.409)	(3.708)	(3.569)	(3.719)
Uncertainty and interaction terms				
Uncertainty in banking (UncBank$_{jt}$)	−1.608**	0.229	−1.084**	−1.778***
	(0.669)	(0.410)	(0.503)	(0.631)
Fown(0/1) × UncBank$_{jt}$	−0.642	0.033	1.648**	0.516
	(0.927)	(0.628)	(0.720)	(1.024)
Uncertainty in banking (UncBank$_{kt}$)	−0.935	−1.618**	−0.778**	−0.020
	(0.743)	(0.740)	(0.325)	(0.431)
ΔLog GDP deflator$_{kt}$	−0.151	−0.215**	−0.064	−0.171
	(0.112)	(0.105)	(0.145)	(0.107)
ΔLog real GDP$_{kt}$	0.038	0.011	0.011	0.014
	(0.139)	(0.139)	(0.141)	(0.155)
Observations	2,572	2,563	2,464	2,569
R^2	0.29	0.28	0.28	0.28
Number of banks	633	633	611	633

Table 2.5: **Uncertainty and loan supply: financial integration**
The table reports fixed effects regressions. The dependent variable is the change in loans divided by total assets of the previous period. The explanatory variables include macro variables, bank-level variables, the openness measure, the cross-sectional uncertainty measures derived from bank-level data (UncBank) (as denoted in columns 1-4), and its interaction with the openness variable. All bank-level variables are lagged by one period. The sample comprises yearly data of banks in 48 countries over the time period 1998-2012. The regressions take into account bank and year fixed effects. Standard errors are clustered by individual bank and depicted in parentheses. All variables are centered around their means if they are interacted to facilitate interpretation of estimated coefficients. The openness measure and all measures for uncertainty in banking derived from bank-level data are standardized. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1)	(2)	(3)	(4)
Dependent variable:	*Measure of uncertainty*			
ΔLoans/assets$_{t-1}$	Total assets dispersion	Short-term funding dispersion	Productivity dispersion	RoA dispersion
Macro variables				
ΔLog GDP deflator$_t$	0.196	0.203	0.190	0.156
	(0.247)	(0.240)	(0.232)	(0.267)
ΔLog real GDP$_t$	0.190*	0.638***	0.246**	0.450***
	(0.111)	(0.114)	(0.102)	(0.101)
Bank-level variables				
Liquid assets/assets$_{t-1}$	0.080***	0.082***	0.067***	0.083***
	(0.024)	(0.025)	(0.025)	(0.025)
Capital/assets$_{t-1}$	0.127**	0.147**	0.152**	0.133**
	(0.063)	(0.062)	(0.062)	(0.063)
Deposits/assets$_{t-1}$	0.071**	0.077**	0.065*	0.073**
	(0.035)	(0.035)	(0.034)	(0.035)
Log total assets$_{t-1}$	−3.581***	−3.541***	−3.478***	−3.647***
	(0.969)	(0.969)	(0.952)	(0.981)
Comm. loans/(comm. loans + assets)$_{t-1}$	0.063	0.081	0.096*	0.071
	(0.049)	(0.050)	(0.051)	(0.050)
Openness$_t$	−1.986***	−2.004***	−1.614***	−1.958***
	(0.504)	(0.639)	(0.608)	(0.578)
Uncertainty and interaction terms				
Uncertainty in banking (UncBank$_t$)	−5.250***	−2.450***	−4.148***	−0.561**
	(0.634)	(0.399)	(0.463)	(0.260)
Openness$_t$ × UncBank$_t$	0.798***	0.666***	0.879***	0.580***
	(0.125)	(0.169)	(0.231)	(0.196)
Observations	8,810	8,810	8,810	8,810
R^2	0.22	0.21	0.22	0.21
Number of banks	1,942	1,942	1,942	1,942

Table 2.6: **Uncertainty and loan supply: alternative measures of uncertainty**
The table reports fixed effects regressions. The dependent variable is the change in loans divided by total assets of the previous period. The explanatory variables include macro variables, bank-level variables, an alternative uncertainty measure (UNC) (as denoted in columns 1-4), and interactions of the latter with the bank-level variables. All bank-level variables are lagged by one period. The sample comprises yearly data of banks in 48 countries over the time period 1998-2012. The regressions take into account bank and year fixed effects. Standard errors are clustered by individual bank and depicted in parentheses. All variables are centered around their means to facilitate interpretation of estimated coefficients. All measures for uncertainty are standardized. The p-values are as follows: ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1)	(2)	(3)	(4)
Dependent variable:	*Measure of uncertainty*			
ΔLoans/assets$_{t-1}$	Bank stock return volatility	Stock market volatility	Firm return dispersion	GDP volatility
Macro variables				
ΔLog GDP deflator$_t$	0.361***	0.344***	0.417**	0.302***
	(0.058)	(0.063)	(0.171)	(0.095)
ΔLog real GDP$_t$	0.488***	0.619***	0.283*	0.399***
	(0.091)	(0.087)	(0.145)	(0.086)
Bank-level variables				
Liquid assets/assets$_{t-1}$	0.087***	0.105***	0.101***	0.099***
	(0.023)	(0.025)	(0.027)	(0.024)
Capital/assets$_{t-1}$	0.142***	0.147***	0.139**	0.156***
	(0.054)	(0.056)	(0.059)	(0.054)
Deposits/assets$_{t-1}$	0.052*	0.067**	0.032	0.055*
	(0.031)	(0.031)	(0.032)	(0.030)
Log total assets$_{t-1}$	−3.727***	−3.579***	−3.723***	−3.513***
	(0.893)	(0.900)	(1.018)	(0.867)
Comm. loans/(comm. loans + assets)$_{t-1}$	0.095**	0.086*	0.104**	0.090**
	(0.044)	(0.045)	(0.051)	(0.046)
Uncertainty and interaction terms				
Uncertainty (UNC$_t$)	−1.555***	−0.291	−1.180**	−3.669***
	(0.246)	(0.294)	(0.550)	(0.434)
Liquid assets/assets$_{t-1}$ × UNC$_t$	0.005	0.019	0.031*	0.042***
	(0.009)	(0.012)	(0.016)	(0.012)
Capital/assets$_{t-1}$ × UNC$_t$	0.071***	0.020	−0.018	0.148***
	(0.015)	(0.024)	(0.039)	(0.032)
Deposits/assets$_{t-1}$ × UNC$_t$	0.010	0.017*	0.026	0.000
	(0.007)	(0.009)	(0.020)	(0.013)
Log total assets$_{t-1}$ × UNC$_t$	0.195***	−0.033	0.011	0.366***
	(0.054)	(0.066)	(0.152)	(0.099)
Comm. loans/(comm. loans + assets)$_{t-1}$	−0.003	−0.011	−0.059*	0.012
× UNC$_t$	(0.012)	(0.019)	(0.033)	(0.035)
Observations	10,277	10,248	8,562	10,230
R^2	0.21	0.21	0.20	0.22
Number of banks	2,354	2,344	1,828	2,348

Table 2.7: **Uncertainty and loan supply: country-year fixed effects**
The table reports fixed effects regressions. The dependent variable is the change in loans divided by total assets of the previous period. The explanatory variables include bank-level variables, the cross-sectional uncertainty measures derived from bank-level data (UncBank) (as denoted in columns 1-4), and interactions of the latter with the bank-level variables. All bank-level variables are lagged by one period. The sample comprises yearly data of banks in 48 countries over the time period 1998-2012. The regressions take into account bank and country-year fixed effects. Standard errors are clustered by individual bank and depicted in parentheses. All variables are centered around their means if they are interacted to facilitate interpretation of estimated coefficients. All measures for uncertainty in banking derived from bank-level data are standardized. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1)	(2)	(3)	(4)
Dependent variable:	*Measure of uncertainty*			
ΔLoans/assets$_{t-1}$	Total assets dispersion	Short-term funding dispersion	Productivity dispersion	RoA dispersion
Bank-level variables				
Liquid assets/assets$_{t-1}$	0.075***	0.094***	0.088***	0.078***
	(0.023)	(0.029)	(0.025)	(0.023)
Capital/assets$_{t-1}$	0.124**	0.230***	0.161***	0.110*
	(0.058)	(0.070)	(0.061)	(0.057)
Deposits/assets$_{t-1}$	0.059*	0.042	0.058*	0.064*
	(0.033)	(0.037)	(0.033)	(0.033)
Log total assets$_{t-1}$	−3.608***	−3.052***	−3.370***	−3.594***
	(0.969)	(0.999)	(0.978)	(0.895)
Comm. loans/(comm. loans + assets)$_{t-1}$	0.098**	0.156***	0.094**	0.088*
	(0.047)	(0.055)	(0.048)	(0.046)
Uncertainty and interaction terms				
Liquid assets/assets$_{t-1}$ × UncBank$_t$	0.082***	−0.004	0.098***	0.025
	(0.023)	(0.015)	(0.023)	(0.017)
Capital/assets$_{t-1}$ × UncBank$_t$	0.118***	−0.101***	−0.064*	0.082***
	(0.045)	(0.039)	(0.035)	(0.030)
Deposits/assets$_{t-1}$ × UncBank$_t$	−0.024	0.010	0.005	−0.043**
	(0.021)	(0.018)	(0.025)	(0.017)
Log total assets$_{t-1}$ × UncBank$_t$	0.479***	−0.456***	−0.372*	0.255**
	(0.166)	(0.165)	(0.216)	(0.130)
Comm. loans/(comm. loans + assets)$_{t-1}$	−0.066*	−0.105***	−0.005	−0.019
× UncBank$_t$	(0.035)	(0.037)	(0.045)	(0.025)
Observations	10,282	10,282	10,164	10,282
R^2	0.31	0.30	0.30	0.31
Number of banks	2,355	2,355	2,323	2,355

Table 2.8: **Uncertainty and loan supply: subgroup size**
The table reports fixed effects regressions. The dependent variable is the change in loans divided by total assets of the previous period. The explanatory variables include macro variables, bank-level variables, the cross-sectional uncertainty measures derived from bank-level data (UncBank) (as denoted in columns 1-4), and interactions of the latter with the bank-level variables. The level of aggregation is changed from the country to bank size, that is, standard deviations are taken across (i) small and (ii) large banks in the sample. A bank is defined as large if its assets are above the median of all banks in the respective country. All bank-level variables are lagged by one period. The sample comprises yearly data of banks in 48 countries over the time period 1998-2012. The regressions take into account bank and year fixed effects. Standard errors are clustered by individual bank and depicted in parentheses. All variables are centered around their means if they are interacted to facilitate interpretation of estimated coefficients. All measures for uncertainty in banking derived from bank-level data are standardized. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1)	(2)	(3)	(4)
Dependent variable:	*Measure of uncertainty*			
ΔLoans/assets$_{t-1}$	Total assets dispersion	Short-term funding dispersion	Productivity dispersion	RoA dispersion
Macro variables				
ΔLog GDP deflator$_t$	0.335***	0.331***	0.332***	0.342***
	(0.059)	(0.059)	(0.059)	(0.059)
ΔLog real GDP$_t$	0.658***	0.650***	0.630***	0.658***
	(0.083)	(0.085)	(0.084)	(0.084)
Bank-level variables				
Liquid assets/assets$_{t-1}$	0.100***	0.094***	0.097***	0.098***
	(0.024)	(0.024)	(0.024)	(0.024)
Capital/assets$_{t-1}$	0.128**	0.138**	0.140**	0.136**
	(0.053)	(0.054)	(0.054)	(0.054)
Deposits/assets$_{t-1}$	0.056*	0.058*	0.065**	0.062**
	(0.031)	(0.031)	(0.031)	(0.031)
Log total assets$_{t-1}$	−3.814***	−3.597***	−3.620***	−3.838***
	(0.862)	(0.914)	(0.906)	(0.915)
Comm. loans/(comm. loans + assets)$_{t-1}$	0.097**	0.099**	0.092**	0.092**
	(0.045)	(0.045)	(0.045)	(0.044)
Uncertainty and interaction terms				
Uncertainty in banking (UncBank$_t$)	−0.747**	−0.256	0.077	−1.224***
	(0.314)	(0.352)	(0.127)	(0.391)
Liquid assets/assets$_{t-1}$ × UncBank$_t$	−0.003	0.021*	−0.030***	0.015
	(0.009)	(0.013)	(0.007)	(0.010)
Capital/assets$_{t-1}$ × UncBank$_t$	−0.051***	−0.013	0.011	0.016
	(0.019)	(0.026)	(0.013)	(0.019)
Deposits/assets$_{t-1}$ × UncBank$_t$	0.005	−0.008	−0.027***	0.008
	(0.007)	(0.010)	(0.006)	(0.008)
Log total assets$_{t-1}$ × UncBank$_t$	−0.122**	−0.066	−0.122**	0.075
	(0.057)	(0.078)	(0.050)	(0.066)
Comm. loans/(comm. loans + assets)$_{t-1}$	−0.019	0.010	−0.023**	−0.009
× UncBank$_t$	(0.016)	(0.019)	(0.011)	(0.017)
Observations	10,283	10,283	10,283	10,283
R^2	0.21	0.20	0.21	0.21
Number of banks	2,355	2,355	2,355	2,355

Table 2.9: **Uncertainty and loan supply: subgroup specialization**
The table reports fixed effects regressions. The dependent variable is the change in loans divided by total assets of the previous period. The explanatory variables include macro variables, bank-level variables, the cross-sectional uncertainty measures derived from bank-level data (UncBank) (as denoted in columns 1-4), and interactions of the latter with the bank-level variables. The level of aggregation is changed from the country to bank specialization, that is, standard deviations are taken across (i) savings and cooperative banks and (ii) commercial banks in the sample. All bank-level variables are lagged by one period. The sample comprises yearly data of banks in 48 countries over the time period 1998-2012. The regressions take into account bank and year fixed effects. Standard errors are clustered by individual bank and depicted in parentheses. All variables are centered around their means if they are interacted to facilitate interpretation of estimated coefficients. All measures for uncertainty in banking derived from bank-level data are standardized. The p-values are as follows: ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1)	(2)	(3)	(4)
Dependent variable:	*Measure of uncertainty*			
ΔLoans/assets$_{t-1}$	Total assets dispersion	Short-term funding dispersion	Productivity dispersion	RoA dispersion
Macro variables				
ΔLog GDP deflator$_t$	0.307***	0.330***	0.313***	0.303***
	(0.059)	(0.059)	(0.059)	(0.058)
ΔLog real GDP$_t$	0.662***	0.598***	0.590***	0.644***
	(0.084)	(0.084)	(0.086)	(0.086)
Bank-level variables				
Liquid assets/assets$_{t-1}$	0.094***	0.111***	0.078***	0.074***
	(0.022)	(0.026)	(0.025)	(0.023)
Capital/assets$_{t-1}$	0.146***	0.176***	0.135***	0.083
	(0.048)	(0.058)	(0.051)	(0.052)
Deposits/assets$_{t-1}$	0.063**	0.066**	0.078**	0.058*
	(0.029)	(0.033)	(0.033)	(0.031)
Log total assets$_{t-1}$	−3.692***	−3.423***	−3.313***	−3.962***
	(0.923)	(0.905)	(0.907)	(0.935)
Comm. loans/(comm. loans + assets)$_{t-1}$	0.163***	0.220***	0.154***	0.182***
	(0.050)	(0.057)	(0.050)	(0.048)
Uncertainty and interaction terms				
Uncertainty in banking (UncBank$_t$)	−2.651***	−1.368*	−1.987***	−2.526***
	(0.941)	(0.816)	(0.433)	(0.432)
Liquid assets/assets$_{t-1}$ × UncBank$_t$	0.000	−0.021	0.013	0.023
	(0.016)	(0.022)	(0.014)	(0.016)
Capital/assets$_{t-1}$ × UncBank$_t$	−0.012	−0.066	−0.007	0.070*
	(0.037)	(0.048)	(0.031)	(0.036)
Deposits/assets$_{t-1}$ × UncBank$_t$	−0.009	−0.017	−0.033***	−0.001
	(0.020)	(0.019)	(0.013)	(0.018)
Log total assets$_{t-1}$ × UncBank$_t$	0.131	−0.348*	−0.287**	0.367**
	(0.198)	(0.180)	(0.137)	(0.156)
Comm. loans/(comm. loans + assets)$_{t-1}$	−0.082**	−0.139***	−0.057**	−0.095***
× UncBank$_t$	(0.034)	(0.040)	(0.025)	(0.030)
Observations	10,283	10,283	10,283	10,283
R^2	0.21	0.21	0.21	0.21
Number of banks	2,355	2,355	2,355	2,355

Chapter 3

Liquidity Provision, Financial Vulnerability, and Internal Adjustment to a Sudden Stop

3.1 Motivation

The global financial crisis and the euro area sovereign debt crisis led to massive reversals in capital flows into European periphery countries. In response to these developments – and the associated stress in the financial sector – the Eurosystem has launched massive liquidity assistance programs. While countries in the euro area periphery (Greece, Ireland, Italy, Portugal, Spain; henceforth GIIPS) could access liquidity provided by the Eurosystem, European periphery countries pegging against the euro but outside the euro area could not (Bulgaria, Estonia, Latvia, Lithuania; BELL). Because of the fixed exchange rate regime, neither the GIIPS nor the BELL countries could respond immediately to this liquidity shock through a devaluation of their currency. Hence, the necessary adjustment to the liquidity shock had to take place internally.

In this paper, we exploit this setting to shed light on the following questions: Did enhanced liquidity provision by the Eurosystem, e.g. long-term refinancing operations and the full allotment policy, affect the pattern of internal adjustment after the 2008 financial crisis? And if it did, what is the key channel through which it affected adjustment dynamics?

Figures 3.1 to 3.3 illustrate the macroeconomic background in the BELL and the GIIPS countries. The private capital flows series of BELL and GIIPS countries demonstrate that private liquidity inflows into these countries evaporated rapidly (Figure 3.1). The Eurosystem responded by means of non-standard monetary policy measures. These measures are implemented by the national central banks, and their balance sheets record increased liquidity provision through lending operations on the asset side, and a corresponding increase in liabilities vis-à-vis the entire Eurosystem (ECB, 2013). Because cross-border payment flows in the euro area are settled via the TARGET2 payment system, net balances of the national central banks in TARGET2 reflect the uneven distribution of central bank liquidity within the Eurosystem (Cour-Thimann, 2013; ECB, 2013; Lipponer and Ulbrich, 2012). The strong increase in TARGET2 net liabilities of the national central banks in the GIIPS countries as shown in Figure 3.2 documents that banks in these countries increasingly turned to liquidity provided by the Eurosystem as a substitute for dried-up or even reversing private capital inflows (Cecchetti et al., 2012). In contrast, the BELL countries – not being members of the Eurosystem – did not have access to those liquidity support measures.

Figure 3.3 illustrates that the macroeconomic adjustment dynamics in the GIIPS and the BELL countries are also markedly different: In the GIIPS countries, nominal and real unit labor costs have decreased modestly, while prices have remained basically constant since the crisis. In the BELL countries, by contrast, real and nominal unit labor costs have decreased strongly, while prices in fact increased.

To identify the impact of Eurosystem liquidity provision on the internal adjustment since the liquidity shock, we draw on cross-sector, cross-country panel data. Two sources of variation in the data allow us to identify this effect. First, we use the variation in the access to and amount of liquidity provided by the Eurosystem across the BELL and the GIIPS countries. Second, we use the variation in the degree of financial vulnerability across the sectors of the economy. Our empirical specification builds on the seminal work of Rajan and Zingales (1998). We focus on identifying the interaction of liquidity support by the Eurosystem with a measure of financial vulnerability. Using sectoral data and focusing on this interaction effect enables us to disentangle the effect of liquidity provision on adjustment to the liquidity shock from other common omitted variables by including time-varying country-specific and time-varying sector-specific fixed effects. Hence, concerns about potential omitted variables constituting conflicting alternative explanations are minimized.

Our analysis yields the following robust results: First, liquidity provision by the Eurosystem reduces adjustment in *real* unit labor costs and *real* wages, especially in financially vulnerable sectors. Second, financially vulnerable sectors with access to central bank liquidity increase prices *by a smaller amount* relative to financially vulnerable sectors without liquidity support. Third, we do not find a significant effect on either the adjustment in labor productivity or the adjustment in nominal unit labor costs and nominal wages.

Our finding that liquidity provision by the Eurosystem affects adjustment by *reduc-*

ing price increases in financially vulnerable sectors relates to recent theoretical work analyzing the effects of liquidity shocks in models featuring financial frictions. In a standard New-Keynesian DSGE model with financial frictions, Christiano et al. (2015) show that a jump in financing costs induces firms to increase prices. The intuition is that the increase in the costs of working capital increases marginal costs, which firms pass on to consumers by increasing prices. We conjecture that the more financially vulnerable the sector, the stronger this channel should be.

Similarly, Gilchrist et al. (2015) develop a menu-cost model with heterogeneous firms, in which firms face financial frictions while setting prices in a customer-markets setting. Firms with limited access to external liquidity have an incentive to increase prices in response to adverse financial shocks compared to firms with better access to liquidity. These results are consistent with firms that aim at preserving internal liquidity in order to avoid raising (costly) external finance. Lastly, Dou and Ji (2015) build a dynamic structural finance model with imperfect capital markets. One of their key findings is that financially constrained firms are more inclined to increase markups.[1]

Although these papers do not directly analyze how liquidity provision by the central bank interacts with liquidity shocks, it is straightforward to link these theoretical mechanisms to our findings: A number of recent studies have convincingly shown that liquidity provision by the Eurosystem has successfully improved funding conditions in the euro area. Rogers et al. (2014) and Fratzscher et al. (2014) use high-frequency data and show that the Eurosystem's non-standard policy measures increased asset prices and reduced borrowing costs and the fragmentation in bond markets. Von Borstel et al. (2016) show that non-standard monetary policy was effective in lowering bank lending rates for non-financial firms in the GIIPS countries as well. Liquidity provision by the Eurosystem thus improved the liquidity situation of banks and, through this channel, improved access to external funds for firms. Specifically, central bank liquidity provision alleviated the impact of the liquidity shock induced by the sudden stop in the GIIPS countries. From a theoretical point of view, the alleviation of the liquidity shock in the GIIPS countries relative to the BELL countries should have lowered the incentive for firms in the GIIPS countries to increase prices relative to firms in the BELL countries. Furthermore, this relative difference should be most pronounced for financially vulnerable firms. Our results show that this mechanism seems to be supported by the data.

Our findings suggest that differences in the adjustment of prices are potentially a

[1] Fagan and McNelis (2014) use a modified version of the model in Mendoza (2010) to show that access to central bank liquidity mitigates adverse real effects on GDP, consumption, and investment due to sudden stops.

key channel through which liquidity provision affects internal adjustment after sudden stops. In this respect, our analysis is related to the arguments put forth by Schmitt-Grohé and Uribe (2016), who stress the importance of downward nominal wage rigidities. They argue that the optimal policy in this setting should be geared towards generating price inflation to deflate real wages. Specifically, we find that liquidity provision by the Eurosystem reduces price increases in financially vulnerable sectors. The weaker increase in prices together with nominal wages not being affected differentially leads to lower adjustment in real wages. Ultimately, real unit labor costs are adjusted less due to the Eurosystem's liquidity provision.

Furthermore, the analysis in Schmitt-Grohé and Uribe (2016) implies that without sufficient inflation, downward nominal wage rigidities prevent real wages from falling to levels consistent with full employment. Hence, our finding that liquidity provision mitigated the reduction in real wages in financially vulnerable sectors motivates testing whether liquidity support had differential effects also on employment dynamics across sectors after the sudden stop. Consistent with the channels described in Schmitt-Grohé and Uribe (2016), we find evidence that more financially vulnerable sectors reduce employment more strongly in countries with higher liquidity support.

Our finding that liquidity provision mitigates the reduction in real wages and, at the same time, increases unemployment in financially vulnerable sectors is also related to the literature on wageless versus jobless recoveries after financial crises. Calvo et al. (2012) document that recoveries after financial shocks are followed by greater unemployment the lower inflation is during the recovery. Our results add to this literature by emphasizing the role of liquidity provision in the recovery from financial crises. Specifically, our findings suggest that liquidity provision tends to support the making of a jobless recovery in financially vulnerable sectors.

The analysis in this paper also highlights an important trade-off with respect to adjustment: On the one hand, liquidity provision mitigates adjustment pressure in certain sectors, which allows the burden of the shock to be distributed over a longer period of time. On the other hand, there is the risk of a substantial delay or even prevention of the necessary structural adjustment. Indeed, our results show that the effect of liquidity provision is not limited to the absorption of the shock in the early quarters after the sudden stop but seems to shape the adjustment path quite persistently. However, it is important to bear in mind that our cross-country/cross-sector analysis – while allowing for a cleaner identification of the effect of liquidity provision than a purely aggregate analysis – is not suitable to draw conclusion about the role of central bank liquidity in the adjustment dynamics since the crisis in the aggregate. For instance, it could be that liquidity provision shifts adjustment in real wages and employment growth to the less financially vulnerable sectors without any effect in the aggregate.

Our main results are robust to the inclusion of various control variables which account for potential alternative explanations for our findings. These variables include information on financial support from the EU and/or the IMF, on reforms aimed at increasing labor market flexibility and expectations of devaluations in the BELL countries. In addition, we check the sensitivity of the results to alternative measures of financial vulnerability and liquidity provision. Furthermore, we analyze the effect of potential indirect flows of Eurosystem liquidity to BELL countries through global banks. Finally, the results are robust to different clustering of standard errors and to controlling for country-sector specific fixed effects.

There is already a small volume of literature studying internal adjustment in the BELL and the GIIPS countries after the crisis. Blanchard et al. (2013) argue that in the case of Latvia, adjustment via internal devaluation was successful but came at high costs in terms of output and employment losses. Gros and Alcidi (2015) provide an overview of the differences in the adjustment in the GIIPS and the BELL countries. They find that adjustment was weaker in the euro area periphery. Similar results are provided by Lindner (2011) and Hansson and Randveer (2013). Kang and Shambaugh (2014) analyze adjustment in relative prices and unit labor costs in the GIIPS countries and Baltic countries. They find that adjustment in unit labor costs was mainly due to falling employment.

Similarly to this strand of literature, we compare the GIIPS and the BELL countries to shut down the currency devaluation channel. However, in contrast to the existing literature we use this set-up to identify the role of liquidity provision by the Eurosystem in shaping adjustment dynamics in the GIIPS relative to the BELL countries.

The rest of the chapter is organized as follows. In Section 3.2 we discuss the empirical implementation and the data needed to answer the question of whether liquidity provision by the Eurosystem affected internal adjustment dynamics after the liquidity shock. In Section 3.3, we present and discuss the main results. Additional results and robustness analyses are presented in Section 3.4. In Section 3.5 we investigate the effects of liquidity provision on the employment dynamics. Section 3.6 concludes.

3.2 Empirical Implementation and Data

3.2.1 Empirical Model

We aim to identify the effect of enhanced liquidity provision by the Eurosystem on internal adjustment since the liquidity shock induced by the sudden stop accompanying the crises in the European periphery. Our main hypothesis is that adjustment pressure due to the liquidity shock is higher in more financially vulnerable sectors. As a consequence, liquidity provided by the Eurosystem – mitigating the liquidity shock – could affect the path of internal adjustment differently across this sectoral dimension. We are, therefore, interested in exploring an empirical relationship of the following form:

$$\Delta_t \log(Y_{ikt}) = \alpha_{i\tau} + \alpha_{it} + \alpha_{k\tau} + \alpha_{kt} + \gamma\,[FV_k \times LP_{it}] + [FV_k \times X_{it}] + \varepsilon_{ikt} \qquad (3.1)$$

where i indicates the country, k the sector, t the quarter since the country-specific sudden stop, and τ is the actual (calendar) quarter. $\Delta_t \log(Y_{ikt})$ corresponds to adjustment since the liquidity shock in either nominal unit labor costs, real unit labor costs, and their components, i.e. nominal wages, real wages, labor productivity or prices. We include a full set of time-varying fixed effects α, to control for all observed and unobserved time-varying country-specific and sector-specific effects. We account for arbitrary shocks occurring at actual calendar quarters ($\alpha_{i\tau}$ and $\alpha_{k\tau}$) because shocks hit at a given point in (calendar) time rather than in a given quarter since the sudden stop. This accounts for differences in timing of sudden stops across countries. FV_k is the measure for financial vulnerability. Following a large section of literature building on Rajan and Zingales (1998) (e.g. Aghion et al., 2014; Manova, 2013), the measure of financial vulnerability varies across sectors but is time-invariant, as indicated by the subscript k. LP_{it} refers to the measure of liquidity provision by the Eurosystem. The measure varies over time and across countries. X_{it} is a vector of time-varying country controls which we also interact with our measure of financial vulnerability to control for potentially confounding factors.

The parameter of interest is γ, capturing the differential effect of an increase in the provision of Eurosystem liquidity on adjustment given a higher sectoral financial vulnerability. A positive (negative) coefficient indicates that, conditional on financial vulnerability, adjustment was higher (lower) given more liquidity provision. We identify this parameter by exploiting two sources of variation. The first is the variation between countries in liquidity provision by the Eurosystem. The second is the within-country variation in financial vulnerability across sectors. Throughout the analysis, unless otherwise specified, we base our inference on standard errors clustered at the country level to control for within-country correlation of the errors over time and across sectors (Bertrand et al., 2004; Petersen, 2009). In order to investigate our question empirically, we need data and information on:

- country-specific timing of the liquidity shock
- country-specific measure of liquidity provision by the Eurosystem
- sector-specific measure of financial vulnerability
- internal adjustment since the liquidity shock

We discuss each of these items in the following. An overview of the various data sources we rely on is presented in the Data Appendix. Summary statistics for the variables are given in Tables 3.1 and 3.2.

3.2.2 Dating the Liquidity Shock

Previous literature shows that European periphery countries experienced a sudden stop in private capital flows (Gros and Alcidi, 2015; Merler and Pisani-Ferry, 2012; Tornell and Westermann, 2012). We interpret sudden changes in private net capital flows into the BELL and GIIPS countries as a substantial liquidity shock that necessitates internal adjustment.

Private capital inflows are defined as the total financial account (where a positive entry reflects a capital inflow) minus capital transfers due to official rescue programs. Changes in TARGET2 net liabilities are also reflected in the financial account. They can be roughly interpreted as a measure for the substitution of dried-up private capital inflows with central bank liquidity in the euro area crisis countries. Therefore, in the case of the GIIPS countries, we also subtract the increase in TARGET2 net liabilities of their national central banks.

To determine the liquidity shock periods in the BELL and the GIIPS countries, we apply the Zivot-Andrews (1992) endogenous break-point test to the private capital inflow series. For the time series of private capital flows into each country, we test the null of a unit root against the alternative of a stationary process with a break in the intercept at an endogenously determined point in time. Depending on data availability, the time range spans from the 1990s or early 2000s to the 3rd quarter of 2013. The number of lags included is based on the Bayesian information criterion (BIC), the time range is trimmed by 15% from both sides.

Merler and Pisani-Ferry (2012) identify sudden stops by applying a methodology proposed by Calvo et al. (2004). They show that Greece and Ireland experienced multiple sudden stop periods during the crisis. We are only interested in the adjustment since the first of these sudden stops. Shocks occurring *after* the first sudden stop will be accounted for by the time-varying country-specific fixed effects included in the empirical model. Hence, for Greece and Ireland, we only use data until the first quarter of 2010 in order to capture the first occurrence of the sudden stop in Greece and Ireland.

The private capital inflows series for the GIIPS and the BELL countries are shown in Figure 3.4. The vertical lines indicate the last quarter before the sudden stop period as identified by the break-point test. Greece, Ireland, and the Baltics experienced a sudden stop as early as 2008. Bulgaria followed in the 1st quarter of 2009. For Portugal, the sudden stop occurred in the 2nd quarter of 2010; in Italy and Spain, the sudden stop happened in the 2nd quarter of 2011. For most countries, the sudden stop led not only to a reduction in net capital inflows, but also to net capital outflows (Figure 3.4).

For the BELL countries, results of the break-point test support the impression gained by visual inspection. The same holds for the GIIPS countries, for which the results are also in line with the sudden stop periods identified by Merler and Pisani-Ferry (2012).

3.2.3 Liquidity Provision by the Eurosystem

As our baseline measure of liquidity provision by the Eurosystem, we use data on TARGET2 net balances. Cour-Thimann (2013) shows that the presence of TARGET2 net balances is closely related to the liquidity provided by the Eurosystem through non-standard measures, including the fixed-rate, full-allotment refinancing policy, the expanded collateral framework, long-term refinancing operations, and outright purchases (Securities Markets Programme, SMP, and the Covered Bond Purchase Programme, CBPP).[2]

These data provide a direct measure of when and to what extent banks in the GIIPS countries have drawn on central bank liquidity as a substitute for dried-up private liquidity inflows. This can be seen by looking at the composition of (a simplified version of) the total financial account (*TotalFA*) in the balance of payments (Cour-Thimann, 2013):

$$TotalFA = PrivateFA + OfficialInflows + \Delta \mathrm{T2}NetLiab - \Delta ForeignReserves \quad (3.2)$$

[2] For the discussion on TARGET2 balances, see also Auer (2014); Bindseil and König (2011); Kohler (2012); Sinn and Wollmershäuser (2012).

Given that private liquidity – captured in the private financial account (*PrivateFA*) – stops flowing into the country or even flows out of the country, ceteris paribus the compensation of these flows through liquidity provided by the Eurosystem leads to an increase in TARGET2 net liabilities (T2*NetLiab*). This holds true for any kind of central bank liquidity provision, hence also for national central banks' emergency liquidity assistance, or ELA (Cour-Thimann, 2013). Therefore, we use TARGET2 net liabilities as our preferred measure of central bank liquidity provision in the GIIPS countries.[3]

Non-euro area members cannot accumulate liabilities vis-à-vis the Eurosystem in the TARGET2 payment system. We therefore set TARGET2 net balances to zero for Estonia and Latvia prior to their introduction of the euro in 2011 and 2014 respectively, and for the whole period for Bulgaria and Lithuania.

TARGET2 net liabilities in the GIIPS countries were negligible before the crisis but grew considerably starting from the 2nd quarter of 2008 in Ireland and Greece, the 2nd quarter of 2010 in Portugal, and the 2nd quarter of 2011 in Italy and Spain. TARGET2 net liabilities peaked in the 4th quarter of 2010 in Ireland at about 74% of GDP and in the 3rd quarter of 2012 at about 48% in Greece. The peak amounted to roughly 44% in Portugal in the 2nd quarter of 2012, 39% in Spain in the 2nd quarter of 2012, and 18% in Italy in the 3rd quarter of 2012. Since then, TARGET2 net liabilities decreased but remained well above the pre-crisis figures in most countries. Estonia had mostly positive net claims against the Eurosystem since introducing the euro, while Latvia's net liabilities amount to about 10% of GDP at the end of the observation period, i.e. in the 2nd quarter of 2014.[4]

3.2.4 Financial Vulnerability

We measure financial vulnerability using the euro area-wide aggregate borrowing growth rate of a given sector over the period from 2003 (1st quarter) to 2008 (1st quarter). This measure varies across sectors but not across countries. Growth in borrowing acts as a measure of financial vulnerability because sectors borrowing more before the crisis should also be most affected by a negative liquidity shock.

The measure might reflect the structural need to obtain external funding, but could also be partly driven by the pre-crisis credit boom. What is important for our purpose is that, in either case, sectors relying more on external funding before the sudden stop should be most affected by the withdrawal of liquidity induced by the sudden stop. Consequently, the need for internal adjustment should be highest in these sectors.

[3] In a robustness exercise, we also measure liquidity provision by the refinancing operations of the Eurosystem.

[4] This description is based on country-specific data on TARGET2 net liabilities that are not reported.

We use this variation in financial vulnerability across sectors to identify the differential effect of Eurosystem liquidity provision on adjustment dynamics at the sector level.

Financial vulnerability is measured at the euro area level. We thus assume that financial frictions vary across sectors, not across countries. Because our financial vulnerability measure varies across sectors but not across countries, it is related to the measure of financial dependence by Rajan and Zingales (1998). They build a measure of financial dependence based on the fraction of firms' capital expenditure not financed by cash flows, which has been used extensively in subsequent work.[5] However, the financial vulnerability measure of Rajan and Zingales (1998) is available only for industries within the manufacturing sector. Hence, using their measure is not an option for us because our data also include other sectors, such as services. Finally, an important feature of our measure is that it is predetermined, i.e. it is not affected by developments after the sudden stop. Otherwise, we could not rule out reverse causality because the path of internal adjustment might in turn affect the need for (domestic or cross-border) funding.

We show the measure of financial vulnerability in Figure 3.5. The construction, real estate, and science sectors are the most financially vulnerable. The high value for construction partly reflects the pre-crisis boom in the housing market. However, as noted above, a high value for the vulnerability measure implies that the construction sector should be affected more by the withdrawal of liquidity and needs to make a greater adjustment. The sectors that are least dependent on external finance are total industry and the information technology sector.

We run a number of robustness tests to check the sensitivity of our results to changing the exact definition of the financial vulnerability measure. We also construct an alternative measure of financial vulnerability based on asset tangibility along the lines of Manova (2013) and show that our findings are robust.

3.2.5 Internal Adjustment Since the Sudden Stop

Both the BELL and the GIIPS countries were unable to respond to the liquidity shock induced by the sudden stop through currency devaluations. Because of the fixed exchange rate regime, they had to adjust entirely through internal adjustment. Our variables measuring internal adjustment are sectoral nominal and real unit labor costs. These variables are proxies for cost competitiveness. In addition to real and nominal unit labor costs, we also analyze their components, i.e. real and nominal wages, la-

[5] The measure is derived as the median of this fraction across publicly traded firms in each industry in the US manufacturing sector.

bor productivity, and prices to investigate any potential compositional effects (Darvas, 2012).[6] We compute sectoral unit labor costs using Eurostat data for nine sectors based on the NACE Rev. 2 classification.[7] Nominal unit labor costs (ULC) (i.e. labor costs over labor productivity) in sector i in country k are defined as the ratio of total compensation to real gross value added (GVA) in each sector for each quarter t. To account for the number of self-employed people in a given sector, we multiply this ratio by the total number of employees (*total employment*) relative to the total number of dependent employees:[8]

$$ULC_{ikt} = \frac{Labor\ cost_{ikt}}{Labor\ prod._{ikt}} = \frac{Total\ compen._{ikt}}{Real\ GVA_{ikt}} \times \frac{Total\ empl.(pers.)_{ikt}}{Total\ dep.employees\ (pers.)_{ikt}} \quad (3.3)$$

We construct real unit labor costs ($RULC$) by dividing ULC_{ikt} by the sectoral price deflator P_{ikt} :

$$RULC_{ikt} = \frac{ULC_{ikt}}{P_{ikt}} \quad (3.4)$$

By applying log differences, (approximate) percentage changes in unit labor costs can be decomposed into the following components:

$$\begin{aligned}\Delta\log ULC_{ikt} &= \Delta\log RULC_{ikt} + \Delta\log P_{ikt} \\ &= \Delta\log RealWages_{ikt} - \Delta\log Labor\ prod._{ikt} + \Delta\log P_{ikt} \quad (3.5)\end{aligned}$$

Real wages are defined as real total compensation divided by total hours worked, and labor productivity as real gross value added divided by total hours worked.

We calculate internal adjustment to the sudden stop based on nominal and real

[6] There are no seasonally adjusted data on the sectoral variables used to compute unit labor costs for all countries. We account for seasonality by computing four-quarter moving sums of flow variables (total compensation, gross value added) and four-quarter moving averages of stock variables (total employment, number of employees) for each quarter. This approach provides us with annualized measures of the variables which enter the computation of unit labor costs. As a result, unit labor costs have the interpretation of an annualized variable as well.

[7] Estimation is based on 9, not the usual 10, sectors as there are no data for dependence on external finance for the financial & insurance sector. See the Data Appendix for a detailed overview of the sectoral disaggregation.

[8] The methodology used by Eurostat to compute the nominal unit labor cost index as part of the Macroeconomic Imbalance Procedure is essentially the same but includes real GDP instead of real gross value added in the denominator (http://ec.europa.eu/eurostat/web/macroeconomic-imbalances-procedure/methodology). Our time series of nominal and real unit labor costs based on all sectors (not reported) closely tracks the seasonally adjusted series provided by Eurostat as part of the quarterly national accounts database (ESA 95).

unit labor costs, nominal and real wages, and sectoral prices as follows:

$$\Delta_t \log Y_{ikt} = -1 \times [\log Y_{ikt} - \log Y_{ikt=0}] \tag{3.6}$$

where $Y = [ULC, RULC, Nominal\ wages, Real\ wages, P]$, i denotes the country, k the sector and t the quarter since the sudden stop. We define $t = 0$ as the last quarter before the sudden stop. The term in brackets measures the change in unit labor costs since the sudden stop period relative to the pre-sudden stop value. The term is multiplied by minus one to capture the fact that *more* adjustment is associated with a *reduction* in the respective variable. Regarding labor productivity, an *increase* reflects *more* adjustment so we do not multiply the term by minus one.

Table 3.1 shows summary statistics for the adjustment measures based on sectoral nominal and real unit labor costs as well as their components for the GIIPS and the BELL countries. Based on nominal unit labor costs, adjustment in the GIIPS countries was strongest in the real estate sector (10.3%) and weakest in the trade, travel, and food services sector (-9.3%). For the BELL countries, the highest (lowest) adjustment took place in the industry (information and communication) sector, with a reduction in unit labor costs of 3.7% (-22.7%). The table shows that real and nominal unit labor costs vary considerably. Additionally, the high standard deviations indicate that there is also considerable variation over time within sectors, which will be relevant for the subsequent empirical analysis.[9]

3.3 The Effect of Liquidity Provision on Internal Adjustment

We report the results for adjustment in nominal unit labor costs in Table 3.3 and the results for real unit labor costs in Table 3.4. All regressions include the full set of time-varying country-specific and time-varying sector-specific fixed effects. Column 1 in Tables 3.3 and 3.4 shows the results of a "plain vanilla" regression which – besides the fixed effects – includes only the interaction of TARGET2 net liabilities with the measure of financial vulnerability. In the remaining columns we show the results from regressions including additional control variables. Note that all control variables are interacted with the financial vulnerability measure.

In column 2, we show the results of a regression that controls for official rescue packages from the European Union and the IMF. Countries in our sample have had

[9] These numbers are based on detailed summary statistics for individual sectors which, for the sake of brevity, are not reported. They may be obtained from the authors upon request.

access to official rescue programs, such as funds provided under the European rescue facilities EFSF (European Financial Stability Facility), EFSM (European Financial Stabilization Mechanism), ESM (European Stability Mechanism), bilateral loans from EU countries, and IMF loans. We include the official rescue packages because they are an additional channel through which the effects of the liquidity shock induced by the sudden stop can be mitigated. In column 3 we add employment figures at the sector level. As argued by Kang and Shambaugh (2014), part of the internal adjustment might be induced by mass lay-offs during the crisis. This labor shedding reflects a collapse in demand rather than structural internal adjustment. We account for this labor shedding effect. We lag the employment variable by one quarter to avoid simultaneity problems when including this sectoral variable. In column 4 we add the real and nominal effective exchange rate as well as the 3-month forward exchange rate. Even in a fixed exchange rate regime, the value of the domestic currency might vary. By including both nominal and real effective exchange rates we implicitly control for trade-weighted inflation differentials. The 3-month forward exchange rate captures potential currency devaluation expectations in the BELL countries. In column 5 we control for the general macroeconomic conditions by including year-on-year growth rates of nominal GDP and of the GDP deflator. In addition, we add trade openness, defined as the sum of exports and imports over GDP. Finally, column 6, which is our preferred specification, includes all control variables simultaneously.[10]

Turning to the parameter of interest – the interaction effect of liquidity provision by the Eurosystem and financial vulnerability – the results in Tables 3.3 and 3.4 give a robust message. We find no statistically significant effects in the regressions on nominal unit labor costs. That is, enhanced liquidity provision did not affect the differential adjustment pattern between more and less financially vulnerable sectors. By contrast, for real unit labor costs, the point estimate is always negative and significant at conventional significance levels. Based on our preferred specification in column 6, an increase of one standard deviation in liquidity provision reduces real unit labor cost adjustment by roughly 8 percentage points for each one standard deviation higher value of financial vulnerability.

To illustrate the magnitude of this effect, the sector with the highest financial vulnerability (construction) should reduce real unit labor costs by 1.3% less than the sector with the lowest financial vulnerability (trade, travel and food services) when increasing liquidity support by one standard deviation (approximately 0.19).[11] By way of comparison, the average adjustment in real unit labor costs is 2.5%.

[10]Summary statistics of all control variables are presented in Table 3.2.

[11]The calculation is based on the following formula: $0.08 \times 0.19 \times (1.12 - 0.26) = 0.0132$

The differences in the responses of real and nominal unit labor costs pose the question as to what mechanism drives the reaction of real unit labor costs but is missing for nominal unit labor costs. To dig deeper into the transmission mechanism, we reestimate Equation (3.1) for adjustment in real and nominal wages, labor productivity, and prices. We show the results of these exercises in Table 3.5. Column 1 shows the results using real wages as the dependent variable, column 2 using nominal wages, column 3 labor productivity and column 4 prices. We report only the results from our preferred specification including all control variables (interacted with the financial vulnerability measure) simultaneously.

The results show that liquidity support by the Eurosystem does not differentially affect the adjustment dynamics of nominal wages (column 2) and labor productivity (column 3). By contrast, the parameter on the interaction of liquidity support with financial vulnerability is negative and highly significant in the regression using real wages as the dependent variable (column 1). Hence, more financially constrained sectors adjust real wages less when liquidity provision through the Eurosystem increases. This is akin to the results for real unit labor costs. Probably most surprising is the positive and highly significant coefficient in the price regression (column 4). The positive coefficient implies that, conditional on financial vulnerability, higher liquidity provision by the Eurosystem leads to lower price increases. This is surprising given that non-standard monetary policy measures are considered to be inflationary. Our result, however, reflects the interplay between liquidity provision and a large negative liquidity shock. In this respect, our finding is consistent with theories emphasizing the inflationary effects of liquidity shocks as reviewed in the introduction (Gilchrist et al., 2015). By mitigating the liquidity shock, the liquidity support program has also reduced the inflationary pressure of the shock, and this effect is most pronounced for financially vulnerable sectors.

The results for the components of (real) unit labor costs shed light on the channel through which liquidity provision by the Eurosystem affects adjustment dynamics after the liquidity shock induced by the sudden stop. We find that liquidity provision does not affect adjustment of nominal wages. However, prices increase by a lower amount in countries with access to Eurosystem liquidity (GIIPS countries), and this effect is particularly strong in financially vulnerable sectors. As Equation (3.4) illustrates, a lower price increase coupled with constant nominal wages and nominal unit labor costs leads to a lower reduction in real wages and real unit labor costs in the GIIPS countries relative to the BELL countries (the countries without access to Eurosystem liquidity). These effects are most pronounced in the sectors that are most financially vulnerable.

3.4 Additional Results and Robustness

3.4.1 Alternative Measures of Liquidity Provision

We have so far captured the effect of liquidity provision by the Eurosystem through TARGET2 net liabilities. TARGET2 net liabilities reflect liquidity provision by the Eurosystem as long as the latter meets asymmetric funding needs of banking systems across national borders of the euro area. This is the case during the period under review because the banking systems in distressed countries lost access to private interbank markets as a whole.

To demonstrate that our approach is sensible, we replace TARGET2 net liabilities in Equation (3.1) with the refinancing operations of banks in the GIIPS countries with their respective national central banks (NCBs). The refinancing operations give us the most direct measure of liquidity provision by the Eurosystem to the financial system. The drawback is that we do not capture liquidity provision by NCBs outside the common monetary policy framework, such as Emergency Liquidity Assistance (ELA) Cour-Thimann (2013). For the BELL countries, we set the amount of refinancing at zero. Consistent with the treatment of the TARGET2 net liabilities, we include the volume of refinancing operations relative to 2007 GDP in the regression equation.

We present the results of this exercise in Table 3.6. We show the results for the six dependent variables (real and nominal unit labor costs, real and nominal wages, labor productivity and prices) from our preferred specification, which includes all control variables simultaneously. The results are qualitatively and quantitatively very similar to our main result. The effect of the interaction between central bank refinancing operations and financial vulnerability is negative and highly significant in the regression using real unit labor costs and real wages. Also, the effect remains positive and highly significant in the regression using prices as the dependent variable.

All in all, the results from this robustness test suggest that TARGET2 net liabilities do indeed capture, first and foremost, the effect emanating from liquidity provision by the Eurosystem.

We have so far assumed that the central banks of the BELL countries were unable to support their financial system because they committed to defending the fixed exchange rate peg to the euro. However, insofar as foreign currency reserves were sufficiently high, the BELL central banks potentially had scope to provide liquidity support to the financial system. If this is the case, our previous results would be misleading. We test for this alternative by replacing in Equation (3.1) the TARGET2 net liabilities with the accumulated change in the size of the respective national central banks' balance sheets over the adjustment horizon, that is, since the liquidity shock. The idea is that central bank operations providing additional liquidity support increase the asset side of the central bank balance sheet.

In Table 3.7, we present the results of the regressions using the size of the central bank balance sheet (scaled by 2007 GDP) as a measure of liquidity provision. Our results are qualitatively the same as in our benchmark model. In line with the findings of the baseline regression, the effect is negative and statistically significant for real unit labor costs and real wages, and positive and significant for prices. The point estimates are somewhat smaller compared to the baseline regressions in Tables 3.3 to 3.5.

3.4.2 Reverse Causality

A potential concern with respect to our analysis so far is the fact that liquidity provision by the Eurosystem might not be exogenous to the adjustment dynamics. If this is the case, reverse causality might bias our findings.[12]

We address the issue of reverse causality in two ways. In a first exercise, instead of using the contemporaneous TARGET2 net liabilities, we use TARGET2 net liabilities lagged by four quarters. We argue that liquidity provision by the Eurosystem one year ago should not be determined by today's stance of adjustment at the sector level. The results of this test, presented in Table 3.8, are similar to our benchmark results. The interaction effect is insignificant in the regressions for nominal unit labor costs and nominal wages, but negative and highly significant in the real wages and real unit labor costs regression, and positive and highly significant in the price regression. However, the interaction effect now becomes significant in the labor productivity regression (at the 5% level). The point estimate of the interaction effect in the price, real wages and real unit labor costs regressions is similar in size to the effect in the baseline regression. We take this as an additional indication against reverse causality.

The second approach we take to address the issue of reverse causality consists of replacing the TARGET2 net liabilities with a dummy variable indicating whether or not a country was a member of the euro area at the time of the sudden stop. In our case, prior to the Baltic countries' EMU membership, this is identical to an indicator variable taking the value of one for the GIIPS countries and zero for the BELL countries. The main advantage of this "GIIPS dummy" is that it is clearly exogenous and predetermined. We assume that euro area membership captures, first and foremost, the effects emanating from access to liquidity provided by the Eurosystem. The results

[12]We again emphasize here that reverse causality or endogeneity is not an issue for our measure of dependence on external finance because it is calculated based on a period preceding our estimation period.

are presented in Table 3.9. All our previous results are confirmed by this exercise.

3.4.3 International Liquidity Flows through Global Banks

An implicit assumption in the analysis so far is that banks in the BELL countries could not tap the liquidity provided by the Eurosystem. This assumption holds true only for truly domestic banks in the BELL countries. However, some large European banks have a presence in the BELL countries either through affiliates or subsidiaries (Cetorelli and Goldberg, 2011; De Haas et al., 2012). These large European banks might have channeled liquidity provided by the Eurosystem to the BELL countries via their internal capital market. For this reason, we take the full specification and additionally add a variable capturing the cumulative change in the private financial account for the BELL countries (relative to 2007 GDP). Any capital inflow through banks, other financial intermediaries and private investors increases the private financial account.[13] Hence, the private financial account gives a complete picture of private liquidity flows into the BELL countries. We allow this variable to affect internal adjustment conditional on financial vulnerability.

We show the results in Table 3.10. First, our key results are not affected by this exercise. Second, except for nominal wages, the effect of the interaction between the cumulated private financial account and the measure of financial vulnerability is always insignificant. Hence, additional external liquidity inflows, for example through large European banks, did not differentially affect the adjustment path since the sudden stop.

3.4.4 Alternative Measures of Financial Vulnerability

We replace our baseline measure of financial vulnerability with the share of tangible assets in total assets at the sector level (averages over the period from 2000 to 2007).[14] Sectors with a better supply of tangible assets that can be posted as collateral to obtain external financing should be less vulnerable to the liquidity shock (Manova, 2013). We include the inverse of asset tangibility in the regression equation to facilitate comparison with our baseline measure of financial vulnerability.

[13] Controlling for this channel seems particularly important in the BELL countries, especially towards the end of the sample when private capital flows reversed. We do not add the private financial account alongside the TARGET2 net liabilities for the GIIPS countries because TARGET2 net liabilities and the private financial account are almost perfectly negatively correlated for the GIIPS countries. That is, whenever there was a capital outflow from the GIIPS countries, the TARGET2 net liabilities increased to offset the outflow. In this respect, for the GIIPS countries the private financial account does not contain additional information above and beyond the TARGET2 net liabilities.

[14] Balance sheet data at the sector level are obtained from the BACH database. See the Data Appendix.

According to the results in Table 3.11, replacing the financial vulnerability measure based on MFI loan growth with the measure of financial vulnerability based on the share of tangible and liquid assets in total assets does not affect our main finding. In fact, both statistical significance and the size of the interaction effect are very similar to the baseline results presented above.

We also conducted a host of robustness tests directly concerning our baseline measure of financial vulnerability. We used a dummy variable indicating whether a sector is above-average in terms of financial vulnerability, we ranked the sectors according to the financial vulnerability measure, and we changed the window over which we calculate the growth rate in borrowings from MFIs. We give a compact presentation of the findings in Table 3.12. In general, these sensitivity tests confirm our previous findings.

All in all, we conclude from the results presented in this section that our findings are not very sensitive to the exact specification of the external financial vulnerability measure based on growth in MFI loans. Also, our results are robust against the use of alternative indicators of financial vulnerabilities proposed in the literature.

3.4.5 Controlling for Country-Sector Specific Effects

So far, we have identified the differential effect of liquidity provision on the adjustment dynamics from the variation in financial vulnerability across sectors within and between countries. We explicitly included the variation between countries for identification purposes because we aim to understand the different adjustment dynamics in the GIIPS versus the BELL countries. A drawback of this strategy is that we cannot rule out that structural, time-invariant country-sector specific characteristics might bias our results. To address this issue, we re-estimate our baseline specification given in Equation (3.1) but add a full set of (time-invariant) country-sector specific fixed effects. The regression equation now reads:

$$\Delta_t \log(Y_{ikt}) = \alpha_{i\tau} + \alpha_{it} + \alpha_{k\tau} + \alpha_{kt} + \alpha_{ik} + \gamma\,[FV_k \times LP_{it}] + [FV_k \times X_{it}] + \varepsilon_{ikt} \quad (3.7)$$

The country-sector specific fixed effects α_{ik} capture all observed and unobserved country-sector specific structural characteristics. The parameter on the interaction between liquidity provision and financial vulnerability, γ, is now identified only from the within-country variation in financial vulnerability across sectors. Given that we now use the within-country-sector variation for identification, we base our inference on standard errors clustered at the country-sector level.[15] In this way, we explicitly

[15] Using clustered standard errors at the country-sector level in the baseline regression does not change our main finding.

control for potential error correlation within the country-sector pairs over time (see, e.g., Jiménez et al., 2014).

The results are shown in Table 3.13. All in all, the results suggest that our findings are robust to controlling for structural country-sector specific effects.

3.4.6 Controlling for Adjustment in Labor Productivity

Our results so far show that liquidity provision by the Eurosystem reduced adjustment in real wages and real unit labor costs, and reduced price inflation in financially vulnerable sectors. We test whether this result holds if we additionally control for past adjustment in labor productivity. The idea is that sectors that can adjust labor productivity faster, for instance for technological reasons, due to sector-specific labor market characteristics or due to labor market reforms with sectoral effect, might also exhibit faster adjustment in prices, wages and unit labor costs. To study these effects – and to check the robustness of our results – we include adjustment in lagged labor productivity in our baseline regressions.

The results are presented in Table 3.14. The results show that labor productivity enters all regressions, except the price regression, with a significant coefficient. The parameter is positive in the real unit labor costs and the nominal unit labor costs regression. Hence, sectors with a faster adjustment in labor productivity also adjusted faster in terms of real and nominal unit labor costs. Interestingly, sectors with a faster adjustment in labor productivity adjusted more slowly in terms of real and nominal wages. This indicates that part of the adjustment in labor productivity is passed through to the labor force.

Turning to the interaction effect, the results show that our main findings are not affected by including lagged labor productivity adjustment. The effect remains negative in the real wages and real unit labor costs regression, and positive in the price regression.

3.5 The Effect of Liquidity Provision on Employment

Our analysis so far has provided robust evidence that more financially vulnerable sectors reduced real wages less in countries with more liquidity provision by the Eurosystem. This finding motivates testing whether liquidity support had differential effects also on employment dynamics across sectors after the sudden stop. According to Schmitt-Grohé and Uribe (2016), the lower reduction in real wages over the adjustment period should lead to a higher reduction in employment (i.e. higher unemployment) after the sudden stop. We test this hypothesis by redoing our entire exercise including all robustness checks for adjustment in employment after the sudden stop. We provide the results for adjustment in employment in Table 3.15. The interaction between liquidity provision and financial vulnerability always enters the regression with a negative sign and is significant in most specifications. The negative coefficient implies that more financially vulnerable sectors have, on average over the adjustment horizon, reduced employment more strongly in countries with higher liquidity provision.

3.6 Conclusions

Did the enhanced liquidity provision by the Eurosystem, e.g. long-term refinancing operations and the full allotment policy, affect the pattern of internal adjustment after the sudden stop following the 2008 financial crisis? And if it did, what is the key channel through which it affects adjustment dynamics? This paper sheds light on this issue. We directly compare the GIIPS countries and the Eastern European BELL countries. Both groups of countries experienced a sudden stop in capital flows during the recent crisis. But they could not adjust via devaluation of their currency, either because of their membership in the euro area or because their currencies were pegged to the euro. As part of our empirical strategy to identify the effect, we turn to sectoral data for the BELL and the GIIPS countries. We analyze the effects of liquidity provision by the Eurosystem on adjustment depending on the external financing needs of the sectors, controlling for all time-varying observed and unobserved country and sector heterogeneity with country-time and sector-time fixed effects.

The analysis yields the following results. Enhanced liquidity provision by the Eurosystem significantly lowers the adjustment in *real* unit labor costs in sectors that depend more on external finance. We do not find robust evidence for an effect on adjustment in *nominal* unit labor costs. The analysis of the components of unit labor cost adjustment shows that higher liquidity provision leads to a lower reduction in *real* wages, conditional on financial vulnerability. The main channel behind these results is that financially vulnerable sectors increase prices *by a smaller amount* when liquidity provision by the Eurosystem increases. Eurosystem liquidity provision has no significant effect on the adjustment in labor productivity. Moreover, we cannot find any evidence of an effect on the adjustment in nominal wages, pointing to the existence of substantial nominal wage rigidities.

Our results indicate that liquidity assistance leads to differential adjustment paths across the sectors of the economy. A policy conclusion from this result would therefore require an answer to the question of whether or not it is desirable for sectors with a high degree of financial vulnerability, such as construction, to make lower adjustments relative to sectors with a low degree of vulnerability, such as the public sector. Obviously, the answer depends, first, on how important a specific sector is considered to be for the overall economy. Such an assessment should, not least, take into account the fact that adjustment processes in certain sectors, such as the construction sector, might have wider implications for financial stability. Second, it depends on an evaluation of an important trade-off with respect to adjustment: On the one hand, liquidity provision mitigates adjustment pressure in certain sectors, which allows the burden of the shock to be distributed over a longer period of time. On the other hand, there is the risk of a substantial delay or even the prevention of necessary structural adjustment. Indeed, our results show that the effect of liquidity provision is not limited to the absorption of the shock in the early quarters after the sudden stop, but seems to shape the entire adjustment path quite persistently. Clearly, the answers to these questions are beyond the scope of this paper. In the light of our key finding that enhanced central bank liquidity plays an important role for asymmetric internal adjustment to sudden stops, it contributes to the foundation on which the discussion should take place.

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Appendix to Chapter 3

3.A Data

Data Sources

TARGET2 net balances: Original data on the TARGET2 net balances of the national central banks vis-à-vis the Eurosystem are taken from the Deutsche Bundesbank. Since September 2015, the data from May 2008 onwards have been made publicly available via the *ECB Statistical Data Warehouse* (SDW). Where individual country data for periods prior to May 2008 are shown, we use publicly available data on TARGET2 net balances provided on the website *Eurocrisismonitor.com* instead. These data are compiled mainly from the balance sheets of national central banks (see Steinkamp and Westermann, 2014, for details).

Rescue programs: Data on rescue programs were compiled from information and reports provided on the websites of the European Commission, the EFSF, and the ESM. Data on IMF programs were compiled using the *IMF Financial Data Query Tool.* Websites:

- http://ec.europa.eu/economy_finance/assistance_eu_ms/index_en.htm (European Commission)
- http://www.efsf.europa.eu/about/index.htm (EFSF)
- http://www.esm.europa.eu/ (ESM)
- http://www.imf.org/external/np/fin/tad/query.aspx (IMF)

Financial accounts: Data on financial accounts are taken from the financial accounts database of Eurostat (BPM5).

National accounts: Macroeconomic data on GDP, GDP deflators, and trade as well as sectoral data on gross value added, compensation of employees, total hours worked, total employment, and total number of employees are from the quarterly national accounts database of Eurostat (ESA 95).

Exchange rates: Data on three-month forward exchange rates for the BELL countries are taken from Datastream. Data for nominal and CPI-based real effective exchange rates are taken from Eurostat.

Financial vulnerability: The pre-sudden stop MFI loan growth measure is based on data about MFI loans to sectors in the euro area from the ECB Statistical Data Warehouse. The sectors given in our dataset are matched with the sector aggregation as given in the Eurosystem data in the following way (Eurosystem classification in parentheses): A (A); B-E (B,C,D+E); F (F); G-I (G, H+J, I); J (H+J); K (-), L (L+M+N); M-N (L+M+N); O-Q (Z=all remaining activities); R-U (Z).

Asset tangibility: Asset tangibility is measured as the ratio of firms' tangible fixed assets to total assets. The balance sheet data is obtained from the BACH database (https://www.bach.banque-france.fr/). The BACH database contains comparable information on the financial statements and balance sheets of eleven European countries aggregated by sectors. The BACH database covers the following countries: Austria, Belgium, Czech Republic, France, Germany, Italy, Poland, Portugal, Slovakia and Spain. For each country-sector we calculate the median asset tangibility ratio over time until the year 2007. For most countries, the sample starts in the year 2000, and for some countries it starts later. The sector-specific asset tangibility ratio is then calculated by taking the cross-country median.

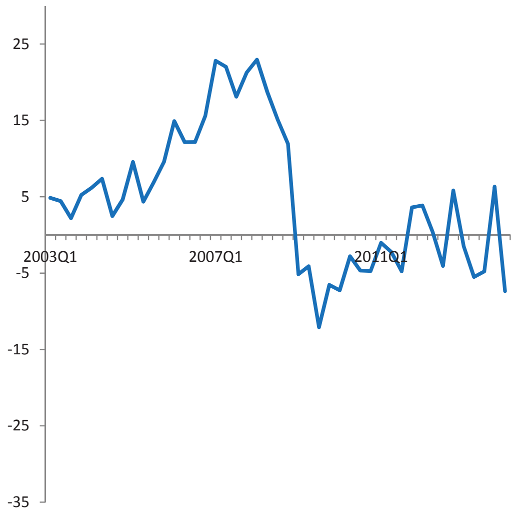
List of Sectors According to NACE Rev. 2

Sector symbol	Sector name	NACE Rev. 2 sectors contained
A	Agriculture, forestry & fishing	A Agriculture, forestry and fishing
B-E	Industry excl. construction	B Mining and quarrying C Manufacturing D Electricity, gas, steam and air conditioning supply E Water supply; sewerage, waste management and remediation activities
F	Construction	F Construction
G-I	Trade, travel & food Service	G Wholesale and retail trade; repair of motor vehicles and motorcycles H Transportation and storage I Accommodation and food service activities
J	Information & communication	J Information and communication
L	Real estate	L Real estate activities
M-N	Professional, science, tech & admin	M Professional, scientific and technical activities N Administrative and support service activities
O-Q	Public admin, education & social work	O Public administration and defence; compulsory social security P Education Q Human health and social work activities
R-U	Arts, recreation & other services	R Arts, entertainment and recreation S Other service activities T Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use U Activities of extraterritorial organisations and borders

3.B Figures and Tables

Figure 3.1: **Private capital inflows in BELL and GIIPS countries**
The graphs show private net capital inflows in BELL and GIIPS countries (in % of 2007 GDP). Private net capital flows are defined as the total net financial account minus payments due to EU and IMF rescue programs and changes in TARGET2 net liabilities. Data source: Deutsche Bundesbank, Eurostat, European Commission, ECB, and IMF.

(a) BELL countries



(b) GIIPS countries

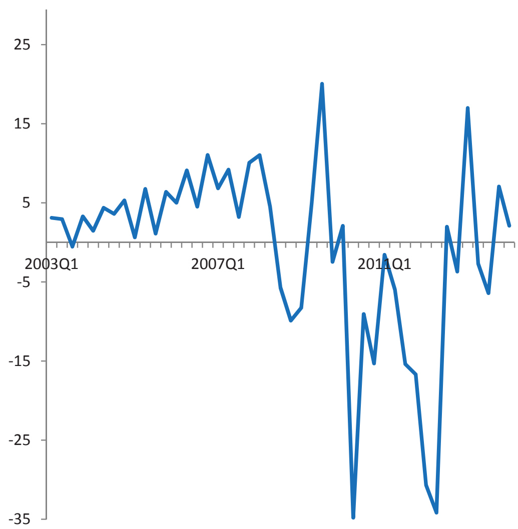
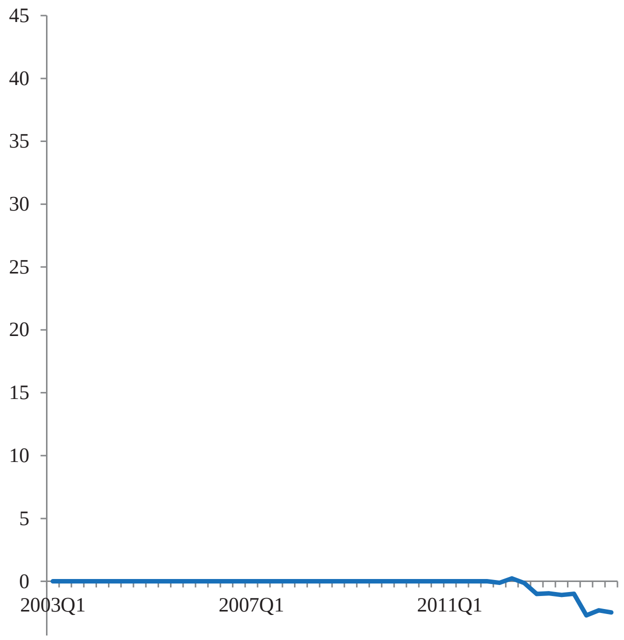


Figure 3.2: **TARGET2 net liabilities in BELL and GIIPS countries**
The graphs show the TARGET2 net liabilities of BELL and GIIPS countries (in % of 2007 GDP). Data source: Deutsche Bundesbank, ECB.

(a) BELL countries



(b) GIIPS countries

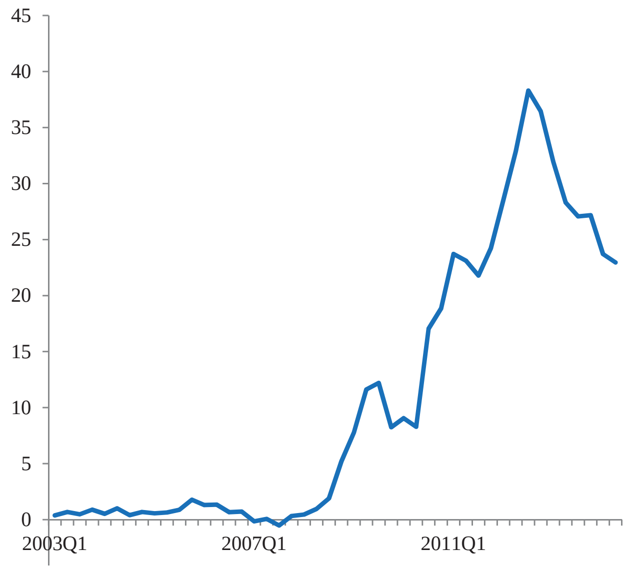
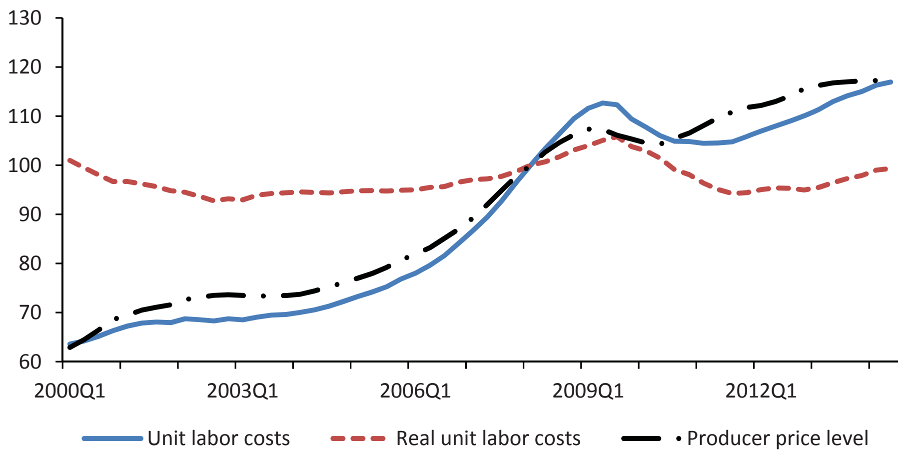


Figure 3.3: **Macroeconomic adjustment in BELL and GIIPS countries**
The graphs show nominal unit labor costs, real unit labor costs and the producer price level in the GIIPS and BELL countries indexed to the first quarter of 2008. Data source: Eurostat.

(a) BELL countries



(b) GIIPS countries

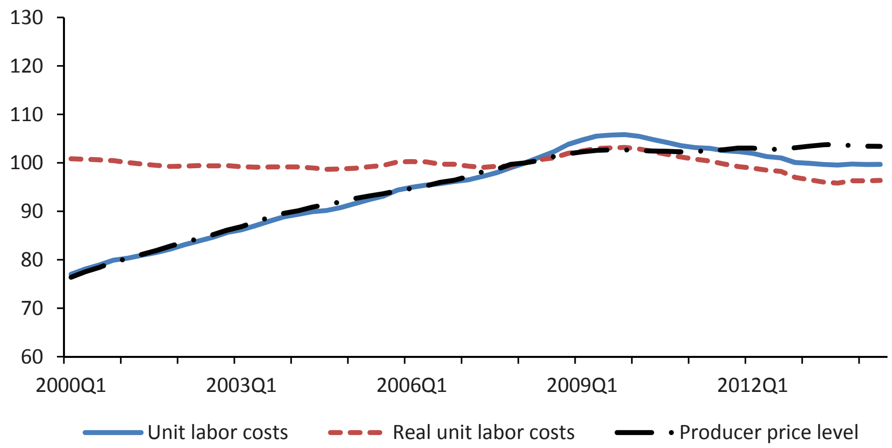
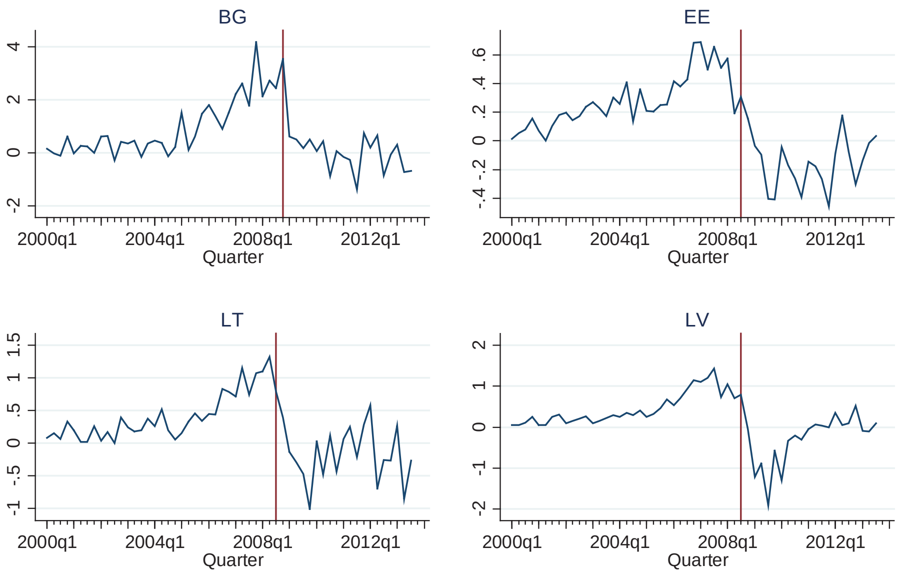


Figure 3.4: **Sudden stops in private capital flows**
The graphs show private net capital inflows (in billion euros) in GIIPS and BELL countries. Private net capital flows are defined as the total net financial account minus payments due to EU and IMF rescue programs and changes in TARGET2 net liabilities. The vertical line indicates the last quarter before the sudden stop period: BG 2008Q4, EE LT LV 2008Q3, EL 2008Q1, ES 2011Q1, IE 2008Q1, IT 2011Q1, PT 2010Q1. Country legend: BG Bulgaria, EE Estonia, LT Lithuania, LV Latvia, EL Greece, ES Spain, IE Ireland, IT Italy, PT Portugal. Data source: Eurostat, European Commission, Eurocrisismonitor.com, ECB, and IMF.

(a) BELL countries



(b) GIIPS countries

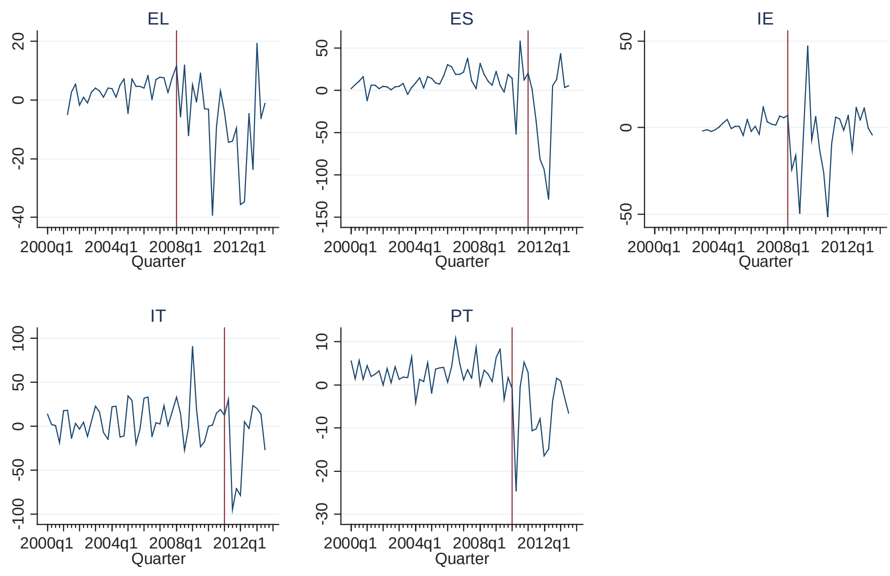


Figure 3.5: **Financial vulnerability**
The graph shows the measure of financial vulnerability across sectors. Financial vulnerability is measured based on the pre-sudden stop MFI loan growth rate across sectors. The MFI loan growth rate is the aggregate growth rate from 2003Q1 to 2008Q1. The sector classification is based on NACE Rev. 2. Data source: ECB.

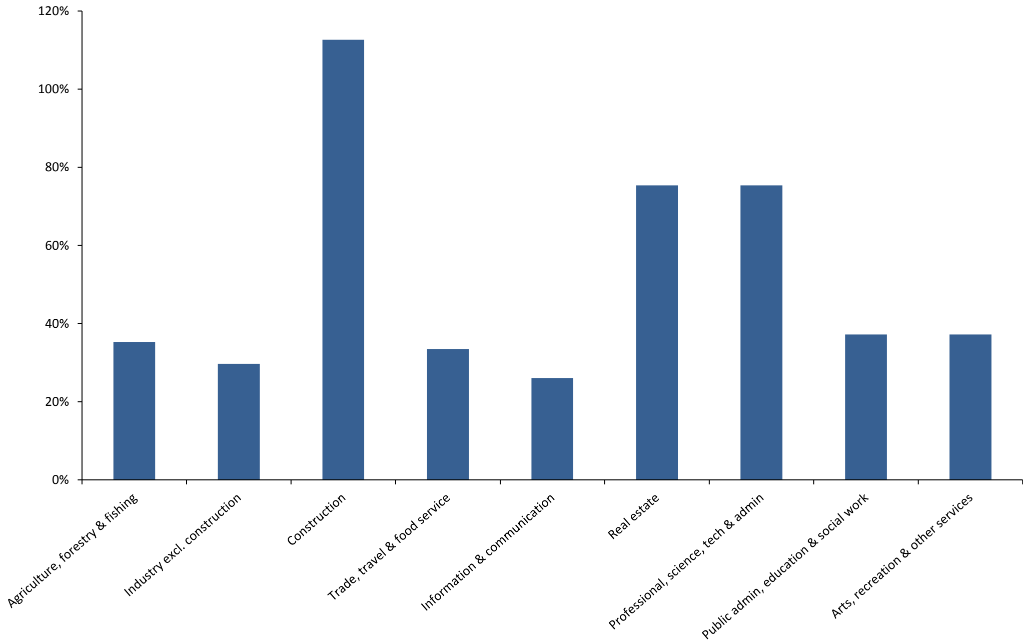


Table 3.1: **Summary statistics: sectoral adjustment variables**
The table shows summary statistics for the sectoral adjustment variables of the baseline empirical model: Sectoral nominal unit labor costs (ULC), real unit labor costs (RULC), real wages, nominal wages, labor productivity, and prices. All variables are defined in terms of adjustment, i.e. as percentage of their pre-sudden stop values. The sample is based on the estimation sample.

Variable	Country group	Observations	Mean	Standard deviation	Min.	Max.
Nominal unit labor costs (ULC) (% of pre-sudden stop)	BELL	828	−6.1	20.8	−108.2	36.8
	GIIPS	828	−0.9	13.5	−60.3	49.5
	Total	1656	−3.5	17.7	−108.2	49.5
Real unit labor costs (RULC) (% of pre-sudden stop)	BELL	828	−2.4	21.1	−116.1	47.6
	GIIPS	828	−2.6	23.6	−172.3	53.2
	Total	1656	−2.5	22.4	−172.3	53.2
Real wages (% of pre-sudden stop)	BELL	828	−4.2	23.1	−106.2	37.9
	GIIPS	828	−4.1	27.1	−228.1	29.1
	Total	1656	−4.2	25.2	−228.1	37.9
Nominal wages (% of pre-sudden stop)	BELL	828	−7.9	21.9	−89.9	31.2
	GIIPS	828	−1.7	6.6	−36.3	21.8
	Total	1656	−4.8	16.5	−89.9	31.2
Labor productivity (% of pre-sudden stop)	BELL	828	3.2	16.8	−34	54.5
	GIIPS	828	2.5	13.8	−41.6	58.9
	Total	1656	2.9	15.4	−41.6	58.9
Prices (% of pre-sudden stop)	BELL	828	−4.5	12.2	−46.2	37.1
	GIIPS	828	−0.4	12.8	−43.7	65.8
	Total	1656	−2.5	12.7	−46.2	65.8

Table 3.2: **Summary statistics: control variables**
The table shows summary statistics for the control variables of the baseline empirical model. The sample is based on the estimation period (quarter since sudden stop 0 to 22). REER and NEER denote the real and nominal effective exchange rate. Growth rates are indicated as quarter-on-quarter (qoq) or year-on-year (yoy) rates. For variables which only vary across countries but not sectors, the number of observations and summary statistics are based on the same values for each sector in a given country and quarter.

Variable	Country group	Observations	Mean	Standard deviation
TARGET2 net liabilities (% of 2007 GDP)	Total	2024	14.58	19.25
Total rescue program (% of 2007 GDP)	BELL	1012	3.57	6.74
	GIIPS	1012	15.37	22.86
	Total	2024	9.47	17.85
REER (CPI based, qoq growth, %)	BELL	1012	0.13	1.22
	GIIPS	1012	−0.10	1.38
	Total	2024	0.02	1.31
NEER (qoq growth, %)	BELL	1012	0.11	0.88
	GIIPS	1012	0.07	1.10
	Total	2024	0.09	1.00
3m-forward exchange rate (LCU per EUR, qoq growth, %)	BELL	1012	−0.02	0.36
	GIIPS	1012	0.00	0.00
	Total	2024	−0.01	0.25
GDP (nominal, yoy growth, %)	BELL	1012	2.34	9.18
	GIIPS	1001	−1.34	4.02
	Total	2013	0.51	7.33
GDP deflator (yoy growth, %)	BELL	1012	2.47	3.92
	GIIPS	1001	0.54	2.01
	Total	2013	1.51	3.27
Trade (% of GDP)	BELL	1012	135.41	24.81
	GIIPS	1012	89.98	46.54
	Total	2024	112.70	43.66
Total employees (lagged, thous. pers.)	BELL	1012	141.02	176.35
	GIIPS	1012	758.87	1093.99
	Total	2024	449.94	842.10

Table 3.3: **Liquidity provision and adjustment in nominal unit labor costs**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment in nominal unit labor costs (ULC) since the sudden stop. The specifications (1) to (6) are based on Equation (3.1) and vary with respect to the control variables included. The measure for liquidity provision is given by the TARGET2 net liabilities relative to 2007 GDP. The measure for financial vulnerability (FV) is based on pre-sudden stop MFI loan growth (2003Q1-2008Q1). The dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase) in unit labor costs. All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

Dependent variable: Adjustment in ULC (% of pre-sudden-stop)	(1)	(2)	(3)	(4)	(5)	(6)
FV ×						
Target2 net liabilities/GDP	−1.603	0.248	−1.395	−1.749	−0.075	0.251
	(3.366)	(2.824)	(3.078)	(3.269)	(1.761)	(1.527)
Rescue program/GDP		−3.929**				−1.099
		(1.860)				(1.516)
Employment			−7.670			−5.274
			(11.115)			(5.681)
REER				−1.386**		−1.647***
				(0.659)		(0.497)
NEER				−0.019		1.402
				(2.143)		(1.469)
3m-forward exchange rate				−0.040		−0.137
				(0.299)		(0.332)
Nominal GDP growth					1.308	1.243
					(1.122)	(1.412)
GDP deflator					−1.022*	−0.864
					(0.688)	(0.829)
Trade openness					5.284***	4.689**
					(1.781)	(1.927)
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,656	1,656	1,656	1,656	1,647	1,647
R^2	0.57	0.60	0.63	0.57	0.63	0.65

Table 3.4: **Liquidity provision and adjustment in real unit labor costs**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment in real unit labor costs (RULC) since the sudden stop. The specifications (1) to (6) are based on Equation (3.1) and vary with respect to the control variables included. The measure for liquidity provision is given by the TARGET2 net liabilities relative to 2007 GDP. The measure for financial vulnerability (FV) is based on pre-sudden stop MFI loan growth (2003Q1-2008Q1). The dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase) in unit labor costs. All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

Dependent variable: Adjustment in RULC (% of pre-sudden-stop)	(1)	(2)	(3)	(4)	(5)	(6)
FV ×						
Target2 net liabilities/GDP	-8.297^{***}	-8.986^{***}	-7.853^{***}	-8.241^{***}	-9.055^{***}	-8.005^{***}
	(2.282)	(2.217)	(2.093)	(2.205)	(1.793)	(0.949)
Rescue program/GDP		1.462				-2.128^{*}
		(1.480)				(1.120)
Employment			-12.266^{***}			-17.507^{***}
			(2.710)			−(4.871)
REER				−0.089		−0.377
				(0.915)		(0.694)
NEER				2.074		1.31
				(1.620)		(1.524)
3m-forward exchange rate				−0.329		−0.385
				(0.557)		(0.380)
Nominal GDP growth					0.547	0.362
					(1.371)	(1.167)
GDP deflator					−0.436	−0.712
					(1.140)	(0.942)
Trade openness					−2.984	-4.947^{***}
					(1.699)	(1.069)
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,656	1,656	1,656	1,656	1,647	1,647
R^2	0.62	0.63	0.63	0.62	0.63	0.63

Table 3.5: **Liquidity provision and adjustment in wages, labor productivity and prices**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment since the sudden stop in real wages (column (1)), nominal wages (column (2)), labor productivity (column (3)), and prices (column (4)). The specifications (1) to (4) are based on Equation (3.1). The measure for liquidity provision is given by the TARGET2 net liabilities relative to 2007 GDP. The measure for financial vulnerability (FV) is based on pre-sudden stop MFI loan growth (2003Q1-2008Q1). In columns (1), (2), and (4), the dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase). All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1) Real wages	(2) Nominal wages	(3) Labor productivity	(4) Prices
FV x				
LP	−10.010***	−0.465	2.246	3.710***
	(2.029)	(1.373)	(1.277)	(1.095)
Rescue program/GDP	−1.006	−0.418	−0.188	0.874
	(1.383)	(0.714)	(1.717)	(0.745)
Employment	−15.355***	−2.008	1.223	6.721**
	(3.071)	(2.343)	(6.143)	(2.026)
REER	0.915	−0.662	−0.943	−0.641*
	(0.839)	(0.829)	(0.743)	(0.287)
NEER	−0.081	0.356	1.124	−0.116
	(1.210)	(1.352)	(1.762)	(0.485)
3m-forward exchange rate	−0.714	−0.314	0.387	0.029
	(0.515)	(0.296)	(0.215)	(0.189)
Nominal GDP growth	−1.361	−0.076	0.846	1.252*
	(3.002)	(0.816)	(1.909)	(0.671)
GDP deflator	0.199	−0.139	−0.579	−0.531
	(2.060)	(0.383)	(1.154)	(0.836)
Trade openness	−12.616***	−1.461	6.546***	5.117***
	(1.951)	(1.899)	(1.370)	(1.129)
Country × quarter FE	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes
Observations	1,647	1,647	1,647	1,647
R^2	0.72	0.71	0.47	0.63

Table 3.6: **Measuring liquidity provision using central bank refinancing operations**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment since the sudden stop in real unit labor costs (column (1)), nominal unit labor costs (column (2)), real wages (column (3)), nominal wages (column (4)), labor productivity (column (5)), and prices (column (6)). The specifications (1) to (6) are based on Equation (3.1) and include the full set of control variables as given in column (6) of Tables 3.3 and 3.4. The measure for liquidity provision is given by the amount of central bank refinancing operations relative to 2007 GDP. The measure for financial vulnerability (FV) is based on pre-sudden stop MFI loan growth (2003Q1-2008Q1). Except for column (5), the dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase). All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1) Real unit labor costs	(2) Nominal unit labor costs	(3) Real wages	(4) Nominal wages	(5) Labor productivity	(6) Prices
FV ×						
Refinancing operations	−7.444***	−0.158	−9.104***	−0.683	1.939	3.272***
	(0.882)	(1.245)	(1.760)	(1.297)	(1.380)	(0.925)
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
FV × control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,647	1,647	1,647	1,647	1,647	1,647
R^2	0.65	0.65	0.71	0.71	0.47	0.62

Table 3.7: **Measuring liquidity provision using the size of national central banks' balance sheet**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment since the sudden stop in real unit labor costs (column (1)), nominal unit labor costs (column (2)), real wages (column (3)), nominal wages (column (4)), labor productivity (column (5)), and prices (column (6)). The specifications (1) to (6) are based on Equation (3.1) and include the full set of control variables as given in column (6) of Tables 3.3 and 3.4. The measure for liquidity provision is given by the size of national central banks' balance sheet relative to 2007 GDP (CB balance sheet). The measure for financial vulnerability (FV) is based on pre-sudden stop MFI loan growth (2003Q1-2008Q1). Except for column (5), the dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase). All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1) Real unit labor costs	(2) Nominal unit labor costs	(3) Real wages	(4) Nominal wages	(5) Labor productivity	(6) Prices
FV ×						
CB balance sheet	−5.682**	1.053	−8.682***	−0.763	3.128	2.805**
	(1.836)	(1.294)	(2.514)	(1.788)	(1.789)	(1.131)
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
FV × control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,647	1,647	1,647	1,647	1,647	1,647
R^2	0.66	0.65	0.71	0.71	0.48	0.61

Table 3.8: **Lagging the liquidity provision variable**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment since the sudden stop in real unit labor costs (column (1)), nominal unit labor costs (column (2)), real wages (column (3)), nominal wages (column (4)), labor productivity (column (5)), and prices (column (6)). The specifications (1) to (6) are based on Equation (3.1) and include the full set of control variables as given in column (6) of Tables 3.3 and 3.4. The measure for liquidity provision is four-quarter lagged TARGET2 net liabilities relative to 2007 GDP. The measure for financial vulnerability (FV) is based on pre-sudden stop MFI loan growth (2003Q1-2008Q1). Except for column (5), the dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase). All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1) Real unit labor costs	(2) Nominal unit labor costs	(3) Real wages	(4) Nominal wages	(5) Labor productivity	(6) Prices
FV ×						
LP_{t-4}	-8.745^{***}	0.853	-11.613^{***}	-0.661	3.187^{**}	4.545^{***}
	(0.661)	(1.917)	(1.878)	(1.581)	(1.352)	(0.883)
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
FV × control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,647	1,647	1,647	1,647	1,647	1,647
R^2	0.65	0.65	0.72	0.71	0.47	0.63

Table 3.9: **GIIPS indicator as a proxy for liquidity provision**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment since the sudden stop in real unit labor costs (column (1)), nominal unit labor costs (column (2)), real wages (column (3)), nominal wages (column (4)), labor productivity (column (5)), and prices (column (6)). The specifications (1) to (6) are based on Equation (3.1) and include the full set of control variables as given in column (6) of Tables 3.3 and 3.4. The measure for liquidity provision is given by the GIIPS indicator, which takes a value of one for GIIPS and zero for BELL countries. The measure for financial vulnerability (FV) is based on pre-sudden stop MFI loan growth (2003Q1-2008Q1). Except for column (5), the dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase). All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1) Real unit labor costs	(2) Nominal unit labor costs	(3) Real wages	(4) Nominal wages	(5) Labor productivity	(6) Prices
FV ×						
GIIPS indicator	−18.693***	−1.254	−22.764***	−2.657	4.763	7.979**
	(2.165)	(2.700)	(4.814)	(2.284)	(3.348)	(3.259)
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
FV × control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,647	1,647	1,647	1,647	1,647	1,647
R^2	0.66	0.65	0.72	0.71	0.47	0.62

Table 3.10: **International liquidity flows**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment since the sudden stop in real unit labor costs (column (1)), nominal unit labor costs (column (2)), real wages (column (3)), nominal wages (column (4)), labor productivity (column (5)), and prices (column (6)). The specifications (1) to (6) are based on Equation (3.1) and include the full set of control variables as given in column (6) of Tables 3.3 and 3.4. The measure for liquidity provision is given by the TARGET2 net liabilities relative to 2007 GDP. The measure for financial vulnerability (FV) is based on pre-sudden stop MFI loan growth (2003Q1-2008Q1). The regressions include the private financial account relative to 2007 GDP in addition to the baseline set of control variables. Except for column (5), the dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase). All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1) Real unit labor costs	(2) Nominal unit labor costs	(3) Real wages	(4) Nominal wages	(5) Labor productivity	(6) Prices
FV ×						
LP	−8.405***	0.873	−10.337***	0.370	1.920	4.561***
	(1.218)	(1.732)	(2.020)	(1.472)	(1.809)	(0.649)
Private financial account	0.562	−1.208	0.492	−1.530**	0.573	−1.536**
	(1.219)	(2.005)	(1.197)	(0.617)	(1.837)	(0.633)
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
FV × control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,620	1,620	1,620	1,620	1,620	1,620
R^2	0.65	0.64	0.72	0.70	0.47	0.64

Table 3.11: **Alternative measure of financial vulnerability: asset tangibility**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment since the sudden stop in real unit labor costs (column (1)), nominal unit labor costs (column (2)), real wages (column (3)), nominal wages (column (4)), labor productivity (column (5)), and prices (column (6)). The specifications (1) to (6) are based on Equation (3.1) and include the full set of control variables as given in column (6) of Tables 3.3 and 3.4. The measure for liquidity provision is given by the TARGET2 net liabilities relative to 2007 GDP. The measure for financial vulnerability (FV) is given by the share of tangible and liquid assets in the total balance sheet. Except for column (5), the dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase). All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	Real unit labor costs	Nominal unit labor costs	Real wages	Nominal wages	Labor productivity	Prices
FV ×						
LP	-8.014^{***}	0.409	-9.888^{***}	-0.155	1.814	3.347^{***}
	(0.937)	(1.161)	(1.816)	(0.698)	(1.105)	(0.490)
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
FV × control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,647	1,647	1,647	1,647	1,647	1,647
R^2	0.67	0.65	0.73	0.72	0.50	0.60

Table 3.12: **Alternating the measure of financial vulnerability**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment since the sudden stop in real unit labor costs (column (1)), nominal unit labor costs (column (2)), real wages (column (3)), nominal wages (column (4)), labor productivity (column (5)), and prices (column (6)). The specifications (1) to (6) are based on Equation (3.1) and include the full set of control variables as given in column (6) of Tables 3.3 and 3.4. The measure for liquidity provision is given by the TARGET2 net liabilities relative to 2007 GDP. The measure for financial vulnerability (FV) is based on pre-sudden stop MFI loan growth and varies as indicated in panels (a) and (b). Except for column (5), the dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase). All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1) Real unit labor costs	(2) Nominal unit labor costs	(3) Real wages	(4) Nominal wages	(5) Labor productivity	(6) Prices
	(a) Dummy variable indicating high vs. low financial vulnerability					
FV × LP	−11.352***	2.683	−17.856***	−1.881	7.637**	7.579**
	(1.762)	(3.297)	(3.581)	(2.960)	(2.668)	(2.703)
R^2	0.57	0.63	0.65	0.71	0.48	0.61
	(b) MFI loan growth 2003Q1-2003Q4					
FV × LP	−8.200***	−0.823	−9.033***	−0.451	0.762	2.990***
	(1.125)	(1.151)	(1.899)	(1.184)	(1.194)	(0.647)
R^2	0.64	0.64	0.67	0.71	0.43	0.58
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
FV × control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,647	1,647	1,647	1,647	1,647	1,647

Table 3.13: **Controlling for country-sector fixed effects**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment since the sudden stop in real unit labor costs (column (1)), nominal unit labor costs (column (2)), real wages (column (3)), nominal wages (column (4)), labor productivity (column (5)), and prices (column (6)). The specifications (1) to (6) are based on Equation (3.1) and include the full set of control variables as given in column (6) of Tables 3.3 and 3.4. The measure for liquidity provision is given by the TARGET2 net liabilities relative to 2007 GDP. The measure for financial vulnerability (FV) is based on pre-sudden stop MFI loan growth (2003Q1-2008Q1). Except for column (5), the dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase). All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time, sector-time, and country-sector fixed effects, standard errors in parentheses are cluster-robust at the country-sector level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1) Real unit labor costs	(2) Nominal unit labor costs	(3) Real wages	(4) Nominal wages	(5) Labor productivity	(6) Prices
FV ×						
LP	-6.175^{***}	0.160	-6.611^{**}	0.850	0.497	2.164^{***}
	(0.908)	(1.314)	(2.028)	(0.705)	(1.407)	(0.645)
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Country × sector FE	Yes	Yes	Yes	Yes	Yes	Yes
FV × control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,647	1,647	1,647	1,647	1,647	1,647
R^2	0.91	0.90	0.90	0.92	0.84	0.88

Table 3.14: **Controlling for adjustment in labor productivity**
The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment since the sudden stop in real unit labor costs (column (1)), nominal unit labor costs (column (2)), real wages (column (3)), nominal wages (column (4)), labor productivity (column (5)), and prices (column (6)). The specifications (1) to (6) are based on Equation (3.1) and include the full set of control variables as given in column (6) of Tables 3.3 and 3.4. The measure for liquidity provision is given by the TARGET2 net liabilities relative to 2007 GDP. The measure for financial vulnerability (FV) is based on pre-sudden stop MFI loan growth (2003Q1-2008Q1). The regressions include lagged adjustment in labor productivity in addition to the baseline set of control variables. Except for column (5), the dependent variable is defined in terms of adjustment, i.e. an increase (decrease) corresponds to a reduction (increase). All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1) Real unit labor costs	(2) Nominal unit labor costs	(3) Real wages	(4) Nominal wages	(5) Labor productivity	(6) Prices
FV ×						
LP	−9.005***	−1.058	−8.844***	0.437	−0.017	3.432***
	(1.278)	(1.355)	(1.411)	(1.298)	(0.109)	(0.832)
Labor productivity$_{t-1}$	0.468**	0.593***	−0.519**	−0.412***	1.022***	0.119
	(0.181)	(0.143)	(0.165)	(0.111)	(0.009)	(0.111)
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
FV × control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,566	1,566	1,566	1,566	1,566	1,566
R^2	0.70	0.78	0.77	0.78	0.98	0.64

Table 3.15: **Liquidity provision and adjustment in employment**

The table shows the differential effect of liquidity provision by the Eurosystem on sectoral adjustment since the sudden stop in employment. The specifications (1) to (11) are based on Equation (3.1) and include the full set of control variables as given in column (6) of Tables 3.3 and 3.4. The measures for liquidity provision and financial vulnerability vary according to the description of variables in the first column. Liquidity provision is either given by the TARGET2 net liabilities relative to 2007 GDP (LP in columns (1) and (9) to (11), or lagged by four quarters LP_{t-4}, column (2)), the size of the national central banks' balance sheet (column (3)), the amount of central bank refinancing operations (column (4)), or the GIIPS indicator (column (5)). The measure for financial vulnerability is either based on pre-sudden stop MFI loan growth (2003Q1-2008Q1) (FV in columns (1) to (5) and (9) to (11); or high vs. low, FV(0/1) in column (7); or based on 2003Q1-2003Q4, FV_{2003} in column (8)) or asset tangibility (column (6)). Column (9) includes the private financial account relative to 2007 GDP in addition to the baseline set of controls. Column (10) includes lagged adjustment in labor productivity in addition to the baseline set of control variables. Column (11) includes country-sector fixed effects. All control variables are standardized (zero mean, unit standard deviation). All control variables are interacted with FV. All specifications include country-time and sector-time fixed effects, standard errors in parentheses are cluster-robust at the country level (country-sector level for column (11)). ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) International liquidity	(10) Labor productivity$_{t-1}$	(11) Country-sector FE
FV × LP	−1.537**								−1.778***	−0.881*	−0.342
	(0.601)								(0.510)	(0.384)	(0.435)
FV × LP_{t-4}		−1.901**									
		(0.731)									
FV × CB balance sheet			−1.335*								
			(0.709)								
FV × Refinance op.				−1.455**							
				(0.560)							
FV × GIIPS indicator					−3.494*						
					(1.606)						
Tangibility × LP						−0.285					
						(0.326)					
FV(0/1) × LP							−4.401**				
							(1.589)				
FV_{2003}× LP								−1.431**			
								(0.560)			
Country × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector × quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × sector FE	No	No	No	No	No	No	No	No	No	No	Yes
FV × control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,647	1,647	1,647	1,647	1,647	1,647	1,620	1,647	1,647	1,566	1,647
R^2	0.81	0.81	0.81	0.81	0.81	0.80	0.81	0.82	0.95	0.86	0.81

Chapter 4

How Effective is Macroprudential Policy During Financial Downturns? Evidence from Caps on Banks' Leverage

4.1 Motivation

The use of macroprudential policy is an important aspect of the regulatory response to the global financial crisis, and several advanced economies have updated their regulatory and supervisory structures over the last few years in consequence.[1] Various macroprudential policy tools are available, and they are expected to prevent the build-up of systemic risk in the financial system. Using these tools sensibly is challenging however. On the upside, lower systemic risk might reduce the probability and severity of financial crises, but on the downside, there might be leakages or other unintended consequences. Against this backdrop, the topic has gained a lot of attention among policy makers and researchers alike. Besides comprehensive theories that grasp the relevant trade-offs and channels, an empirical evaluation of the effects of macroprudential policies is key to understanding their usefulness and shortcomings. In this respect, countries which have already implemented macroprudential tools in the past provide valuable examples for a study of these effects.

[1] In the USA for instance, the Financial Stability Oversight Council (FSOC) was established under the Dodd-Frank Act in 2010 with a mandate to identify and respond to threats to financial stability. In Europe, countries have designated national macroprudential authorities (following the proposal by the European Systemic Risk Board (ESRB) in 2011) that conduct macroprudential policies. Within the euro area, this responsibility is shared with the supranational Single Supervisory Mechanism (SSM). The SSM, which entered into operation in November 2014, has not only microprudential but also macroprudential responsibilities and has tools at its disposal such as the countercyclical capital buffer and capital buffers for systemically important institutions (see the capital requirements regulation and directive CRR/CRD IV).

An important intermediate goal of macroprudential policy is to smooth the credit or financial cycle (Arregui et al., 2013). It particularly aims to prevent excessive credit booms building up, as they might ultimately lead to systemic financial crises with potentially adverse effects on the real economy. Kaminsky and Reinhart (1999) show that crises in emerging market usually follow credit-fuelled booms in economic activity.[2] Similarly, empirical evidence for advanced economies suggests that credit booms help to predict periods of financial distress (Schularick and Taylor, 2012) and that recessions were deeper if they had been preceded by a financial crisis (Jordà et al., 2013). At the same time, macroprudential policy aims at easing the adverse effects like excessive deleveraging that are caused by binding constraints during downturns. The results of recent studies such as Cerutti et al. (2016) suggest that macroprudential policies are indeed effective in reducing excessive lending and in dampening the financial cycle during boom times. However, less is known about the stabilising role of macroprudential policy during financial downturns. This point deserves attention because it is especially the years after a financial crisis, which can be defined as an extreme financial downturn, that are more likely to see financial markets not working properly in their function of channelling funds to productive investments in the real economy. It is during precisely these periods that macroprudential policy might contribute to reducing these financial strains.

This paper addresses the question of whether there is a stabilising role for macroprudential policy in the aftermath of a financial crisis. To answer this question, I focus on the implementation of a cap on the leverage of banks (often referred to simply as the leverage ratio), which obliges banks to hold a minimum amount of equity capital relative to their total assets. Evidence of the relevance of this for the current regulatory debate is that the Basel Committee on Banking Supervision (BCBS) is currently testing the implementation of a 3% leverage ratio until the end of 2017 as part of the Basel III framework (BCBS, 2014). The stated goal of the leverage ratio is to prevent excessive leverage building up in the financial system and to function as a backstop for the risk-weighted regulatory capital ratios (BCBS, 2014). If there is an unforeseen increase in asset risk, it is this backstop function in particular which makes such a leverage cap a useful buffer against excessive deleveraging by banks in their attempt to meet regulatory requirements for risk-weighted equity capital ratios.[3] In addition,

[2] For the literature on the ability of financial indicators such as the credit-to-GDP gap to predict systemic financial crises, see also Borio and Drehmann (2009), Alessi and Detken (2011), and Duca and Peltonen (2013).

[3] The findings by Behn et al. (2016) provide empirical support for this line of reasoning. They show that in response to a credit risk shock, German banks using the internal ratings-based (IRB) approach of Basel II to determine risk weights reduced lending by more than banks applying the standard approach with fixed risk weights did.

a leverage cap can mitigate the externalities generated by a potential run on banks' short-term funding liabilities such as repos during a liquidity crisis (Morris and Shin, 2008). For this reason, the cap on banks' leverage can be classified as a macroprudential policy instrument which increases the resilience of the financial system (Claessens, 2015), and so it is worthwhile to assess its role in the provision of real credit after the crisis more carefully.

To answer this question empirically, we apply a difference-in-differences approach in order to compare real credit growth before and after the crisis across countries that implemented a cap on leverage before the crisis and those that did not. The sample I draw on is a panel of 69 advanced and emerging countries of which eight countries introduced a leverage cap prior to the crisis.[4] The data on the use of macroprudential policy, which includes the implementation of the leverage cap, are taken from the dataset by Cerutti et al. (2016). This dataset in turn is based on the Global Macroprudential Policy Instruments (GMPI) survey conducted by the IMF.

The results show, first, that real credit growth in countries that introduced a leverage cap before the crisis – as compared to those that did not – was significantly higher in economic and statistical terms in 2009-14, after the crisis, than it was in 2002-08 before the crisis. In the baseline regression, the effect amounts to a real credit growth rate that is about six percentage points higher on average. This indicates that macroprudential policy can indeed have a stabilising effect during financial downturns. Second, the stabilising effect is stronger for those countries in which banks entered the crisis with a higher equity capital ratio. This suggests that banks can draw on the capital buffers built up before the crisis to stabilise lending to the private sector afterwards.

This paper relates to several empirical studies dealing with the impact of macroprudential policy on financial markets and real outcomes. Several papers analyse the impact of one or more macroprudential policy instruments on bank behaviour in single countries. Bruno and Shin (2014) find that the macroprudential policies that Korea introduced in 2010 and that were targeted at banks' short-term liabilities effectively reduced the vulnerability to capital inflow reversals. For the UK banks, Aiyar et al. (2014b) document that there is a significant amount of leakage around macroprudential policy, as branches of foreign banks which are not under the regulation of the national supervisor counteract the reduction in lending by UK-owned banks and foreign subsidiaries that is induced by higher time-varying bank-specific capital requirements. Jiménez et al. (2014) use detailed Spanish credit register data to analyse the effect of

[4] Clearly, the small number of "treated" countries makes it important to check how far the results are driven by individual countries in the treatment group and how sensitive the results are to the different choices of the control group. These checks are provided in the robustness section.

dynamic provisioning on the credit supply cycle and the real economy. The authors find that the regulation effectively smoothes the credit supply cycle and supports firm performance in bad times. Buch et al. (2014) show that banks which were affected by the German bank levy introduced in 2011 reduced lending and increased their deposit rates. Danisewicz et al. (2015) find a significant differential effect on lending to other banks between UK branches and subsidiaries of global banks after the introduction of macroprudential regulation in the home countries of the banks. Like three of these papers, this study also uses a difference-in-differences approach to identify the effect of macroprudential regulation on the outcome variable. I deviate in so far as I focus on the effect of one instrument in several countries. I also focus on the aggregate growth rate of credit to the private sector and do not look at lending by individual banks.

There are other studies which investigate the effect of macroprudential policy across different countries. The finding by Aiyar et al. (2014a) is that higher capital requirements in the UK led to a slowdown in cross-border credit provided by UK banks. Claessens et al. (2013) analyse bank-level data from 48 countries over 2000-10 and show that macroprudential policies such as caps on debt-to-income and loan-to-value ratios are effective in reducing leverage and asset growth during boom times. They find only limited evidence that countercyclical measures have a stabilising effect in downturns though. These results are confirmed for a panel of 119 countries over 2000-13 by Cerutti et al. (2016), who assess the impact of a combined index of several macroprudential policy instruments and find that macroprudential policy is effective in dampening credit growth but works less well in busts. Complementing these existing studies, I take a closer look at the years after the Global Financial Crisis and focus on one instrument to analyse the stabilising role of macroprudential policy during financial downturns more deeply.

The rest of the chapter is organised as follows. Section 4.2 describes the data and provides descriptive statistics. Section 4.3 presents the empirical specification and identifying assumptions. Section 4.4 shows the estimation results. Section 4.5 provides several robustness checks. Section 4.6 concludes.

4.2 Data and Descriptive Statistics

4.2.1 Caps on Banks' Leverage

A regulatory cap on the leverage of banks requires banks to hold a minimum amount of equity capital relative to their total assets. The data on the caps on leverage are taken from the dataset on macroprudential policy measures by Cerutti et al. (2016). This is in turn based on the Global Macroprudential Policy Instruments (GMPI) survey by the IMF. In this paper I consider the sample of emerging and advanced economies that is defined in the IMF World Economic Outlook 2014 (Cerutti et al., 2016; IMF, 2014). There are 69 countries in the final estimation sample, and they are shown in Table 4.1. Eight countries actually introduced a cap on the leverage of banks prior to the crisis, and these were Canada, Chile, Ecuador, Jordan, Paraguay, Saudi Arabia, St. Kitts and Nevis, and the United States. Most of them brought in the leverage cap in the year 2000 or earlier. The exceptions are Ecuador, which introduced the cap in 2001, and Jordan, which introduced one in 2003. It is mostly emerging market economies that have had experience with macroprudential policy in the past, and this is reflected in the presence of only two advanced countries in this sample, Canada and the USA. Information is only available on the year of implementation and not on the actual size of the cap.

To gain a first impression of the data, I compare the countries which implemented the leverage cap with those that did not in terms of the descriptive statistics of their key macroeconomic variables. The descriptive statistics shown in Table 4.2 illustrate that countries which introduced the cap had higher GDP growth rates on average but lower interest rates and inflation. The private credit-to-GDP ratio was more than 11 percentage points lower at about 53.4 rather than 65.1 in these countries. The ratio of equity capital to total assets held by banks was also smaller, by about 1.5 percentage points. While not all of these observable differences are very large, it is important to account for country-specific differences when evaluating the effect of the macroprudential policy tool. Clearly the implementation of the leverage cap was not random but was based on several country characteristics. These might be observed variables such as GDP growth, the level of the interest rate, or the credit-to-GDP ratio. It is, however, more likely that implementation was based on unobservable characteristics such as the preference for leverage or financial stability in general or the overall quality of institutions. This line of argumentation supports the application of a difference-in-differences approach, which directly incorporates the idea that the selection through the decision to implement the regulation is based on unobservable characteristics.

Figure 4.1 shows the evolution of the capital-to-assets ratios of banks over time in both groups of countries. It can be seen that capital ratios were relatively stable in countries without the cap over the whole sample but they increased steadily in the countries which introduced the cap in the pre-crisis period. By 2009 the capital ratios were on average at a very similar level of about 10 percent for both groups of countries. Capital ratios also increased in the post-crisis period while staying slightly lower in the countries with the cap. The former observation might appear surprising as it contradicts the idea that in times of crisis we expect banks to deleverage. However, given the sudden increase in the risk of certain assets, stable or even increasing capital ratios are likely to be the result of banks trying to keep their capital stable relative to risk-weighted assets in order to meet the regulatory minimum requirements. If this was achieved primarily through a reduction of mainly risky assets, capital relative to total unweighted assets might actually increase. The important point is that a higher capital-to-assets ratio might make the minimum regulatory capital requirement based on risk-weighted assets less binding during times of higher asset risk.

To test this channel directly it would be necessary to evaluate whether the leverage caps do indeed relax the binding regulatory minimum capital requirements. However, this study does not have access to any information on regulatory capital ratios. Equally, we do not know whether the build-up of capital ratios prior to the crisis was really the result of the introduction of the leverage cap. This is because banks might choose to hold the same buffer even in the absence of the regulation. Therefore the study will take an indirect approach so as to shed some light on the buffer channel, and it relies on narrative evidence for countries such as Canada, showing that the cap might indeed have worked as described by Bordeleau et al. (2009).

4.2.2 Real Credit Growth

A key variable is the growth of credit, the rate of which can be seen as an intermediate target of macroprudential policy (Arregui et al., 2013). Achieving this target in practice means restricting the build-up of potentially excessive credit booms and stabilising credit provision in downturns. This study follows this approach and considers the impact on the growth rate of real credit from a multi-country perspective. It takes the period after the global financial crisis as an example of a pronounced financial downturn in which the stabilising role of macroprudential policy on credit growth can be analysed. The direct crisis response was a mixture of various immediate rescue measures, but this study analyses the stabilising effect in the years after the crisis and thus takes a medium-term perspective. Some studies have evaluated the countercyclical role of macroprudential policy tools, but the countercyclical effects might not come into full effect if the financial downturn is not so large. Therefore, I explicitly analyse the period after the global financial crisis, and my main focus is on how the policy increases the loss-absorbing capacity of the financial system for dealing with sizable systemic shocks.

Taking this further, this study focuses on real credit provided by domestic banks to the domestic private sector. The choice of this variable is guided by the notion that it is resident banks that will be affected primarily by the regulation and that regulatory authorities care most about credit provision to the private sector when they are looking to stabilise the economy as a whole. Figure 4.2 shows the evolution of the real credit growth rate over time. It can be seen from visual inspection that the difference in levels is considerable prior to the crisis, but the paths of real credit growth rates in both groups of countries nevertheless show a similar pattern described by an upward trend. The rates declined sharply in the crisis year 2009 and remained at lower levels in both groups of countries. However, the rate fell by less in those countries which had a leverage cap in place. Interestingly, rates remain at lower levels throughout the post-crisis period.

Clearly, there are competing explanations for the effect observed. It might be that the countries which implemented the cap prior to the crisis were those countries which were affected less by the crisis. It might also be that we are only seeing a standard adjustment to a pre-crisis boom that was more pronounced in the countries which had not introduced the measure. I will check the sensitivity of my result to these alternative explanations. In sum, the descriptive analysis gives a first indication of the stabilising effect of caps on the leverage of banks on real credit growth after the crisis, and this will be analysed in detail in the following sections.

4.3 Empirical Specification

4.3.1 Difference-in-Differences Approach

I identify the effect of caps on leverage on real credit growth after the crisis using a difference-in-differences approach with two-way fixed effects:

$$\Delta \ln \mathit{RealCredit}_{it} = \alpha_i + \alpha_t + \beta \left[D_{\text{PostCrisis}} \times D_{\text{LEV}} \right] + x'_{it}\gamma + \varepsilon_{it} \tag{4.1}$$

The dependent variable is the growth rate of real credit ($\Delta \ln \mathit{RealCredit}$). Index i indicates the country and t the year. $D_{\text{PostCrisis}}$ is a dummy variable indicating the post-crisis period starting from 2009. D_{LEV} is a dummy indicating whether a given country had a leverage cap prior to the crisis.[5] The time period of the baseline estimation covers the years 2002 to 2014. The parameter of interest is β as it captures the differential effect on real credit growth of the leverage cap in the post-crisis period. If it turns out to be positive we can conclude that macroprudential regulation has a stabilising effect on real credit growth. A possible channel through which this effect works is that banks can draw on pre-crisis capital buffers that they built up before the

[5] The indicator is equal to one if the country had introduced the cap before 2008 so that it was in place before the crisis. However, all the countries with a leverage cap prior to the crisis had already introduced it by 2003.

crisis because of the regulation, and this prevents them from deleveraging and cutting back lending.

My approach differs in its terminology from the usual difference-in-differences setting for two reasons. First, the treatment is not fully defined by the introduction of the leverage cap itself, but rather it is defined as the leverage cap being already in place conditional on the crisis happening. Theoretically, the treatment would thus be absent if either i) no financial crisis hit or ii) no country had caps on leverage when the crisis hit. Second, I do not claim that the control group is not affected by the event, entirely the contrary in fact, as it will very much be affected by the crisis. The point is that the countries in the treated group, i.e. those which had a cap on leverage in place when the crisis hit, were affected differently. Despite these subtle distinctions, it is valid to use the difference-in-difference methodology to measure the intended effect as long as the identifying assumptions hold.

4.3.2 Identifying Assumptions

Two main assumptions have to hold for the effect to be identified: both groups of countries have to exhibit a parallel trend for the real credit growth rate and the crisis has to be an exogenous event. The parallel trend assumption states that in the absence of treatment, real credit growth would have developed in a similar way in both groups of countries after the crisis. This assumption cannot be tested directly, but one can shed light on its plausibility by testing whether there is a significant differential effect for the years before the crisis. One way to do this is to allow the difference-in-differences coefficient to vary over time and to set the post-crisis period artificially equal to one in the three years preceding the actual post-crisis period, 2006 to 2008.

$$\Delta \ln RealCredit_{it} = \alpha_i + \alpha_t + \beta_t \left[D_{\text{Year} \geq 2006} \times D_{\text{LEV}} \times D_t \right] + x'_{it}\gamma + \varepsilon_{it} \qquad (4.2)$$

All variables have the same definition as in Equation (4.1). The difference is that $D_{\text{Year}\geq 2006}$ is now equal to one starting from as early as 2006 and the interaction with D_t captures dummies indicating a specific year to get a time-varying coefficient. My assumption is that it is only in the post-crisis period that there should be a significant differential effect on credit growth between the countries with a leverage cap and those without one. Therefore the coefficients β_t should turn out not to be significantly different from zero in the three years before the post-crisis period. Figure 4.3 illustrates the results of the test for the pre-treatment effect. In all three years preceding the actual post-crisis period, there is no significant difference between the two groups of countries, and this argues in favour of parallel trends. Taking this evidence, I proceed further with the analysis.

The assumption that the global financial crisis was exogenous in the sense that it was unexpected appears plausible. Only if countries expected that they would be hit by a financial crisis and introduced the leverage cap for that reason would the results be invalidated by this assumption. I argue that this case is rather implausible as it would require first that countries implementing the measure correctly predict the date and severity of the crisis and, second, that countries introduce their caps on leverage for precisely this reason.

Regarding the anticipation of the crisis, Figure 4.2 shows that real credit growth rates are also lower after the crisis than before the crisis in countries which had leverage caps. This argues against the hypothesis that the impact of the crisis was fully anticipated. In this sense my approach is similar to that of others who have used the global financial crisis as an exogenous event and compared post-crisis and pre-crisis outcomes, such as Cetorelli and Goldberg (2011), who analyse lending by global banks.

Furthermore, the reasons for introducing a leverage cap are likely to differ across countries. As described above, the desire to smooth the credit cycle and prevent excessive credit booms emerging can be seen as one of the main reasons for having a macroprudential policy. Lim et al. (2011) argue that for the United States the cap on the leverage of banks was not even introduced for macroprudential purposes but rather to limit risks at the individual bank level. In Canada, the regulatory constraint on leverage has been in place since the 1980s and is mainly intended to reduce the overall leverage in the system (Bordeleau et al., 2009). It appears that prior to the crisis, the leverage cap was generally seen not as a macroprudential tool but primarily as a microprudential tool. I thus argue that the decision to implement caps on the leverage of banks is driven not by expectations about financial crises but rather by country characteristics such as institutional quality or a preference for a more stable financial system, though not all of these characteristics are necessarily observable. The two groups of countries might well differ in this important respect, but these potentially unobservable characteristics are exactly those which are captured by the difference-in-differences approach. To show the relevance of the difference-in-differences approach, and how it is meaningful, I will show the impact on the outcome variable of some key country-specific variables which are constant over time.[6]

It might still be that countries which had caps on leverage before the crisis were hit less hard by the financial crisis and thus also experienced a less pronounced fall

[6] As the impact of constant country-specific variables is absorbed in the baseline specification, I will use the correlated random effects approach (Mundlak, 1978; Wooldridge, 2010), which allows us to measure the impact of time-constant variables even in a fully specified fixed-effects regression.

in their credit growth rates. For this reason it will be important to test whether the country-specific severity of the financial crisis itself can explain the differential effect in post-crisis real credit growth as a competing explanation for the stabilising effect. The results will be shown in the section on robustness.

4.4 Estimation Results

4.4.1 The Stabilising Effect of Caps on Banks' Leverage

The specification for identifying the stabilising effect of macroprudential regulation on domestic credit to the private sector as presented in Equation (4.1) in Section 4.3.1 is estimated via OLS. Standard errors are clustered at the country level to account for heteroscedasticity and serial correlation of the errors (Bertrand et al., 2004; Petersen, 2009).

Table 4.3 shows the estimation results. The results give evidence of a stabilising effect on real credit growth from caps on banks' leverage. The point estimate in column 1 for the baseline specification suggests that the real credit growth rate was about six percentage points higher after the crisis for those countries that had a leverage cap prior to the crisis than for those that did not. The effect can be considered sizeable in economic terms given that the average real credit growth rate in the sample is 13.6 percent with a standard deviation of 16.4 percent. The estimated coefficient is statistically significant at the 1 percent level. The baseline specification includes the real GDP growth rate and the monetary policy rate in order to capture the stance of the macroeconomic environment. The positive and significant coefficients of both variables indicate that a better macroeconomic stance is related to higher credit growth. Therefore it appears reasonable to include both variables in the baseline specification. For comparison, I estimate the specification without additional control variables in column 2. This leads to an estimated effect of 8.9 percentage points, which is statistically significant but considerably higher. Furthermore, the finding of a stabilising effect also holds if I lag both macroeconomic variables by one period, as shown in column 3.

Table 4.4 shows that the result remains stable – both quantitatively and in terms of statistical significance – across the inclusion of different sets of time-varying control variables. Many of the control variables turn out to be insignificant and do not add to the goodness of fit measured by the R-squared. This is particularly so for the private credit-to-GDP ratio (column 2) and the index of macroprudential regulation by Cerutti et al. (2016), which captures the range of other macroprudential measures targeted at either borrowers or financial institutions (column 5). Controlling for other macroprudential policy instruments is necessary as those instruments might interact with each other in a non-trivial way in their effect on the credit supply from banks (Kashyap et al., 2014). The specification in column 6 additionally controls for the impact of a cap on leverage introduced after the crisis, though this does not appear to have a significant impact on real credit growth either. In addition, the occurrence of a banking or currency crisis negatively affects the real credit growth rate but does not interfere with the stabilising effect of the cap on leverage either (column 7).

4.4.2 The Role of Country-Specific Characteristics

The heterogeneity of characteristics across countries may influence both the decision to implement the leverage cap and the outcome variable, i.e. real credit growth. The fixed effects specification effectively controls for the impact of these variables, so it is key in identifying the desired effect of the leverage cap on real credit growth. Because it controls for both observable and unobservable country-specific characteristics, however, I cannot investigate the impact of time-constant observables any more. By using a correlated random effects model, we can still include time constant variables and detect their impact on the outcome variable.[7] The application of this approach gives an idea of those country characteristics that actually drive the results.

Table 4.5 shows the results. Column 1 is from a specification which includes the following time-constant country characteristics: the pre-crisis (2002-07) average of the real GDP growth rate; the monetary policy rate; and the credit-to-GDP ratio. The coefficient of the interaction term is the same as in the baseline case (column 1 of Table 4.3), which it should be for the method to be correctly implemented.[8] We see that a higher private credit-to-GDP ratio before the crisis is associated with lower real credit growth rates. Column 2 further indicates that a higher equity capital ratio for banks before the crisis is on average related to higher growth of real credit. In Section 4.4.3 it will be shown that this can be explained by the stabilising effect of pre-crisis capital on credit growth after the crisis. No significant effect is found for the pre-crisis deposit ratio. Interestingly, the dummy indicating whether a given country had a leverage cap before the crisis does not have a significant effect on real credit growth either, even though the point estimate is relatively large in absolute terms. Without over-interpreting the result, it can at least be said that it challenges the notion that

[7] The correlated random effects model goes back to Mundlak (1978). See Wooldridge (2010) for the case of an unbalanced panel. Technically, the correlated random effects model controls for fixed-effects by including all time-varying variables along with their group-specific mean over time. This identifies the same coefficients of time-varying variables as in the fixed-effects estimation but additionally allows time-constant variables to be included in the regression.

[8] The coefficient differs slightly in column 2 because it is based on a smaller estimation sample due to the limited availability of the control variables included.

the leverage cap was highly effective in reducing the build-up of a major credit boom before the crisis. The finding is in line with Cerutti et al. (2016), who do not find a significant effect on credit growth from caps on banks' leverage either when looking at the impact of individual instruments.

If we plausibly assume that a higher credit-to-GDP ratio or a higher equity capital ratio are important in the decision being taken to introduce a cap on leverage in order to mitigate the build-up of a potentially excessive credit boom, not including them in the regression would lead to a biased estimate of the effect of the leverage cap because we see from the regression that they clearly have an effect on the real credit growth variable. In sum, the illustrative evidence for the role of country-specific variables therefore supports the use of a difference-in-differences approach in the first place. This is because the method is effective in taking into account the potentially confounding influence on key pre-crisis differences of constant country characteristics.

4.4.3 Does the Effect Work Through the Pre-Crisis Capital Ratio?

One channel through which the stabilising effect of leverage caps might work is that after the crisis, banks might draw on capital buffers built up prior to the crisis. This would mean they do not have to cut lending due to deleveraging to the same extent as banks in countries that did not implement the regulation. I can investigate this channel empirically by interacting the pre-crisis capital ratio (*CapRatio*) with the interaction term of the baseline specification, and I additionally include all two-way interactions not captured by the fixed effects:

$$\begin{aligned} \Delta \ln \mathit{RealCredit}_{it} = & \alpha_i + \alpha_t + \beta_1 \left[D_{\text{PostCrisis}} \times D_{\text{LEV}} \right] + \beta_2 \left[D_{\text{PostCrisis}} \times \mathit{CapRatio}_i \right] \\ & + \beta_3 \left[D_{\text{PostCrisis}} \times D_{\text{LEV}} \times \mathit{CapRatio}_i \right] + x'_{it}\gamma + \varepsilon_{it} \end{aligned} \tag{4.3}$$

To make sure that I capture the capital ratio with which the banks in a given country entered the crisis, I take the average of the years 2006 and 2007.

Table 4.6 shows the result. The coefficient of the triple interaction term tells us that the stabilising effect is significantly higher for those countries in which the pre-crisis capital ratios of the banks are higher. The size of the stabilising effect that is dependent on the pre-crisis capital ratio is plotted in Figure 4.4 for the range of values observed for the pre-crisis capital ratios of the countries that had implemented the regulation.[9] We see that the stabilising effect does indeed increase with a higher capital ratio and is statistically significant for capital ratios of about seven percent and above. This gives strong support to the argument that the leverage cap is effective in making banks build up buffers before the crisis that then stabilise their lending after the crisis.

This finding is in line with Demirgüç-Kunt et al. (2013), who document how banks with lower leverage before the crisis showed on average a better stock market performance during the global financial crisis. Similarly, Berger and Bouwman (2013) show for the US that banks with a higher capital ratio perform better during banking crises.

4.4.4 The Effect on Total Asset Growth and the Contribution of Its Subcomponents

The results so far suggest that the pre-crisis implementation of the leverage cap stabilised credit to the private sector after the crisis. The next question is whether lending to the private sector was achieved through a general expansion of total assets or via a reduction of claims on other sectors of the economy. To answer this, I replace the dependent variable in the baseline specification with the total asset growth rate and decompose it into the contributions by various subcomponents, which are claims on the non-financial private sector (*PrivSecClaims*, as in the previous analysis); claims on non-residents; the central bank; the public sector; and financial institutions (*FinInstClaims*). The total asset growth rate is decomposed in the following way:

$$\begin{aligned} &\frac{TotalAssets_{it} - TotalAssets_{it-1}}{TotalAssets_{it-1}} \\ &= \frac{PrivSecClaims_{it} - PrivSecClaims_{it-1}}{TotalAssets_{it-1}} + \dots \\ &+ \frac{FinInstClaims_{it} - FinInstClaims_{it-1}}{TotalAssets_{it-1}} \end{aligned} \tag{4.4}$$

Total asset growth and its subcomponents on the right hand side of this equation are now used as dependent variables in the baseline specification. This procedure allows the way that the subcomponents contribute to the overall effect on total asset growth of caps on leverages to be quantified. As we are still in the difference-in-differences set up, the interpretation of the results is always relative to the countries without the

[9] The total effect is given by $\beta_1 + \beta_3 \times CapRatio_i$ and depends on the value of the pre-crisis capital ratio. The standard errors of the total effect cannot be read from the regression table. They are computed as $SE = \sqrt{var(\beta_1) + CapRatio^2 \times var(\beta_3) + 2\, CapRatio \times cov(\beta_1, \beta_3)}$ (see also Brambor et al., 2006).

leverage cap.

The results are shown in Table 4.7. Column 1 shows the effect of the leverage cap on total asset growth to be positive. Banks in countries with the leverage cap have on aggregate expanded their balance sheet by 4.5 percentage points more than have banks in other countries. The effect is statistically significant at the 10 percent level. Column 2 shows that credit to the private sector contributed the largest part to this overall effect, giving about 3.2 percentage points of the total of 4.5. From columns 3 and 4, we see that the relative increase in claims on non-residents and the central bank after the crisis also contributed positively to the overall effect on asset growth. In contrast, there was a relative decrease in claims on the public sector and financial institutions, which therefore negatively contributed to the overall asset growth (columns 5 and 6). In terms of statistical inference, only the contribution by the claims on the private sector is significant. The results suggest that claims on the private sector were by far the most important component of the overall credit provided to the economy.

4.5 Robustness

4.5.1 Competing Explanations

Some of the results from above suggest that a closer look is needed at the role of the financial cycle prior to the crisis. I must therefore check whether adjustment to the pre-crisis credit boom is a competing explanation for the effect I found. The reason for this exercise is that the pattern of real credit growth rates we observe is compatible with the story that those countries that did not implement macroprudential regulation were in the upturn of the financial cycle before the crisis and therefore saw their growth rates adjust accordingly afterwards. In this case, the observed effect would not have anything to do with macroprudential regulation but would rather reflect a standard adjustment to the pre-crisis credit boom. We can test for this alternative explanation by including the credit-to-GDP ratio from just before the crisis from the average of 2006 and 2007, and interacting it with the post-crisis indicator to check for the competing differential effect. As it turns out, however, the result is not significant and the initial stabilising effect remains strong, statistically and economically, as can be seen in column 1 of Table 4.8.

Another competing explanation might trace the development of post-crisis real credit growth back to the impact of the financial crisis and the severity with which it and the subsequent Great Recession hit those countries. As a consequence of larger losses in real output, credit might grow at lower rates in the following years. I use the drop in the GDP growth rate in the crisis year 2009 to measure the severity of the crisis and check its differential effect as part of the specification. As it turns out, the stabilising effect is limited quantitatively by this exercise, so the severity of the crisis might play a role (column 2 of Table 4.8). However, the severity of the crisis effect is not statistically significant itself and the stabilising effect of the leverage cap remains sizable in economic terms.

A further test of competing explanations involves the effect of the pre-crisis average from 2002-07 of the regulatory quality indicator provided by the Worldwide Governance Indicators database (World Bank) to test whether the differential effect on credit growth is driven by a higher level of regulatory quality. The results suggest that this is not the case either (column 3). The same holds true for the effect of a systemic banking crisis in 2007/08 measured as a dummy variable drawn from the database by Laeven and Valencia (2012, 2013) in column 4.

4.5.2 Subsample Analysis

The treatment group, consisting of the countries which actually implemented the cap on leverage, is relatively small at only eight in the baseline specification. To make sure that the results are not driven by the impact of one individual country, it is reasonable to check how robust the results are to the exclusion of one of these countries from the sample. This is done in Table 4.9. The results show that the effect varies somewhat in size but remains statistically significant no matter which country is excluded from the sample.

Table 4.10 presents the results from four additional robustness checks for different subsamples. There might be other macroprudential measures which affected real credit growth after the crisis, and therefore I estimate the effect using only countries in the control group which did not introduce any macroprudential regulation before the crisis. The results are shown in column 1. Another robustness check considers the subsample of emerging market economies only (column 2).[10] Then I narrow the estimation period down to the years 2005-12, dividing the period symmetrically into four pre-crisis and four post-crisis years (column 3). To check more carefully that the effect really captures the difference between the post-crisis and pre-crisis periods, I also exclude the explicit crisis years 2008 and 2009 from the sample (column 4). The clear picture that emerges from all of these robustness exercises is that the finding of a stabilising effect on real credit growth from caps on the leverage of banks after the crisis remains valid.

[10] I do not run the corresponding subsample analysis for the advanced economies because only two of them (USA and Canada) have a leverage cap.

4.6 Conclusions

The purpose of the study is to investigate empirically the effect of a cap on banks' leverage on credit growth after a financial crisis. The results give information on how macroprudential policy works with an instrument that is currently tested under the Basel III regulatory framework on banking supervision.

I approach the question by applying a difference-in-differences approach to a panel of 69 advanced and emerging market economies over the period 2002-14. I compare the growth rate of real credit before and after the crisis across groups of countries that had a leverage cap prior to the crisis and those that did not. The results show the leverage cap to have a stabilising effect on real credit growth. The stabilising effect is of about six percentage points. It is higher for countries with a higher aggregate bank capital ratio prior to the crisis. This finding is in line with the interpretation that the leverage cap made banks build up buffers before the crisis, which they could draw on after the crisis had hit to continue lending to the private sector. The stabilising effect on credit to the private sector was the most important part of a generally stabilising effect on the growth of banking assets after the crisis. The findings are robust to various robustness checks. In particular, the adjustment to the pre-crisis credit boom and the severity of the crisis can be ruled out as competing explanations.

A comprehensive analysis of the cost and benefits of the implementation of a cap on the leverage of banks is beyond the scope of this paper. Still, the results point towards a potentially stabilising role of such macroprudential policy instruments in financial downturns. This is a dimension of the overall effect of macroprudential policy that should be incorporated into a comprehensive cost-benefit analysis of the regulatory trade-off. In this sense, this study is complementary to existing empirical analyses because it highlights the ex-post rather than ex-ante dimension of macroprudential policy. This holds true in particular considering that even if macroprudential policy is effective in smoothing financial cycles, it might not be able to prevent future financial downturns and crises from happening after all. Therefore, the question of whether and through which channels macroprudential policy helps in stabilising the real economy during financial downturns remains an interesting area for further research.

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Appendix to Chapter 4

4.A Data

Domestic credit to the private sector: Data on credit to the private sector by resident banks are taken from the IMF Other Depository Corporation Survey, which is part of the International Financial Statistics (IFS). The series was complemented by the series on private credit-to-GDP ratios from the World Development Indicators (WDI) database, which was multiplied by nominal GDP. The credit series in local currency units was deflated using the yearly CPI index from the IMF IFS.

Macroprudential policy tools: The information on the implementation of the leverage cap and on other macroprudential measures (borrower and financial institutions-targeted macroprudential index) is taken from the dataset provided by Cerutti et al. (2016). The dataset is based on the Global Macroprudential Policy Instruments (GMPI) survey conducted by the IMF and can be accessed via the following link: http://www.imf.org/external/pubs/cat/longres.aspx?sk=42791.0

Macroeconomic control variables: Data are either taken from the IMF International Financial Statistics (IFS) or the World Development Indicators (WDI) by the World Bank (both databases accessed via Datastream). In detail:

- Real GDP growth rate (in %): Based on GDP in constant 2005 USD (IMF IFS).
- Monetary policy rate (in %): Based on the central bank policy rate. When this was unavailable, the money market rate was used instead. When that was also unavailable, the discount rate was used (IMF IFS).
- CPI inflation rate (in %): Based on the consumer price index taken from the IMF IFS.
- Private credit-to-GDP ratio (in %): Series on domestic credit to private sector (in % of GDP) taken from the WDI database.
- GDP per capita: The series in current international USD is taken from the WDI database.

Regulatory quality: The indicator ranges from -2.5 (weak) to 2.5 (strong) and is taken from the Worldwide Governance Indicator (WGI) database of the World Bank. See Kaufmann et al. (2011) for details.

(Systemic) banking crisis, sovereign debt crisis, currency crisis: The indicators are taken from the database by Laeven and Valencia (2012, 2013).

Aggregate balance sheet variables: The variables total assets and claims on the subsectors of the economy (non-financial private sector, non-residents, public sector (central plus state/local government), central bank), and the ratio of equity capital (position: shares and other equity) to total assets are taken from the Other Depository Corporation Survey, which is part of the International Financial Statistics (IFS) by the IMF.

4.B Figures and Tables

Figure 4.1: **Capital-to-assets ratio of banks 2002-14**
The graph shows the average capital-to-assets ratio (in %) of banks over 2002-14 for countries with and without a leverage cap prior to 2008. The vertical line indicates the start of the post-crisis period (2009). The sample is based on the estimation sample (69 countries). The capital ratios are winsorised at the 1% and 99% quantiles. Data source: IMF IFS.

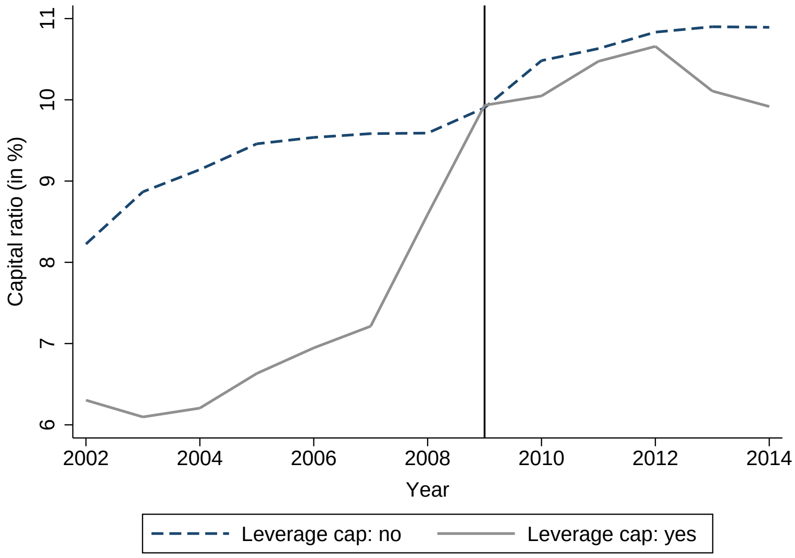

Figure 4.2: **Real credit growth rates 2002-14**
The graph shows the average growth rates of real credit (in %) over 2002-14 for countries with and without a leverage cap prior to 2008. The vertical line indicates the start of the post-crisis period (2009). The sample is based on the estimation sample (69 countries). The growth rates are winsorised at the 1% and 99% quantiles. Data source: IMF IFS.

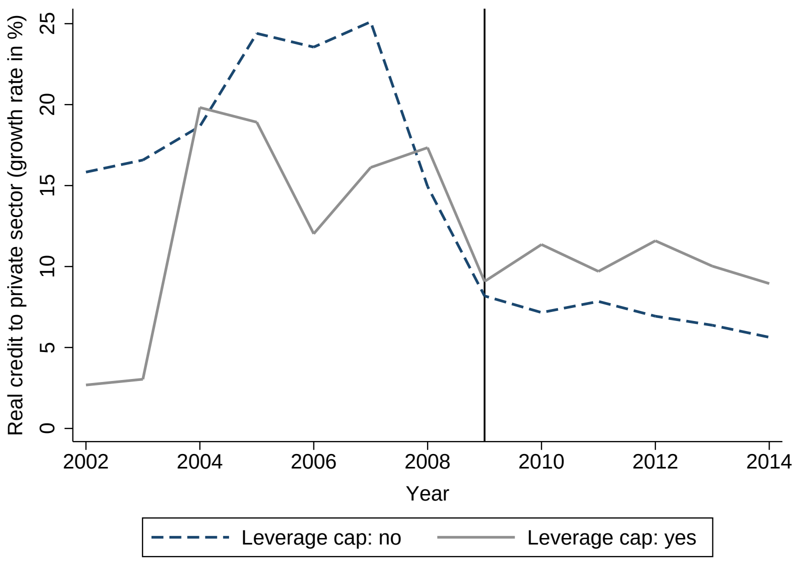

Figure 4.3: **Pre-treatment differential effects**
The graph shows the differential effect of caps on leverage on real credit growth in the three years preceding the post-crisis period (2006-08). Estimation is based on Equation (4.2).

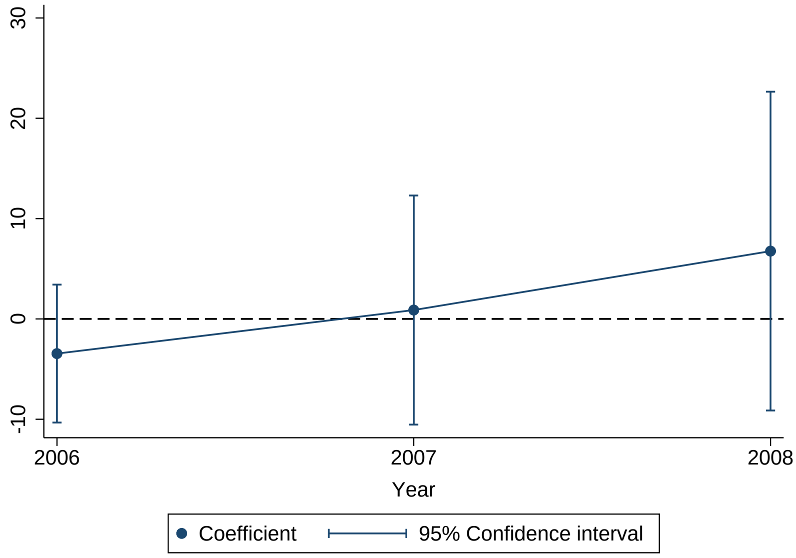

Figure 4.4: **The effect of the leverage cap on real credit growth conditional on the pre-crisis capital ratio**
The graph shows the effect of the leverage cap on real credit growth (solid line, measured on horizontal axis, in percentage points) for different values of the pre-crisis capital ratio (vertical axis, in %) based on the estimation results in Table 4.6. The estimates are surrounded by 95% confidence bands (dashed lines).

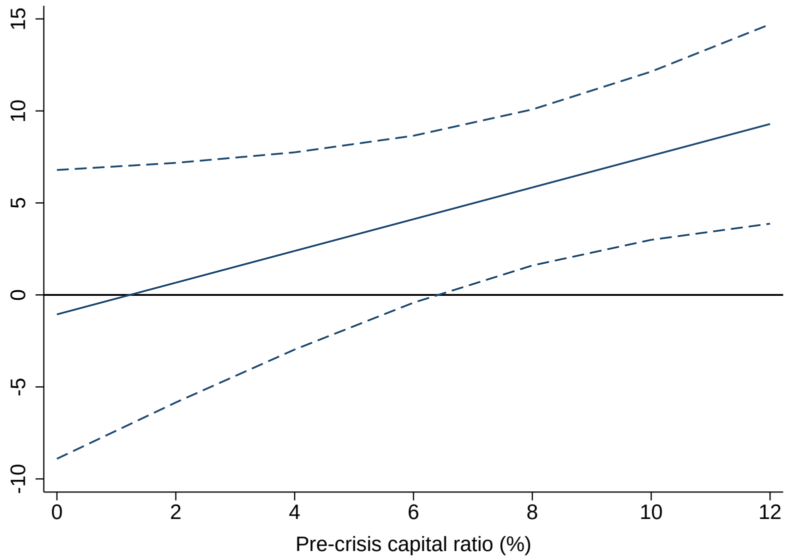

Table 4.1: **List of countries included in estimation sample**
The table shows the 69 countries included in the estimation sample. The upper panel shows the countries which implemented a cap on banks' leverage prior to the crisis of 2008 and the lower panel shows those that did not. The countries are grouped into advanced and emerging countries using the definition by the IMF (Cerutti et al., 2016; IMF, 2014).

	Advanced	Emerging	
Leverage cap: yes	Canada	Chile	Paraguay
	United States	Ecuador	Saudi Arabia
		Jordan	St. Kitts and Nevis
Leverage cap: no	Australia	Albania	Malaysia
	Austria	Algeria	Mauritius
	Belgium	Angola	Mexico
	Cyprus	Armenia	Morocco
	Czech Republic	Belize	Pakistan
	Estonia	Botswana	Philippines
	Finland	Brazil	Poland
	France	Bulgaria	Romania
	Germany	Cape Verde	Russia
	Iceland	Colombia	Serbia
	Ireland	Costa Rica	South Africa
	Israel	Croatia	Thailand
	Italy	Dominican Republic	Trinidad and Tobago
	Japan	El Salvador	Turkey
	Korea	Fiji	Ukraine
	Latvia	Georgia	
	Malta	Guyana	
	Netherlands	Hungary	
	Portugal	Indonesia	
	Slovakia	Kazakhstan	
	Slovenia	Kuwait	
	Spain	Lithuania	
	Sweden	Macedonia	
Total number	25		44

Table 4.2: **Summary statistics**
The table shows summary statistics for the dependent variable (growth rate of real credit to the private sector, in %) and the explanatory variables to be used in the empirical specification. The sample is based on the estimation sample following the baseline specification in the results section (69 countries, years 2002-14). All variables are winsorised at the 1% and 99% quantiles. See the Data Appendix for detailed description and data sources.

Variable	Country group	Observations	Mean	Standard deviation	Min	Max
Real credit to the private sector (growth rate, in %)	Leverage cap: yes	89	11.62	11.44	−14.10	60.74
	Leverage cap: no	730	13.81	16.86	−14.10	78.34
	Total	819	13.57	16.37	−14.10	78.34
Real GDP growth rate (in %)	Leverage cap: yes	89	3.87	3.35	−5.60	14.22
	Leverage cap: no	730	3.30	3.76	−11.77	18.23
	Total	819	3.36	3.72	−11.77	18.23
Monetary policy rate (in %)	Leverage cap: yes	89	4.56	3.40	0.13	15.36
	Leverage cap: no	730	5.95	9.97	0.08	150.00
	Total	819	5.80	9.49	0.08	150.00
CPI inflation rate (in %)	Leverage cap: yes	89	3.99	3.04	−0.73	14.99
	Leverage cap: no	730	4.77	7.01	−1.09	109.59
	Total	819	4.68	6.70	−1.09	109.59
Private credit-to-GDP ratio (in %)	Leverage cap: yes	89	53.39	28.57	14.62	134.99
	Leverage cap: no	725	65.06	40.55	4.20	172.41
	Total	814	63.78	39.57	4.20	172.41
GDP per capita (Thous. international USD)	Leverage cap: yes	89	23.09	15.98	4.78	54.63
	Leverage cap: no	730	20.29	14.02	2.86	76.89
	Total	819	20.60	14.27	2.86	76.89
Financial institutions-targeted macroprudential index (0–10)	Leverage cap: yes	82	3.01	1.31	1.00	5.00
	Leverage cap: no	677	1.38	1.27	0.00	6.00
	Total	759	1.55	1.37	0.00	6.00
Borrower-targeted macroprudential index (0–2)	Leverage cap: yes	82	0.34	0.57	0.00	2.00
	Leverage cap: no	677	0.34	0.63	0.00	2.00
	Total	759	0.34	0.62	0.00	2.00
Regulatory quality (-2.5–2.5)	Leverage cap: yes	89	0.30	0.88	−1.28	1.65
	Leverage cap: no	717	0.52	0.76	−1.49	1.92
	Total	806	0.50	0.78	−1.49	1.92
Banking crisis (0/1)	Leverage cap: yes	43	0.12	0.32	0.00	1.00
	Leverage cap: no	487	0.10	0.30	0.00	1.00
	Total	530	0.10	0.31	0.00	1.00
Sovereign debt crisis (0/1)	Leverage cap: yes	43	0.02	0.15	0.00	1.00
	Leverage cap: no	487	0.00	0.05	0.00	1.00
	Total	530	0.00	0.06	0.00	1.00
Currency crisis (0/1)	Leverage cap: yes	43	0.02	0.15	0.00	1.00
	Leverage cap: no	487	0.01	0.08	0.00	1.00
	Total	530	0.01	0.09	0.00	1.00
Capital-to-assets ratio (in %)	Leverage cap: yes	63	8.34	3.78	0.00	14.03
	Leverage cap: no	691	9.91	4.26	0.00	22.56
	Total	754	9.77	4.24	0.00	22.56
Deposit-to-assets ratio (in %)	Leverage cap: yes	63	55.93	9.67	39.19	76.98
	Leverage cap: no	709	47.50	17.55	10.22	79.26
	Total	772	48.19	17.19	10.22	79.26

Table 4.3: **Difference-in-differences regression**
The table shows the regression results of the main difference-in-differences regression based on Equation (4.1) for the period 2002-14. The dummy variable D_{LEV} indicates countries that implemented a cap on the leverage of banks prior to the crisis of 2008. The dummy $D_{\text{PostCrisis}}$ captures the post-crisis period and is equal to one from the year 2009 on and zero otherwise. The dependent variable is the rate of growth of real credit (in %). The number of observations varies according to the availability of control variables. All specifications include country-fixed and time-fixed effects. Cluster-robust standard errors at the country-level are given in parentheses. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively. All variables are winsorised at the 1% and 99% quantiles.

Dependent variable: Real credit growth (%)	(1)	(2)	(3)
$D_{\text{LEV}} \times D_{\text{PostCrisis}}$	6.029***	8.937***	5.889**
	(2.123)	(2.761)	(2.241)
Real GDP growth (%)	1.638***		
	(0.248)		
Monetary policy rate (%)	0.197***		
	(0.073)		
Real GDP growth (lag, %)			1.150***
			(0.207)
Monetary policy rate (lag, %)			0.284***
			(0.048)
Country FE	y	y	y
Year FE	y	y	y
Countries	69	69	69
Observations	819	819	817
R^2	0.38	0.28	0.34

Table 4.4: **Difference-in-differences regression: time-varying controls**
The table shows the regression results of the main difference-in-differences regression for different sets of time-varying control variables based on Equation (4.1) for the period 2002-14. The dummy variable D_{LEV} indicates countries that implemented a cap on the leverage of banks prior to the crisis of 2008. The dummy $D_{\text{PostCrisis}}$ captures the post-crisis period and is equal to one from the year 2009 on and zero otherwise. The dependent variable is the rate of growth of real credit (in %). The number of observations varies according to the availability of control variables. All specifications include country-fixed and time-fixed effects. Cluster-robust standard errors at the country-level are given in parentheses. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively. All variables are winsorised at the 1% and 99% quantiles.

Dependent variable: Real credit growth (%)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$D_{\text{LEV}} \times D_{\text{PostCrisis}}$	6.029***	5.943***	6.178***	5.889***	5.373**	6.028**	6.276**
	(2.123)	(2.065)	(2.129)	(2.118)	(2.322)	(2.382)	(2.862)
Real GDP growth (%)	1.638***	1.629***	1.643***	1.640***	1.562***	1.566***	1.492***
	(0.248)	(0.248)	(0.253)	(0.249)	(0.242)	(0.248)	(0.286)
Monetary policy rate (%)	0.197***	0.297	0.197***	0.166**	0.153**	0.176**	0.105
	(0.073)	(0.190)	(0.073)	(0.075)	(0.076)	(0.075)	(0.084)
Inflation rate (%)		−0.148					
		(0.281)					
Private credit-to-GDP (%)			0.012				
			(0.044)				
GDP per capita (log)				−8.814			
				(14.017)			
MacroPru index (fin. sector)					−1.808		
					(1.848)		
MacroPru index (borrower)					−2.054		
					(1.605)		
Leverage cap (0/1)						−4.585	
						(12.568)	
Banking crisis (0/1)							−5.693*
							(3.042)
Sovereign debt crisis (0/1)							8.712
							(8.559)
Currency crisis (0/1)							−18.379***
							(5.040)
Country FE	y	y	y	y	y	y	y
Year FE	y	y	y	y	y	y	y
Countries	69	69	69	69	69	69	62
Observations	819	819	814	819	759	759	530
R^2	0.38	0.38	0.38	0.38	0.37	0.37	0.35

Table 4.5: **Correlated random effects regression**
This table displays the estimation result of the correlated random effects specification which controls for time-fixed and country-fixed effects and includes constant country-specific regressors for the period 2002-14: the average over 2002-07 of the real GDP growth rate, the monetary policy rate, and the credit-to-GDP ratio. The average capital and deposit-to-assets ratio in the two years before the crisis (2006/07) are added in column 2 and the dummy variable D_{LEV} indicating countries that implemented a cap on the leverage of banks prior to the crisis of 2008 in column 3. The number of observations varies according to the availability of control variables. Cluster-robust standard errors at the country-level are given in parentheses. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively. All variables are winsorised at the 1% and 99% quantiles.

Dependent variable: Real credit growth (%)	(1)	(2)	(3)
$D_{\text{LEV}} \times D_{\text{PostCrisis}}$	6.029***	6.147**	6.029***
	(2.140)	(2.329)	(2.142)
Real GDP growth (%)	1.638***	1.624***	1.638***
	(0.250)	(0.278)	(0.250)
Monetary policy rate (%)	0.197***	0.202***	0.197***
	(0.073)	(0.073)	(0.073)
Avg. real GDP growth 2002-07 (%)	1.101**	1.050*	1.106**
	(0.514)	(0.619)	(0.514)
Avg. monetary policy rate 2002-07 (%)	0.043	0.245	0.060
	(0.363)	(0.417)	(0.363)
Avg. credit-to-GDP ratio 2002-07 (%)	−0.076***	−0.078***	−0.076***
	(0.017)	(0.017)	(0.017)
Avg. capital ratio 2006/07 (%)		0.260*	
		(0.154)	
Avg. deposit ratio 2006/07 (%)		0.003	
		(0.039)	
D_{LEV} (0/1)			−3.991
			(7.062)
Country FE	y	y	y
Year FE	y	y	y
Countries	69	61	69
Observations	819	746	819
R^2	0.54	0.54	0.54

Table 4.6: **The effect of the leverage cap on real credit growth conditional on the pre-crisis capital ratio**
The table shows the regression results of the main difference-in-differences regression augmented by an additional interaction of the interaction term with the pre-crisis capital ratio (*CapRatio*, average over 2006/07) based on Equation (4.3) for the period 2002-14. The dummy variable D_{LEV} indicates countries that implemented a cap on the leverage of banks prior to the crisis of 2008. The dummy $D_{\text{PostCrisis}}$ captures the post-crisis period and is equal to one from the year 2009 on and zero otherwise. The dependent variable is the rate of growth of real credit (in %). All specifications include country-fixed and time-fixed effects. Cluster-robust standard errors at the country-level are given in parentheses. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively. All variables are winsorised at the 1% and 99% quantiles.

Dependent variable: Real credit growth (%)	(1)
$D_{\text{LEV}} \times D_{\text{PostCrisis}}$	−1.059
	(3.923)
$D_{\text{PostCrisis}} \times CapRatio$	−0.368
	(0.349)
$D_{\text{LEV}} \times D_{\text{PostCrisis}} \times CapRatio$	0.862**
	(0.416)
Real GDP growth (%)	1.562***
	(0.282)
Monetary policy rate (%)	0.195**
	(0.081)
Country FE	y
Year FE	y
Countries	61
Observations	746
R^2	0.61

Table 4.7: **The effect of the leverage cap on total asset growth and the contribution of subcomponents**
The table shows the effect of the leverage cap on total asset growth of banks and its subcomponents for the period 2002-14. The dummy variable D_{LEV} indicates countries that implemented a cap on the leverage of banks prior to the crisis of 2008. The dummy $D_{\text{PostCrisis}}$ captures the post-crisis period and is equal to one from the year 2009 on and zero otherwise. The number of countries and observations varies according to the availability of the dependent variable. The dependent variable in column 1 is total asset growth (in %). The dependent variables in columns 2-6 measure the contributions of the respective subcomponent to total asset growth and are defined as the yearly change in that subcomponent relative to the total assets of the previous period (in %). The names of the subcomponents are given in the header of each column and comprise claims on the non-financial private sector, non-residents, the central bank, the public sector (central and state/local governments), and other financial institutions. All specifications include country-fixed and time-fixed effects. Cluster-robust standard errors at the country-level are given in parentheses. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively. All variables are winsorised at the 1% and 99% quantiles. The decomposition effects in the first row of results do not exactly add up to the total effect in column 1 due to missing data on some components and winsorising.

Dependent variable: Change in claims subcomponent relative to total assets of previous period	(1) Total Assets	(2) Private Sector	(3) Non-residents	(4) Central bank	(5) Public sector	(6) Financial institutions
$D_{\text{LEV}} \times D_{\text{PostCrisis}}$	4.559*	3.205**	1.367	0.565	−0.076	−0.462
	(2.476)	(1.570)	(0.854)	(0.752)	(0.507)	(0.414)
Real GDP growth (%)	1.016***	0.690***	0.118	0.111	−0.012	0.035*
	(0.272)	(0.127)	(0.074)	(0.090)	(0.009)	(0.020)
Monetary policy rate (%)	0.244***	0.075**	0.101***	0.095***	0.001	0.003
	(0.032)	(0.033)	(0.009)	(0.016)	(0.003)	(0.003)
Country FE	y	y	y	y	y	y
Year FE	y	y	y	y	y	y
Countries	66	66	66	66	65	66
Observations	761	761	761	739	748	761
R^2	0.33	0.33	0.33	0.33	0.33	0.33

Table 4.8: **Robustness: competing explanations**
The table reports the results of the baseline specification for the period 2002-14 augmented by the interaction term of the post-crisis indicator and i) the pre-crisis credit boom variable (measured as the average credit-to-GDP ratio over 2006/07) in column 1, ii) the severity of the crisis (measured as the drop in the 2009 GDP growth rate) in column 2, iii) regulatory quality (measured as the average of the regulatory quality indicator taken from the World Bank's Worldwide Governance Indicators database over 2002-07) in column 3, and iv) the indicator of a systemic banking crisis in 2007/08 based on the database by Laeven and Valencia (2012, 2013) in column 4. The dummy variable D_{LEV} indicates countries that implemented a cap on the leverage of banks prior to the crisis of 2008. The dummy $D_{\text{PostCrisis}}$ captures the post-crisis period and is equal to one from the year 2009 on and zero otherwise. The dependent variable is the rate of growth of real credit (in %). All specifications include country-fixed and time-fixed effects. Cluster-robust standard errors at the country-level are given in parentheses. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively. All variables are winsorised at the 1% and 99% quantiles.

Dependent variable: Real credit growth (%)	(1)	(2)	(3)	(4)
$D_{\text{LEV}} \times D_{\text{PostCrisis}}$	6.250***	5.256**	6.450**	5.408***
	(2.250)	(2.371)	(2.610)	(1.963)
Pre-crisis credit boom $\times D_{\text{PostCrisis}}$	0.011			
	(0.032)			
Severity of crisis $\times D_{\text{PostCrisis}}$		−0.461		
		(0.433)		
Regulatory quality $\times D_{\text{PostCrisis}}$			2.512	
			(1.759)	
Systemic banking crisis $\times D_{\text{PostCrisis}}$				−5.103
				(3.160)
Real GDP growth (%)	1.633***	1.541***	1.576***	1.632***
	(0.245)	(0.257)	(0.239)	(0.241)
Monetary policy rate (%)	0.193***	0.205***	0.150*	0.209***
	(0.070)	(0.075)	(0.089)	(0.069)
Country FE	y	y	y	y
Year FE	y	y	y	y
Countries	69	69	68	69
Observations	819	819	806	819
R^2	0.38	0.39	0.38	0.39

Table 4.9: **Robustness: excluding countries from treatment group**
The table shows the results of robustness checks based on the baseline specification over 2002-14. The country denoted in the header of each column was excluded in that regression. The dummy variable D_{LEV} indicates countries that implemented a cap on the leverage of banks prior to the crisis of 2008. The dummy $D_{\text{PostCrisis}}$ captures the post-crisis period and is equal to one from the year 2009 on and zero otherwise. The dependent variable is the rate of growth of real credit (in %). All specifications include country-fixed and time-fixed effects. Cluster-robust standard errors at the country-level are given in parentheses. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively. All variables are winsorised at the 1% and 99% quantiles.

Dependent variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Real credit growth (%)	Canada	Chile	Ecuador	Jordan	St. Kitts & Nevis	Paraguay	Saudi Arabia	United States
$D_{\text{LEV}} \times D_{\text{PostCrisis}}$	6.030***	6.026***	6.339***	5.420**	5.422**	5.012**	7.043***	6.790***
	(2.123)	(2.123)	(2.338)	(2.271)	(2.263)	(2.084)	(2.065)	(2.200)
Real GDP growth (%)	1.636***	1.640***	1.641***	1.648***	1.700***	1.627***	1.642***	1.638***
	(0.248)	(0.248)	(0.250)	(0.252)	(0.251)	(0.261)	(0.251)	(0.248)
Monetary policy rate (%)	0.198***	0.198***	0.198***	0.197***	0.198***	0.207***	0.197***	0.197***
	(0.073)	(0.073)	(0.073)	(0.073)	(0.072)	(0.065)	(0.074)	(0.073)
Country FE	y	y	y	y	y	y	y	y
Year FE	y	y	y	y	y	y	y	y
Countries	68	68	68	68	68	68	68	68
Observations	812	815	806	806	806	806	806	806
R^2	0.38	0.38	0.38	0.38	0.39	0.39	0.38	0.38

Table 4.10: **Robustness: subsample analysis**
The table shows robustness checks for various subsamples following the baseline specification. Column 1 shows the results of the specification which only includes countries as part of the control groups which did not implement any macroprudential policy measure prior to the crisis. Column 2 reports results for the subsample of emerging economies only. Column 3 reports results for the estimation period 2005-12. Column 4 reports results excluding the years 2008/09 from the estimation. The dummy variable D_{LEV} indicates countries that implemented a cap on the leverage of banks prior to the crisis of 2008. The dummy $D_{\text{PostCrisis}}$ captures the post-crisis period and is equal to one from the year 2009 on and zero otherwise. The dependent variable is the rate of growth of real credit (in %). All specifications include country-fixed and time-fixed effects. Cluster-robust standard errors at the country-level are given in parentheses. ***,**,* denote statistical significance at the 1%, 5%, and 10% levels respectively. All variables are winsorised at the 1% and 99% quantiles.

Dependent variable: Real credit growth (%)	(1) No MacroPru	(2) Emerging economies	(3) 2005-12	(4) Exclude 2008/09
$D_{\text{LEV}} \times D_{\text{PostCrisis}}$	7.800*	7.759***	6.191**	7.232***
	(4.145)	(2.598)	(2.720)	(2.353)
Real GDP growth (%)	1.223***	1.664***	1.625***	1.823***
	(0.257)	(0.301)	(0.227)	(0.297)
Monetary policy rate (%)	−1.013	0.211***	−0.194	0.231***
	(0.741)	(0.066)	(0.177)	(0.070)
Country FE	y	y	y	y
Year FE	y	y	y	y
Countries	24	44	69	69
Observations	275	529	521	689
R^2	0.41	0.39	0.43	0.40

Concluding Remarks and Outlook

In the wake of the global financial crisis, many countries have updated their regulatory framework. This thesis has contributed to the research on financial stability and to the ongoing debate on regulatory reform.

Chapter 1 of the thesis analyzed credit risk co-movements in sovereign debt markets during the financial crisis and the subsequent euro area sovereign debt crisis. In addition, it investigated to what extent high co-movements might be the outcome of contagion and through which channels contagion occurs. There were two main findings. First, credit risk comoved considerably, in particular among euro area countries and during the sovereign debt crisis. Second, there is evidence that contagion occurred through both fundamental and non-fundamental channels.

Chapter 2 assessed the impact of uncertainty on banks' loan supply. The results showed that higher uncertainty in banking negatively affects bank lending. This negative effect is alleviated for banks that are better capitalized and hold more liquid assets. The effect is also less pronounced for banks in more financially open countries, whereas it seems to be unaffected by the ownership status of the bank (domestic *versus* foreign-owned).

Chapter 3 studied how liquidity provided by the Eurosystem affected internal adjustment in European periphery countries after the crisis. The key result which emerged from this analysis was that Eurosystem liquidity provision lowered the adjustment in real unit labor costs and real wages, and led to lower price increases in sectors that are more financially vulnerable.

Chapter 4 investigated if a macroprudential policy instrument, caps on banks' leverage, stabilizes bank lending during financial downturns. The main finding of the study was that caps on banks' leverage indeed have a stabilizing effect on real credit growth during financial downturns. The channel through which this stabilizing effect works is that banks subject to the leverage cap can draw on higher capital buffers which they have built up before the crisis.

In sum, the findings of this thesis can provide useful insights for the ongoing regulatory debate. One general conclusion is that there is a rationale for both short-term policy measures in response to a crisis and long-term regulatory reform.

The finding of non-fundamentals based contagion in sovereign bond markets calls for short-term policy measures in response to a crisis that are able to affect investors' expectation and for rescue mechanisms which can provide immediate support. The non-standard monetary policy measures by the ECB and the implementation of the European Stability Mechanism (ESM) might be seen in this light.

Another conclusion is that short-term policy responses to a crisis might have unintended consequences. In the euro area, it was first and foremost monetary policy that alleviated the immediate and adverse effects of the sudden stop in private capital inflows due to the crisis. However, such a policy response can have unintended consequences. Financial institutions might rely on the enhanced liquidity provided by the central bank also in the medium to long term if international capital markets continue not to work properly. This in turn might lead to a delay in necessary macroeconomic adjustment. This thesis gave evidence that liquidity provision by the Eurosystem indeed affected macroeconomic adjustment over the medium and long term. The results point towards a general trade-off between mitigating a negative liquidity shock and delaying adjustment. The use of fiscal or macroprudential policies may reduce the need to rely on liquidity provision and relax this trade-off. In consequence, there is a need for coordination of policies internationally and within existing political and monetary unions.

A further implication is the relevance of the insights from microprudential regulation for a comprehensive macroprudential framework. The thesis showed that the negative impact of uncertainty is mitigated for banks with higher capital and liquidity holdings. Banks with a high loss-absorbing capacity and sufficient liquidity buffers are likely to contribute to the stability of the financial system as a whole. Therefore, an updated regulatory framework should not only seek to establish new instruments but also to build on existing microprudential tools to achieve macroprudential goals. This in turn supports the new rules relating to bank capital and liquidity requirements under Basel III, the implementation of a leverage ratio in addition to the minimum risk-weighted capital ratio, and the use of new instruments.

Moreover, this thesis argues for long-term policies and a sustainable framework of financial regulation. The thesis showed that weak economic fundamentals and cross-border bank linkages might increase the vulnerability of a country to sudden shifts in investors' sentiment. This finding indicates a need for policies that address weak economic fundamentals. At the same time, it provides a rationale for supervising banks at the supranational level in order to oversee their activities across borders. An important step in this respect was the implementation of the Single Supervisory Mechanism (SSM) in the euro area. In addition, the creation of new rules for bank resolution under the Single Resolution Mechanism (SRM) are useful to break the link between sovereigns and banks through the removal of explicit and implicit government guarantees.

Furthermore, many countries have updated their regulatory and supervisory structures, which now incorporate the use of macroprudential policy. The findings of this thesis imply that a comprehensive regulatory framework should take into account the potentially stabilizing (or destabilizing) effect of any macroprudential instrument especially during financial downturns. Referring to previous conclusions, macroprudential policy should be coordinated with other policies such as monetary and fiscal policy at the national and international level. In addition, complementarities and inconsistencies between the macroprudential and the microprudential sphere of banking supervision should be taken into account.

This thesis focused on the key insights from the financial crisis and the economic consequences of actual policies. Consequently, less emphasis was put on the benefits such as improved risk-sharing possibilities that are likely to arise from economies being more financially integrated. Regulation and policies should be designed in a way that they address market failures and externalities but do not attenuate the benefits from financial integration. A badly designed regulation might undermine market discipline or prevent financial institutions from providing their key intermediary function, that is, from efficiently allocating funds to productive investments. Another issue is that the effectiveness of regulation might be impaired by gaps in the regulatory perimeter. Entities such as shadow banks might shift their activities to unregulated parts of the financial system putting them at the risk of fragility. While these challenges were not discussed in this thesis, they certainly are interesting avenues for further research.

In conclusion, it is important to develop further understanding of how effective different policies and new regulations actually are and how they interact with each other. This is particularly important because international financial markets are subject to continuous change, and the sources of future financial fragility might yet be unknown. Therefore, academic research and policy analysis should keep accompanying the regulatory debate.