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ESSAYS ON THE EURO ZONE SOVEREIGN DEBT CRISIS AND FINANCIAL MARKETS

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Essays on the Euro zone Sovereign Debt Crisis and Financial Markets

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Chapter 1

Sovereign debt crisis and financial markets

1.1 Introduction

A sovereign debt crisis is generally linked to the perceived inability of a country to pay its public debt. A country's public debt is considered sustainable when government budget constraints can be met without disrupting the country's monetary and fiscal policies. This implies that the amount of public debt should not exceed the present value of all future primary surpluses. Government's borrowings usually exceed the capacity to repay when a country reaches critical high debt levels and suffers from low economic growth.

The euro zone sovereign crisis was prompted by the financial crisis started in 2007 that lead to a reassessment among investors of asset prices, growth prospects and sustainability of large external deficits in the euro area. That was particularly the case for periphery countries that displayed high macroeconomic imbalances. In these countries, the reassessment determined a private credit outflow, tightening of credit and troubles on the national banking systems. Governments were forced to step in and to increase their budgets. For those countries that were already experiencing high levels of debt that created additional concerns about their sustainability. Countries like Greece, Ireland and Portugal first, Spain and Italy then, started to report increasing levels of public debt and rising bond yields in government securities. As a consequence these countries were facing rising bond yields spreads *vis-à-vis* the rest of the union intensifying the internal imbalances.

At the same time, the periphery sovereign's troubles translated into new banking sector problems at the euro area level as the credit tightening linked to sovereign default risk perceptions impeded the well functioning of the common monetary policy.

Much of the existing literature on sovereign debt crisis focused on their national dimension. However, there is an important difference between countries that control their own monetary policy and those that instead belong to a currency union. The firsts can always count on their central banks behaving as lender of last resort in case of troubles on their sovereigns. The governments of these countries can always force the central bank to buy the government securities and avoid default, the main problem being a possible increase in inflation.[1] In a currency union instead, governments loose their ability of issuing debt over which they have full control. In the euro zone, the European Central Bank for instance is prevented by its statute from acquiring debt securities issued by member countries. Missing a lender of last resort financial markets become very powerful as liquidity problems can force these countries' sovereigns into default.

The present thesis aims to study the euro zone sovereign crisis from a macroeconomic perspective with a focus on the interaction between sovereign risk, financial markets and the real economy at the euro area currency union-wide level.

A vast body of research recently focused on the periphery country dimension of the sovereign debt crisis. On the one hand the literature looked in depth at sovereign bond yields spreads and contagion. Credit risk, liquidity risk and risk aversion proved to be the three main sources of risk determining the behaviour of sovereign yields with respect to the benchmark bond, normally the one of Germany. On the macroeconomic dimension, debt levels and current account imbalances were found to be the main drivers of the yields together with general risk aversion and financial uncertainty.

On the other hand,[2] the literature on sovereign risk and banking focused on the transmission of the sovereign's turmoil to banks and ultimately to the real economy. Empirical studies conducted at the national level, in periphery countries, highlighted two channels of transmission: the bank capital and

[1] However if this privilege is used to maintain a budget deficit that leads to demand that is excessive with respect to the economy's productive capacity for too long, the resulting increase in prices would have disastrous economic and social consequences.

[2] Additionally a vast part of the literature focuses on fiscal policy and sovereign debt crisis. In this thesis we completely abstain from its study.

collateral channel. These studies reported an increase in lending rates driven by the higher sovereign interest rates. The theoretical literature explored extensively the role of bank's balance sheet showing that the greater is the default risk, the weaker are the bank's balance sheets. The key idea is that sovereign default risk raises the funding costs of the private sector because of the increase in the costs of financial intermediation. However, in the euro zone, the banking sectors of the different countries are tightly linked via the interbank markets and are characterised by high cross-border exposure to sovereign debt. In this environment the increased costs of intermediation and the reduction in credit not only affect the periphery countries but their effect transmits also to the core region.

The contribution of this dissertation is to go beyond the periphery dimension of the euro area sovereign debt crisis and to provide a comprehensive study of the determinants of the behaviour of euro area asset markets and of the union-wide banking sector's transmission role.

From an empirical point of view, the contribution of this thesis is the use of a comprehensive approach to study in depth the relation between sovereign bonds and equity markets in the euro area. This comprehensive approach allows to discover patterns between assets and countries that would be otherwise neglected. For instance relative imbalances between the core and the periphery of the euro zone and balance of payments dynamics played a major role for the behaviour of these markets, not only for bonds, as highlighted in the previous literature, but also for stocks. Moreover, this thesis attests the driving role of macroeconomic variables before and during the sovereign debt crisis for the behaviour of asset markets, as opposed to the debated view in the literature of a change in investor's perceptions on the economic situation.

From a theoretical point of view, the contribution of this thesis is to develop a two-country DSGE framework, as opposed to closed-economy models as those used in the literature on sovereign debt, wherein to explain the role of the banking sector in the transmission of the sovereign risk within the union. One of the main results suggests that the banking sector and, in particular the banking structure, is the key for the transmission of sovereign default risk within the euro area. The study of the different degrees of banking integration further suggests that a well integrated banking sector reduces the negative consequences of sovereign default at the euro area level.

Another finding shows that financial intermediaries are also determinant for the transmission of other sources of shock within the union and, ultimately, for the behaviour of asset markets. Without credit constraints, asymmetric shocks in the union imply asymmetric impacts on the core and periphery asset markets. The existence of credit constraints at the international bank level prompts more synchronization in asset markets' responses and a more homogeneous sharing of the effects of shocks between countries. This consequently affects the behaviour of asset markets at the euro area union-wide level. The ignorance of such relation was a relevant missing bloc in the open economy financial macroeconomics DSGE literature.

1.2 Overview

This dissertation consists of three chapters, all of them are self-contained works that are presented following the chronological order of development during the period of the Ph.D of the author.

The first part of the thesis consists of an empirical study on the euro zone asset markets. Chapter 2 is a joint work with Wessel Vermeulen that studies the macroeconomic determinants of the behaviour of euro zone asset's markets. It computes and analyses the dynamic comovements of stock and bonds for the core and the periphery of the euro zone focusing on the geographical and asset dimension of the markets. This comprehensive approach allows to shade new light on European financial markets with respect to studies that focus at only one dimension. The cross-country panel regressions highlight the importance of macroeconomic variables and of the heterogeneity in fundamentals between the core and the periphery of the union but not a primary role for investor's change in perceptions on the economic situation. The regressions confirmed the importance of variables like relative inflation, stock market uncertainty, economic growth differentials and policy rate and additionally, they find a significant impact for balance of payments-related variables. Results suggest that further economic integration would be desirable but that, at the moment, Europe is a tale of two regions.

The second part of this dissertation consists of two chapters dealing with the modelling of the euro zone financial markets and the study of the international transmission of shocks. Chapter 3 is a joint work with Olivier Pierrard. It focuses on the international transmission of sovereign debt default and looks at the spillover from the periphery to the core. The shock is mainly transmitted to the other region via financial intermediaries and in particular via the bank balance sheet channel and the collateral channel.

The study of different degrees of banking integration suggests the desirability of more banking integration for the euro area welfare. The policy analysis, on the one hand reinforces the recent debate on the need of counter-cyclical requirements in order to reduce output volatility; on the other hand, it shows that extending the Taylor rule to target sovereign spreads does not really allow to reduce output and inflation volatility. In general, for any policy, the welfare costs of stabilising the economy are much lower under a well integrated banking sector.

Chapter 4 develops a new theoretical framework useful to study the behaviour of euro zone financial markets. It expands the model of Chapter 3 by introducing international equity markets. This framework allows to explore, for the first time in the literature, the relation between financial intermediaries and asset markets for the euro zone. Results point to the key role of this interaction as a driver of the time varying stock-bond correlation. Thank to this general equilibrium model, by looking at the correlation on the equity and sovereign bond markets, it is possible to detect the sources of shocks that hit the euro area. For instance, a technology shock determines a negative correlation on the stock-bond market; a financial expectation shock a positive one and a sovereign risk shock an heterogeneous behaviour of periphery and core stock-bond markets as highlighted in Chapter 2.

Chapter 2

Macro-economic determinants of European stock and government bond correlations: A tale of two regions[1]

2.1 Introduction

In the first decade following the introduction of the Euro, Euro-zone financial markets showed an increasing degree of integration and of economic and financial convergence.[2] This showed up both in the equity and sovereign bond markets. With respect to the latter, it appeared that differences in current accounts, balance of payments, debt ratios and growth rates were

[1] This chapter is based on Perego and Vermeulen (2013).

[2] See for instance Kim et al. (2006), discussed further below. Just before the crisis broke, the European Commission celebrated the 10 year anniversary of the euro with the publication of a booklet that documents the "macroeconomic stability" and "financial integration" that resulted from the monetary union. Joaquín Almunia, Commissioner for Economic and Monetary Affairs, wrote: "[F]or the world, the euro is a major new pillar in the international monetary system and a pole of stability for the global economy." (European Commission, 2008, p. iii).

not captured by the markets.[3] However, after the revelation of the Greek financial mis-report and the beginning of the sovereign debt crisis at the end of 2009, the differences in fundamentals showed up in bond spreads as fears of southern countries' defaults mounted. One well-known piece of evidence at this point was the flight-to-quality from southern countries' bonds towards their "risk-free" northern counterparts. Instead the equity markets did not suffer such a strong flight-to-quality between countries but suffered from higher volatility. Starting from those two observations, this work studies the dynamic correlations of the bond, stock and bond-stock markets of the Euro-zone and tries to test their relations with the evolution of the macroeconomic determinants before and during the recent crisis.

Understanding the time varying behaviour of the stock and bond correlations and which factors affect their development is of primary importance for investors as well as for policy makers. Asset allocations and risk management directly rely on the correlation between a portfolio's assets, where negative correlations across regions and assets offer opportunities for diversification and for the hedging of risks. Moreover, a well-functioning financial market is crucial for the wider economy. Since stocks and government bonds account for a dominant share in all traded financial assets as well as in banks' balance sheets, the determinants of such comovements become of interest for regulatory and monetary authorities as well. In particular, macroeconomic determinants of stock and bond returns correlations, such as inflation, economic growth and balance of payment indicators can provide useful information for monetary policy on the status of financial markets and the expectations of investors. In addition, it is essential to understand the role of macroeconomic determinants, which include fiscal variables, in order to implement optimal policies at the national level and their coordination in the Euro-zone. Since the spreading of the financial turmoil and the sovereign debt crisis in the Euro-zone, European countries started showing divergent macro-financial behaviour, which triggered concerns about the preservation of the single currency.

While the previous literature has focused on the stock, bond and stock-bond market categories separately, assessing the role of macroeconomic determinants at the national level (see Section 2.2), this work studies the three categories in the Euro-zone in a new way by analysing all the relations

[3]Besides economic indicators, there are institutional (e.g. government setup, health and elderly insurance) and sociological (e.g. participation rate, demography) differences that are highlighted now but were of little concern before.

simultaneously. This general approach to financial markets enables us to highlight patterns between assets and countries that would otherwise remain hidden and ignored, thereby giving important insights on the European financial integration. Therefore, we will pay attention to the differences within the Euro-zone. Specifically, for the estimations we do not consider the European Monetary Union (EMU) as one economic unit but -with the benefit of hindsight- we divide our sample of Euro-zone countries in two groups (north and south) and proceed in two steps.

First, for each country pair and asset combination we compute the time-varying dynamic conditional correlations (DCC) using the Engle (2002) methodology, which has proved a useful methodology to reflect relations among markets. By grouping together the correlation pairs at the asset-region level we study six categories of correlations: cross-asset for both regions, cross-region for both assets and cross asset-region correlations (i.e. north-bond south-stock and north-stock south-bond).

In the second step we conduct a panel study to find the macroeconomic determinants of the six pairwise correlations. Theory predicts differentiated impacts of macroeconomic fundamentals based on cash flow determinants, risk determinants and the interaction of the two.[4] We will analyse to what extent the impact of such determinants have changed since the European debt crisis. This method allows us to look at all country-asset relations simultaneously and show how macroeconomic factors affected these relations differently.

We find that the division between north and south helps to visualise the divergence in the Euro-zone for the cross-asset correlation and subsequently helps to explain the underlying determinants of such divergence. The disintegration of the bond market over time is clearly leading to the heterogeneous effects on the other asset markets. Additionally, our regression results show that the correlations are mostly driven by two factors: the relative uncertainty between countries and balance of payments dynamics, represented by the current account and government debt. We find that the balance of payments dynamics are not only important for the difference in the pricing of bonds between countries, but even for the stock markets. However, current account dynamics appear of secondary importance once we control for other economic fundamentals and unobserved fixed effects. Moreover, we find no evidence that the results are driven primarily by a

[4] E.g. Campbell and Ammer (1993), Ilmanen (2003) and Li (2002), discussed further below.

change in investors' perceptions on the economic situation, but that the variation in economic fundamentals can explain most of the development of markets' comovements. For instance, we find that relative imbalances between the northern and southern European countries have a major impact on the correlations, not only in the sovereign bond market, but also in the stock market.

We interpret these results as a potential risk for the Euro-zone, but not as indicators of irreversible developments. The results confirm that there is heterogeneity among the Euro-zone members with respect to their economic fundamentals, which is in turn reflected in the financial markets. However, the way these determinants interact with the correlation in financial markets indicates that further economic integration and growth would work positively on financial integration although, for the moment, our results indicate that the Euro-zone is a divided union.

To our knowledge this is the first work that looks at the time-varying correlations of bond, stock and bond-stock markets jointly and at their determinants, directing attention to the different patterns for the northern and southern countries of the Euro-zone. In this way we extend the existing literature by combining the rising sovereign bond market literature with the well-documented stock-bond factor pricing and international stock market convergence literature for the Euro-zone, and we shed new light on their interaction.

The remainder of the chapter is set out as follows: Section 2.2 reviews the literature, Section 2.3 estimates the asset market correlation and documents the DCC results, Section 2.4 presents the panel regressions and Section 4.6 concludes.

2.2 Related Literature

We will work with dynamic conditional correlations as a measure of market relations. Such correlations can be interpreted as a measure of interdependence and integration, but a careful discussion on that is beyond the scope of this chapter. Nevertheless, the general observation is that markets with very similar fundamentals both in terms of supply and demand dynamics will be positively correlated. While there is a wide literature on assessing the international (as well as European) correlations of equity and bond markets as distinct entities, the literature on the cross-asset correlations has gained momentum only recently.[5,6] The literature in this field moved in two directions: one investigating comovement in the cross-asset market and attesting the asymmetric nature of stock and bond market conditional variances and a second strand trying to introduce economic variables in order to determine the factors driving the bond-stock market correlation.

Strictly belonging to the first category and employing a DCC model, we have the studies of Scruggs and Glabadanidis (2003) and de Goeij and Marquering (2004) on the stock-bond correlation in the US. Both studies find a time-varying relation in conditional covariances. Scruggs and Glabadanidis (2003) find that bonds respond symmetrically to bond shocks and are "unaffected" by stock returns' shocks while stock variance responds asymmetrically to both stock and bond returns' shocks. De Goeij and Marquering (2004) highlight the asymmetric leverage effect in the conditional covariances: stock-bond covariances tend to be relatively low after bad news in the stock market and good news in the bond market.

Cappiello et al. (2006) add to the previous papers both in terms of methodology -by introducing an asymmetric dynamic conditional correlation model- and sample selection as they include European, Australasian as well as North American markets using data from 1987 to 2002. Regarding the Euro-zone they found an almost perfect correlation among bond yields after the introduction of the monetary union as well as an increased correlation of the stock returns in the Euro-zone. Regarding the degree of correlation of the stock-bond market, they attest a stable and positive long-term relation before and after the introduction of the single currency.[7] Nevertheless, they found evidence of a "flight-to-quality" effect, defined as a move of capital from equities to safer assets in times of financial turmoil.

With respect to the second direction of research, on the determinants of comovements, the work of Kim et al. (2006) is the closest to our approach, studying the integration across the bond and stock markets within the Euro-zone as well as Japan and the US. Their attention is focused on the introduction of EMU and its effect on the within-market financial integration as well as the interdependence between financial markets. They

[5]A good survey for works dealing with the European stock market integration but using different methodologies can be found in the literature review of Kim et al. (2005). For a review on the sovereign bond integration see Laopodis (2008, 2010).

[6]Throughout the chapter we refer to sovereign bonds simply as bonds. In no part of this chapter do we consider the corporate bond market.

[7]The correlation of the EMU bond returns and the American and Australasian stock returns moved from slightly positive to slightly negative with the breaking point in 1999.

find that real economic integration and the absence of currency risk leads to financial integration, e.g. intra-bond and intra-stock markets integration. However, monetary policy convergence may have created uncertainty about the economic future of the European monetary union thereby stimulating a segmentation, e.g. a small but negative correlation between stock and bond markets. Their time horizon spans from March 1994 to September 2003. We employ data on the Euro period (2000-2012) on a selection of Euro-zone bond and stock markets. Our results confirm the segmentation of these markets until the fall of 2008. We show that by differentiating among European regions and by taking into account cross-asset relations, a different pattern of correlations in European markets appears since the start of the European debt crisis.

Kim et al. (2006) also look for the determinants of stock-bond correlations within countries given macroeconomic variables that are linked to open economies such as exchange rate volatility. Nevertheless, they find only marginal effects for the monetary variables. We extend their analysis by taking into account more macroeconomic variables that are potentially capturing the different price factors. Secondly, we test the determinants in a panel of across countries-assets correlations as opposed to within-country correlations.

Andersson et al. (2008) conduct a similar estimation for the within country stock-bond correlations regressed on national economic variables such as inflation, GDP growth and stock market uncertainty. They find that macroeconomic variables can only explain a small part of the variation in correlations.. Finally, Li (2002) develops a theoretical foundation to support his estimation of dynamic stock-bond correlations regressed on uncertainty and inflation factors. In one of his tests he uses a dynamic conditional correlation model on a panel of G7 countries taken as individual cross-section observations.

Concerning intra-bond market analysis two studies we relate to are Barrios et al. (2009) and Caggiano and Greco (2012). These studies test the bond spread of each country relative to the German Bund with certain risk factors such as the market perceived risk of defaults and liquidity risk as well as macro financial variables. Caggiano and Greco (2012) in addition test for a change in the determinants between periods and find several financial variables to become more important during the crisis.

Concerning the international stock-market integration there have been many studies. Kim et al. (2005) apply the same strategy as for their later article between bonds and stocks. Using real economic and financial variables they try to explain dynamic correlations and find that the financial variables are the best explanatory factors in their within-country setup. Bracker et al. (1999), while using a different measure for countries influence on each other, use a similar cross-country setup as we do where all countries in the data set are compared to each other with relative and difference variables such as relative exports and imports and the difference of inflation and real interest rates.

While the previous empirical studies attempt to find the determinants of comovements of assets limiting themselves to one of the three categories, bond-stock, bond-bond and stock-stock, we argue that it is essential to analyse all the categories of correlations in the Euro-zone simultaneously.

Our work also builds on the prediction in the theoretical literature of well-known asset pricing models as well as on new literature that attempts to incorporate the behaviour of these assets into general equilibrium models.[8] The idea is to use the most appropriate environment to assess all (general equilibrium) effects of specific policies (in particular monetary policy) and variables on the comovements of the returns. Moreover, this work builds on two-country general equilibrium models for the Euro-zone that highlight the (negative) role of imbalances within the Euro-area for the real economy and the subsequent need for coordination.[9] Unfortunately most of the models developed so far either focused on the closed economy dimension of the correlation between stocks and bonds -disregarding the impact of sovereign risk on it- or studied the role of imbalances and sovereign risk on the real economy but not on the bond-stock correlation specifically.

2.3 Estimating Comovements

In this section we introduce the data and present the results of the estimation of the dynamic conditional correlations that will be used for the panel regressions in Section 2.4. In order to study the properties of the Euro-zone equity and government bond returns we use a multivariate dynamic conditional correlation model by Engle (2002). These dynamic correlations are specified and estimated in two steps: first an univariate estimation is computed for all series; secondly, while using the standardised residuals from

[8] See Campbell et al. (2013) for review.

[9] See among others Roeger and in 't Veld (2013), Brzoza-Brzezina et al. (2013), Badarau et al. (2013) and Fagan and Gaspar (2009).

the first stage, a multivariate estimation results in the dynamic conditional correlations. Statistical properties of the data and details on the estimation of the DCC model are presented in the appendix 2.A and 2.B.

2.3.1 Data

Our empirical analysis is conducted on a sample of 11 European countries, which have belonged to the Euro-zone since the beginning of the common currency area and thus have been in the same institutional-monetary framework during the entire time span of 2000-2013.[10] We will group the countries into northern countries–Germany, France, Belgium, Finland, Austria and the Netherlands–and southern countries–Greece, Ireland, Italy, Portugal and Spain.[11]

The data used for this study are indices for stocks and bonds taken from Datastream. For equity we employed the MSCI price indices while for bonds the 10 years benchmark DS government indices. Daily data is collected on the sample period spanning from 3 January 2000 until 30 October 2013. We have then a total of 3608 observations per series.

As usual stock returns are more volatile than bonds, positively skewed and with a relatively high degree of kurtosis.[12] Between regions the stock returns do not indicate differences between the two regions. In contrast, bond

[10] Among the founding members Luxembourg is excluded and Greece, which joined the Euro-zone in 2001, is included in the sample. Luxembourg is the smallest economy among the founding members and used to be in a monetary union with Belgium before, while the availability of data is more limited. Greece is a major subject in the European debt crisis and joined the Euro relatively soon so that it has a comparable environment with the other countries in the sample.

[11] We do not provide a formal test for our allocation of countries to regions. Note that the 'southern' countries were often bundled together in the popular media in the acronym PIIGS, which is perhaps more appropriate since Ireland is geographically not located in the south of Europe. The descriptive statistics of the bond markets provide a basis for the division of regions. A recent IMF study uses a similar division (Jaumotte and Sodsriwiboon, 2010), while they group Ireland in the north for its positive current account balance. In our division, countries that belong to the 'south' have all been "net debtors" under the threat of bail out as in Chen et al. (2013). One can find similar divisions in the literature on financial markets during the European debt crisis (e.g. Schmitz and von Hagen, 2011; Grammatikos and Vermeulen, 2012) The problem is not so much in bundling the north, but rather in bundling the south. The economic situations that exist in each of them are not the same and treating them as such may obscure this fact. Nevertheless, since we aim to find general patterns between regions and we will control for each country's situation the problem is mitigated.

[12] See for details the appendix 2.A.

returns indicate severe differences in the standard deviation and skewness between northern and southern bonds. Indications of such a differentiated market for European bonds was absent from previous studies (e.g. Cappiello et al., 2006) and it is a signal of a strong change in performance behaviour since the spreading of the (sovereign bond) crisis.

2.3.2 Dynamic Conditional Correlation Estimation

We estimate a $k \times k$ DCC Multivariate Garch model, with $k = 22$.[13] We specify and estimate the model in two steps following the methodology described by Engle (2002). For the univariate regression we use a Garch specification common to all the series. However, some series need some additional pre-processing steps in order to take care of the different volatility regimes that characterise the euro area stock and bond market.[14] For the multivariate regression we estimate the $k \times k$ correlation matrix of all the possible pairwise correlations. By doing so we force the parameters of the DCC to be common between all the pairwise correlations.[15] Finally, although the DCC is estimated on daily data we average the results at quarterly frequency in order to continue the study at a frequency compatible with macroeconomic variables.

2.3.3 Dynamic Conditional Correlation Results

We will graphically present the results divided in different categories, considering the country-asset subgroups at the aggregate level. Data are grouped at the country-asset level as follows: North-stock (Ns), North-bond (Nb), South-stock (Ss), South-bond (Sb). The main six categories we study are the within region cross-asset markets (Ns-Nb, 6×5 correlations, and Ss-Sb, 5×4 correlations), the cross-country markets (Ns-Ss, 6×5 correlations, and Nb-Sb, 6×5 correlations) and the cross-region cross-asset correlations

[13] This is the dimension of the full correlation matrix composed by the 11 countries for the two assets.

[14] All these procedures as well as further details on the data are presented in the appendix 2.B.

[15] Note that for the panel regressions we do not use all the resulting correlations, notably we exclude the asset correlations within the same country. As an alternative, we estimated pair-wise dynamic correlations, allowing for different DCC-parameters for each correlation, and use these for the panel regressions. Appendix 2.D indicates that there is no qualitative difference in the regression results relative to our benchmark.

(Ns-Sb, 6×5 correlations and Nb-Ss, 6×5 correlations).[16] For the purpose of presentation, we aggregate the resulting 20 or 30 pairwise correlations for each category using a weighted average, where the weights are given by the stock market capitalisation for stock returns and the government gross liabilities for the bond returns. For both assets we used the reference value of the year 2002 to avoid having the weighting measures correlating with the return series.[17] For each category we plot this weighted mean and a band representing the minimum and maximum in Figure 2.3.1.[18]

These dynamic correlations show an interesting picture of market movements of stock and bond returns between the two regions. There is one obvious case: the inter-bond market. In panel (1) a process towards perfect correlation of the European government bond market is visible since the launch of the Euro. This is in line with the findings of previous and longer-sample studies attesting to a drastic increase in the correlation of the Euro-bond markets since the introduction of the common currency. It shows that around the first half of the decade government bonds all over the Euro-zone were considered to be equally risky and almost perfect substitutes, although small differences in the levels of the yields remained. Previous studies are in support of the idea that the introduction of the common currency lead to increased correlation both in the bond and stock market.[19]

Since the beginning of 2008 this pattern in the bond market reversed dramatically as it became apparent that southern economies were major affected by the financial crisis and were at risk of default. Credit agencies downgraded and investors revalued Southern bonds in line with the underlying risk. The correlation between northern and southern bonds started to decrease, becoming negative in the last two years. The drop in correlation from approximately one to zero or negative values, shows clearly the period in which the southern bond market behaviour detached from the northern one. This is in line with the widening of the Euro-zone sovereign bond yield

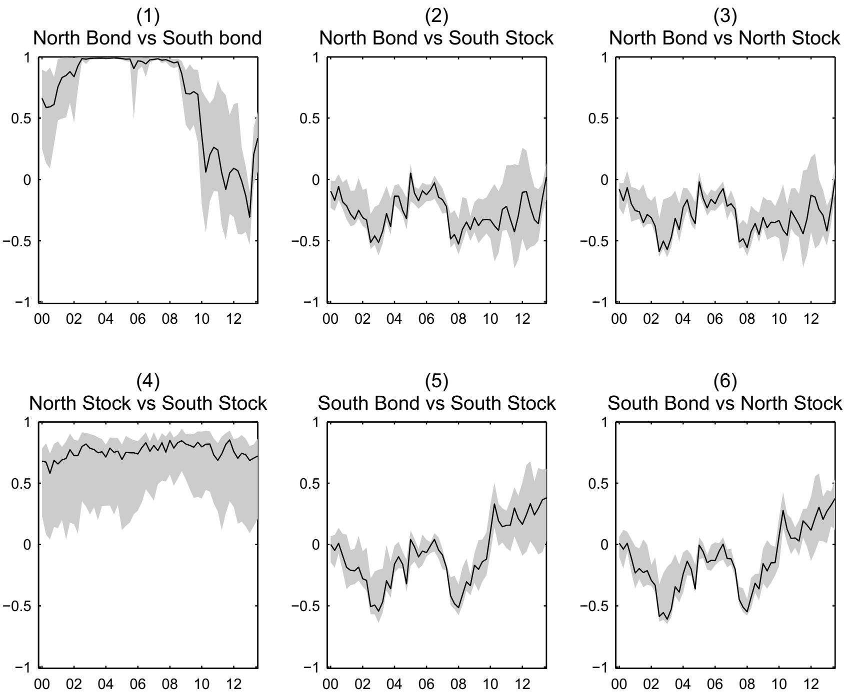
[16] We do not consider the within asset-within region categories Nb-Nb, Ns-Ns, Sb-Sb and Ss-Ss. Additionally, we exclude correlations between stocks and bonds for the same country, which is why the number of correlations series for Ns-Nb and Ss-Sb is $6 \times (6-1)$ and $5 \times (5-1)$ respectively.

[17] Stock market capitalisation was obtained from Standard & Poor's Global Stock Markets Factbook and gross government liabilities figures come from the OECD.

[18] Plots on the daily frequency are presented in appendix 2.B.2.

[19] Among others Cappiello et al. (2006) considers the period between the 1950's and 2003. Kim et al. (2006) show a similar striking increase in correlation in the European bond market studying the period 1994–2003.

Figure 2.3.1: Quarterly Weighted Dynamic Conditional Correlations



Weighted average dynamic correlation series based on 30 country-asset pairs for each category (panel) except for South-stock South-bond where there are 20 pairs. The weights are constant over time and based on stock market capitalisation and gross government liabilities figures for 2002. Shaded areas denote the minimum and the maximum for every category at each point in time.

spreads (Deutsche Bank, 2009; ECB, 2008, 2009), and consistent with the view of de Grauwe and Ji (2012) on the mis-pricing of sovereign risk within the Euro-zone.

We interpret the correlations plots as evidence for a similar reaction across assets and across regions. For this reason we look at the correlations between stock and bond returns across the two regions. Looking at panels (3) and (5) of Figure 2.3.1 jointly we can observe the change in the within-region cross-asset correlations. Up until mid-2008 the pattern is similar in the two pictures showing a business cycle-like behaviour remaining in the negative part of the correlation distribution. This is in line with Kim et al. (2006)

and their findings of a negative correlation between bond and stock within the Euro-zone.

From mid-2008 onwards there is a divergence in the pattern of the southern and northern stock-bond markets. In contrast to previous studies, once we control for geographical blocs we find evidence of an increase in correlation in the southern stock-bond market. It indeed seems that markets based on geography started to react differently to common information as if there were not two categories of assets but more. While in the north the correlation remains negative, the southern countries' correlations increase ending up to be positive. The increase in correlation between southern bonds and stocks can be explained by a joint selling of these assets against a third (safe) one.

The same pattern is visible in the comparison of panels (2) and (6) where the two bond markets are compared to the other region's stock market. It seems that the divergence between the patterns is due to the change in the performance of the southern bond market as shown in panel (1). This cross-area cross-asset comparison shows how after 2008 there was a change in the conditional correlation not only in the southern area stock-bond market but also at the cross regional level. What used to be considered a safe asset (southern bond) started to co-move with the northern stock; a generally perceived more risky market. In other words the safe asset in the 'risky' area became more correlated with the risky asset in the 'safe' area. Similarly, although the bands appear to have narrowed shortly around 2008, there is not much indication that the relations changed structurally.

The inter-regional stock market in panel (4) does not show any of the dramatic changes that are observed in the other panels. The stock market was, and remains, highly correlated as given in the graph. There were some minor drops during the crisis but not significantly lower values than in other periods.

The next step is to study the drivers or determinants of these correlation dynamics.

2.4 Estimating Determinants

2.4.1 Estimation Technique

We present regression results to understand the behaviour over time of the six correlation categories. There is one major difference in the way we set up our regressions compared to the literature discussed before. Studies on bond-stock correlations often have one regression per cross-section, using SURE, or separate OLS or time-series regressions. One of the implications of such strategy is that each estimated coefficient is allowed to differ across the cross-section, which may be an appropriate assumption, and failing to recognise such heterogeneity when it is true would lead to potential biases (Baltagi, 2008).

Our choice of fixed coefficients for the cross-section is supported by the selection of countries. Arguably each country must be treated on its own merits but the same fundamentals should apply in the broader context of the European economy. Since we control for pair- and time-fixed effects we control for most of pairwise and time varying unobserved effects that could be correlated with the regressors. Secondly, a separate estimation for each cross-section demands more from the time-dimension of the data. This would require us, like in other studies, to use much more data, and in particular data from before the monetary union which is a very different European context indeed. Using a higher frequency is not preferable, because many of the economic variables are available at no higher frequency than quarterly. For the same reason, we average the DCC series of the previous section over each quarter in order to match the other data.

Studies on the determinants of correlations of the same asset between countries often use one benchmark country. We present cross-country panel regressions where each cross-section is a pair of two countries for a given set of assets. This setup allows us to have a fairly robust inference of what might be the fundamental economic determinants that drive the correlations over time as opposed to obtaining country specific elasticities. Nevertheless, the dynamic correlations are strongly correlated over the pairs, in the same way as stock and bond returns show a strong correlation at the cross-section (at least at the regional level) and so do the pairwise dynamic correlations. However, the pairwise macroeconomic fundamentals may be widely different. It is this heterogeneity that we exploit in order to find the main determinants of the correlations series. Therefore, the combination of the panel construction using pairwise analysis and the inclusion of time- and pair-fixed effects allows us to analyse the role of economic fundamentals very precisely and independently of outside shocks. For instance, the fixed effects will control for such shocks as news on the state of the world economy and EMU integration and policy discussions at the EU level.

The regression models may be summarised as follows,

$$\tilde{\rho}_{i,j,t,p} = \gamma_p \tilde{\rho}_{i,j,t-1,p} + \boldsymbol{\beta}'_p \mathbf{x}_{i,j,t-1,p} + \boldsymbol{\alpha}'_{ij,t,p} + \varepsilon_{i,j,t,p}, \tag{2.4.1}$$
$$\text{for } i,j = 1,\ldots,20/30 \text{ and } i \neq j;\ t = 2000q2,\ldots,2013q3;$$
$$p = \{\text{Nb v Sb, Ns v Ss, Nb v. Ns, Sb v. Ss, Nb v. Ss, Ns v. Sb}\};$$
$$\text{where } \tilde{\rho}_{i,j,t,p} = \frac{1}{2}\log\left(\frac{1+\rho_{i,j,t,p}}{1-\rho_{i,j,t,p}}\right).$$

The dependent variable, $\tilde{\rho}_{i,j,t,p}$, is the Fischer transformed correlation for each country pair, i, j, for each quarter, t, and each category, p. The original correlation series are bounded between minus one and one, but the Fisher-transformed series are unbounded.[20] The model includes a lag dependent variable to capture the dynamic transition of the lagged independent variables, $\mathbf{x}_{i,j,t-1,p}$.[21] The set of independent variables is discussed below. We use lagged versions of all the independent variables in order to ensure that the coefficients are not affected by reverse causality.[22] The consequence is that regressors might also pick up part of the expectations of the past quarter that are formed by realisations of the past data, which are subsequently used for decisions in the asset markets.

The parameter $\boldsymbol{\alpha}'_{ij,t,p}$ represents the fixed effects included for each regression. All regressions include cross-section fixed effects, meaning a time constant dummy for each country pair. It is possible to use a different set of cross-section dummies, namely country specific fixed effect, resulting in two sets of country dummies. However, the pair-fixed effect captures more variation and principally controls for relative pair relations such as distance, historical, financial and trade links and financial integration between any two

[20] A Panel unit-root test, taking into account cross-dependence, using methods developed in Pesaran (2004, 2007) indicates no evidence for a unit root in any of the correlation series, see appendix 2.C.

[21] Lagged dependent variables are subject to Nickel-bias, since the lag-dependent variable is by construction correlated with the error term. However, the bias decreases with the time span, and in our case the average time span of 50 periods would imply a very limited bias. More critically, unbiased estimators that have been developed depend on cross-section asymptotics and small time-span and hence are not particularly fit for the dataset at hand where the time span is much larger than the cross-section (Baltagi, 2008, p. 148).

[22] The correlations are averaged over the quarter, whereas market participants may have daily updated information on these statistics. Information on these correlations early in the quarter may affect macroeconomic variables later in the same quarter. For instance, a decrease in the correlation early within a quarter, may trigger portfolio rearrangements which in turn affects stock-market volatility and possibly government responses.

countries that a double set of country dummies does not necessarily control. In the second specification we also include a cross-section fixed set of time dummies for which we use the combination of quarter- and year-dummies.

Each equation p is separately estimated over a panel of 20 or 30 country pairs over about 54 quarters.[23] Since we only look at cross-country effects we do not include in any of the results those observations that come from the same country.[24]

A constant set of independent variables, $\mathbf{x}_{ij,t-1,p}$, is used in each regression and obtained from Datastream at a quarterly frequency. For this reason the dependent variable -which was calculated at the daily frequency- is averaged over each quarter window. The independent variables are as follows,

$$\mathbf{x}_{ij,t-1,p} = [dInfl_{i,j,t-1}\ rVol_{i,j,t-1}\ dDebt_{i,j,t-1}\ dCa_{i,j,t-1}\ dG_{i,j,t-1}\ Rate_{t-1}]'.$$

The variables are meant to capture the current market situation and general macroeconomic conditions. The difference of inflation rates between two countries, $dInfl$, is used often in the literature to capture the fact that bonds are more sensitive to inflation than stocks. Uncertainty is measured through the ratio of the respective stock market volatilities, $rVol$. We use the realised stock variance series from the initial return series as a measure of this uncertainty. The government budgetary health is measured by its relative debt position, $dDebt$, the absolute difference of the countries' debt-to-GDP figures. In the same way, the current account measures a country's net external asset position, dCa, capturing the sustainability of the public and private development. Differential in economic growth, dG, is another important factor in explaining the difference in stock and bond performance as well as correlations of bonds and stocks between countries.[25] Since all the countries in our sample are in the Euro-zone there is no nominal exchange rate risk and all countries face the same benchmark rate captured in $Rate$, which is the policy rate of the ECB.

[23]Data of independent variables is missing for some of the more recent periods for some countries. Therefore the dataset is not perfectly balanced. Only the category "South stock v. South bond" has a cross-section of 20, all the others have 30.

[24]For instance, for the "North Stock v. North Bond" case we exclude the within country correlation. They could be easily included but all the independent variables that are represented as ratio or difference would be without variation and hence not explain anything.

[25]We use GDP growth, rather than GDP/capita growth, assuming that not only productivity growth matters for financial performance but also the size of the market, which may be affected by population movement including labour migration.

The selection of the variables is partly based on general economic theory and empirical findings in the literature. With the discussion of the results, section 2.4.2 will briefly review the literature for each category, recalling what was found before and what can be expected from theory. Previous studies, such as those mentioned above, occasionally let their selection of regressors be guided by theory. For instance, for models concerning bonds versus stocks, there are clear predictions on the signs of cash-flow/growth variables (negative as stocks tend to benefit more from economic growth than bonds), inflation indicators and monetary policy (positive, as such factors affect the discount factor of both securities in the same way).[26] Other studies may present a search for variables that give empirical results. In general, basic macroeconomic variables are expected to play a role on the correlations of the general country-asset indices at the frequency and time-span we use. Such channels, namely those related to real economics, monetary measures and risk, therefore appear with the set of variables above. However, not all variables in each regression would be expected to have necessarily a significant explanatory power. Other variables were tried as well, such as the relative government budget deficit, the unemployment rate, forecasting variables (e.g. expected inflation) and different measures of the same variables (difference instead of ratios and *vice versa*). The ones we present give intuitive and consistent results.

We keep the set of variables fixed between the regressions for two reasons. Firstly, the set of variables are sufficiently general that they can be expected to play a role for each correlation, especially since we are looking at relatively tight economic union at the medium- to long-term horizon. A more short-term outlook would require a much greater emphasis on liquidity and credit related indicators. Secondly, we find that variables that are not generally predicted to play a role in fact do, and the other way around. For expected results, including additional variables made little difference. For completeness, we keep the set of variables fixed for all the regressions.

The combination of the pair fixed effects and time dummies will make the (adj.-)R^2 of any regression high, but it is not immediately clear what fraction of the explained variance can be attributed to the other regressors. Therefore, a partial-R^2 is reported for each regression. This partial-R^2 is defined as the share of the explained variance that is orthogonal to the unobserved fixed effects.[27]

[26] See further Section 2.4.2

[27] The partial-R^2 is calculated in two steps. First regress the $\tilde{\rho}_{i,j,p,t}$ on the unobserved

Is there a structural break?

As discussed in the introduction, new awareness on the true state of Eurozone economies may have resulted in a fundamental change in the perception among investors. This may in turn explain the dramatic fall in the correlations of the bond markets as shown in Figure 2.3.1. In contrast, the panel setup of the estimation aims to explain the comovements of assets based on fundamental economic indicators. The question that remains is to what extent is there still a change in how countries' situations were perceived after controlling for the actual situation?

In order to test whether the fundamental variables explain the larger part of the story we can proceed in two ways. One is to include additional variables that may proxy for such expectations. Some studies have used implied volatility measures, volatility indices and other variables that may be correlated with investors' perceptions and therefore could function as approximations to investors' expectations. The limitations of such variables are their sparse availability for the cross-section we study and such variables may be very well correlated with fundamentals, in particular those we may have omitted.

A second method is to include a dummy for the crisis period, like the studies that included a dummy for the period where the EMU started (Cappiello et al., 2006). We allow this dummy to be interacted with each of the explanatory variables so we can capture the extent to which these variables changed their role in investors' behaviour. One could similarly split the sample in two sub-samples and estimate the regressions separately but the drawback of this procedure is that all parameters have to be estimated with half the observations. With the dummy procedure this loss is mitigated. The estimation equation becomes,

$$\begin{aligned} \tilde{\rho}_{i,j,t,p} &= \gamma_p \tilde{\rho}_{i,j,t-1,p} + \boldsymbol{\beta}'_p \mathbf{x}_{i,j,t-1,p} + \boldsymbol{\delta}'_p d_t \times \mathbf{x}_{i,j,t-1,p} + \boldsymbol{\alpha}'_{ij,t,p} + \varepsilon_{i,j,t,p}, \\ d_t &= \begin{cases} 1 & t \geq 2008q1 \\ 0 & \text{otherwise} \end{cases}. \end{aligned} \tag{2.4.2}$$

where $\boldsymbol{\delta}'_p$ are the coefficients on the independent variables interacted with the dummy variable, d_t, and everything else defined as before.

fixed effects (using the same sample as the full regression). Then regress the residuals of this regression on the unobserved fixed effects and the other regressors. The R^2 of the last regression is the partial-R^2.

The date of the structural break is based on the dynamic correlations series, such as those plotted in Figure 2.3.1. The break coincides with the start of financial crisis. It can be argued that the financial crisis was followed by a European debt crisis which may be dated to start around the first quarter of 2010. Although this may be true, it is interesting to see that the decrease in correlations in the European bond market started much earlier than 2010, although a negative spike in early 2010 is certainly visible in the plot. Secondly, we performed a test, based on the lm-statistic, to obtain the optimal date for the cross-section dummies, presented in appendix 2.G . This test suggests different dates for each category, where most dates are between 2008 and early 2010. Regressions with a dummy equal to 1 for $t \geq 2010q1$, presented in appendix 2.G, does not indicate substantial qualitative differences relative to our benchmark results.

If a coefficient in $\boldsymbol{\delta}_p'$ is significant, then it indicates primarily that the role played by the respective variable has changed from one period to the next. Such a change can be explained in two ways: on the one hand it could represent a re-interpretation by investors of economic fundamentals; on the other hand, we could also observe a significant coefficient for a variable if there is a non-linear effect of the fundamental variable on the dynamic correlation as opposed to the linear form we model here.[28] More importantly, if there is no significant coefficient on the interaction dummy, then neither is the case.

2.4.2 Panel Data Results

We present the results divided by asset market category. For each category, we first briefly review the relevant literature and then present the results.

[28]For instance, debt can be at a stable difference for two countries. Small changes in this difference over time may covary slightly with the correlation of the two markets of such countries. During the crisis, one of the countries could face more fiscal problems than another, for example by having to bail out a larger bank, which adds to the deficit and enters the debt ratio. Subsequently, investors respond to these developments and correlation of the markets, between those two countries, stops or reverses. This means that during the crisis, a large effect on debt causes a large effect on the correlation, while there was no similar change in the ratio in the non-crisis period. The estimator will likely not distinguish between what is due to the oversized change in the fundamental and what is due to the supposed change in perception of the relevance of the ratio to investors. In conclusion, only if we assume that the size of the change in the ratios does not affect the marginal effect on correlation can we assume that a significant coefficient on the interaction variable indicates that the underlying ratios has regained (or lost) some relevance.

Estimations, in every table, follow the same sequence of model specifications: 1) only pair fixed effect, 2) pair and time fixed effects, and 3) inclusion of crisis indicators.[29]

Standard errors are computed by bootstrap to account for the use of the estimated dependent variable and they are robust to heteroskedasticity, serial correlation and cross-section correlation in the errors. Note that for the explanatory variables, when concerning north and south, the southern country is the numerator for ratios and the first variable in differences. In case of within region estimation, the stock country is first.[30]

Bond market

The literature on the European bond market correlations is very modest while there is a vast production on the assessment of government bond spreads determinants. Spreads and correlation are indeed closely related as an increase in spreads normally determines a decrease in correlation. Even if the two variables are not the same measure, we refer to this literature as the benchmark for our estimation and comparison. Previous studies focused both on the effect of liquidity related factors on yields at high frequency data and the effect of credit risk based on macroeconomic fundamentals at lower frequency.

Codogno et al. (2003) study the determinants of EMU yield spreads on the period 1999-2002. With a dataset at a monthly frequency they find that differences in debt-to-GDP ratios have no significant effect on relative asset swap spreads when considered separately, but become significant when interacted with international risk variables. They find that international risk factors dominate liquidity risk factors and suggest that interest rate risk factors rather than debt-to-GDP affected yield differentials.

Barrios et al. (2009) study the period between 2003-2009. Their empirical evidence highlights the importance of international factors, such as general risk perception, but also to a smaller extent domestic factors, such as a deteriorating financial outlook. More interestingly for the low-frequency case

[29] In appendices 2.D, 2.E and 2.F we present panel estimations based on different underlying criteria of the DCC estimation, realised correlations and a joint system-estimation of all the six regressions respectively. All the results presented below are echoed in these alternative specifications.

[30] For instance, for the case if between regions and a variable x for each country belonging to the S(outh) or the N(orth), $rx = x_S/x_N,\ dx = x_S - x_N$. In the case of within region but between two assets s(tock) and b(ond), $rx = x_s/x_b,\ dx = x_s - x_b$.

are the statistically significant coefficients of macroeconomic fundamentals on the spread. Among others, fiscal conditions and the current account have a strong impact on government bond yield spreads. In particular fiscal balance and current account surpluses decrease the spread, while debt tends to increase it even if not in a linear way.[31] Using data from debt at-issuance, Schuknecht et al. (2010) find that yields increase with debt ratio and budget deficits, and that these factors also played a role before the crisis.

More recently de Grauwe and Ji (2012) highlight the role of changes in perception of default risk in the Euro-zone. They focus their analysis on two macroeconomic variables: debt-to-GDP and current account. They find a significant and non-linear effect of debt on the spreads while they do not find any significant effect of the current account. Moreover, they find evidence of a structural break around the year 2008 with respect to debt-to-GDP and its non-linear effect.

For the choice of our variables we mainly focus on credit risk in order to determine the impact of macroeconomic variables (as opposed to liquidity). Debt sustainability depends firstly on expected budget surpluses or deficits which is in turn determined by future economic activity and the interest rate. Secondly, the current account is a good indicator for measuring the overall asset position of the economy. The inflation differential could be expected to play a role when there are widely diverging regional prices.

Table 2.4.1 presents the results with respect to the bond market correlation. Starting with the first column the correlation between bond markets seems to be determined by all the regressors. In particular a deterioration in the current account for a southern relative to a northern country decreases the correlation in line with the documented results on bond yield spreads, while an increase in southern inflation and GDP growth increases the correlation in the bond market.[32]

If European countries in the Euro-zone converge, the south must have, on average, a higher GDP per capita growth rate than the north. Such

[31] As Barrios et al. (2009) explain, countries with historically high debt levels might benefit from liquid bond markets, but suffered because of the reaction of financial markets if debt rose above a certain unsustainable threshold.

[32] By construction, the variable on current account, dCA is the difference between the southern and northern current account and it is almost always negative since the southern countries, except for Ireland, have generally a bigger current account deficit compared to the north over the time sample. Hence a positive sign in front of the coefficient should be read as a decrease of the correlation due to a worsening in the current account of the south with respect to the north.

Table 2.4.1: Bond market panel regressions

	Dependent variable: Dynamic Correlation		
	(1)	(2)	(3)
	1-way FE	2-way FE	Crisis
Lag Dependent	0.8831***	0.5990***	0.6187***
	(0.0123)	(0.0396)	(0.0378)
dInfl	0.0426***	0.0205	−0.0242
	(0.0114)	(0.0195)	(0.0209)
rVol	−0.1934***	−0.0812**	−0.0479
	(0.0574)	(0.0336)	(0.0550)
dDebt	−0.6380***	−0.3238***	−0.3064**
	(0.1431)	(0.1091)	(0.1220)
dCa	1.2989***	0.2308	0.3757
	(0.2148)	(0.1963)	(0.3106)
dG	0.0239**	0.0078	0.0275*
	(0.0109)	(0.0075)	(0.0142)
Rate	0.1179***	−0.2044***	0.0445
	(0.0178)	(0.0246)	(0.0483)
d × dInfl			0.0778***
			(0.0296)
d × rVol			−0.0809
			(0.0690)
d × dDebt			0.0392
			(0.0547)
d × dCa			−0.4886
			(0.3532)
d × dG			−0.0371**
			(0.0182)
d × Rate			−0.4793***
			(0.0630)
d			−0.9268***
			(0.2805)
Observations	1512	1512	1512
Number of pairs	30	30	30
Adjusted R^2	0.910	0.937	0.938
Partial R^2	0.911	0.449	0.463
Time dummies		yes	yes

Bootstrap based standard errors (100 reps.) in parentheses. Pair fixed effects always included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

favourable economic performance should lead to a further integration of the respective sovereign bond markets. Hence the positive sign of the GDP coefficient, which captures both GDP per capita and population growth rates, can be interpreted as the catching-up of the southern countries with the north.

Moreover, we see that relative financial uncertainty, as measured by the corresponding stock market volatility, decreases the correlation between the northern and southern bonds. Finally and intuitively, differences in sovereign debt between the regions decrease the correlations of bonds.

The other specifications show that only the debt and stock market volatility remain the most significant explanatory variables for the bond market correlations. Time fixed effects wipe out the effects of inflation, current account and GDP growth. The coefficients of the other variables are roughly halved while the standard errors remain roughly the same, making these coefficients fall out of the usual significance criteria. Only the coefficient on the policy rate changes in sign. Additionally, the fall of the partial R^2 between columns 1 and 2 indicate that the time-fixed effects control substantially for unobserved effects that are correlated with the regressors.[33]

If non-linear effects are present, as suggested by de Grauwe and Ji (2012) and Caggiano and Greco (2012), then allowing for different coefficients between the two periods for each variable could uncover non-linear or non-constant marginal effects. Column (3) shows that for debt there is no indication that there are such effects. Debt is still significant, while there appears no significant change in its elasticity for the crisis period. The coefficient in fact is positive, indicating the role of relative debt level might have decreased.[34] Although the coefficients on volatility appear individually not significant, a joint test of the two coefficients indicates that volatility remains an important determinant even when we control for the crisis dummy.

The interaction on ECB rate suggests that only since the crisis period

[33]The reason that in the first columns of the tables the partial-R^2 is occasionally larger than the adjusted R^2 is due to the fact that we take the normal R^2, rather than the adjusted, for the partial-R^2 calculation.

[34]In appendix 2.G, where the dummy starts in 2010, this coefficient is significant and halves the net effect of debt during the crisis, indicating that indeed relative debt levels have not become suddenly much stronger indicators.This finding can be explained by the observation that at the same time when southern countries faced their economic challenges, northern countries bailed out banks and gave guarantees to EU stability programs sharply increasing their own debt levels as well.

this variable helps to explain a convergence of correlations, because as the policy rate was lowered the negative coefficient indicates a net positive effect for the correlation. The coefficient on GDP is significantly positive for the core equation while significantly negative for the crisis period, causing the net effect to be close to zero. The crisis dummy itself indicates that the mean of the correlations decreased and appears to capture the largest part of the effect of the crisis. Notably, the role of debt is not changed in the crisis.

To summarise we find that debt and uncertainty in the financial markets are consistent explanatory variables for the comovement of the bond market prices. GDP growth appears to be related to comovement but has reversed effects in the two periods. Current account and inflation appear unrelated to the comovements of bonds.

Stock market

The literature on the comovements of European stock markets focused primarily on the determinants of integration after the introduction of the EMU. The attention has been devoted to evaluating the impact of exchange rates as the main driver of stock market comovements. In addition, various variables have been proposed as alternative drivers, especially those related to real economic convergence and monetary policy criteria. The idea is that asset returns reflect the business cycle to a certain extent. Having more synchronous business cycle means being more interdependent and prone to common shocks. From here studies address how shocks can be transmitted through economic variables, e.g. convergence in trade, dividend yields, GDP growth, interest and inflation rates.

Fratzscher (2002) found that the reduction in exchange rate volatilities and the convergence in GDP growth and monetary policy (correlation of inflation) resulted in Euro-area equity market integration. Hardouvelis et al. (2006) consider the process of EMU integration over the period 1992–1998 with a focus on currency risk. They find that both forward interest rate differentials and inflation differentials are statistically significant determinants of the degree of stock market integration in the Euro-zone. Interestingly, they find that in 1994, a period they characterise as determined by pessimism in Europe and a sharp increase in the global bond yields, the degree of integration reduced. Concerns about the ability of highly indebted governments to control budget deficits led to a widening in the interest rate spreads among

Table 2.4.2: Stock market panel regression

	Dependent variable: Dynamic Correlation		
	(1)	(2)	(3)
	1-way FE	2-way FE	Crisis
Lag Dependent	0.5827***	0.4018***	0.3838***
	(0.0215)	(0.0267)	(0.0266)
dInfl	−0.0381***	0.0008	−0.0156
	(0.0076)	(0.0087)	(0.0120)
rVol	−0.0608**	−0.1355***	−0.0922**
	(0.0275)	(0.0247)	(0.0368)
dDebt	0.3088***	0.1746*	0.1538
	(0.0413)	(0.0984)	(0.1131)
dCa	−0.8137***	−0.3331**	−0.7323***
	(0.1144)	(0.1336)	(0.2239)
dG	−0.0004	0.0236***	0.0165
	(0.0080)	(0.0076)	(0.0109)
Rate	0.0121*	0.0507*	−0.0176
	(0.0073)	(0.0289)	(0.0396)
d × dInfl			0.0283*
			(0.0152)
d × rVol			−0.1263***
			(0.0341)
d × dDebt			0.0210
			(0.0508)
d × dCa			0.6637***
			(0.1958)
d × dG			0.0075
			(0.0154)
d × Rate			0.1399**
			(0.0549)
d			−0.0894
			(0.1982)
Observations	1512	1512	1512
Number of pairs	30	30	30
Adjusted R^2	0.438	0.554	0.561
Partial R^2	0.495	0.354	0.363
Time dummies		yes	yes

Bootstrap based standard errors (100 reps.) in parentheses. Pair fixed effects always included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

European countries and a reduction in integration.

Kim et al. (2005) considered the period 1989–2003, before and after the introduction of the common currency. They find that increasing stock market comovements can be explained with the overall macroeconomic convergence process associated with the introduction of the Euro rather than the specific effects of the elimination of foreign exchange rate risk due to the currency unification. Among others, GDP growth and stock market capitalisation to GDP ratio were the main drivers of stock market convergence.

Table 2.4.2 presents our results for the stock market. When only pair fixed effects are considered, the key determinants of the stock market correlation seem to be differentials in inflation (in line with Hardouvelis et al., 2006), relative uncertainty, differentials in debt and in the current account. When we introduce time-fixed effects, relative volatility in the stock market becomes a principal variable together with the current account and GDP growth. The signs on relative debt, current account balance and growth are opposite to what was found for the bond market. The higher the relative degree of inflation and volatility in the stock market the lower the correlation between the two areas. The bigger the current account imbalance the more southern and northern stock markets are correlated. This seems a counter-intuitive result at first. A possible explanation could be that government expenditures in the south stimulated demand allowing for private sector convergence with the north. This explanation is supported by the positive effect of relative debt on this correlation.

Hence, while this government policy causes a major repricing of bonds, it helps the development of the two areas, increasing the correlation in the stock market. Also the GDP coefficient could be puzzling at first analysis, since increased differential in GDP growth increases correlations. This result can be interpreted in the same light as a catching-up effect of the southern countries with the northern ones.

Looking at the differentiated coefficients for the crisis period, it appears that the effect of current account falls majorly during the crisis, while the other variables are not affected in the same way. In contrast, we find that stock market volatility became a stronger determinant during the crisis. The policy rate shows a significant positive coefficient for the second period, which stands in contrast with the negative coefficients in the bond market case. Using the same reasoning as before implies that the decreasing rates in the crisis period decreased the comovements in the stock market.

Bond-Stock correlation

Theoretical models, belonging to the bond-stock literature, point out that factors that affect the payments of stocks and bonds differ. While both stock and bond prices are the discounted sums of their future cash flows, bonds earn a fixed nominal cash flow while stocks' cash flows are an infinite stream of uncertain dividends. Therefore, these models predict that changes in factors that affect the discount rates are likely to increase the bond-stock correlation while asymmetric shocks in other dimensions tend to decrease it (Campbell and Ammer, 1993; Li, 2002; Ilmanen, 2003; Christiansen, 2010). Empirical studies that use these predictions tested them for within-country correlations only.[35]

There are two sets of determinants to take into account. The first category includes real interest rate changes, monetary policy, and expected inflation. The second category includes unexpected inflation, economic growth and uncertainty measures such as stock market volatility. While expected inflation is already priced in the discount factors of both assets, unexpected inflation can hamper the asset that pays a predetermined amount. Similarly, expectations of strong GDP growth can help stocks and hurt bonds. On the contrary, in periods of high volatility in the equity market, stocks perform badly while bonds are less affected. Furthermore, one can observe flight-to-quality dynamics from the equity market into the sovereign bond market. Hence the main drivers of periods of low correlation in bond-stock returns have been suggested to be unexpected inflation and stock market uncertainty.

Ilmanen (2003) suggests that stock-bond correlation is at its lowest when equities are weak and volatility is high (i.e. flight-to-quality behaviour) but also when inflation and growth are low. Li (2002) presents results based on an asset pricing model that includes inflation expectations next to the previously noted determinants. Kim et al. (2006) -focusing specifically on the process of integration of European stocks and bonds between 1994 and 2003- find that real economic integration and the absence of currency risk lead to increased comovements. However, monetary policy convergence may have created uncertainty about the economic future of the European Monetary Union and consequently decreased comovements.

Andersson et al. (2008) study the US and Germany. For both markets

[35] Christiansen (2010) being the exception in also calculating correlations relative to the US and an EU index.

Table 2.4.3: Northern region Stock-Bond panel regression

	Dependent variable: Dynamic Correlation		
	(1)	(2)	(3)
	1-way FE	2-way FE	Crisis
Lag Dependent	0.6614***	0.3731***	0.3563***
	(0.0100)	(0.0292)	(0.0250)
dInfl	−0.0038	0.0003	0.0104
	(0.0154)	(0.0128)	(0.0127)
rVol	0.0464***	0.0627***	0.0575***
	(0.0109)	(0.0141)	(0.0140)
dDebt	−0.1088*	−0.2243**	−0.2782***
	(0.0574)	(0.0985)	(0.0969)
dCa	−0.0642	−0.1414	0.0538
	(0.1124)	(0.1174)	(0.1282)
dG	−0.0011	0.0013	−0.0036
	(0.0034)	(0.0037)	(0.0060)
Rate	−0.0214***	−0.1110***	−0.2648***
	(0.0028)	(0.0126)	(0.0165)
d × dInfl			−0.0121
			(0.0150)
d × rVol			−0.0707*
			(0.0378)
d × dDebt			0.1498***
			(0.0520)
d × dCa			−0.2655
			(0.1829)
d × dG			−0.0020
			(0.0080)
d × Rate			0.2937***
			(0.0202)
d			−0.9425***
			(0.0631)
Observations	1560	1560	1560
Number of pairs	30	30	30
Adjusted R^2	0.466	0.622	0.640
Partial R^2	0.468	0.241	0.279
Time dummies		yes	yes

Bootstrap based standard errors (100 reps.) in parentheses. Pair fixed effects always included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

they find evidence of a negative effect of stock market volatility on the stock-bond relation and a positive effect of expected inflation. They find that GDP growth has a negative impact but is not always statistically significant.

Table 2.4.3 and 2.4.4 present, respectively, the stock-bond relation in the northern and southern regions. As we are considering the within region markets we should pay attention to the interpretation of the results. The relative variables are now referring to differences within one region. For this reason we exclude six pairs for the north and five for the south, namely those that refer to correlations of stocks and bonds within the same country.

In the northern region the correlation between stock and bond markets seems to be determined uniquely by the policy rate, debt and volatility. While the policy rate is in line with the literature, the sign of relative volatility is counter-intuitive. The sign on debt suggests that a relative increase in debt would have a repercussion on the stock market of the corresponding country since there is a divergence in the correlation between these two country-assets. These results are constant among the different specifications although the crisis appears to diminish most of the effects. The crisis dummy itself indicates that the mean of the correlations decreased. Among the six models that we present, this model is the one that has the greatest difficulties in finding intuitive and significant determinants.

The southern correlation, Table 2.4.4, delivers better results. The bond-stock correlation is expectedly decreased by the interest rate and GDP growth and additionally by debt and stock market volatility when we control for pair and time fixed effects. Relative changes in the debt positions as well as stock market uncertainty in the southern countries leads to a flight-to-quality within the same region. Heterogeneity in the level of debt-to-GDP leads to a decrease in the stock-bond correlation in the region. The addition of crisis indicators does not alter the main regression as the crisis dummy does not have an impact on this correlation.

All the determinants for both the northern and southern regions are in line with theoretical predictions and the findings of the previous literature. The fact that the model behaves better for the within-region case of the south compared to the north may be explained by the relative degree of heterogeneity in the south relative to that among the northern countries. As noted before, pooling southern countries together may obscure a relative high degree of heterogeneity among them, while in pooling countries in the north this is much less the case. However, we can also find an indication for increased heterogeneity within the northern region. For instance the

Table 2.4.4: Southern region Stock-Bond panel regression

	Dependent variable: Dynamic Correlation		
	(1)	(2)	(3)
	1-way FE	2-way FE	Crisis
Lag Dependent	0.6828^{***}	0.3571^{***}	0.3577^{***}
	(0.0226)	(0.0340)	(0.0329)
dInfl	0.0105	0.0062	0.0017
	(0.0064)	(0.0057)	(0.0089)
rVol	−0.0224	-0.0452^{**}	−0.0253
	(0.0323)	(0.0193)	(0.0288)
dDebt	−0.0838	-0.1337^{***}	-0.1286^{**}
	(0.0637)	(0.0517)	(0.0522)
dCa	0.1775	0.1687	0.1845
	(0.1704)	(0.1281)	(0.1553)
dG	-0.0105^{**}	-0.0096^{***}	-0.0134^{***}
	(0.0043)	(0.0035)	(0.0046)
Rate	-0.0913^{***}	-0.1130^{***}	-0.2391^{***}
	(0.0049)	(0.0129)	(0.0171)
d × dInfl			0.0088
			(0.0130)
d × rVol			−0.0353
			(0.0400)
d × dDebt			−0.0112
			(0.0215)
d × dCa			−0.0821
			(0.1491)
d × dG			0.0094
			(0.0126)
d × Rate			0.2490^{***}
			(0.0249)
d			−0.0981
			(0.0714)
Observations	976	976	976
Number of pairs	20	20	20
Adjusted R^2	0.700	0.797	0.803
Partial R^2	0.702	0.215	0.242
Time dummies		yes	yes

Bootstrap based standard errors (100 reps.) in parentheses. Pair fixed effects always included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

combined coefficients for debt in Table 2.4.3 column 3 (-0.2782+0.1498), roughly equals the coefficient found for debt in Table 2.4.4 column 3 (-0.1286).

Table 2.4.5 presents the case of North bond-South stock (Nb-Ss). The Nb-Ss estimation confirms the previous literature's results with respect to expected inflation, volatility, GDP growth and the policy interest rate. An increase in the relative debt or a deterioration of the current account is related to the reduction of correlation, confirming flight-to-quality dynamics. Once we control for time and pair fixed effects the coefficients on fiscal measure as well as on the current account lose significance. While controlling for the crisis period, the current account becomes relevant in explaining the correlation. Again the crisis-dummy indicates that there was a shift downward of the mean of the correlation.

In the North-stock and South-bond case (Ns-Sb) (Table 2.4.6) an increase in the relative volatility makes southern bonds co-move more closely with northern stocks. The effect of the interest rate is in line with the prediction of theoretical models. GDP growth increases the correlation while an increase in debt in the south reduces it when we control for time fixed effects.

Controlling for the crisis shows that the marginal effect of the current account seems to be completely driven by the crisis period with a negative sign. A worsening in the current account of the south relative to the north determines an increase in the correlation of Ns-Sb since 2008. If anything, this result is the clearest indication thus far that a fundamental variable is related differently before and during the crisis. The significance of the interacted coefficient for inflation suggests that also this variable is mostly driven by the crisis. The crisis dummy is also significantly negative for this category.

A comparison of Table 2.4.5 with Table 2.4.6 shows how the same macroeconomic variables had a differentiated impact on the two categories: stock market uncertainty worked as a hedge in the first category while increased the correlation for the second; the GDP growth differentials worked in line with the literature for the first while suggested to increase the correlation in the second. Moreover, in the North-stock South-bond category it seems that the current account is an important driver of the divergence between the two correlations, as it is only statistically significant since the crisis.

We can conclude that, looking at all the categories considered, the results suggest quite clearly the relevance of macroeconomic variables in explaining a significant portion of the international financial market correlations in

Table 2.4.5: North Bond-South Stock panel regression

	Dependent variable: Dynamic Correlation		
	(1)	(2)	(3)
	1-way FE	2-way FE	Crisis
Lag Dependent	0.6628***	0.4169***	0.4017***
	(0.0181)	(0.0414)	(0.0387)
dInfl	0.0252***	0.0110**	0.0226***
	(0.0037)	(0.0049)	(0.0053)
rVol	−0.0523***	−0.0617***	−0.1048***
	(0.0165)	(0.0150)	(0.0185)
dDebt	−0.0811**	0.0500	0.0812
	(0.0340)	(0.0795)	(0.0708)
dCa	0.2095**	0.2267	0.2871*
	(0.0860)	(0.1510)	(0.1709)
dG	0.0058	−0.0082**	−0.0065
	(0.0039)	(0.0041)	(0.0050)
Rate	−0.0313***	−0.1103***	−0.2390***
	(0.0035)	(0.0127)	(0.0178)
d × dInfl			−0.0162**
			(0.0080)
d × rVol			0.1185***
			(0.0315)
d × dDebt			−0.0563
			(0.0414)
d × dCa			−0.0281
			(0.1662)
d × dG			−0.0049
			(0.0098)
d × Rate			0.2567***
			(0.0187)
d			−0.9640***
			(0.0796)
Observations	1512	1512	1512
Number of pairs	30	30	30
Adjusted R^2	0.462	0.599	0.614
Partial R^2	0.467	0.251	0.282
Time dummies		yes	yes

Bootstrap based standard errors (100 reps.) in parentheses. Pair fixed effects always included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 2.4.6: North Stock-South Bond panel regression

	Dependent variable: Dynamic Correlation		
	(1)	(2)	(3)
	1-way FE	2-way FE	Crisis
Lag Dependent	0.6490***	0.3069***	0.2927***
	(0.0241)	(0.0150)	(0.0152)
dInfl	0.0020	−0.0098*	0.0053
	(0.0047)	(0.0052)	(0.0062)
rVol	0.0995***	0.0628***	0.0330
	(0.0234)	(0.0192)	(0.0266)
dDebt	0.1788***	−0.2565***	−0.2998***
	(0.0438)	(0.0471)	(0.0442)
dCa	−0.1836	0.1511	0.1423
	(0.1171)	(0.1072)	(0.1041)
dG	0.0165***	0.0096***	0.0042
	(0.0044)	(0.0037)	(0.0043)
Rate	−0.0866***	−0.0883***	−0.2812***
	(0.0025)	(0.0128)	(0.0202)
d × dInfl			−0.0326***
			(0.0091)
d × rVol			0.0708*
			(0.0376)
d × dDebt			0.0977***
			(0.0283)
d × dCa			0.2846***
			(0.0795)
d × dG			0.0016
			(0.0103)
d × Rate			0.3885***
			(0.0233)
d			−0.3321***
			(0.1003)
Observations	1512	1512	1512
Number of pairs	30	30	30
Adjusted R^2	0.701	0.805	0.820
Partial R^2	0.703	0.185	0.249
Time dummies		yes	yes

Bootstrap based standard errors (100 reps.) in parentheses. Pair fixed effects always included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

the Euro-zone. For instance, the outcome of the previous tables indicates that current account and debt dynamics impact both on the private and public sector, with an opposite sign, as well as on the different geographical markets. The results indicate that an increase in the southern debt decreases the correlation between the northern and southern bond markets (Table 2.4.1) while increasing the stock market correlation (Table 2.4.2). Moreover, it decreases the correlation between northern stocks and southern bonds (Table 2.4.6). These results suggest that a debt increase in the south did not change the pattern of the correlation in a way that is counter to European financial homogenisation, except in the bond market where we observe that increase of debt level affects negatively the correlation between the two regions. Furthermore, current account imbalances seem a primary factor for the correlations during the crisis (Tables 2.4.2 and 2.4.6). A worsening of the current account for the south *vis-à-vis* the north increases the stock market correlation while it decreases the North-bond South-stock correlation since the crisis.

Stock market volatility decreases the correlation between northern and southern stocks (Table 2.4.2) logically but also decreases correlation between the bond markets in the two regions (Table 2.4.1) and appears to make southern bonds move more like northern stocks (Table 2.4.6).

Hereby we have also shown the relevance of a more general and joint-analysis of European financial markets. Instead of a strict focus on one market, and looking for the roles of specific financial variables, we are able to provide evidence of the determinants of standard macroeconomic variables across the different markets.[36] The risk of an analysis on a single market is that it may deliver a partial view of the Euro-zone asset markets and in particular of the impact that macroeconomic variables have on them.

Moreover, the hypothesis that there was a revaluation of macroeconomic fundamentals or a non-linear effects in their developments that caused the disintegration of markets between northern and southern Euro-zone is not strongly supported by any of the tables. Admittedly, there is a general downward shift in the correlations as given by the coefficient on the crisis period dummy. However, there is no model where the dummy

[36] Using the joint-estimation results of appendix 2.F we can test the joint-significance of individual regressors across the 6 equations. Using the estimation with bootstrapped standard errors, the result indicates that the coefficients on inflation cannot be rejected of being jointly equal to zero at 1% (p-value is 0.036), while all the other coefficients indicate strong evidence again the corresponding null-hypothesis.

variable indicates a significant and consistent change in the role played by the macroeconomic variables. In contrast, many of the coefficients on the interaction variables indicate that the net effect has decreased in an absolute sense, while most of these coefficients are insignificant. The occasional significant sign does not provide strong enough evidence to attribute this to the change in the role played by the underlying variable. The only exception to this conclusion is the policy rate, which is consistently significant across the different markets. The robustness check in appendix 2.G, where the crisis is specified as starting in the first quarter of 2010, does not change these conclusions.

These results are partly in contrast to what has been reported in some research (for instance Caggiano and Greco, 2012). This difference can to some extent be explained by the setup of our estimations. We focused squarely on medium and long-term developments using broad macroeconomic indicators as opposed to specialised macro-financial indicators. Secondly, our pairwise panel setup allows for the control of many unobserved effects. Moreover, we did not allow for contemporaneous effects, but estimated the effect of the independent variables with a one quarter lag in order to forgo the risk of reverse causality. Therefore, the results we find in this chapter may be interpreted as the equilibrium marginal effects of the regressors, rather than indicators of news-shocks. Thirdly, since we use all pairwise combinations, as opposed to using a single benchmark market (e.g. Germany or the US), we can interpret our results as neutral to a particular benchmark and instead as fundamental drivers within the Euro-zone.

2.5 Conclusion

Since the spreading of the financial turmoil and the sovereign debt crisis in the Euro-zone, it has been clear that European countries ceased to behave uniformly triggering concerns about the preservation of the single currency. In order to understand what occurred in the financial markets we proposed to analyse these markets in a multi-dimensional fashion. We did this by looking simultaneously at all correlations for two regions and two asset markets. The division of regions into North and South worked well to visualise the divergence in the Euro-zone and subsequently explain the underlying determinants of such divergence.

The comparison of the conditional correlations of the between-regions and between-assets shows how, after 2008, there was a change in the dynamics not only in the southern area stock-bond market but also at the cross regional level. What used to be considered a safe asset (southern bond) started to co-move with the deemed risky Northern one. The safe asset in the "risky" area became more correlated with the risky asset in the "safe" area as well as with stocks in the south. In contrast, the dynamics on the stock market did not show any fall in correlation apart from a short-term and relatively minor drop between 2010 and 2011.

We presented cross-country panel regressions to find the determinants of the international dynamic correlations. By using all possible pairs of countries for each correlation category, and in particular the heterogeneity in the macroeconomic fundamentals, we obtained a fairly robust inference of what might be the fundamental economic determinants that drive the correlations over time for our sample. The panel estimations of assets' correlations between countries also allowed to introduce variables that highlighted differences between those countries.

We find as main determinants for the overall set of equations: relative stock market volatility, debt and current account, growth, inflation differentials and monetary policy. Not all of these factors are important for each regression however, and in particular inflation differentials proves to be the weakest determinant out of all the equations. The results are mostly consistent with the theory for individual markets when available. Additionally, debt and current account have not been considered in the literature for all of the correlations we study, such as for the international stock market correlations. The inflation, volatility, policy rate and economic growth variables have been tried in the literature with mixed results.

We find that the correlation between bond markets seems to be mostly determined by differences in debt levels and stock market volatility, our measure of financial uncertainty. The correlations of stocks and bonds between regions behave as expected by theory of cash flow determinants on the one hand, and by macroeconomic fundamentals that indicate relative economic performance between countries on the other hand. So, while inflation, stock market volatility, economic growth and policy rate have the correct signs according to theory, we find an additional significant impact for the current account in some of the specifications and for debt only when considering the southern region. Finally, the correlation of the stock markets between north and south are mostly affected by current account and economic growth on top of stock market volatility, and to a lesser extent by differences in debt levels.

Although we looked at the original Euro-zone countries, the results do have implications for new and future member states. For instance, our results indicate a trade-off of using unfunded government spending for private sector stimulants at the risk of bond-market disintegration. Similarly, economic growth proves to be a major driver behind financial integration. Current account dynamics, recently highlighted as fundamentally important within Europe, prove to have its effects on financial markets as well. Future research might look more specifically at an expanded set of countries including new Euro-zone members and those European countries outside the Euro-zone in order to evaluate the role of fundamentals as countries join the monetary union or are otherwise strongly economically and politically dependent on it. Future research could also expand on the regressors, and in particular look more closely at financial variables and spill-over effects in this bilateral setting.

Although many studies have doubted the robustness of the union, the general perspective was that over time, the EU would develop as an ever integrating set of markets. We find that there is a mixed picture. Our results do not indicate that European financial integration is fundamentally hampered by the macroeconomic differences. These differences do affect the integration, but not in ways that would be irreversible, meaning that as long as the economies strive to grow and do so on sound macroeconomic foundations, then this will be reflected in their financial markets. At the moment, when we allow for regional division, not only cross-asset correlations within regions behave differently, but also the variation of cross-assets cross-regions dynamics can be explained with macroeconomic factors such as the relative uncertainty between countries and balance of payments dynamics. We do not find such effects when we look at each region separately, which shows that Europe indeed is still a tale of two regions.

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2.A Descriptive statistics daily returns

Table 2.A.1: Daily data descriptive statistics

Asset returns	Mean	St Dev	Skewness	Kurtosis	ACF2
			Stocks		
Austria	0.00016	0.0158	0.0334	11.5143	0.0000
Belgium	0.00001	0.0141	−0.2269	12.2145	0.0000
France	−0.00004	0.0149	0.1418	7.8487	0.0000
Finland	−0.00007	0.0224	−0.0851	9.4977	0.0000
Germany	0.00009	0.0155	0.1438	7.6402	0.0000
Netherlands	0.00003	0.0144	0.0423	8.3565	0.0000
Greece	−0.00041	0.0199	0.2914	7.6454	0.0000
Ireland	−0.00015	0.0173	−0.2645	12.0679	0.0000
Italy	−0.00008	0.0148	0.1093	8.4179	0.0000
Spain	0.00009	0.0158	0.3521	9.1959	0.0000
Portugal	−0.00011	0.0119	0.0805	10.7024	0.0000
			Bonds		
Austria	0.00010	0.0033	−0.2272	5.4112	0.0000
Belgium	0.00010	0.0036	−0.1437	8.0121	0.0000
France	0.00010	0.0035	−0.0769	5.8869	0.0000
Finland	0.00009	0.0032	−0.0811	4.5306	0.0000
Germany	0.00010	0.0034	−0.0485	4.7261	0.0000
Netherlands	0.00010	0.0033	−0.1236	4.4186	0.0000
Greece	−0.00005	0.0138	3.6221	154.6728	0.0000
Ireland	0.00007	0.0055	0.7672	36.3590	0.0000
Italy	0.00008	0.0044	1.0414	27.1074	0.0000
Spain	0.00008	0.0045	1.3057	23.6396	0.0000
Portugal	0.00006	0.0074	−0.0299	56.5008	0.0000

ACF2 is the Ljung-Box Q-test for squared residual autocorrelation (up to 20 lags), p-values reported. For every series we consider daily returns on the period 2000-2013 for a total of 3608 observations.

2.B Dynamic Conditional Correlation Estimation

2.B.1 Methodology

This appendix explains in detail the DCC methodology used in the chapter. We estimate a DCC Multivariate Garch model using the methodology described by Engle (2002).

The univariate estimation, discussed below, results in standardised residual $\epsilon_{i,t} = z_{i,t}/\sigma_{i,t}$, where $z_{i,t}$ represents the residuals for each country-asset $i = 1, \ldots k$ series at each time period $t = 1, \ldots T$, and $\sigma^2_{i,t}$ its time varying variance.

The standardised residuals, $\epsilon_{i,t} = z_{i,t}/\sigma_{i,t}$, of the univariate study are passed to the multivariate stage under the assumption that the returns from the initial assets, r_t, are conditionally multivariate normal with mean zero and covariance matrix H_t, equation (2.B.1). This assumption is important for the maximum likelihood estimation of the model.

The model reads:

$$r_t|\Psi_{t-1} \sim N\ (0,\ H_t), \tag{2.B.1}$$

$$H_t = D_t R_t D_t, \tag{2.B.2}$$

$$D_t = diag\left\{\sqrt{\sigma^2_{i,t}}\right\}, \tag{2.B.3}$$

$$\epsilon_t = D_t^{-1} z_t, \tag{2.B.4}$$

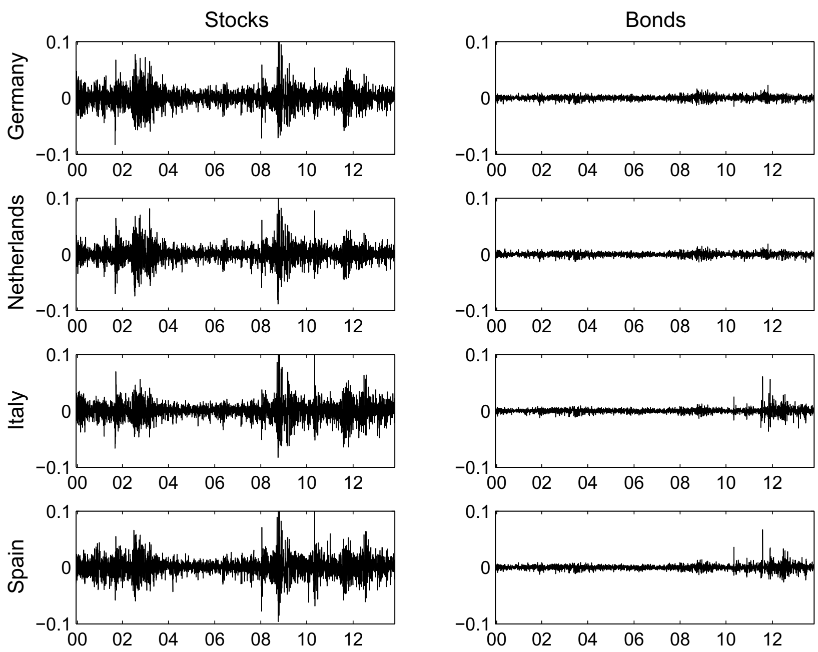
$$Q_t = (1 - \alpha - \beta)\,\bar{Q} + \alpha\epsilon_{t-1}\epsilon'_{t-1} + \beta Q_{t-1}, \tag{2.B.5}$$

$$\bar{Q} \approx E_t(\epsilon_{t-1}\epsilon'_{t-1}), \tag{2.B.6}$$

$$R_t = diag(Q_t)^{-1/2} Q_t diag(Q_t)^{-1/2}. \tag{2.B.7}$$

With k assets, D_t is the $k \times k$ diagonal matrix of the time varying standard deviations, $\sigma_{i,t}$, from the univariate estimation with $\sqrt{\sigma^2_{i,t}}$ on the i^{th} diagonal. The expression for $\sigma_{i,t}$ could be a simple Garch model as well as any other formulation. The choice of this process is discussed below. Given a sample of T observations, ϵ_t is the $k \times T$ series of standardised residuals. Finally R_t is the time varying correlation matrix and $\bar{Q}$ is approximately the

Figure 2.B.1: Selected bond and stock returns



unconditional covariance of the standardised residuals from the first stage estimation.[37]

Equations (3) and (4) refer to the univariate stage of the estimation while (5) to (7) to the multivariate one. In order to decide the best process to employ in the univariate stage we look at the descriptive statistics (Table 2.A.1) of daily raw returns and at their time plots. Figure 2.B.1 shows a representative sample of the countries' returns, exhibiting the broad difference among stocks and bonds on one hand, and north and south on the other.

The statistics in Table 2.A.1 suggest the necessity for a Garch model that is able to detect the specific nature of the data. By observing the behaviour of the returns for the bond series in Figure 2.B.1 it is clear that there was a strong change in volatility since the beginning of the sovereign

[37] Aielli (2006) shows that the DCC as set out by Engle (2002) needs theoretical corrections in the formulation but for empirical work there is no relevant difference in using either method (Aielli, 2013).

debt crisis from 2010 onwards. This increase was by far more visible in southern countries than in northern ones. Looking at the stock returns we can instead detect an initial period of high volatility referring to the dot.com financial crisis and, after 2008 another period of high volatility linked to the current financial crisis. This pattern is visible both in the northern stock markets as well as in the southern ones.

The second stage of the estimation requires standard normal distributed residuals.[38] In order to achieve this and capture the short term volatility some series need additional pre-processing steps. Namely, we proceed by: 1) standardise the returns via a moving window of the unconditional variance (equation [2.B.10] and [2.B.9]) and 2) we take care of changes of the overall volatility by introducing a crisis dummy (equation [2.B.13]).

The decision to introduce either of these two features is based on the correct identification of the univariate process and on the Ljung-Box Q-test for the residuals.[39] Table 2.B.1 indicates how we treated each series. An AR(P)-Garch (1,1) is then fitted to all the series:

$$r_t = \mu + \sum_{p=0}^{P} \alpha_p r_{t-p} + z_t, \tag{2.B.8}$$

$$\tilde{r_t} = r_t / \sqrt{h_t}, \tag{2.B.9}$$

$$h_t = (1 - J) + J * \frac{1}{S} \sum_{s=1}^{S} r_{t-s}^2, \tag{2.B.10}$$

$$z_t = \sigma_t \epsilon_t, \tag{2.B.11}$$

$$\epsilon_t \sim N(0, 1), \tag{2.B.12}$$

$$\sigma_t^2 = \omega + \alpha z_{t-1}^2 + \beta \sigma_{t-1}^2 + \delta I_t, \tag{2.B.13}$$

where (2.B.13) is the Garch formulation of Bollerslev (1986), and expresses the choice of the process for the univariate series and the elements of the

[38] If the normality assumption is violated, the Gaussian likelihood has a quasi-likelihood interpretation (Engle and Sheppard, 2001)

[39] An Igarch specification would not be appropriate for our dataset. By splitting the sample we did not find any evidence of a unit root process in the two subsamples showing that fitting an Igarch on the full sample appears to be a spurious regression due to the change in the volatility regime in the post crisis period. Results for the second stage -obtained from an Egarch specification- gave qualitatively similar results for the DCC and panel estimations.

matrix D_t in (2.B.3). The coefficient β determines the degree of memory of the process; α the impact of new information and $\omega/(1-\alpha-\beta)$ determines the unconditional volatility. Equation (2.B.10) shows how we computed the moving window unconditional variance of length S, that is used to standardise the returns before entering the Garch. When $J = 0$, the series are not standardised by the slow moving variance.[40] The last term in (2.B.13) is the dummy for the crisis, with $I_t = 1$ for selected series from 2010 onwards. The introduction of the dummy changes the unconditional variance of the model helping to capture the drastic increase in volatility we see in the returns.

The DCC is computed and estimated in two stages following Engle et al. (2008).

Univariate estimation results

Table 2.B.1 reports the parameters' estimates for all markets. Southern bonds required mostly an autoregressive part and the adjustment via crisis dummy. Some stocks and the Italian bond series required the moving windows standardisation.

Once the single univariate series are estimated, and before passing the standardised residuals to the multivariate stage we ensure that there is no further autocorrelation in the standardised residuals and squared standardised residuals. Table 2.B.2 presents the same descriptive statistics as Table 2.A.1 with respect to the standardised residuals' series. Additionally, it reports the Ljung-Box Q-test for squared residual autocorrelation (up to 20 lags), by which we do not reject the null hypothesis of lack of autocorrelation at the 5% level, except for the Greek stocks, Italian and Belgium bonds.

[40] In this Section, we are interested in the short run behaviour of the series. Before continuing with the DCC we filter the returns of the long memory dynamics allowing to be fairly confident that what we find as macroeconomic determinants in the panel regressions are not driven by these dynamics left from the univariate regressions.

Table 2.B.1: Garch parameters

Asset returns	Model	J	δ	α	β
			Stocks		
Austria	GARCH	-	-	0.0938^{***}	0.8957^{***}
Belgium	GARCH	-	-	0.1096^{***}	0.8800^{***}
France	GARCH	-	-	0.0900^{***}	0.9017^{***}
Finland	GARCH	-	-	0.0324^{***}	0.9658^{***}
Germany	GARCH	yes	-	0.0850^{***}	0.8438^{***}
Netherlands	GARCH	-	-	0.0934^{***}	0.8961^{***}
Greece	AR(1)GARCH	-	-	0.0882^{***}	0.9115^{***}
Ireland	GARCH	-	-	0.0937^{***}	0.8960^{***}
Italy	GARCH	yes	-	0.0869	0.8847^{***}
Spain	GARCH	yes	-	0.1034	0.8709^{**}
Portugal	AR(1)GARCH	-	-	0.0949^{***}	0.8989^{***}
			Bonds		
Austria	GARCH	-	-	0.0445^{***}	0.9421^{***}
Belgium	AR(1)GARCH	-	yes**	0.0638^{***}	0.9179^{***}
France	GARCH	-	-	0.0493^{***}	0.9360^{***}
Finland	GARCH	-	-	0.0383^{**}	0.9535^{***}
Germany	GARCH	-	-	0.0360^{***}	0.9559^{***}
Netherlands	GARCH	-	-	0.0372^{***}	0.9529^{**}
Greece	AR(1)GARCH	-	yes	0.1335^{***}	0.8602^{***}
Ireland	AR(1)GARCH	-	yes	0.0881^{***}	0.9039^{***}
Italy	AR(2)GARCH	yes	-	0.0659^{***}	0.8302^{***}
Spain	AR(1)GARCH	-	yes	0.0620^{***}	0.9265^{***}
Portugal	AR(1)GARCH	-	yes**	0.0941^{***}	0.8913^{***}

Parameters of the first stage univariate estimation set out in the text.
Standard errors are based on the Hessian matrix. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
The coefficients for the crisis dummy, δ, vary between 15% and 5% significance.

Table 2.B.2: Univariate residuals descriptive statistics

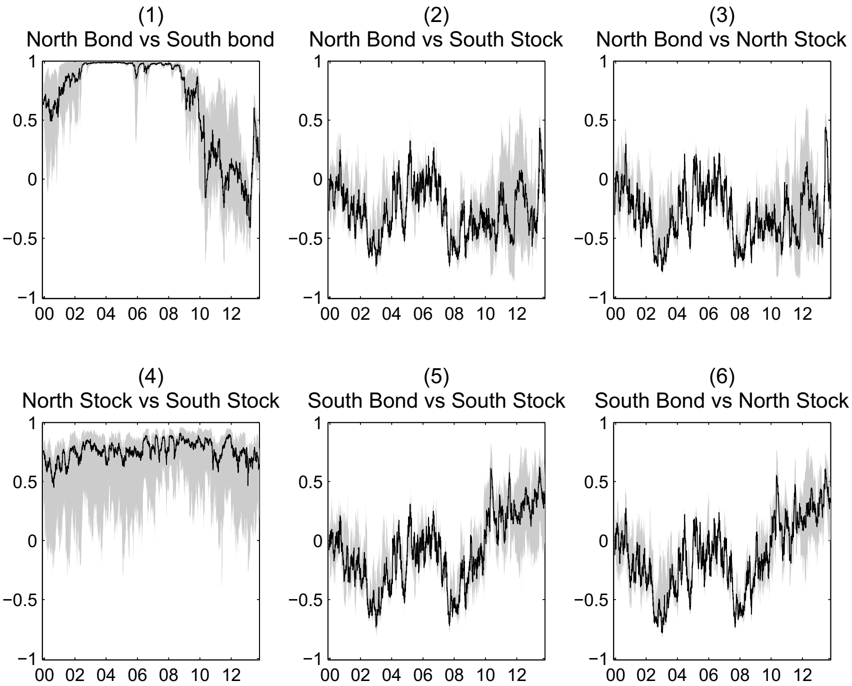
Asset returns	Mean	St Dev	Skewness	Kurtosis	ACF2
			Stocks		
Austria	0.0308	0.999	−0.2285	4.2812	0.7628
Belgium	0.0144	0.999	−0.2894	4.8881	0.3938
France	0.0043	0.999	−0.1999	4.0151	0.0730
Finland	0.0082	0.999	−0.1863	6.9048	0.9424
Germany	0.0128	1.000	−0.2068	3.5210	0.0346
Netherlands	0.0045	1.000	−0.1752	3.7742	0.1241
Greece	−0.0451	0.998	0.0939	4.6001	0.0450
Ireland	0.0032	0.999	−0.4205	6.4650	0.6806
Italy	−0.0063	1.000	−0.3273	3.9543	0.0821
Spain	0.0106	0.999	−0.1754	3.9588	0.0621
Portugal	−0.0508	0.999	−0.0839	4.9606	0.8851
			Bonds		
Austria	0.0363	0.999	−0.1470	4.1246	0.9240
Belgium	−0.0042	1.000	−0.1372	4.0593	0.0430
France	0.0348	1.000	−0.0578	3.9308	0.4391
Finland	0.0316	1.000	−0.1148	3.8124	0.8385
Germany	0.0328	0.999	−0.1466	3.7724	0.8557
Netherlands	0.0356	1.000	−0.1394	3.7791	0.9335
Greece	−0.0163	0.998	−0.3087	8.5171	0.8001
Ireland	−0.0102	1.000	0.2291	9.1341	0.9785
Italy	−0.0104	1.000	−0.2179	3.9710	0.0374
Spain	−0.0051	1.000	0.1500	5.7135	0.0537
Portugal	−0.0051	0.999	−0.3040	8.2831	0.8562

ACF2 is the Ljung-Box Q-test for squared residual autocorrelation (up to 20 lags), p-values reported.

2.B.2 Daily dynamic conditional correlation results

This appendix shows the weighted DCC results as estimated in the multivariate model before transforming the daily results into quarterly frequency.

Figure 2.B.2: Daily weighted Dynamic Conditional Correlations



Weighted average dynamic correlation series based on 30 country-asset pairs for each category (panel) except for South-stock South-bond where there are 20 pairs. The weights are constant over time and based on stock market capitalisation and gross government liabilities figures for 2002. Shaded areas denote the minimum and the maximum for every category at each point in time.

2.C Panel Unit Root Test

This appendix gives the result of the cross-dependence and panel unit root tests following Pesaran (2004, 2007) and described in Baltagi (2008) on the quarterly correlations. The cross-sectional dependence describes whether a panel unit root test should take into account cross-section dependence. The test results show that it should. The panel unit root test can be conducted in three fashions, normal, including cross-section fixed effects and including cross-section and time fixed effects. One should also include lags, where the lag-length can be defined by an information criteria. The AIC indicates a lag-length of one is sufficient. The H_0 is unit-root. Since the H_0 is always rejected, none of the tests indicate that the series follow a unit root.

Table 2.C.1: Panel unit root test

	Panel unit root			cross-section
	1	2	3	dependence
critical values				
1%	−2.00	−2.60	−3.15	2.65
5%	−1.72	−2.34	−2.88	1.96
10%	−1.58	−2.21	−2.74	1.67
Nb v. Ns	−6.45	−4.78	−4.77	20.13
Nb v. Sb	−10.62	−11.78	−11.77	70.68
Nb v. Ss	−6.69	−5.49	−5.49	103.26
Sb v. Ss	−6.68	−7.43	−7.43	13.28
Ns v. Sb	−7.78	−8.77	−8.77	109.64
Ns v. Ss	−7.00	−4.20	−4.20	76.35

Cross-section augmented DF, CADF, (H_0: series have a unit-root) tests and Cross-sectional dependence, CD, (H_0: no cross dependence) following Pesaran (2004, 2007) described in Baltagi (2008). Critical values are given, CD is normally distributed under H_0. For the Panel unit root, model 2 includes cross-section (cs) fixed effects, model 3 time and cs fixed effect. Lag-length is 1. All based on quarterly figures of the GARCH-DCC results.

2.D Bilateral estimated DCC

This appendix presents the panel estimation results for the six categories in the case of pair and time fixed effects. These regressions are conducted on bivariate, separately estimated, DCC models as opposed to a joint estimation where all correlations series share the same parameters. The bivariate estimation has the advantage to be more flexible as allows to estimate pairwise specific parameters. However, panel results prove to be robust to the DCC model's choice showing qualitatively similar macroeconomic determinants' dynamics.

Table 2.D.1: Bilaterally calculated correlations

	Dependent variable: DCC Correlation (Bilateral)					
	(1)	(2)	(3)	(4)	(5)	(6)
	Nb v. Sb	Ns v. Ss	Nb v. Ns	Sb v. Ss	Nb v. Ss	Ns v. Sb
Lag dep.	0.5258***	0.4199***	0.3158***	0.5274***	0.4202***	0.4493***
	(0.0459)	(0.0415)	(0.0295)	(0.0484)	(0.0432)	(0.0213)
dInfl	0.0113	0.0059	0.0005	0.0027	0.0063*	−0.0106***
	(0.0251)	(0.0070)	(0.0088)	(0.0039)	(0.0034)	(0.0037)
rVol	−0.0945**	−0.1119***	0.0420***	−0.0412***	−0.0350***	0.0473***
	(0.0424)	(0.0200)	(0.0102)	(0.0130)	(0.0109)	(0.0153)
dDebt	−0.5364***	0.1147	−0.1665**	−0.1229***	0.0532	−0.1906***
	(0.1535)	(0.0820)	(0.0756)	(0.0359)	(0.0511)	(0.0422)
dCa	0.3069	−0.2787***	−0.1079	0.1932*	0.1283	0.0652
	(0.2342)	(0.1008)	(0.0871)	(0.0993)	(0.0980)	(0.0832)
dG	0.0122	0.0177***	0.0003	−0.0070***	−0.0063**	0.0073***
	(0.0096)	(0.0056)	(0.0028)	(0.0025)	(0.0027)	(0.0027)
rate	−0.1801***	0.0316	−0.0788***	−0.0756***	−0.0698***	−0.0606***
	(0.0267)	(0.0223)	(0.0090)	(0.0092)	(0.0097)	(0.0086)
Observations	1512	1512	1560	976	1512	1512
Num. of pairs	30	30	30	20	30	30
Adjusted R^2	0.923	0.574	0.571	0.844	0.560	0.850
Partial R^2	0.354	0.282	0.188	0.383	0.236	0.313

Dependent variables are bilaterally calculated DCC correlations, quarterly averaged. Bootstrap based standard errors (100 reps.) in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Time dummies always included

2.E Realised Correlations

One disadvantage of the use of dynamic correlations such as the DCC is that the series are estimated as opposed to observed data. This feature is addressed in the panel estimation by the use of bootstrapped standard errors that will take into account the additional estimation variance resulting from the first stage estimation. Alternatively one can avoid the first stage estimation by using the realised correlations. We compute quarterly realised correlation based on the returns' series and use the resulting correlations as the dependent variables in the panel estimations. The results for the two-way fixed effects are presented in Table 2.E.1.

All the results we present in the main text are echoed for all coefficients in this setup. The main noticeable difference is the much smaller role for the lagged dependent variable, which can be explained by the lack of time-smoothing as is present in the DCC series. Consequently, also both R^2 measures are noticeably smaller across the different equations.

Table 2.E.1: Realised Correlations with two-way fixed effects

	Dependent variable: Realised Correlation					
	(1)	(2)	(3)	(4)	(5)	(6)
	Nb v. Sb	Ns v. Ss	Nb v. Ns	Sb v. Ss	Nb v. Ss	Ns v. Sb
Lag dep.	0.3170^{***}	0.0382^{*}	0.0530	−0.0144	0.1105^{**}	-0.0749^{***}
	(0.0440)	(0.0225)	(0.0341)	(0.0323)	(0.0499)	(0.0173)
dInfl	0.0085	−0.0002	0.0054	0.0060	0.0154^{*}	−0.0070
	(0.0367)	(0.0140)	(0.0188)	(0.0105)	(0.0089)	(0.0082)
rVol	−0.1128	-0.2285^{***}	0.0911^{***}	-0.0753^{***}	-0.0941^{***}	0.1016^{***}
	(0.0720)	(0.0447)	(0.0215)	(0.0288)	(0.0268)	(0.0257)
dDebt	-0.9525^{***}	0.2694^{*}	-0.3304^{**}	-0.2395^{***}	0.0929	-0.3661^{***}
	(0.2640)	(0.1551)	(0.1645)	(0.0842)	(0.1234)	(0.0779)
dCa	0.8895^{**}	-0.5550^{***}	−0.1603	0.3947^{*}	0.4305	0.1522
	(0.4524)	(0.1908)	(0.1906)	(0.2030)	(0.2628)	(0.1672)
dG	0.0902^{***}	0.0317^{***}	0.0089	-0.0128^{***}	-0.0158^{***}	0.0133^{***}
	(0.0181)	(0.0094)	(0.0060)	(0.0046)	(0.0061)	(0.0050)
Rate	-0.1977^{***}	0.1048^{***}	-0.1072^{***}	-0.1312^{***}	-0.0749^{***}	-0.1231^{***}
	(0.0486)	(0.0317)	(0.0162)	(0.0204)	(0.0155)	(0.0174)
Observations	1512	1512	1560	976	1512	1512
Num. of pairs	30	30	30	20	30	30
Adjusted R^2	0.873	0.358	0.435	0.690	0.405	0.717
Partial R^2	0.145	0.070	0.051	0.041	0.043	0.050

Dependent variable are realised correlations, calculated from daily returns at quarterly windows.Bootstrap based standard errors (100 reps.) in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Time dummies always included.

2.F Joint-estimations

Since we argue that the interaction among the six categories is relevant and should be analysed simultaneously, one could argue that the joint estimation of six categories simultaneously would be appropriate. Instead of equation-by-equation estimation, one can make a system of six equations and estimate this directly.

Here we present results that compare the estimation presented in the text (for the two-way fixed effect models) (panel a) with a joint estimations of the six equations using GMM (panel b). In order to reduce the number of parameters of the system all series were firstly made orthogonal from the pair and time fixed effects, thereafter the system was estimated. The results of the joint estimation present both normal and bootstrap based standard errors. The general results of the individual equation estimations remain, although some individual coefficients differ in their level of significance or even sign. The most structural difference between the two methods is seen for the common EU rate, which may be attributed to the lack of cross-sectional heterogeneity.

Table 2.F.1: Joint estimation of the 2-way fixed effects model (panel a)

	Dependent variable: Dynamic correlations					
	(1)	(2)	(3)	(4)	(5)	(6)
	Nb v. Sb	Ns v. Ss	Nb v. Ns	Sb v. Ss	Nb v. Ss	Ns v. Sb
			a) Independent regressions			
Lag dep.	0.5990^{***}	0.4018^{***}	0.3731^{***}	0.3571^{***}	0.4169^{***}	0.3069^{***}
	(0.0396)	(0.0267)	(0.0292)	(0.0340)	(0.0414)	(0.0150)
dInfl	-0.0205	-0.0008	0.0003	0.0062	0.0110^{**}	-0.0098^{*}
	(0.0195)	(0.0087)	(0.0128)	(0.0057)	(0.0049)	(0.0052)
rVol	-0.0812^{***}	-0.1355^{***}	-0.0627^{***}	0.0452^{***}	-0.0617^{***}	0.0628^{***}
	(0.0336)	(0.0247)	(0.0141)	(0.0193)	(0.0150)	(0.0192)
dDebt	-0.3238^{***}	0.1746^{*}	-0.2243^{**}	-0.1337^{***}	0.0500	-0.2565^{***}
	(0.1091)	(0.0984)	(0.0985)	(0.0517)	(0.0795)	(0.0471)
dCa	0.2308	-0.3331^{***}	-0.1414	0.1687	0.2267	0.1511
	(0.1963)	(0.1336)	(0.1174)	(0.1281)	(0.1510)	(0.1072)
dG	0.0078	0.0236^{***}	0.0013	0.0096^{***}	-0.0082^{**}	0.0096^{***}
	(0.0075)	(0.0076)	(0.0037)	(0.0035)	(0.0041)	(0.0037)
Rate	-0.2044^{***}	0.0507^{*}	-0.1110^{***}	-0.1130^{***}	-0.1103^{***}	-0.0883^{***}
	(0.0246)	(0.0289)	(0.0126)	(0.0129)	(0.0127)	(0.0128)

Panel a, estimates with pair and time fixed effects as presented in text. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Pair fixed effects and time dummies always included. In order to reduce the number of parameters for the system estimation all series were firstly made orthogonal from the pair and time fixed effects.

Table 2.F.2: Joint estimation of the 2-way fixed effects model (panel b)

	Dependent variable: Dynamic correlations					
	(1)	(2)	(3)	(4)	(5)	(6)
	Nb v. Sb	Ns v. Ss	Nb v. Ns	Sb v. Ss	Nb v. Ss	Ns v. Sb
	b) GMM System regressions					
Lag dep.	0.5544	0.4333	0.3405	0.4212	0.4558	0.2998
	(0.0194)***	(0.0167)***	(0.0169)***	(0.0187)***	(0.0163)***	(0.0180)***
	(0.0361)***	(0.0346)***	(0.0209)***	(0.0528)***	(0.0335)***	(0.0433)***
dInfl	0.0046	−0.0097	0.0100	0.0074	0.0096	−0.0030
	(0.0135)	(0.0069)	(0.0093)	(0.0047)	(0.0048)**	(0.0050)
	(0.0156)	(0.0096)	(0.0135)	(0.0056)	(0.0062)	(0.0051)
rVol	−0.0470	−0.1320	0.0615	−0.0514	−0.0388	0.0685
	(0.0269)*	(0.0118)***	(0.0073)***	(0.0104)***	(0.0093)***	(0.0101)***
	(0.0353)	(0.0177)***	(0.0145)***	(0.0172)***	(0.0163)***	(0.0161)***
dDebt	−0.2001	0.2455	−0.1996	−0.1266	0.0827	−0.1627
	(0.0650)***	(0.0374)***	(0.0494)***	(0.0259)***	(0.0296)***	(0.0282)***
	(0.0874)**	(0.0583)***	(0.0899)**	(0.0317)***	(0.0525)	(0.0440)***
dCa	0.4504	−0.3565	−0.1082	0.0335	0.1346	0.1491
	(0.1591)***	(0.0883)***	(0.0811)	(0.0735)	(0.0663)**	(0.0623)***
	(0.2305)*	(0.1556)**	(0.1426)	(0.1356)	(0.0881)	(0.1404)
dG	0.0038	0.0115	0.0018	−0.0093	−0.0069	0.0005
	(0.0071)	(0.0039)***	(0.0042)	(0.0026)***	(0.0027)***	(0.0029)
	(0.0109)	(0.0089)	(0.0051)	(0.0024)***	(0.0051)	(0.0032)
Rate	−0.0655	−0.0268	0.0038	0.0244	0.0331	0.0259
	(0.0412)	(0.0132)**	(0.0097)	(0.0105)***	(0.0093)***	(0.0114)**
	(0.0518)	(0.0136)**	(0.0115)	(0.0166)	(0.0071)***	(0.0197)

Panel b, GMM estimation of 6 equations jointly. Standard errors in paranthesis, upper standard GMM, lower bootstrap based (100 reps.). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Pair fixed effects and time dummies always included. In order to reduce the number of parameters for the system estimation all series were firstly made orthogonal from the pair and time fixed effects.

2.G Alternative Crisis Period Indicator

We present statistics for varying structural break dates, ranging from 2007q1 to 2010q4 in Table 2.G.1.

Table 2.G.1: LM-statistic over varying structural break dates

break point	Nb v. Sb	Ns v. Ss	Nb v. Ns	Sb v. Ss	Nb v. Ss	Ns v. Sb
2007q1	865.45	993.85	1421.32	933.33	1231.20	785.59
2007q2	874.01	1013.71	1421.40	937.50	1253.20	790.73
2007q3	867.34	1020.55	1422.00	943.65	1255.49*	791.67
2007q4	883.71	1009.34	1420.60	942.94	1244.57	790.14
2008q1	861.01	1008.98	1420.48	940.08	1244.87	789.54
2008q2	883.02	1044.61**	1420.95	964.01*	1258.89**	796.94**
2008q3	867.11	1028.12	1420.71	945.99	1251.76	792.85
2008q4	868.52	1010.69	1424.03**	940.76	1244.27	789.76
2009q1	865.85	1011.18	1419.39	940.70	1239.25	789.57
2009q2	872.31	1011.50	1420.23	940.95	1239.23	789.67
2009q3	889.06	1003.67	1419.66	935.40	1248.23	788.21
2009q4	899.29*	1005.62	1419.64	935.50	1247.81	788.26
2010q1	886.91	1004.77	1419.75	936.39	1247.47	787.89
2010q2	884.89	1005.91	1419.87	936.00	1247.47	788.42
2010q3	898.43	1017.88	1422.04*	957.71	1250.76	796.14*
2010q4	920.97**	1042.72*	1420.64	977.12**	1242.27	788.65

LM statistics, $(n * R^2)$, of the estimation with varying structural break dates. ** indicates highest value, * 2nd highest.

Following the discussion in the text in section 2.4.1 we present results with an alternative starting date of the crisis dummy indicator, namely starting at 2010q1. This date would approach closer to what is considered the start of the European debt crisis but foregoes the signalling effect of the broader financial crisis that was underway for some time at that point.

Table 2.G.2: Alternative crisis-dummy, starting 2010q1

	Dependent variable: Dynamic Correlation					
	(1)	(2)	(3)	(4)	(5)	(6)
	Nb v. Sb	Ns v. Ss	Nb v. Ns	Sb v. Ss	Nb v. Ss	Ns v. Sb
Lag dep.	0.6018***	0.3558***	0.3584***	0.3482***	0.4101***	0.2952***
	(0.0395)	(0.0317)	(0.0238)	(0.0322)	(0.0353)	(0.0150)
dInfl	0.0264	0.0131	−0.0008	0.0054	0.0211***	0.0018
	(0.0209)	(0.0117)	(0.0127)	(0.0064)	(0.0046)	(0.0052)
rVol	−0.1058**	−0.1040***	0.0534***	−0.0290	−0.0729***	0.0570**
	(0.0438)	(0.0314)	(0.0122)	(0.0221)	(0.0140)	(0.0232)
dDebt	−0.3690***	0.1357	−0.2436**	−0.1435**	0.0648	−0.2799***
	(0.1165)	(0.1119)	(0.0950)	(0.0631)	(0.0705)	(0.0452)
dCa	0.2922	−0.5806***	−0.0101	0.2001*	0.1412	0.1616
	(0.2417)	(0.1852)	(0.1020)	(0.1172)	(0.1262)	(0.0985)
dG	0.0256***	0.0177**	0.0027	−0.0103***	−0.0071***	−0.0020
	(0.0098)	(0.0075)	(0.0049)	(0.0033)	(0.0026)	(0.0038)
Rate	−0.2376***	0.0013	−0.1457***	−0.1402***	−0.1365***	−0.1414***
	(0.0256)	(0.0302)	(0.0099)	(0.0094)	(0.0111)	(0.0135)
d × dInfl	−0.0297*	−0.0540***	0.0128	0.0031	−0.0352**	−0.0477***
	(0.0168)	(0.0180)	(0.0313)	(0.0137)	(0.0148)	(0.0092)
d × rVol	0.0848	−0.0806**	−0.0687	−0.0791	0.1375***	0.1353***
	(0.0606)	(0.0336)	(0.0722)	(0.0525)	(0.0483)	(0.0406)
d × dDebt	0.1860***	0.0818	0.2341***	0.0411	−0.1520*	0.0085
	(0.0563)	(0.0718)	(0.0744)	(0.0614)	(0.0832)	(0.0405)
d × dCa	0.3603	0.7085**	−0.2199	−0.0036	0.0845	−0.0340
	(0.3497)	(0.2852)	(0.2260)	(0.2687)	(0.2969)	(0.1360)
d × dG	−0.1024***	−0.0087	−0.0175	−0.0015	−0.0081	0.0460***
	(0.0182)	(0.0121)	(0.0121)	(0.0124)	(0.0098)	(0.0156)
d × Rate	0.6500***	0.9373***	0.4548***	0.4805***	0.4549***	0.8607***
	(0.1125)	(0.0955)	(0.1018)	(0.1229)	(0.1097)	(0.1200)
d	−1.2131***	−0.7786***	−0.4556***	0.1372	−0.5701***	−0.2969***
	(0.1522)	(0.1337)	(0.1214)	(0.1117)	(0.1106)	(0.0926)
Observations	1512	1512	1512	1512	976	1560
Num. of pairs	30	30	30	30	20	30
Adjusted R^2	0.938	0.579	0.822	0.612	0.801	0.637
Partial R^2	0.455	0.303	0.256	0.274	0.231	0.273

Bootstrap Standard errors (100 reps.) in parentheses. *** p<0.01, ** p<0.05, * p<0.1 pair and time fixed effects. Crisis period from 2010q1, everything else as specified in main text.

Chapter 3

Sovereign debt default and banking in a currency union[1]

3.1 Introduction

The global financial crisis starting in 2007 prompted a reassessment of asset prices and growth prospects in the euro area (EA hereafter). As a result, in late 2009, countries like Ireland and Spain began to report – much – larger than expected fiscal deficits and rising spreads on sovereign debt. Some downgrades later, most periphery countries – also called GIIPS for Greece, Ireland, Italy, Portugal and Spain – were in deep troubles, with surges in sovereign bond yields and fears of default. At the same time, countries perceived as safe – we call them core countries – saw their sovereign yields reducing to a historical low, as shown on the left-hand-side of Figure 3.1.1. The sovereign crisis also led to credit restrictions to the private sector in the whole euro area. The right-hand-side of Figure 3.1.1 shows that between 2010 and 2012, interest rates on loans to non-financial corporations (NFC) increased by more than 100 basis points in the periphery and by approximately 60 basis points in the core.[2] We therefore observe spillovers

[1]This chapter is based on Perego and Pierrard (2014).

[2]In the core, the average increase in the loan rate from 2010Q1 to 2011Q4 was of 60 bps with a minimum increase of 46 bps for France and a maximum of 76 bps for Finland. The region is therefore rather homogeneous. In the periphery the average was of 132 bps but hiding a high degree of heterogeneity. Countries like Greece and Portugal faced an increase respectively of 194 bps and 216 bps whereas countries like Spain and Ireland of approximately 80 bps and Italy of 91 bps.

from default risk on periphery sovereign debt (or default realization in the case of Greece) to the private credit and to the core countries.

Recently, several empirical papers focus on the role the banking system played in the transmission of sovereign risks. On the one hand, Brutti and Sauré (2012) using a VAR model show that strong interdependence between banks and cross-border exposures to sovereign debt explain up to two-thirds of the transmission of the euro debt crisis. Also, De Bruyckere et al. (2012) underline two important banking channels of transmission: the capital channel as sovereign default weakens the asset side of the bank's balance sheet and the collateral channel as sovereign bonds are often used as collateral on the interbank market in order to obtain funds needed to provide credit to the private sector. On the other hand, some papers suggest that the banking sector is less integrated than it used to be. For instance, the ECB (2012) or Abascal et al. (2013) acknowledge a deepening of financial integration until 2007 mainly through the important role of the single currency, but also show that this integration receded between 2008 and 2011.[3]

In this chapter, we build a dynamic general equilibrium model to better understand the role of banking in general and the role of the banking structure in particular, in the transmission of a – sovereign – shock. We show that the model reproduces quite well historical observations when we introduce some degree of banking fragmentation. However, we observe that a better integrated banking sector would have reduced the negative consequences of default at the aggregate EA level. It would also limit the welfare cost of stabilizing policies. Our contribution to the literature is twofold. *First*, we enlarge the literature on sovereign default by studying default in a currency union. There exist several models with explicit default modelling. In partial equilibrium setups, Eaton and Gersovitz (1981) and Arellano (2008) model default as an optimal choice of the government. Instead, in Bi and Leeper (2010) and Juessen et al. (2011), default results from a binding fiscal limit impeding the government to raise enough funds to repay the debt. Another strand of the literature on sovereign default, to which our work contributes, focuses on the interaction between sovereign risk and the financial sector. In a partial equilibrium setup Gennaioli et al. (2010) and Bolton and Jeanne (2011)

[3] Appendix 3.A provides data from various sources to give a snapshot of financial integration at different dates. We indeed observe that until 2008, the EA banking sector became highly integrated. Public and private debt obligations of the troubled countries of the euro zone were largely held by creditors in other parts of the euro zone and, moreover, banks were also closely connected through cross-border interbank market. From 2009 onwards, banking data however show a gradual fragmentation as well as a 'flight-to-quality'.

study the interaction between sovereign default risk and the banking system. Both studies explore the role of bank's balance sheet and show that the greater is the default risk, the weaker are the bank's balance sheets. This determines international contagion and reduction in investment. Using a closed-economy new-Keynesian model, Mallucci (2013) also shows how the cyclicality of bank's balance sheets magnifies the impact of sovereign debt crisis on the real economy. Corsetti et al. (2013) analyse the impact of strained government finances on macroeconomic stability and the transmission of fiscal policy. The key idea is that sovereign risk raises the funding costs of the private sector because of the increase in the costs of financial intermediation. van der Kwaak and van Wijnbergen (2013) analyse the interaction between bank rescues, financial fragility and sovereign debt default. All these papers study the internal, *i.e.* closed-economy, transmission of sovereign debt default although data suggest important international spillovers. Guerrieri et al. (2012) study this international propagation but using a real business cycle model, that is without any nominal dimension and therefore without monetary policy. It is worth noting some of the above-mentioned papers look at default *risk* whereas others look at default *realization*, which makes their results difficult to compare. Our model considers a currency union with a common monetary policy and introduces both default risk and default realization. As we will see later, a common monetary policy in case of asymmetric shocks may have important consequences, and 'realization' spillovers may differ from the 'risk' ones. *Second*, we contribute to the literature on financial frictions and banking in a currency union. Most papers with banking (frictions) use closed-economy new-Keynesian models, as for instance Gerali et al. (2010) or Gertler and Karadi (2011). Enders et al. (2011), Guerrieri et al. (2012) or Kollmann (2013) combine banking and the international dimension but without monetary policy, be it common or not. This chapter is one of the few attempts to introduce banking frictions in a currency union.

More precisely, we build a 2-country new-Keynesian model of a currency union, that is with a common monetary policy. Trade between countries follows Gali and Monacelli (2008). Regarding the banking sector representation, we follow Enders et al. (2011) and Kollmann (2013) by introducing a perfectly competitive banking sector playing at the EA wide level, paying a cost whenever capital is lower than requirements (bank capital channel). In our setup, sovereign bonds are not only bank assets but also a collateral securing bank borrowings (bank collateral channel). The banking sector may move from integration to fragmentation. Under fragmentation, a geographical diversification of assets entails costs for the bank. Default arises endogenously as in Corsetti et al. (2013), when actual debt-to-GDP becomes too close to a feasible – or sustainable – maximum level. The bank transmits this default to the real economy mainly through the bank capital and collateral channels. As already explained, we make the distinction between a default risk and a default realization. We calibrate the model on EA data.

First, we find that using an integrated bank approach, realization has a deeper impact on output than risk, mainly through the bank capital and the bank collateral channels (lower excess capital and lower eligible collateral with realization). Second, the integrated bank assumption allows to share almost perfectly between regions the periphery sovereign troubles whereas fragmentation prevents the full sharing of the periphery turmoil. The situation in the periphery deteriorates further which benefits to the core region because of a too loose – for the core – monetary policy. The aggregate situation at the EA wide level is worse with fragmentation, because of an unadapted common monetary policy. This result is in line with the findings of Bignon et al. (2013) showing that a currency union is only desirable under banking integration.[4] Third, our model reproduces the best empirical data when we introduce only some degree of fragmentation. Fourth, from a policy point of view, we see that counter-cyclical capital requirements targeting output growth reduces seriously the volatility of output without implying a too high welfare cost. Extending the Taylor rule to include sovereign spreads does not really allow to reduce output volatility. In general, whatever the policy, the welfare costs of stabilizing the economy are much lower under a well integrated banking sector.

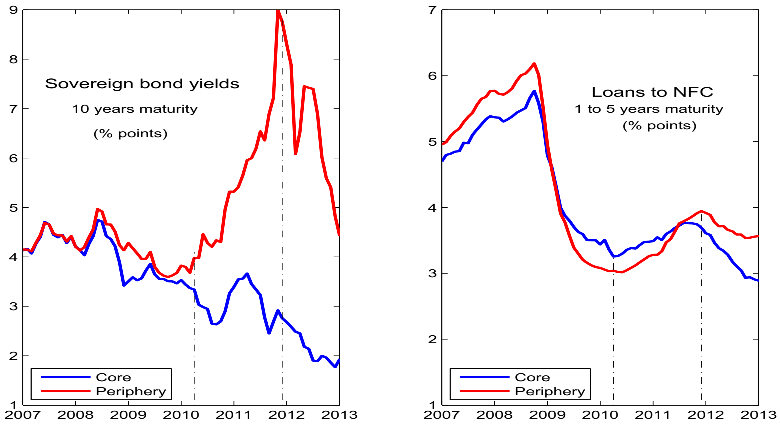
Section 3.2 details the model. Section 3.3 explains the calibration. Section 3.4 presents the dynamic simulations. Section 3.5 concludes.

3.2 Model

We develop a two-country model for the euro area. We call the first country/region as *core* and we denote it by c hereafter. We call the second country/region as *periphery* and we denote it by p hereafter. We introduce nominal rigidities, monetary policy and an endogenous probability of default on the government debt. Households in each region $j \in \{c, p\}$ work for the firms, consume and invest in deposits at the bank and in domestic sovereign

[4] Their modelling approach is however different. They build a 2-country model *à la* Rocheteau and Wright (2005) with money and banks.

Figure 3.1.1: Evolutions of selected interest rates



Notes. Evolution of 10 years sovereign bond yields and of 1 to 5 years maturity loans to non financial corporations (NFC) for core and periphery countries. Core countries include: Austria, Belgium, Germany, France, Finland whereas periphery countries are: Greece, Ireland, Italy, Portugal and Spain. The aggregated series has been created by weighting each country by their GDP. The vertical dotted lines signal the beginning of the sovereign debt crisis (2010Q1) and its acknowledged end (2011Q4).

Data sources: Datastream and the ECB Statistical Data Warehouse.

bonds. The production side of the economy is composed of final and intermediate firms and entrepreneurs. The entrepreneurs transform consumption goods into capital goods. In order to do so they borrow from the bank in the form of one-period loans and invest in firm's capital. Intermediate firms are monopolists that produce differentiated goods. In each country final firms combine these goods into a final one. There exists a single bank playing at the EA wide level receiving deposits from households, investing in international sovereign markets and providing loans to entrepreneurs. Although there exists a single bank playing at the EA wide level we allow for different levels of geographical integration/fragmentation between its assets/liabilities. Government expenditures are financed via lump-sum taxes from the households and public debt. Moreover the government might default on its debt if the economy gets too close to its fiscal limit. We assume symmetric countries in the sense that parameters are country invariant. The only departure from symmetry is that the core country has a lower debt level than the periphery country.[5]

3.2.1 Households

In each country $j \in \{c, p\}$, the representative household may consume C_t^j (international) final goods, invest D_t^j in one-period (international) bank deposits or b_t^j in one-period, domestic, sovereign debt. The – predetermined – gross nominal returns on deposits and sovereign bonds are respectively $R_{t-1}^{d,j}$ and $R_{t-1}^{b,j}$. $\epsilon_t^j \geq 0$ captures the share of outstanding sovereign debt lost by households because of – partial – sovereign default.[6] The household also supplies h_t^j hours to firms and receives wages w_t^j. It moreover owns the firms located in j and therefore receives their profits Υ_t^j, as well as a lump-sum income $H_t^{h,j}$ from the government. Finally, the household must pay taxes T_t^j and quadratic portfolio adjustment costs on deposits and sovereign debt, represented respectively by the parameters $\phi_d > 0$ and $\phi_b > 0$ in equation (3.2.1). These costs make the household's portfolio choices less sensitive to interest rate differentials.[7] It is worth noting that we segment both the sovereign debt market and the labour market at the household's level, i.e. the household in j may only hold debt from government j and work in country j. The household's budget constraint is:

$$\begin{aligned} & C_t^j + D_t^j + b_t^j + T_t^j + \frac{\phi_d}{2}(D_t^j - D_{t-1}^j)^2 + \frac{\phi_b}{2}(b_t^j - \bar{b}^j)^2 \\ & = w_t^j h_t^j + \frac{R_{t-1}^{d,j}}{\Pi_t^j} D_{t-1}^j + \frac{R_{t-1}^{b,j} - \epsilon_t^j}{\Pi_t^j} b_{t-1}^j + \Upsilon_t^j + H_t^{h,j} \ , \end{aligned} \quad (3.2.1)$$

where Π_t^j is final goods inflation and, throughout the chapter, $\bar{z}$ represents the steady state of any variable z_t. The household's expected lifetime utility at date s is:

$$\max E_s \sum_{t=s}^{\infty} \beta^{t-s} \left(\ln C_t^j + \psi_d \ln D_t^j - \frac{\psi_n}{2} \left(h_t^j \right)^2 \right). \quad (3.2.2)$$

[5]As a result, public consumption at the steady state is lower in the periphery country because the cost of debt is higher. We could have alternatively assumed that taxes at the steady state are higher in the periphery country.

[6]Equations in the model express default *realization*. However, we will also consider default *risk* and we explain later how to modify the equations accordingly.

[7]See for instance Guerrieri et al. (2012) for similar costs. We could instead use alternative approaches as *e.g.* habit in consumption.

As in Enders et al. (2011), we assume that deposits provide utility to the household and we take a logarithmic utility. We also take a logarithmic instantaneous utility of consumption and a quadratic disutility of hours. $0 < \beta < 1$ is the subjective discount factor and ψ_d, $\psi_n > 0$ are parameters. The household maximizes (3.2.2) with respect to (3.2.1). It gives three first order conditions:

$$(C_t^j)^{-1}\left(1 + \phi'_{d,t}\right) = \frac{\psi_d}{D_t^j} + E_t\, \beta\, (C_{t+1}^j)^{-1}\left(\frac{R_t^{d,j}}{\Pi_{t+1}^j} + \phi'_{d,t+1}\right), \tag{3.2.3}$$

$$(C_t^j)^{-1}\left(1 + \phi_b(b_t^j - \bar{b}^j)\right) = E_t\, \beta\, (C_{t+1}^j)^{-1}\, \frac{R_t^{b,j} - \epsilon_{t+1}^j}{\Pi_{t+1}^j}, \tag{3.2.4}$$

$$\frac{w_t^j}{C_t^j} = \psi_n h_t^j, \tag{3.2.5}$$

where $\phi'_{d,t} = \phi_d(D_t^j - D_{t-1}^j)$. Euler equations (3.2.3) and (3.2.4) state that at equilibrium, marginal costs are equal to expected marginal income from respectively deposits and sovereign bonds. Equation (3.2.5) shows that the wage is equal to the marginal disutility of hours.

3.2.2 Entrepreneurs

In each country $j \in \{c, p\}$, entrepreneurs borrow from the (international) bank in the form of one-period loans L_t^j. They may consume $C_t^{e,j}$ or invest I_t^j in domestic firms. In turn, investment increases firms' capital stock K_t^j according to:

$$K_t^j = (1-\delta)K_{t-1}^j + I_t^j, \tag{3.2.6}$$

where $0 < \delta < 1$ is the capital depreciation rate. Capital provides a net real return r_t^j and entrepreneurs pay a gross nominal interest rate $R_{t-1}^{l,j}$ on loans, as well as an adjustment cost on investment, as in Enders et al. (2011), represented by the parameter $\phi_i > 0$. The entrepreneurs' budget constraint is:

$$C_t^{e,j} + I_t^j + \frac{R_{t-1}^{l,j}}{\Pi_t^j}\, L_{t-1}^j + \frac{\phi_i}{2}(I_t^j - \bar{I}^j)^2 = L_t^j + r_t^j K_{t-1}^j\,. \tag{3.2.7}$$

The entrepreneurs expected lifetime utility at date s is:

$$\max E_s \sum_{t=s}^{\infty} \beta^{t-s}\, \frac{\left(C_t^{e,j}\right)^{1-\sigma_e} - 1}{1-\sigma_e}, \tag{3.2.8}$$

where $\sigma_e > 0$ reflects the curvature of the instantaneous utility of consumption. By simplicity, we take a discount factor similar to the one of the household. We also assume segmented capital markets. The entrepreneurs maximize (3.2.8) with respect to (3.2.6) and (3.2.7). It gives two first order conditions:

$$(C_t^{e,j})^{-\sigma_e} = E_t\ \beta\ (C_{t+1}^{e,j})^{-\sigma_e}\ \frac{R_t^{l,j}}{\Pi_{t+1}^j}\ , \tag{3.2.9}$$

$$(C_t^{e,j})^{-\sigma_e}(1+\phi'_{i,t}) = E_t\ \beta\ (C_{t+1}^{e,j})^{-\sigma_e}\ \left(r_{t+1}^j + (1-\delta)(1+\phi'_{i,t+1})\right),\ \tag{3.2.10}$$

where $\phi'_{i,t} = \phi_i(I_t^j - \bar{I}^j)$. Equation (3.2.9) says that at equilibrium, the marginal income from loans is equal to the expected marginal cost, whereas equation (3.2.10) states that the marginal cost of investment is equal to its expected marginal income.

3.2.3 Firms

In each country $j \in \{c, p\}$, we have a uniform distribution between $[0, 1]$ of intermediate monopolistic firms, indexed by n_j. We also define $-j \in \{c, p\}$ as the complement of j.[8] By simplicity, we ignore time subscripts whenever we have static equations. Let $d_j^j(n_j)$ be the intermediate goods produced in country j by the intermediate firm n_j and sold in country j. Similarly, let $d_j^{-j}(n_j)$ be the intermediate goods produced in country j by the intermediate firm n_j and sold in country $-j$.

Final firms' demand

In each country $j \in \{c, p\}$, there is a final firm combining intermediate goods from the j and $-j$ countries in order to produce a final good A^j according to a CES technology:

$$A^j = \left(\frac{A_j^j}{1-\alpha}\right)^{(1-\alpha)}\ \left(\frac{A_{-j}^j}{\alpha}\right)^{\alpha}\ , \tag{3.2.11}$$

[8] That is $j \cap -j = \emptyset$ and $j \cup -j = \{c, p\}$.

where

$$A_j^j = \left(\int_0^1 \left[d_j^j(n_j) \right]^{\frac{1}{1+\theta}} dn_j \right)^{1+\theta} ,$$

$$A_{-j}^j = \left(\int_0^1 \left[d_{-j}^j(n_{-j}) \right]^{\frac{1}{1+\theta}} dn_{-j} \right)^{1+\theta} .$$

$0 < 1 - \alpha < 1$ is the domestic bias, or equivalently α is an index of openness. $(1+\theta)/\theta > 1$ represents the elasticity of substitution between intermediate goods produced within any given country. The final firm's profit is:

$$P^j A^j - \int_0^1 p^j(n_j)\, d_j^j(n_j)\, dn_j - \int_0^1 p^{-j}(n_{-j})\, d_{-j}^j(n_{-j})\, dn_{-j} , \qquad (3.2.12)$$

where P^j is the final goods price index in country j and $p^j(n_j)$ is the intermediate goods n_j price index in country j. It is worth noting that equation (3.2.12) takes into account that the two countries are part of a monetary union (nominal exchange rate equal one) and includes the law of one price, that is a given intermediate goods must have the same price in the two countries. For each country, let us define the ratio between the intermediate goods price index and the final goods price index $\phi^j(n_j) = p^j(n_j)/P^j$. We also define the real exchange rate of country j *vis à vis* country $-j$ as $Q_j^{-j} = P^{-j}/P^j$. Obviously, $Q_{-j}^j = 1/Q_j^{-j}$ and $Q_j^j = 1$. The final firm maximizes (3.2.12) with respect to (3.2.11). Using the above-mentioned definitions, it gives the two first order conditions:

$$\frac{d_j^j(n_j)}{A^j} = \left(\frac{\phi^j(n_j)}{(1-\alpha)} \right)^{-\frac{1+\theta}{\theta}} \left(\frac{A_j^j}{A^j} \right)^{-\frac{1}{\theta}} , \qquad (3.2.13)$$

$$\frac{d_{-j}^j(n_{-j})}{A^j} = \left(\frac{\phi^{-j}(n_{-j})\, Q_j^{-j}}{\alpha} \right)^{-\frac{1+\theta}{\theta}} \left(\frac{A_{-j}^j}{A^j} \right)^{-\frac{1}{\theta}} . \qquad (3.2.14)$$

Intermediate firms

An intermediate firm located in country j and indexed by n_j uses capital $K_{t-1}^j(n_j)$ and hours $h_t^j(n_j)$ to produce an intermediate good according to the Cobb-Douglas production function. Final firms in the two countries consume this intermediate production:

$$Y^j(n_j) \equiv d_j^j(n_j) + d_j^{-j}(n_j) = \left(K_t^j(n_j) \right)^{\mu} \left(h_t^j(n_j) \right)^{1-\mu} , \qquad (3.2.15)$$

where $0 < \mu < 1$ is the elasticity of output to capital. The intermediate firm receives a – real – intermediate price $\phi_t^j(n_j)$ but has to pay an interest rate r_t^j on capital and a hourly wage w_t^j. Moreover, since intermediate firms are monopolistic, they set the price but with an adjustment cost *à la* Rotemberg (1982) represented by the parameter $\kappa > 0$. The current real profit of an intermediate firm n_j is:

$$\begin{aligned} \Upsilon_t^j(n_j) &= \phi_t^j(n_j)\left(d_{j,t}^j(n_j) + d_{j,t}^{-j}(n_j)\right) - r_t^j K_{t-1}^j(n_j) - w_t^j h_t^j(n_j) \\ &- \frac{\kappa}{2}\left(\frac{\phi_t^j(n_j)\Pi_t^j}{\phi_{t-1}^j(n_j)} - \bar{\Pi}^j\right)^2 \left(A_{j,t}^j + A_{j,t}^{-j}\right), \end{aligned} \tag{3.2.16}$$

where $\Pi_t^j = P_t^j / P_{t-1}^j$. The households hold the intermediate firms and they therefore maximize:

$$\max E_s \sum_{t=s}^{\infty} \beta^{t-s} \frac{C_t^j}{C_{t+1}^j} \Upsilon_t^j(n_j). \tag{3.2.17}$$

with respect to the production equation (3.2.15) and the two demand equations (3.2.13) and (3.2.14). It gives three first order conditions:

$$\frac{h_t^j(n_j)}{K_{t-1}^j(n_j)} = \frac{(1-\mu)\, r_t^j}{\mu\, w_t^j}, \tag{3.2.18}$$

$$\text{mc}_t^j(n_j) = \left(\frac{r_t^j}{\mu}\right)^{\mu} \left(\frac{w_t^j}{1-\mu}\right)^{1-\mu}, \tag{3.2.19}$$

$$\phi_t^j(n_j) + \theta\kappa \frac{\lambda_t^j(n_j)}{d_{j,t}^j(n_j) + d_{j,t}^{-j}(n_j)} = (1+\theta)\, \text{mc}_t^j(n_j) \tag{3.2.20}$$

$$+ E_t \beta \frac{C_t^j}{C_{t+1}^j}\, \theta\kappa \frac{\lambda_{t+1}^j(n_j)}{d_{j,t}^j(n_j) + d_{j,t}^{-j}(n_j)}, \tag{3.2.21}$$

where $\lambda_t^j(n_j) = \left(\frac{\phi_t^j(n_j)\Pi_t^j}{\phi_{t-1}^j(n_j)} - \bar{\Pi}^j\right) \frac{\phi_t^j(n_j)\Pi_t^j}{\phi_{t-1}^j(n_j)} \left(A_{j,t}^j + A_{j,t}^{-j}\right)$.

Equation (3.2.18) shows that the labour-capital ratio is proportional to the capital-labour cost ratio. Equation (3.2.19) defines the marginal cost. Moreover, these two equations imply that the labour-capital ratio and the marginal cost are identical across all intermediates firms located in a given country. Equation (3.2.20) is the new-Keynesian Phillips curve and states that intermediate goods price is a markup over the marginal cost. If prices are perfectly flexible ($\kappa = 0$), the markup is $1 + \theta$ and constant over time. With price rigidities ($\kappa > 0$) the markup becomes variable over time.

Aggregation

In equilibrium, all intermediate firms within a country $j \in \{c, p\}$ are identical and we may drop the index n_j in all above equations. We also have $d^j_{j,t} = A^j_{j,t}$ and $d^{-j}_{j,t} = A^{-j}_{j,t}$. The aggregation of equations (3.2.16), (3.2.18), (3.2.19) and (3.2.20) is straightforward. Moreover, equations (3.2.13), (3.2.14) and (3.2.15) respectively become:

$$\begin{aligned} \phi^j_t \, A^j_{j,t} &= (1-\alpha) \, A^j_t \,, && (3.2.22) \\ Q^{-j}_{j,t} \, \phi^{-j}_t \, A^j_{-j,t} &= \alpha \, A^j_t \,, && (3.2.23) \\ Y^j_t &= A^j_{j,t} + A^{-j}_{j,t} = \left(K^j_t\right)^\mu \left(h^j_t\right)^{1-\mu} . \end{aligned}$$

Using equation (3.2.11), we can simplify further these equations into:

$$\begin{aligned} 1 &= \phi^j_t \, \phi^{-j}_t \,, \\ Q^{-j}_{j,t} &= \left(\phi^j_t\right)^{\frac{2\alpha-1}{\alpha}} \,, \\ \phi^j_t \, Y^j_t &= (1-\alpha) \, A^j_t + \alpha \, Q^{-j}_{j,t} A^{-j}_t = \phi^j_t \, \left(K^j_t\right)^\mu \left(h^j_t\right)^{1-\mu} . && (3.2.24) \end{aligned}$$

Finally, taking the ratio of the real exchange rate at times t and $t-1$ gives:

$$\frac{Q^{-j}_{j,t}}{Q^{-j}_{j,t-1}} = \frac{\Pi^{-j}_t}{\Pi^j_t} \,. \qquad (3.2.25)$$

Summing equation (3.2.24) on j gives $\sum_j \phi^j_t \, Q^j_{c,t} \, Y^j_t = \sum_j Q^j_{c,t} \, A^j_t$, meaning that production is equal to demand in the whole currency area. Equation (3.2.25) shows that a higher inflation in the periphery country than in the core country leads to an increase in the real exchange rate of the core country, equivalent to a depreciation of the core "currency". In other words, a higher real exchange rate means an improved competitiveness.

3.2.4 Banking sector

We specify the banking sector as a bank *à la* Enders et al. (2011), *i.e.* a perfectly competitive bank playing at the EA wide level. At this stage, we assume a full banking integration, meaning that the bank bears no cost for geographical diversification (we explain how we introduce fragmentation in section 3.4.3). The bank is physically located in country c but trades with all countries $j \in \{c, p\}$. More precisely, it receives deposits D_t^j from households, lends L_t^j to firms and buys s_t^j one-period bonds from the government. The bank may also buy B_t^{cb} one-period bonds from the central bank. The bank consumes profits in the two countries, that is it buys $C_t^{b,j}$ goods in each country. Since the central bank is common to the currency union and the bank is located in country c, we first need to express relative price indexes. The global production in the currency union is $Y_t = \sum_j Y_t^j$ and we define $\eta_t = Y_t^c / Y_t$ as the share of the c country. Then:

$$
\begin{aligned}
P_t &= (P_t^c)^{\eta_t} (P_t^p)^{1-\eta_t} \ , \\
\Pi_t &= \frac{P_t}{P_{t-1}} = (\Pi_t^c)^{\eta_t} (\Pi_t^p)^{1-\eta_t} \ , \\
\frac{P_t}{P_t^c} &= \left(Q_{c,t}^p\right)^{1-\eta_t} \ , \\
\frac{P_{t-1}}{P_t^c} &= \frac{\left(Q_{c,t}^p\right)^{1-\eta_t}}{\Pi_t} \ .
\end{aligned}
$$

The bank faces a capital requirement *à la* Enders et al. (2011) implying that it must keep a constant fraction $0 < \gamma < 1$ of loans as own capital. x_t represents excess capital, that is the amount of capital above the legal requirements. A negative x_t therefore means that bank capital is below requirements. The bank's balance sheet constraint is:

$$
(1-\gamma) \sum_j Q_{c,t}^j L_t^j + \sum_j Q_{c,t}^j s_t^j + \left(Q_{c,t}^p\right)^{1-\eta_t} B_t^{cb} = \sum_j Q_{c,t}^j D_t^j + x_t \ . \quad (3.2.26)
$$

Government bonds do not enter the requirement constraint because they were considered as risk-free, in line with standard features of capital regulation (see Guerrieri et al., 2012, for a similar representation). We nevertheless consider the possible inclusion of bonds in the constraint in section 3.4. The bank's budget constraint is:

$$\sum_j Q^j_{c,t} C^{b,j}_t + \sum_j Q^j_{c,t} \frac{R^{d,j}_{t-1}}{\Pi^j_t} D^j_{t-1} + \sum_j Q^j_{c,t} L^j_t + \sum_j Q^j_{c,t} s^j_t + \left(Q^p_{c,t}\right)^{1-\eta_t} B^{cb}_t$$
$$+ \Psi \left(\frac{\sum_j Q^j_{c,t}(1-\epsilon^j_t)^\nu s^j_t}{\sum_j Q^j_{c,t} L^j_t} - \frac{\sum_j \bar{Q}^j_c \, \bar{s}^j}{\sum_j \bar{Q}^j_c \, \bar{L}^j} \right) + \frac{\Gamma_l}{2} \sum_j \left(L^j_t - \bar{L}^j \right)^2 + \Omega(x_t)$$
$$+ \Gamma_d \sum_j \left(D^j_t - \bar{D}^j \right) = \sum_j Q^j_{c,t} D^j_t + \sum_j Q^j_{c,t} \frac{R^{l,j}_{t-1}}{\Pi^j_t} L^j_{t-1}$$
$$+ \sum_j Q^j_{c,t} \frac{R^{b,j}_{t-1} - \epsilon^j_t}{\Pi^j_t} s^j_{t-1} + \left(Q^p_{c,t}\right)^{1-\eta_t} \frac{R_{t-1}}{\Pi_t} B^{cb}_{t-1} + \sum_j Q^j_{c,t} H^{b,j}_t. \quad (3.2.27)$$

The bank pays a gross nominal interest rate $R^{d,j}_{t-1}$ on deposits and receives gross nominal interest rates $R^{l,j}_{t-1}$, $R^{b,j}_{t-1}$ and R_{t-1} on respectively loans to firms, government bonds and central bank bonds. It is worth noting that the return on government bonds is risky, that is government in country j may default with a probability ϵ^j_t. Moreover, the bank faces four different costs. First, there is an operating cost, proportional to the size of the bank balance sheet (we approximate the size of the balance sheet through deposits), represented by the parameter $\Gamma_d > 0$. We find similar costs in Enders et al. (2011). Second, as in Guerrieri et al. (2012), we have quadratic adjustment costs on loans, represented by the parameter $\Gamma_l > 0$. Third, as explained above, there is a cost when capital is below requirements. The cost function must satisfy $\Omega(0) = 0$, $\Omega^{'}(0) \leq 0$ and $\Omega^{''}(.) > 0$ as in Enders et al. (2011). The bank therefore bears a positive cost when $x_t < 0$ and the cost is 0 when the bank exactly meets the requirements. We call the transmission of shocks through this cost the *bank capital channel*. Fourth, banks typically use government bonds as collateral in the secured interbank market. A reduction in their volume or quality decreases the ability of banks to collect funds from other banks and hence to sustain private credit supply. In our model, there is no interbank market and therefore no such collateral role for sovereign bonds. In order to nevertheless reproduce this channel, we introduce a collateral cost whenever the ratio between sovereign bonds and private loans is lower than the steady state. It is worth noting that the numerator of the ratio not only includes the volume of bonds but also a measure of riskiness, through the parameter $\nu \geq 0$, which represents the haircut applied to them. This cost function must therefore satisfy the same requirements as the capital cost, *i.e.* $\Psi(0) = 0$, $\Psi^{'}(0) \leq 0$ and $\Psi^{''}(.) > 0$. We call the transmission of shocks through this cost the *bank collateral channel.* We discuss in more details the role of the capital cost $\Omega(.)$ and the collateral cost $\Psi(.)$ further in this section. The bank's expected lifetime utility at date s is:

$$\max E_s \sum_{t=s}^{\infty} \beta^{t-s} \left(C_t^{b,c}\right)^{\vartheta} \left(C_t^{b,p}\right)^{1-\vartheta} . \tag{3.2.28}$$

The bank derives instantaneous utility from a Cobb-Douglas combination of consumption goods from countries c and p, where ϑ (resp. $1-\vartheta$) is the elasticity of the utility with respect to $C_t^{b,c}$ (resp. $C_t^{b,p}$). By simplicity, we take a discount factor similar to the one of the household. The bank maximizes (3.2.28) with respect to (3.2.26) and (3.2.27). It gives one definition (equation 3.2.29) and five first order conditions:

$$\lambda_t^b = \frac{\vartheta \left(C_t^{b,c}\right)^{\vartheta} \left(C_t^{b,p}\right)^{1-\vartheta}}{C_t^{b,c}} , \tag{3.2.29}$$

$$Q_{c,t}^p = \frac{1-\vartheta}{\vartheta} \frac{C_t^{b,c}}{C_t^{b,p}} , \tag{3.2.30}$$

$$\lambda_t^b (Q_{c,t}^j - \Gamma_d + Q_{c,t}^j \, \Omega^{'}(x_t)) = \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j \frac{R_t^{d,j}}{\Pi_{t+1}^j} , \tag{3.2.31}$$

$$\lambda_t^b \left(Q_{c,t}^p\right)^{1-\eta_t} (1 + \Omega^{'}(x_t)) = \beta E_t \lambda_{t+1}^b \left(Q_{c,t+1}^p\right)^{1-\eta_{t+1}} \frac{R_t}{\Pi_{t+1}} , \tag{3.2.32}$$

$$\begin{aligned} \lambda_t^b \Bigg(Q_{c,t}^j - Q_{c,t}^j \Psi^{'} \left(\frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{\sum_j Q_{c,t}^j L_t^j} - \frac{\sum_j \bar{Q}_c^j \, \bar{s}^j}{\sum_j \bar{Q}_c^j \, \bar{L}^j} \right) \frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{\left(\sum_j Q_{c,t}^j L_t^j\right)^2} \\ + \Gamma_l (L_t^j - \bar{L}^j) + (1-\gamma) Q_{c,t}^j \, \Omega^{'}(x_t) \Bigg) \;=\; \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j \frac{R_t^{l,j}}{\Pi_{t+1}^j} , \end{aligned} \tag{3.2.33}$$

$$\begin{aligned} \lambda_t^b \Bigg(Q_{c,t}^j + Q_{c,t}^j \Psi^{'} \left(\frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{\sum_j Q_{c,t}^j L_t^j} - \frac{\sum_j \bar{Q}_c^j \, \bar{s}^j}{\sum_j \bar{Q}_c^j \, \bar{L}^j} \right) \frac{(1-\epsilon_t^j)^{\nu}}{\sum_j Q_{c,t}^j L_t^j} \Bigg) \\ + \lambda_t^b Q_{c,t}^j \, \Omega^{'}(x_t) \;=\; \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j \frac{R_t^{b,j} - \epsilon_{t+1}^j}{\Pi_{t+1}^j} . \end{aligned} \tag{3.2.34}$$

Equation (3.2.30) says that the ratio core consumption-periphery consumption depends on the relative prices, i.e. the higher is the price of p goods, the higher is the consumption of c goods. Equations (3.2.31), (3.2.32), (3.2.33) and (3.2.34) are Euler equations for – respectively – deposits, central bank bonds, private loans and sovereign bonds.

Discussion

We first focus on the *bank capital cost* $\Omega(.)$. By simplicity, let us assume only one region, no inflation and $\Psi(.) = 0$. Subtracting equation (3.2.31) from equation (3.2.33) and taking a first order Taylor expansion around the steady state gives:

$$\underbrace{(\Gamma_d - \gamma\Omega^{'}(0))}_{>0}\hat{\lambda}_t + \Gamma_l \bar{L}\hat{L}_t - \underbrace{\gamma\Omega^{''}(0)}_{>0}\hat{x}_t = \beta(\bar{R}^l - \bar{R}^d)\hat{\lambda}_{t+1} + \beta(\hat{R}^l_t - \hat{R}^d_t)\,,$$

where a variable with a hat denotes the absolute ($\hat{R}^l_t$, $\hat{R}^d_t$ and $\hat{x}_t$) or relative ($\hat{\lambda}_t$ and $\hat{L}_t$) deviations from the steady state and a variable with a bar denotes the steady state. On the one hand, we see that the convexity of the cost is the crucial assumption. It makes increasing (resp. decreasing) the spread – between the lending rate and the deposit rate – when x_t is below (resp. above) the requirements. We also observe that the higher is the convexity, the higher is the transmission of the capital position to the spread. On the other hand, the assumption $\Omega^{'}(0) \leq 0$ is less important since the parameter in front of $\hat{\lambda}_t$ will always be positive. In the calibration and hence the subsequent analysis, we assume $\Omega^{'}(0) = 0$ and $\Omega^{''}(0) = \Gamma_x > 0$. By looking at equation (3.2.34), we could also point out that a fall in bank excess capital increases the spread $\hat{R}^l_t - \hat{R}^b_t$ exactly in the same way as the spread $\hat{R}^l_t - \hat{R}^d_t$. In section 3.4.2, we conduct a sensitivity analysis on Γ_x.

We then consider the *bank collateral cost* $\Psi(.)$. Once again, we simplify with one single region, no inflation and $\Omega(.) = 0$. To simplify the notation, we also define $(1-\epsilon_t)^{\nu}s_t/L_t \equiv \mathtt{cr}_t$. Subtracting equation (3.2.31) from equation (3.2.33) and taking a first order Taylor expansion around the steady state gives:

$$\begin{aligned}\Gamma_d\hat{\lambda}_t + \Gamma_l\bar{L}\hat{L}_t \quad &- \quad \frac{\bar{\mathtt{cr}}\Psi^{'}(0)}{\bar{L}}(\hat{\lambda}_t - \hat{L}_t) - \underbrace{\left(\frac{\bar{\mathtt{cr}}\Psi^{''}(0)}{\bar{L}} + \frac{\Psi^{'}(0)}{\bar{L}}\right)}_{\equiv\eta}\hat{\mathtt{cr}}_t \\ &= \quad \beta(\bar{R}^l - \bar{R}^d)\hat{\lambda}_{t+1} + \beta(\hat{R}^l_t - \hat{R}^d_t)\,,\end{aligned}$$

where a variable with a hat denotes the absolute ($\hat{R}^l_t$, $\hat{R}^d_t$, $\hat{\epsilon}_t$ and $\hat{\mathtt{cr}}_t$) or relative ($\hat{\lambda}_t$ and $\hat{L}_t$) deviations from the steady state and a variable with a bar denotes the steady state. We observe that the elasticity of $\hat{R}^l_t - \hat{R}^d_t$ to $\hat{\mathtt{cr}}_t$ is $-\eta/\beta$, which has an ambiguous sign. Because we want an increase (resp. decrease) in the collateral ratio to reduce (resp. raise) the spread – between the lending rate and the deposit rate –, we therefore need $\eta > 0$ that is $\bar{\mathtt{cr}}\Psi''(0) > -\Psi'(0)$. In the subsequent analysis, we assume $\Psi'(0) = 0$ and $\Omega''(0) = \Gamma_p > 0$, which meets this requirement. The higher is Γ_p, the higher is the transmission of the collateral position to the spread. Again by looking at equation (3.2.34), we could easily see that the collateral ratio $\hat{\mathtt{cr}}_t$ affects the spread $\hat{R}^l_t - \hat{R}^b_t$ with an elasticity $-\eta(1 + 1/\bar{\mathtt{cr}})/\beta < 0$. In section 3.4.2, we conduct a sensitivity analysis on Γ_p and also on the haircut ν.[9]

3.2.5 Government

In each country $j \in \{c, p\}$, the government consumes G^j_t and transfers lump-sum amounts $H^{h,j}_t$ to the household and $H^{b,j}_t$ to the bank. The government finances it through lump-sum taxes T^j_t from the household or public debt B^j_t according to:

$$H^{h,j}_t + H^{b,j}_t + G^j_t + \frac{R^{b,j}_{t-1} - \epsilon^j_t}{\Pi^j_t} B^j_{t-1} = T^j_t + B^j_t . \tag{3.2.35}$$

This equation also shows that sovereign default may happen through the term $0 \leq \epsilon^j_t \leq 1$. Everything else equal, a strictly positive ϵ^j_t reduces the stock of sovereign debt in the next period. We moreover assume:

$$\begin{aligned} T^j_t &= \bar{T} + \tau\left(B^j_{t-1} - \bar{B}^j\right) , && (3.2.36)\\ B^j_t &= b^j_t + s^j_t , && (3.2.37)\\ G^j_t &= \left(\bar{G}^j\right)^{1-\gamma_g}\left(G^j_{t-1}\right)^{\gamma_g} \exp(u^g_t) . && (3.2.38) \end{aligned}$$

[9] The calibration therefore implies quadratic cost functions $\Omega(.)$ and $\Psi(.)$, under which the bank also incurs costs when the capital or the collateral ratio is above the steady state. The key point is that quadratic functions satisfy the assumptions stated above and, up to a linear approximation, yield the same predictions than more general cost functions. These quadratic cost functions are often used in the literature as for instance Gerali et al. (2010), Andrès et al. (2004) or Harrison (2011).

Equation (3.2.36) with $\tau > 0$ implies that lump-sum taxes react positively to an increase in debt. In other words, the government does not only rely on debt to finance any budget deficit but also raises taxes, as estimated in Bohn (1998), rather than decreasing public consumption. This tax rule is similar to the one used in Corsetti et al. (2013).[10] It is worth noting that a sufficiently high τ parameter is crucial to stabilize the economy.[11] Equation (3.2.37) states that both households and the bank own the sovereign debt. Finally, we define public consumption as a stochastic autoregressive process with $0 < \gamma_g < 1$ and u_t^g i.i.d. (equation 3.2.38).

Default

To determine the default rate ϵ_t^j we tightly refer to the methodology used by van der Kwaak and van Wijnbergen (2013) by introducing an exogenous fiscal limit for the economy. The intuition is that there is a maximum level of taxes that can be raised before the economy becomes politically unstable. This translates through equation (3.2.36) into a maximum level of sovereign debt-to-output ratio BY_t^{max} that the government is able to service. We moreover assume that this maximum *sustainable* level is stochastic and follows:

$$BY_t^{max} = \bar{BY}^{max} + \gamma_b(BY_{t-1}^{max} - \bar{BY}^{max}) + u_t^b \, , \tag{3.2.39}$$

where $0 < \gamma_b < 1$ is the autoregressive component and u_t^b is a i.i.d. shock. This stochasticity aims capturing the uncertainty around political instability in the context of sovereign debt and taxation.[12]

Let us define $\tilde{B}_t^j$ as the level of debt in the economy when no default occurs. This is obviously defined as:

$$G_t^j + \frac{R_{t-1}^{b,j}}{\Pi_t^j} \, B_{t-1}^j = T_t^j + \tilde{B}_t^j \, .$$

[10]The focus of this chapter is not on taxation and we therefore use a lump-sum and non distortionary tax instead of a more sophisticated and distortionary tax scheme.

[11]A linearization of equations (3.2.35) and (3.2.36) gives $\hat{B}_t = (\bar{R}^b - \tau)\hat{B}_{t-1} + \bar{R}^b(\hat{R}_{t-1}^b - \hat{\Pi}_t) + \bar{G}/\bar{B}\,\hat{G}_t + \bar{H}/\bar{B}\,\hat{H}_t - \hat{\epsilon}_t$. We see that after a shock, we need a sufficiently high τ to avoid an explosive path for B_t.

[12]In reality, the maximum sustainable government debt level is not exogenous but depends on expected growth rates, on expected growth volatility or on the expected government ability to raise taxes (see for instance Collard et al., 2014). But this is beyond the scope of this chapter.

If this level of debt-to-output $\tilde{B}^j_t/(4Y^j_t)$ is lower (resp. higher) than the maximum sustainable level BY^{max}_t, the government does not (resp. does) default. In other words, we define the default decision Δ_t as:

$$\Delta_t = \begin{cases} 0 & \text{if } \frac{\tilde{B}^j_t}{4Y^j_t} < BY^{max}_t \\ 1 & \text{otherwise} \end{cases}$$

This default process Δ_t is a step function and we approximate it with the continuous normal cdf:

$$\epsilon^j_t = F\left(\frac{\tilde{B}^j_t}{4Y^j_t} - BY^{max}_t \ ; \ 0 \ , \ \sigma^2\right) \ = \ \Phi\left(\frac{\frac{\tilde{B}^j_t}{4Y^j_t} - BY^{max}_t}{\sigma}\right) . \qquad (3.2.40)$$

where $\sigma > 0$ represents the variance and $\Phi(.)$ is the standard normal cdf. We see that when $\sigma \rightarrow 0$, then $\epsilon^j_t \rightarrow \Delta_t$. A reduction (resp. increase) in the maximum sustainable level of debt-to-output, through the stochastic shock u^b_t in equation (4.3.35), increases (reduces) the default rate in the economy. Similarly, a higher (resp. lower) debt-to-output ratio $\tilde{B}^j_t/(4Y^j_t)$ increases (resp. reduces) the default rate in the economy. Agents observe the current economic conditions and, as a consequence, they form expectations on default according to equation (4.3.38). If we assume that only the periphery country can default, the spread between the periphery and the core sovereign interest rate – abstracting from other general equilibrium dynamics – is therefore given by a wedge reflecting the default expectations:

$$R^{b,p}_t = R^{b,c}_t + E_t[\epsilon^p_{t+1}] \, . \qquad (3.2.41)$$

Realization versus risk

We investigate the effects of both default realization and default risk. With default *realization*, we simply assume $H^{h,j}_t = 0$ and $H^{b,j}_t = 0$. In this case, a – negative – stochastic shock in equation (4.3.35) reduces the maximum sustainable debt, which in turn increases default according to equation (4.3.38). This immediately decreases the government debt (equation 3.2.35) and therefore the assets of the bank (equations 3.2.26 and 3.2.27) and of the households (equation 3.2.1). Since the shock is persistent, expectations of default also increase and hence the sovereign interest rates through equation (3.2.41). As a result, debt starts rising progressively in the subsequent periods. The default realization is therefore transmitted both through prices (higher risk premium) and quantities (partial loss for the holders of sovereign debt).

To deal with only the *risk* dimension of the shock, we want to isolate the price effect from the quantity effect. To do so, we assume that the government does really default as explained above but transfers at the same time a lump-sum amount equivalent to the defaulted amount to the concerned agents (households and the bank):

$$H_t^{h,j} = \frac{\epsilon_t^j}{\Pi_t^j} b_{t-1}^j ,$$

$$H_t^{b,j} = \frac{\epsilon_t^j}{\Pi_t^j} s_{t-1}^j .$$

In other words, $H_t^{h,j}$ and $H_t^{b,j}$ are lump-sum transfers that (i) exactly compensates bond holders (households and the bank) for losses associated with the default realization and at the same time (ii) leaves the current level of debt unchanged. In this way, we capture the effects of higher interest rates on sovereign due to the default risk dimension, but abstract from the consequences of direct wealth loss due to the realization dimension. The same specification has been used by Corsetti et al. (2013). This procedure is helpful to reproduce the sovereign debt crisis' dynamics in the euro area where only Greece effectively, partially, defaulted.

3.2.6 Monetary authority

The central bank sets the policy interest rate R_t according to a standard Taylor rule:

$$R_t = (R_{t-1})^{\gamma_m} \left(\bar{R} \left(\frac{Y_t}{\bar{Y}} \right)^{0.5} \left(\frac{\Pi_{t-1}}{\bar{\Pi}} \right)^{1.5} \right)^{1-\gamma_m} , \qquad (3.2.42)$$

where $0 < \gamma_m < 1$ is the autoregressive parameter. The coefficients on output gap and inflation gap are standard as found for instance in Smets and Wouters (2003).

3.2.7 Closing the model

We close the model with the definitions of domestic demand in country $j \in \{c, p\}$:

$$A_t^j = C_t^j + C_t^{e,j} + C_t^{b,j} + I_t^j + G_t^j + \texttt{costs}_t^j \,,$$

where $\texttt{costs}_t^j$ collects all adjustment and operative costs related to households, entrepreneurs and firms in country j. Moreover, $\texttt{costs}_t^c$ also includes the costs related to the bank. These two definitions imply that we have a zero net-supply of central bank bonds, *i.e.* $B_t^{cb} = 0$.

3.3 Calibration

As already explained, we assume that the core economy and the periphery economy have the same structure, meaning that the parameters are similar in each country. The only difference between the two countries is the steady state level of debt and hence the steady state level of government consumption. The calibration refers to euro area stylized facts in 2010, that is at the onset of the sovereign crisis. Time is discrete and one period represents one quarter. Table 3.3.1 presents an overview of the parameters while the calibration methodology is explained below.

3.3.1 Steady state restrictions

The similar structure of the two economies implies that the steady state inflation is also identical and we assume it to be zero, that is $\bar{\Pi} = \bar{\Pi}^j = 1$ (see later). The similar structure also implies the same marginal costs for the production of intermediate goods and therefore $\bar{\phi}^c = \bar{\phi}^d$ through equation (3.2.20). In turn, equations (3.2.22) and (3.2.23) imply $\bar{\phi}^j = 1$ and $\bar{Q}_j^{-j} = 1$. Regarding the bank, we follow Enders et al. (2011) and consider no excess capital at the steady state ($\bar{x} = 0$). Moreover, we also assume no default ($\bar{\epsilon}^j = 0$). Regarding the steady-state portion of sovereign bond held by households and the bank, we follow Guerrieri et al. (2012) and assume that only one third of debt is held by households both in the core and the periphery.

Table 3.3.1: Parameter values

Parameter	Value	Description
Households		
β	0.99	Discount factor
ϕ_d	0.5	Deposit adjustment cost
ϕ_b	0.1	Bond adjustment cost
ψ_n	18.44	Weight of labour in (dis-)utility
ψ_d	0.01	Weight of deposits in utility
Global bank		
ϑ	0.5	Elasticity of substitution between c and p consumption goods
γ	0.05	Bank capital ratio requirement
Γ_d	0.005	Deposit operating cost
Γ_l	0.01	Loan adjustment cost
Γ_p	0.25	Collateral requirement cost
Γ_x	1.50	Capital requirement cost
ν	8	Elasticity of haircut to default applied to government bonds
Production		
δ	0.025	Capital depreciation rate
σ_e	0.01	Inverse of IES in consumption (entrepreneur)
ϕ_i	0.2	Investment adjustment cost
α	0.3	Index of openess
θ	0.37	Markup in price setting
μ	0.3	Elasticity of production w.r.t. capital
κ	263	Price rigidities
Authorities		
τ	0.13	Elasticity of taxes w.r.t. debt
$\bar{T}/\bar{Y}^j$	0.12	Tax-output ratio objective
$\bar{B}^c/(4\bar{Y}^c)$	0.60	Debt-output ratio objective in the *core* country
$\bar{B}^p/(4\bar{Y}^p)$	0.85	Debt-output ratio objective in the *periphery* country
$\bar{BY}^{max}$	0.92	Maximum sustainable debt-output ratio
σ	0.015	Standard deviation of default pdf
$\bar{\Pi}$	1.00	Gross inflation objective
Shocks		
γ_m	0.85	Autoregressive parameter for Taylor rule
γ_g	0.85	Autoregressive parameter for government spending shock
γ_b	0.8	Autoregressive parameter for sustainable debt-output shock

3.3.2 Parameters governing the steady state

Taking the different Euler equations (3.2.3), (3.2.4), (3.2.9), (3.2.10), (3.2.31), (3.2.32), (3.2.33) and (3.2.34) at the steady state gives:

$$\begin{aligned}\bar{R}^{d,j} &= \frac{1-\mathtt{a}\,\psi_d}{\beta} = \frac{1-\Gamma_d}{\beta}\,,\\ \bar{R} &= \bar{R}^{l,j} = \bar{R}^{b,j} = \frac{1}{\beta}\,,\\ \bar{r}^j &= \frac{1}{\beta} - 1 + \delta\,.\end{aligned}$$

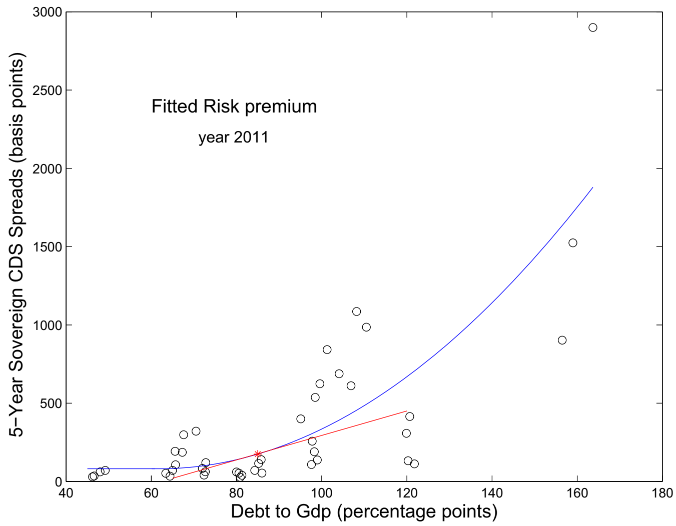
We observe that the deposit rate $\bar{R}^{d,j}$ is negatively related to the deposit operating cost Γ_d, that is the bank compensates the cost of operating deposits through lower interest rates payments. We set the psychological discount factor $\beta = 0.99$ to have annualized interest rates on loans and bonds, as well as the monetary policy rate, equal to 4% at the steady state. We fix the deposit operating cost $\Gamma_d = 0.005$ to have annualized interest rates on deposits equal to 2%. We compute the weight of deposits in utility $\psi_d = \Gamma_d/\mathtt{a}$, where $\mathtt{a}$ is a parameter aggregating other parameters and steady states. Following the RBC literature we assume that hours $\bar{h}^j = 0.2$ meaning that agents work 20% of their time. This allows to determine the labour disutility parameter ψ_n. The production function is a Cobb-Douglas with the capital share $\mu = 0.3$ and setting the depreciation rate at $\delta = 0.025$ implies $\bar{K}^j/\bar{Y}^j = 6.24$ and $\bar{I}^j/\bar{Y}^j = 0.156$, in line with the RBC literature and empirical observations. We calibrate the price markup $\theta = 0.37$ as in Smets and Wouters (2003). Finally, we assume a bias for domestic goods and we calibrate $\alpha = 0.3 < 0.5$. This kind of bias is standard in the NOEM literature, as for instance in Gali and Monacelli (2008). The value we select is in the range used in recent quantitative macro-finance models. For a detailed description, we may for instance refer to Coeurdacier et al. (2007). This bias also determines the *gross* trade (the lower the bias, the higher the gross trade) but not the *net* trade. Since the two countries are symmetric, the net trade is zero at the steady state, whatever the value of α. Moreover, to keep again symmetry between regions, we impose that the bank has an identical preference between consuming core or periphery goods, *i.e.* $\vartheta = 1 - \vartheta = 0.5$.

3.3.3 Parameters related to policies

Following Enders et al. (2011), we set the required bank capital ratio at $\gamma = 0.05$. Empirically, the capital ratio for the major banks in the euro area has been found to be between 3% and 5%. Regarding monetary policy and as already explained above, we set the inflation objective of the central bank at 0%, implying $\bar{\Pi} = 1$. Increasing the inflation objective to a more realistic value of 2% would not modify our results. On the fiscal side, we specify our two-country model for the euro area distinguishing between the core and periphery in terms of debt-to-GDP ratio. The periphery refers to the GIIPS (Greece, Ireland, Italy, Portugal and Spain) for which we assume a debt to GDP ratio $\bar{B}^p/(4\bar{Y}^p) = 85\%$ at steady state while for the core, the rest of the euro zone, we assume a ratio $\bar{B}^c/(4\bar{Y}^c) = 60\%$. These values are the same as Guerrieri et al. (2012) and they aggregate them from the IMF economic outlook for 2010. Taxes-to-output $\bar{T}/\bar{Y}^j$ are set at steady state to 12% of GDP in both regions, which is the level of indirect taxes in the euro area (source: OECD), implying a government consumption of 9.5% of GDP in the core and of 8.5% in the periphery. This asymmetry is due to the different steady state values of debt to GDP in the two regions. The periphery bears a higher interest rate burden on debt and must therefore reduce its steady state public consumption. We set the two parameters governing the default process – *i.e.* the maximum sustainable debt-to-output ratio $\bar{BY}^{max}$ and the standard deviation σ of default pdf – in order to have an elasticity of default risk (or of sovereign risk premium) to debt of 0.1 around the steady state, in the periphery country, as shown in Figure 3.3.1.[13] The same calibration methodology is used by Corsetti et al. (2013) where we refer the reader for an exhaustive list of empirical works on the relationship between fiscal variables and yields on government bonds. As explained in section 3.2, we consider that only the periphery may default.

[13] We choose the year 2011 because it corresponds to the period of troubles on the sovereign debt market. We see an increasing and strictly convex relationship between debt and spread. Removing Greek data would imply a more linear relationship.

Figure 3.3.1: Sovereign risk premia *vs.* debt-to-GDP in EA countries



Notes. The figure plots the 5-year CDS spread for the year 2011 (quarterly observations) against the debt-to-GDP level at quarterly frequency (black dots). The countries shown are: Austria, Belgium, Germany, France, Finland, Greece, Ireland, Italy, Portugal and Spain. The blue line is a quadratic interpolation whereas the red line is the tangent at the debt-to-GDP steady state. *Data sources*: Datastream.

3.3.4 Other steady state implications

First, our calibration implies that the size of the bank balance sheet (total assets or total liabilities) represents 140% of yearly total output $(4 \times (\bar{Y}^c + \bar{Y}^c))$. This number seems realistic. EA data compiled by the ECB show that total assets of euro area credit institutions over euro area GDP was 339% in 2010. However, focusing on loans to EA residents (save for monetary and financial institutions) and holdings of securities issued by EA residents (save for monetary and financial institutions), this ratio reduces to 166% which is therefore close to what we have.[14] Second, we have three private consumptions in

[14]Source: ECB, Statistical Data Warehouse, Monetary statistics, Credit institutions and money market funds balance sheets, Aggregated balance sheet of euro area credit institutions.

each region, from the household, the bank and the entrepreneurs. With respectively 69% of GDP, 2% of GDP and 3% of GDP, we observe that most of the private consumption is at the household's level. Third, all the costs in the model are dynamics, that is they exist only outside the steady state.

3.3.5 Parameters governing the dynamics

This set of parameters does not affect the steady state of the model variables. They instead are set to obtain plausible dynamics. Regarding consumption and as often in the literature, we use a log-utility for households and a linear utility for banks. We assume that the entrepreneurs have a high intertemporal elasticity of substitution in consumption, that is they have a only slightly concave utility function. We set $\sigma_e = 0.01$. Adjustment costs on deposits, bonds, loans and investment (respectively represented by the parameters ϕ_d, ϕ_b, Γ_l and ϕ_i) are standard in DSGE models and their role is to smooth quantity reactions after a stochastic shock. We directly borrow the capital adjustment cost from Enders et al. (2011) and we set $\Gamma_x = 1.5$ to obtain a sufficiently persistent reaction of excess capital x_t, and therefore a strong enough bank capital channel. The collateral adjustment cost is crucial in our model. It gives an additional collateral role to sovereign bonds, both with respect to its volume (important in case of default realization) and quality (important in case of default risk). We set $\Gamma_p = 0.25$ and $\nu = 8$. We discuss further the role of these parameters in section 3.4.2. In the model we assume price rigidities through a menu cost κ *à la* Rotemberg. We calibrate this parameters of the new-Keynesian Phillips curve such as to reproduce the one estimated by Smets and Wouters (2003) with euro area data. There is not much empirical observations regarding the elasticity τ of taxes to debt. For instance, Corsetti et al. (2013) assume that taxes react to debt "sufficiently strongly" to ensure that debt remains bounded throughout their simulations. To objectify this calibration, we first calibrate the autocorrelation of the public expenditure shock (3.2.38) as $\gamma_g = 0.85$ to match the one we observe in EA aggregated data. Then we use this public expenditure shock – in the absence of default risk – to generate fluctuations in public consumption and debt. We set $\tau = 0.13$ to match the relative volatility of public consumption and debt with what we observe in EA data. We fix the remaining autoregressive parameters – γ_m and γ_b – to standard values between 0.8 and 0.85.

3.4 Dynamic simulations

To produce dynamic simulations, we take a first order approximation of the model equations. We study the consequences of a shock to the maximum sustainable debt-output ratio, represented by equation (4.3.35). We calibrate the size of the shock in order to have an initial increase in default of 1%. The default in turn affects the whole economy, including the realized debt-output ratio and again default, through general equilibrium effects. As already mentioned, our calibration implies an elasticity of sovereign interest rates w.r.t. debt-output ratio around 0.1 in the periphery country. In other words, an increase in debt-to-GDP by 1 ppt raises the interest rate on sovereign debt by 0.1 ppt. In the subsequent simulations, we first investigate how default risk *vs.* default realization spreads to the whole economy, with banking integration as presented in section 3.2.4, *i.e.* without cost in case of geographical diversification. Second, we conduct sensitivity analysis on the parameters related to the bank capital channel and the bank collateral channel, to better understand the role of these two frictions. Third, we move from a fully integrated banking system to a more fragmented one and check how it changes the transmission mechanisms. We also compare simulation results with alternative banking to what we know from empirical observations. Fourth and finally, we conduct a couple of policy analysis.

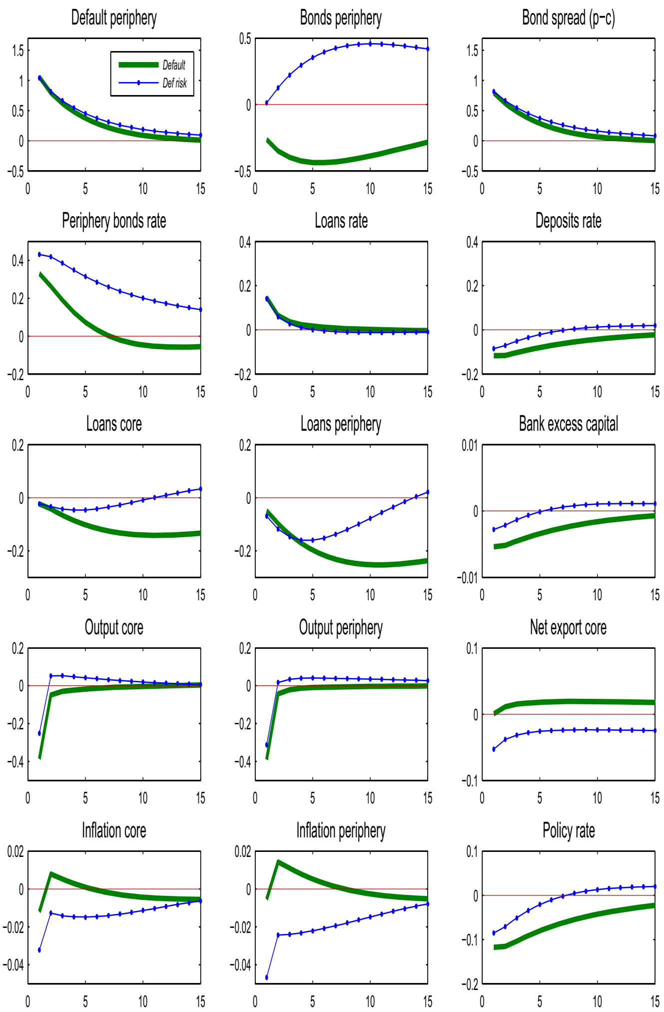
3.4.1 Defaults: from risk to realization

Figure 3.4.1 shows the impulse response functions under the risk assumption and the realization assumption regarding default, as explained in section 3.2. We assume integration in the banking sector as presented in section 3.2.4.

Default risk

Figure 3.4.1 (blue line with dots) shows the model transmission of default risk to the banking sector and the real economy in the two regions. As explained in section 3.2.5, we remind that default risk is in fact a default realization immediately followed by a lump-sum compensation *à la* Corsetti et al. (2013). We obviously observe an increase in the sovereign rate in the defaulted country and a "flight-to-quality" to the core country. The increase in the periphery sovereign rate raises periphery public debt – through higher interest rate burden – whereas the decrease in the core sovereign rate reduces core public debt. Then the transmission from the banking sector to the

Figure 3.4.1: IRFs after a negative maximum sustainable debt-output ratio shock, with banking integration (deviations from the steady state)



Notes. 'Bank excess capital' is normalized with respect to the steady state size of the bank balance sheet. Deviations are expressed respectively in percentage points for ratios and rates and in percentage for volumes. The green line 'Default' represents the scenario with default realization. The evolutions of loan and deposit rates are similar in the two regions.

real economy mainly goes through the bank capital channel and the bank collateral channel. As explained in section 3.2.4, the fall in excess capital raises the spread between the lending and the deposit rates. Moreover, the sovereign bond risk increases the haircut applied to the collateral. The eligible collateral ratio falls and this raises further the spread.[15] As a result, the volume of loans to the real economy shrinks, especially towards the periphery region. Inflation follows a similar pattern. Since inflation is smaller in the periphery country, the real exchange rate appreciates and net exports from the core region fall. In the end, although the sovereign crisis is located in the periphery region, we observe that the – initial – fall in output is quite similar in the two regions. The integrated bank therefore allows for an almost perfect transmission of the crisis.[16]

Default realization

Figure 3.4.1 (green line) shows the model transmission of default realization to the banking sector and the real economy in the two regions. We see that the transmission is different from risk in many respects. First, default realization reduces the debt level in the periphery which limits the surge in the periphery bond rate. Second, the transmission from the banking sector to the real economy is stronger than with the risk scenario. The deeper falls in excess capital and in the eligible collateral ratio increase the bank capital cost and the bank collateral cost. This raises further the spread between the loan rate and the deposit rate, and *in fine* intensifies the fall in loans and in output. As with the risk scenario, we observe that the output follows a quite similar pattern in the two regions, due to integration in the banking sector and its ‘crisis sharing’. Third, although output is lower with realization than with risk, inflation is higher. The lower deposit rate with realization makes the household more willing to consume. The implied lower marginal utility of consumption increases wage claims which in turn raises the marginal cost and hence inflation.[17]

[15] The spread increase is similar in the two regions and therefore, figure 3.4.1 does not make the distinction between the core and periphery loan and deposit rate variables.

[16] We observe that after the initial fall, output immediately jumps above the steady state. This jump is due to a similar jump of labour and wages. One solution to smooth the labour and output reactions would be for instance to introduce a monopolistic labour supply with rigid wages, instead of the perfectly competitive labour market we currently have.

[17] This is also due to the perfectly competitive labour market assumption. A monopolistic labour market with wage rigidities, as already mentioned in footnote 16, would change

In conclusion, we see that realization has a deeper impact on output than risk, mainly through the bank capital and the bank collateral channels (lower excess capital and lower eligible collateral with realization). Moreover, both with risk and realization, the integrated bank assumption allows to share almost perfectly between regions the periphery sovereign troubles.

3.4.2 Sensitivity analysis

We see above that default may transmit from the bank to the real economy through the bank capital and the bank collateral channels. Indeed, a sovereign shock weakens the bank capital position and the bank collateral position. The bank faces higher costs and as a consequence increases the lending-deposit interest rate spread. This reduces private loans. We show theoretically in section 3.2.4 that the higher the convexity of the capital and collateral costs, the higher is the transmission. In this section, we conduct a sensitivity analysis on the parameters governing the convexity, namely Γ_x for the capital cost and Γ_p for the collateral cost. Moreover, the collateral cost depends on the *eligible* collateral, that is the potential collateral less a haircut. The size of the haircut reflects the riskiness associated to the collateral. We conduct a sensitivity analysis on the parameter ν representing the elasticity of the haircut to the riskiness.

The role of convexity in the bank capital channel

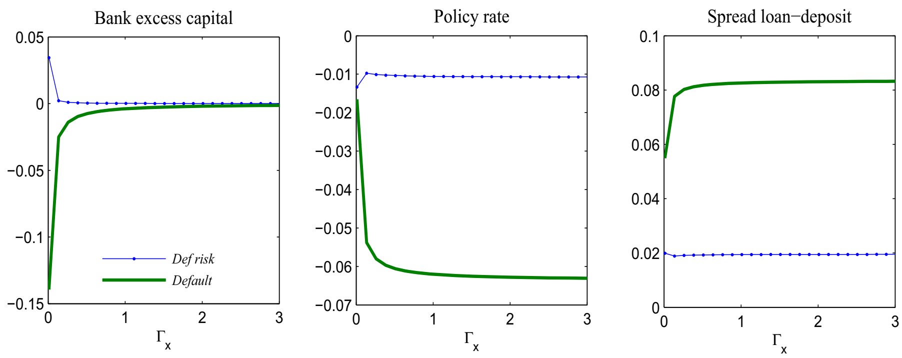
The parameter Γ_x represents the convexity of the bank capital cost $\Omega(.)$. Section 3.2.4 shows theoretically that when $\Gamma_x = 0$, a fall in excess capital x_t has no direct effect on the loan-deposit interest rate spread.[18] The higher Γ_x, the more a fall in excess capital increases the spread. Figure 3.4.2 provides a numerical illustration of the effects of a negative sovereign shock, for different values for the convexity. We give the average effect over the first 15 periods.[19] First, we observe that a change in Γ_x does not really change the transmission with a default risk (blue line with dots). Indeed, risk does not directly affect bank assets and therefore the capital position. The picture is different with a default realization which reduces assets and hence the capital position (green line). When $\Gamma_x = 0$, bank may let excess

inflation behaviour.

[18]Although it may obviously have indirect effects through general equilibrium linkages.

[19]Reactions may become highly volatile with extreme values for the convexity. The average over 15 periods allows to give a more stable and accurate picture of what happens.

Figure 3.4.2: Effects of a negative maximum sustainable debt-output ratio shock with banking integration, for different values of Γ_x (deviations from the steady state)



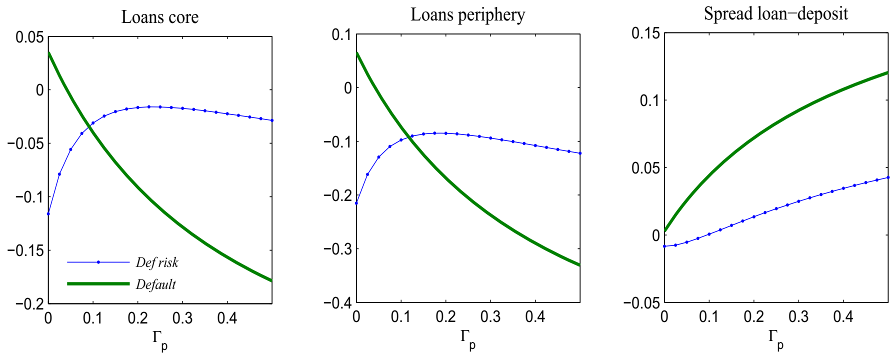
Notes. Average effects over 15 periods. Deviations are expressed respectively in percentage for volumes and in percentage points for rates. The green line 'Default' represents the scenario with default realization. The evolutions of the spread loan-deposit interest rate are similar in the two regions.

capital fall without cost consequences. When Γ_x is higher, the bank must restore its capital position to avoid costs. To do so, the bank increases its spread which slowdowns the economy as revealed by the policy rate. We see that a sufficiently high convexity may increase the transmission to the economy and hence to the policy rate by about 50% (the policy rate falls – on average over the first 15 periods – from 0.04 ppt when $\Gamma_x = 0$ to 0.06 ppt when Γ_x is above 1).

The role of convexity in the bank collateral channel

The parameter Γ_p represents the convexity of the bank collateral cost $\Psi(.)$. Section 3.2.4 shows theoretically that when $\Gamma_p = 0$, a fall in the collateral ratio $\texttt{cr}_t$ has no direct effect on the loan-deposit interest rate spread. The higher Γ_p, the more a fall in collateral increases the spread. Figure 3.4.3 provides a numerical illustration of the effects of a negative sovereign shock, for different values for the convexity. To isolate the convexity effect from the haircut effect, we assume $\nu = 0$, *i.e.* there is no haircut whatever the riskiness of sovereign bonds. Focusing on default realization (green line), we observe that with a small Γ_p, there is almost no transmission of the shock to

Figure 3.4.3: Effects of a negative maximum sustainable debt-output ratio shock with banking integration, for different values of Γ_p (deviations from the steady state)



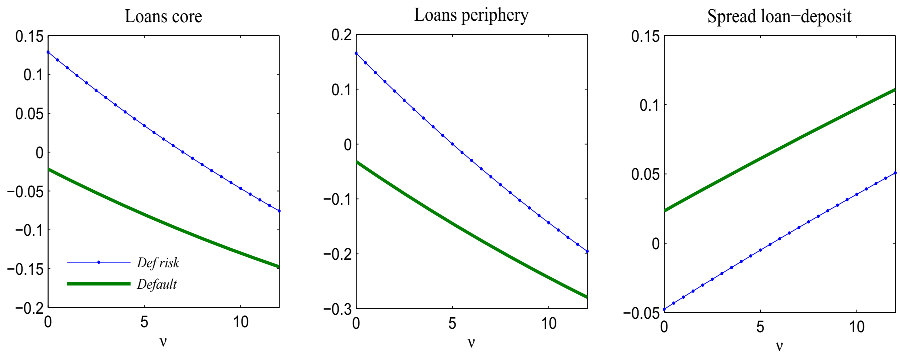
Notes. Average effects over 15 periods. Deviations are expressed respectively in percentage for volumes and in percentage points for rates. The green line 'Default' represents the scenario with default realization. The evolutions of the spread loan-deposit interest rate are similar in the two regions.

the economy. However, the transmission strongly increases along with the convexity. Indeed, default realization reduces the collateral and banks must reduce private loans to avoid high costs. The picture is more ambiguous with a default risk because risk does not reduce available collateral (remember we do not apply any haircut).

The role of haircut in the bank collateral channel

We see from equation (3.2.27) that the bank values sovereign bonds as collateral taking into account their riskiness, because the riskiness determines the size of the haircut applied. The parameter ν controls the elasticity between the riskiness and the haircut applied to the collateral. Figure 3.4.4 shows that the higher is the elasticity, the higher is the shock transmission to the economy, both with the risk scenario and the realization scenario. Indeed, higher values of the haircut reduce eligible collateral which makes bank borrowing more costly. As a consequence, the bank shrinks its balance sheet with lower credit to the private sector. We also observe that the quantitative effect of haircut is sizeable. For instance, without any haircut, a 1% default realization shock reduces private loans to the periphery by 0.05%

Figure 3.4.4: Effects of a negative maximum sustainable debt-output ratio shock with banking integration, for different values of ν (deviations from the steady state)



Notes. Average effects over 15 periods. 'Bank excess capital' is normalized with respect to the steady state size of the bank balance sheet. Deviations are expressed in percentage points. The green line 'Default' represents the scenario with default realization. The evolutions of the spread loan-deposit interest rate are similar in the two regions.

on average over 15 periods whereas the same shock with $\nu = 10$, that is with an haircut of 10%, reduces loans by 0.25% on average.

In conclusion, convexity of the capital and collateral costs increase the transmission of the default realization shock. However, this convexity does not generate enough transmission with default risk. In this latter case, the role of the elasticity of haircut is crucial.

3.4.3 From integration to fragmentation in the banking sector

So far we assume a fully integrated banking system. However, although we have several banks playing at a global level inside the euro area, there are also some banks more exposed to their domestic market. Moreover, banking fragmentation probably increased during the financial crisis of 2007-2008 and the sovereign crisis of 2010-2011 (see section 3.1 for a discussion). In theory, assuming a full integration might induce a too strong transmission from periphery to core and as a result a too weak impact of default in the periphery. There are different ways to introduce fragmentation in the banking sector. For instance, we could assume one bank in each region with only local liabilities and assets, apart from sovereign bond holdings as in Guerrieri et al. (2012). Alternatively, we could keep one single bank but with two different bank capital constraints, one related to the core assets/liabilities and one related to the periphery ones. This would therefore imply two different bank capital costs. The only link between regions would be the maximization of a 'global profit'. Another possibility would be to have two different bank collateral costs, meaning that the bank having more sovereign bonds/collateral from one region has an incentive to increase private lending to the same region, and *vice versa*. A reason could be that it is indeed easier to attest the reliability of both domestic creditors and sovereigns. Another that with an insufficient harmonization of bankruptcy procedure within the EA, banks are more exposed to foreign defaults creating a bias towards domestic-banking. In other words, assets from the same region are complement meaning there is a cost from geographical diversification. In the subsequent analysis, we focus on the third approach because its implementation requires almost no modification of the initial model.[20]

Fragmentation

As shown in equation (3.2.27), the fully integrated bank does not make any distinction between the geographical origin of assets and the bank collateral cost is:

$$\Psi\left(\frac{\sum_j Q^j_{c,t}(1-\epsilon^j_t)^\nu s^j_t}{\sum_j Q^j_{c,t}L^j_t} - \frac{\sum_j \bar{Q}^j_c\ \bar{s}^j}{\sum_j \bar{Q}^j_c\ \bar{L}^j}\right), \tag{3.4.1}$$

with $\Psi(0)=0$, $\Psi^{'}(0)\leq 0$, $\Psi^{''}(.)>0$ and $\nu\geq 0$. With fragmentation, we assume that bonds from region j only help lending – through its collateral role on the secured interbank market – to the same region. In other words, we introduce a double cost making the distinction between core and foreign assets:

$$\mathtt{d}\sum_j \Psi\left(\frac{(1-\epsilon^j_t)^\nu s^j_t}{L^j_t} - \frac{\bar{s}^j}{\bar{L}^j}\right). \tag{3.4.2}$$

In this case, the j collateral is only useful for the j private lending. This modifies first order conditions (3.2.33) and (3.2.34) accordingly. We calibrate equation (3.4.2) as equation (3.4.1), with $\Psi^{'}(0)=0$ and $\Psi^{''}(.)=\Gamma_p>0$ (see

[20] In appendix 3.B, we also present the second alternative (two different capital constraints) and show that we obtain the same kind of results.

table 3.3.1 for the numerical values). $\mathtt{d} = 1/2$ is a new parameter calibrated such that the size of the cost after the shock is similar with the two types of formulation.

Comparison to existing empirical evidence

Before comparing simulation results with an integrated bank and with fragmentation, we first look at the FAVAR estimates from Neri and Ropele (2013) on the macroeconomic effects of the sovereign debt crisis for a subset of core and periphery countries of the euro area. Table 3.4.1 (row 'Data estimates') shows that, according to Neri and Ropele (2013), a 1 ppt increase in default risk in the periphery raises sovereign periphery bond interest rates by 1 ppt (full pass-through) and has no effect on sovereign core bond interest rates (no pass-through). However, the interest rates on private loans increase both in the periphery and the core region, although the increase is more pronounced in the periphery (respectively +0.3 ppt in p and +0.1 ppt in c). These results are in line with what we already observed from figure 3.1.1 in section 3.1. The fall in loans is important, with -1% in the core and -2% in the periphery. As a result the central bank reduces the policy rate by 0.3 ppt. Our simulation results with integration in the banking sector (row 'Model integ.') are qualitatively in line with the FAVAR estimates. Quantitatively, we however observe that banking integration shares too much the periphery troubles with the core region. The increase in the periphery bond rate is limited to 0.4 ppt and the core bond rate falls by 0.4 ppt because of a flight-to-quality. The spread surge – between the periphery and the core bond rates – is therefore close to the data estimates but not its distribution among regions. Similarly, the model with banking integration provides equivalent rises in private lending rates although data show a more pronounced rise in the periphery. Finally, the model cannot reproduce the deep fall in loans – and output – and therefore the strong central bank reaction. Moving from bank integration to fragmentation (row 'Model frag.') prevents the full sharing of the periphery turmoil. As a result, the situation in the periphery deteriorates and is now more in line to what we observe from data estimates. However, the situation in the core becomes too good. We observe that the lending rate to core firms decreases (-0.1 ppt) and therefore the volume of loans increases (+0.1%). We see from the simulations that these two polar banking representations (integration *vs.* fragmentation) also produce polar results with contagion on the one hand and no contagion on the other hand. With fragmentation, the monetary policy is therefore too loose for the core region and too restrictive for the periphery region. Looking at EA aggregated variables, we see that the – negative – effect of the shock is about twice stronger with banking fragmentation than with banking integration (columns R, $L^c + L^p$ and $Y^c + Y^p$ in table 3.4.1). In a currency union, banking integration is therefore desirable in case of an – asymmetric – sovereign shock. Bignon et al. (2013) find a similar conclusion although they use a different modelling approach.

The last line of table 3.4.1 (row 'Model interm.') proposes a model with a banking sector between integration and fragmentation. To do so, we assume a collateral cost as:

$$\begin{aligned} & \mathtt{d}\,\Psi\left(\frac{\lambda s_t^c + (1-\lambda)Q_{c,t}^p(1-\epsilon_t^p)^\nu s_t^p}{\lambda L_t^c + (1-\lambda)Q_{c,t}^p L_t^p} - \frac{\lambda \bar{s}^c + (1-\lambda)\bar{Q}_c^p \bar{s}^p}{\lambda \bar{L}^c + (1-\lambda)\bar{Q}_c^p \bar{L}^p}\right) \\ + \; & \mathtt{d}\,\Psi\left(\frac{(1-\lambda)s_t^c + \lambda Q_{c,t}^p(1-\epsilon_t^p)^\nu s_t^p}{(1-\lambda)L_t^c + \lambda Q_{c,t}^p L_t^p} - \frac{(1-\lambda)\bar{s}^c + \lambda\bar{Q}_c^p \bar{s}^p}{(1-\lambda)\bar{L}^c + \lambda\bar{Q}_c^p \bar{L}^p}\right) \end{aligned} \quad (3.4.3)$$

with $0 \leq \lambda \leq 1/2$. When $\lambda = 1/2$ and $\mathtt{d} = 1/2$, equation (3.4.3) is equivalent to equation (3.4.1) and we are back to the integration case. When $\lambda = 0$, equation (3.4.3) is equivalent to equation (3.4.2) and we are back to the fragmentation case. Any other $0 < \lambda < 1/2$ gives an intermediate degree of fragmentation, the closer to 0 (resp. the closer to 1/2) is λ, the stronger is the fragmentation (resp. integration). In the simulation, we assume $\lambda = 1/3$ and set $\mathtt{d} = 2$ such that the size of the cost after the shock is similar with the two other simulations. We see that this intermediate representation reproduces quite well the empirical evidence, at the exception of the deep fall in loans and output estimated in Neri and Ropele (2013). However, none of the three different models/banks is able to reproduce the fall.[21]

3.4.4 Policies

We see above that default has negative consequences for the currency area as a whole. In this section, we want to check how macro-prudential and monetary policies could – or could not – attenuate the effects of default. We

[21] On the one hand, the fall in loans and output in Neri and Ropele (2013) seems extremely strong, compared to the relatively limited increase in periphery bond rates. On the other hand, we might miss some links – and therefore underestimate the output effects –as for instance the possibility of default also for firms or the non-linear effects.

Table 3.4.1: Maximum pass-through of a 1 ppt increase in default risk in the periphery country to selected market interest rates, spreads and volumes

Rates	$R^{b,c}$	$R^{b,p}$	$R^{b,p}-R^{b,c}$	$R^{l,c}$	$R^{l,p}$	$R^{l,c}-R^{b,c}$	$R^{l,p}-R^{b,p}$
`Data`	+0.0	+1.0	+1.0	+0.1	+0.3	+0.1	-0.7
`Integ.`	-0.4	+0.4	+0.8	+0.2	+0.2	+0.5	-0.3
`Frag.`	-0.1	+0.3	+0.3	-0.1	+0.7	-0.1	+0.5
`Interm.`	-0.2	+0.4	+0.6	+0.1	+0.3	+0.3	-0.1
Volumes	R	L^c	L^p	Y^c	Y^p	L^c+L^p	Y^c+Y^p
`Data`	-0.3	-1.0	-2.0	-2.0	-2.0	–	–
`Integ.`	-0.1	-0.1	-0.2	-0.3	-0.3	-0.1	-0.2
`Frag.`	-0.2	+0.1	-0.4	-0.2	-0.7	-0.2	-0.5
`Interm.`	-0.1	-0.1	-0.2	-0.2	-0.4	–	–

Notes. Pass-through are expressed in percentage points for rates and in percentage for volumes. 'Data' are estimates from the FAVAR study of Neri and Ropele (2013). We aggregate individual countries belonging to their sample to produce aggregated core and periphery data. They do not show results for output but we proxy them with their data on industrial production. We normalize their results to a 1 ppt increase in risk by assuming a constant reaction elasticity. Model 'Integ.' provides simulation results using the banking integration approach from section 3.2.4 and equation (3.4.1). Model 'Frag.' provides simulation results using the fragmentation approach explained in equation (3.4.2). Model 'Interm.' provides simulation results using the intermediate – between integration and fragmentation – approach explained in equation (3.4.3).

assume that macro-prudential and monetary policies are *ex ante* policies, that is policies to prevent the realization of default. Therefore, we focus on default risk shocks – rather than default realization shocks – through a shock to the maximum sustainable debt-output ratio, represented by equation (4.3.35). For each policy, we consider an integrated banking sector *vs.* a fragmented one.

Counter-cyclical capital requirements

In the benchmark model, the capital requirement γ is constant. Basel III instead advocates for a counter-cyclical regulation, that is promoting financial soundness during good times in order to attenuate business cycle fluctuations. More precisely, Basel III foresees a regulatory framework under which a counter-cyclical capital surcharge - within a range of 0 to 2.5% of common equity - in addition to a capital buffer should help insuring a sufficient degree of protection against losses during the downturn of the economic cycle. In our simulation, we assume that γ may react respectively to output growth as in Angelini et al. (2012), private credit growth as in Quint and Rabanal (2013) or default expectations as in DeWalque et al. (2010). We assume a counter-cyclical regulation in the sense that γ is positively correlated to output and credit and negatively correlated to default. The general rule is as follows:

$$\gamma_t = 0.1\ \gamma + 0.9\ \gamma_{t-1} + \rho\ (X_t - \bar{X})\ .$$

When the requirements react to output growth, $X_t = \sum_j Y_t^j / \sum_j Y_{t-1}^j$ and we calibrate $\rho = 0.2 > 0$ according to Angelini et al. (2012). We also use their autoregressive parameter of 0.9. When the requirements react to private credit growth, $X_t = \sum_j L_t^j / \sum_j L_{t-1}^j$ and we calibrate $\rho > 0$ to obtain a similar volatility in γ_t as with the first policy and the banking integration case ($\rho = 0.15$). Finally, when the requirements react to default, $X_t = E_t \epsilon_{t+1}^p$ and we calibrate $\rho < 0$ again to obtain a similar volatility in γ_t as with the first policy and the integration case ($\rho = -0.021$).[22] So far in the model, regulated assets are only private loans ($\sum_j L^j$) as we may see from equation (3.2.26). We here also allow for the inclusion of sovereign bonds in the regulated assets ($\sum_j (L^j + s^j)$). This slightly modifies equation (3.2.26) as well as the first order condition (3.2.34).[23] Table 3.4.2 displays how the volatility of the economy changes depending on the regulation rule, for both integration and fragmentation in the banking system, and with or without the inclusion of sovereign bonds in the regulation. We do not only look at the change in volatility but we also look at the difference in welfare, both

[22]Since we consider a single bank – with or without fragmentation – we assume a EA wide macro-prudential policy.

[23]So far we consider that regulated assets are only private loans (lines 'L' in table 3.4.2) or that all assets (private and public loans) are regulated without any distinction between assets (lines '$L + s$' in table 3.4.2). We could consider any intermediate situation with a weight 1 on private loans and a weight strictly between 0 and 1 on public loans. This would obviously also give intermediate results.

for the core and the periphery households, between the counter-cyclical policy equilibrium and the constant capital requirement equilibrium. To do so we compute a second order approximation of the expected utility equation (3.2.2) and compute the welfare cost – of moving from the acyclical to the counter-cyclical policy rule – as the fraction of consumption an agent would agree to give up each period in return for staying under the acyclical rule.[24]

We see from table 3.4.2 that with the benchmark/acyclical policy, the standard deviation of core and periphery outputs are around 0.25% with an integrated bank. With fragmentation, the volatility of the p region increases dramatically. We assume that the policy aims at reducing the volatility in outputs and that only private loans are considered as regulated assets (lines 'L' in table 3.4.2). We see that the most powerful counter-cyclical policy is the one reacting to output growth, both under integrated banking and under fragmented banking representation. This policy implies a volatility of the capital ratio requirement parameter γ between 0.78 (integrated bank) and 1.21 (fragmentation), meaning that the parameter fluctuates roughly between 4% and 6%. However, this policy increases inflation volatility, but only marginally, and implies a welfare cost for the c region and also the p region in case of fragmentation. We observe that the total welfare cost (sum for the 2 regions) is negligible with an integrated bank but is more important with fragmentation. In the former case, the total cost is $0.026\% - 0.023\% = 0.003\%$, which represents approximately € 0.12 per person per quarter. In the later case, the total cost represents approximately € 19 per person per quarter. In other words, the welfare cost of stabilizing output is much lower under a well integrated banking sector.

We also see that including sovereign bonds as regulated assets improves results, whatever the rule (lines '$L + s$' in table 3.4.2). It reduces further the volatility of output while also decreasing the volatility of inflation. Moreover, changes in the policy parameter γ are lower. However, we have a strong dichotomy regarding welfare, with huge costs for the core and high gains for the periphery. These huge costs for the core – although there is a gain at the EA level – makes the policy more difficult to implement from a political point of view.

[24] This consumption equivalent welfare measure was originally introduced in Lucas (1987). It also obviously depends on the size of the shock.

Table 3.4.2: Effects of alternative counter-cyclical capital requirement rules, assuming a default risk shock

Capital requirements		**Output volatility**		**Inflation volatility**		**γ volatility**	**Welfare costs**	
		Core	Periph	Core	Periph	Bank	Core	Periph
Banking integration								
Acyclical	L	0.238	0.291	0.047	0.068	-	-	-
Output growth	L	-26.6%	-18.6%	0.84%	1.74%	0.784	+0.026%	-0.023%
	L+s	-55.0%	-48.9%	-39.8%	-37.8%	0.484	+3.47%	-7.82%
Credit growth	L	-3.06%	-2.53%	0.84%	0.58%	0.777	+0.017%	-0.016%
	L+s	-31.4%	-32.5%	-39.8%	-38.4%	0.478	+3.51%	-7.85%
Default	L	-0.88%	-0.85%	-2.54%	-1.16%	0.782	-0.029%	-0.032%
	L+s	-29.7%	-31.2%	-44.1%	-40.7%	0.479	+3.42%	-7.83%
Banking fragmentation								
Acyclical	L	0.209	0.625	0.044	0.061	-	-	-
Output growth	L	-53.4%	-13.0%	0.90%	1.97%	1.207	+0.22%	+0.26%
	L+s	-75.4%	-40.7%	-34.5%	-31.6%	0.783	+3.67%	-7.55%
Credit growth	L	-7.72%	-3.80%	0.00%	0.00%	0.884	-0.003%	+0.005%
	L+s	-32.0%	-31.1%	-35.4%	-32.9%	0.586	+14.09%	-6.95%
Default	L	-0.66%	-0.80%	-2.72%	-1.31%	0.727	-0.051%	-0.011%
	L+s	-24.3%	-27.7%	-38.2%	-34.9%	0.479	+3.18%	-6.97%

Notes. The 'Acyclical' line corresponds to the benchmark – acyclical – capital requirement rule (constant γ) and gives the relative standard deviations of output and inflation. We multiply the line by 100 for the easiness of reading. The lines 'Output growth', 'Credit growth' and 'Default' correspond to counter-cyclical rules reacting to these variables. For each counter-cyclical rule, we may regulate only private loans (line 'L') or all loans (line '$L + s$'). Results are expressed as percentage deviation from the benchmark except the 'γ volatility' column expressed in percentage point deviation.

Extended Taylor rule

Equation (3.2.42) gives the Taylor rule we use in all the above simulations, with output gap and inflation gap as inputs. However, a sovereign crisis may harm the banking system and therefore hamper the transmission of monetary policy. As a result, a central bank might want to also include an index of sovereign distress as extra input for the conduct of its monetary policy. To analyze this, we follow Trabandt and Smets (2012) and augment the Taylor rule with the spread between the periphery and core sovereign interest rates:

$$R_t = (R_{t-1})^{\gamma_m} \left(\bar{R} \left(\frac{Y_t}{\bar{Y}} \right)^{\rho_y} \left(\frac{\Pi_{t-1}}{\bar{\Pi}} \right)^{\rho_\pi} \left(\frac{R_t^{b,p}}{R_t^{b,c}} \right)^{\rho_r} \right)^{1-\gamma_m}.$$

For any combination $[\rho_y \;\; \rho_\pi \;\; \rho_r]$, we compute the standard deviation of aggregate (EA wide) output, aggregate inflation and the policy rate. The only restrictions on these parameters we impose *a priori* are $0.2 \leq \rho_y \leq 0.8$, $1.1 \leq \rho_\pi \leq 1.9$ and $-0.2 \leq \rho_r \leq 0.0$. We center these restrictions on the benchmark calibration regarding ρ_y and ρ_π and we impose a counter-cyclical reaction of the policy rate to the spread, that is a negative ρ_r. Figure 3.4.5 shows the results, with each dot representing a specific combination of parameters.[25]

In the benchmark simulations, we impose $\rho_y = 0.5$, $\rho_\pi = 1.5$ and $\rho_r = 0$ and we look for combinations of parameters that could reduce the volatility of inflation and output with respect to this benchmark, without increasing the volatility of the policy rate. In figure 3.4.5, any better combination must be located in the gray area. On the one hand, we see from the first column of figure 3.4.5 that it difficult to reduce substantially the volatility of output without increasing the volatility of the policy instrument. On the other hand, we see from the second column that we can decrease seriously the volatility of inflation by only playing with ρ_y and ρ_π, and keeping $\rho_r = 0$. Finally, the last column shows how we may reduce the volatility of output and inflation, keeping the volatility of the policy rate lower than in the benchmark. We see that the best combination is $\rho_y = 0.5$, $\rho_\pi = 1.1$ and $\rho_r = -0.2$, both with banking integration and with banking fragmentation. A reaction to the sovereign rate spread therefore always improves the situation, even though

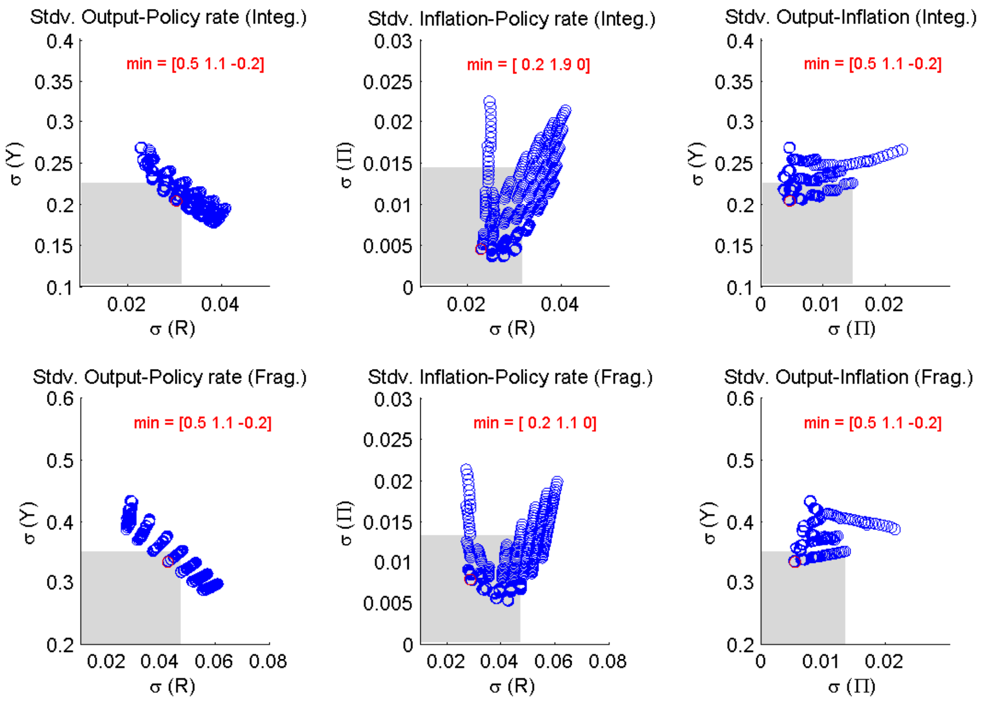
[25] We also look at the standard deviation of the disaggregated variables (distinction between c and p). Results with disaggregated variables are close to the aggregated ones. We therefore do not show them in figure 3.4.5.

the main improvement concerns inflation and is mainly due to the change in the coefficient ρ_π (rather that to the strict negativity of ρ_r). Computing a welfare analysis as above shows that with banking integration, moving from the benchmark rule with coefficients [0.5 1.5 0] to the extended optimal rule with coefficients [0.5 1.1 -0.2] produces a welfare gain in the EA as a whole representing approximately € 20 per person per quarter. However, the aggregate gain hides regional disparities since there is a loss in the core region. In case of banking fragmentation, there is a global cost of € 0.24.

Policy conclusions

From the above policy analysis, we see that counter-cyclical capital requirements targeting output growth reduces seriously the volatility of output without implying a too high welfare cost. Extending the Taylor rule does not really allow to reduce output volatility. In general, whatever the policy, the welfare costs of stabilizing the economy are much lower under a well integrated banking sector. This conclusion is in line with the main findings of Bignon et al. (2013) that the optimality of a currency union is restored only when credit limitations are reduced and banking union is achieved.

Figure 3.4.5: Standard deviations depending on the Taylor rule specification, assuming a default risk shock



Notes. In each subplot, each blue dot represents a parameter combination for the Taylor rule. The red dot represents the parameter combination shown in the min=[p_1 p_2 p_3]. p_1 represents the weight on output gap, p_2 represents the weight on inflation and p_3 represents the weight on the spread. The gray area is delimited by the standard deviations in the benchmark case [0.5 1.5 0]. In the right-hand-side subplots, we only represent combinations when the standard deviation of the policy rate is lower than the one from the benchmark. All variables are EA aggregated.

3.5 Conclusion

This chapter studies the international transmission of sovereign debt default. More precisely, we build a 2-country model of the EA and look at the spillover from the periphery to the core. We show that a well integrated banking sector reduces the negative consequences at the EA wide level and limits the welfare cost of stabilizing policies.

From a modelling point of view, we here impose *ex ante* the type of banking representation (integration *vs.* fragmentation *vs.* intermediate). Obviously, this banking representation is not exogenous but endogenous and evolves according to the economic and/or financial situation. Moving from an exogenous to an endogenous banking structure would be an interesting extension. From a policy point of view, we focus on macro-prudential and monetary policies to attenuate the risk of default. An interesting avenue for future research would be to look at more structural policies, that is to look at policies to keep public debt at fair level in order to avoid the risk – and therefore the realization – of default. For instance, the new Fiscal Compact Treaty, the introduction of common area-wide eurobonds or a deeper level of fiscal union.

3.6 References

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3.A Integration vs. fragmentation of the financial sector in the euro area

Table 3.A.1: Sovereign debt holding

		Holders (% of total stock)			
Sovereign debt from	Year	Domestic banks	Other residents	Non residents	Public institutions
France	2007	13	32	55	0
	2011	14	29	57	0
Germany	2007	30	21	49	0
	2011	23	14	63	0
Greece	2007	11	3	74	13
	2011	19	6	38	36
Ireland	2007	3	4	93	0
	2011	17	2	64	17
Italy	2007	12	34	49	5
	2011	17	29	43	11
Netherlands	2007	9	21	69	0
	2011	11	21	67	1
Portugal	2007	9	15	76	0
	2011	22	14	52	12
Spain	2007	21	21	48	10
	2011	27	20	34	19
Core	2007	23	24	53	0
	2011	19	19	61	0
Periphery	2007	13	27	54	6
	2011	20	24	42	15

Notes. 'Domestic banks' excludes the domestic central bank. 'Other residents' represents the domestic private sector less domestic banks. 'Non-residents' is the non-domestic private sector (bank and non-bank). 'Public institutions' is both domestic and non-domestic public institutions (including the ESCB). Source: Table 1 from Merler and Pisany-Ferry (2012), based on various national sources.

Table 3.A.1 gives a breakdown of sovereign debt by holding sectors. We directly borrow this table from Merler and Pisany-Ferry (2012). Data relate to the year 2007, that is before the start of the financial crisis, and the year 2011, that is at the height of the sovereign debt troubles. We see that in 2007, about 55% of the sovereign debt, both from the core countries and the periphery countries, were held by non-residents. Data cannot distinguish between banks and non-banks in the non-resident sector, as well as between other euro area residents and non-euro area residents. We also notice that domestic banks in the periphery hold relatively few domestic debt (13%). We observe significant changes between 2007 and 2011. First, non-residents reduce their – relative – holdings of periphery debt and increase theirs of core debt. Second, domestic banks in the periphery increase their – relative – holdings of domestic debt. In conclusion, we have a rather globalized sovereign debt market in 2007 whereas we see a flight-to-quality as well as a specialization of periphery banks between 2007 and 2011.

The first columns of Table 3.A.2 use BIS data and focus on the foreign claims of banks located in selected countries vis-à-vis the core region, the periphery region and the non-euro area countries. The foreign claims include claims on public debt but also all other – private – foreign claims. A limitation of the consolidated BIS data is that they do not include information on domestic claims. Data refer to 2009 and 2013, that is before and after the period of sovereign debt troubles. We see that in 2009, banks located in the core region have the same amount of foreign claims vis-à-vis the other core countries as vis-à-vis the periphery countries. Banks located in the periphery countries are more exposed to the core countries than to the other periphery countries. We also notice that all banks have a large exposure outside the euro area. Between 2009 and 2013, we observe a flight-to-quality. Core banks reduce their exposure to periphery and increase their exposure to the other core countries, whereas periphery banks reduce their exposure to other periphery countries to increase – relative – claims outside the euro area. Once again, we conclude that banks' *direct foreign exposures* are diversified in 2009 whereas we see a flight-to-quality between 2009 and 2013.

To better understand the integration of the euro area banking sector, we also look at the wholesale banking market using Monetary Financial Institutions (MFI) statistics compiled by the ECB. The last columns of Table 3.A.2 show that, on average, between 25% and 30% of MFI to MFI lending is cross-border. We however observe huge dispersions between countries depending on their size, with smaller countries having much higher cross-border positions than large countries. From 2009 and 2013, we see a geographical specialization but of limited size. This underlines that banks do not only have direct foreign exposures but also *indirect foreign exposures* through an integrated interbank market.

3.B Fragmentation of the financial sector: an alternative approach

In the main text, we introduce fragmentation through the bank collateral channel. We here look at an alternative fragmentation through the bank capital channel. To do so, we keep one single bank but with two different capital constraints, one related to the core balance sheet items and another related to the periphery ones. More precisely, we split equation (3.2.26) into one equation for each region $j \in \{c, p\}$:

$$(1-\gamma)Q_{c,t}^{j}L_{t}^{j} + Q_{c,t}^{j}s_{t}^{j} + Y_{t}^{j}/Y_{t}\, Q_{c,t}^{j}B_{t}^{cb} = Q_{c,t}^{j}D_{t}^{j} + x_{t}^{j}\,. \tag{3.B.1}$$

We therefore obtain two different excess capital variables x_t^j and therefore two different bank capital costs $\mathtt{d}\,\Omega(x_t^j)$. We calibrate the parameter $\mathtt{d}$ such that the size of the costs after the shock is the same between simulations. This modifies the first order conditions (3.2.31) to (3.2.34). Table 3.B.1 compares the maximum pass-trough of a 1 ppt increase in the periphery default risk under alternative banking specifications. We see that compared with integration, fragmentation worsens the situation in the periphery and improves the situation in the core. It also worsens the situation in the aggregated EA. These results hold whatever we introduce fragmentation through the bank collateral cost $\Psi(.)$ as in the main text or through the bank capital cost $\Omega(.)$ as in equation (3.B.1). Quantitatively, we however observe that the collateral fragmentation produces stronger effects than the capital fragmentation. We could obviously combine the two fragmentation and this would increase further the asymmetry between the core and the periphery regions.

Table 3.A.2: Selected banking statistics

		Direct Exposure Foreign claims vis-à-vis vis-à-vis (%)			**Indirect exposure Loans to MFIs (%)**	
Banks from	Year	Core	Periphery	Other	Domestic	Euro Area
Austria	2009	19	9	72	74	26
	2013	16	5	79	81	19
Belgium	2009	32	21	46	20	80
	2013	30	17	53	30	70
France	2009	19	24	58	82	18
	2013	25	18	57	85	15
Germany	2009	20	21	59	74	26
	2013	23	14	64	79	21
Greece	2009	6	1	92	21	79
	2013	22	1	78	55	45
Ireland	2009	15	14	71	76	24
	2013	9	3	88	57	43
Italy	2009	52	7	41	86	14
	2013	50	4	46	84	16
Netherlands	2009	27	16	57	42	58
	2013	35	8	57	59	41
Portugal	2009	19	38	43	49	51
	2013	21	30	49	67	33
Spain	2009	12	12	77	68	32
	2013	9	7	84	78	22
Core	2009	22	21	58	71	29
	2013	25	14	61	76	24
Periphery	2009	25	12	63	75	25
	2013	23	6	71	77	23

Notes. The Direct Exposure column shows the percentage of outstanding amount of consolidated foreign claims of reporting banks per country with respect to the core and periphery countries of the Euro area, as well as with respect to all other countries. Source: BIS Quarterly Review 2010 and 2014, table 9B and author's calculations. The Indirect Exposure column presents the percentage of outstanding amounts of loans of reporting banks to other financial institutions belonging to the same country and to the rest of the EA (excl. the ESCB). Source: ECB, Statistical Data Warehouse and author's calculations.

Table 3.B.1: Maximum pass-through of a 1 ppt increase in default risk in the periphery country to selected market interest rates and volumes

Rates		$R^{b,c}$	$R^{b,p}$	$R^{l,c}$	$R^{l,p}$	R	
`Model integ.`		-0.4	+0.4	+0.2	+0.2	-0.1	
`Model frag.`	$\Psi(.)$	-0.1	+0.3	-0.1	+0.7	-0.2	
`Model frag.`	$\Omega(.)$	-0.0	+0.4	+0.2	+0.2	-0.1	
Volumes		L^c	L^p	Y^c	Y^p	$L^c + L^p$	$Y^c + Y^p$
`Model integ.`		-0.1	-0.2	-0.3	-0.3	-0.1	-0.2
`Model frag.`	$\Psi(.)$	+0.1	-0.4	-0.2	-0.7	-0.2	-0.5
`Model frag.`	$\Omega(.)$	-0.0	-0.4	-0.2	-0.3	-0.2	-0.3

Notes. Pass-through are expressed in percentage points for rates and in percentage for volumes. 'Model integ.' provides simulation results with banking integration, explained in section 3.2.4 and equation (3.4.1). 'Model frag. $\Psi(.)$' provides simulation results with fragmentation through the bank collateral channel, explained in equation (3.4.2). 'Model frag. $\Omega(.)$' provides simulation results with fragmentation through the bank capital channel, explained in equation (3.B.1).

Chapter 4

Stock and sovereign bond dynamics in the Euro Area[1]

4.1 Introduction

The understanding of the relation between stock and sovereign bond correlations is of primary importance for investors as well as for policy makers. From a finance point of view this correlation suggests a measurement of risk and diversification of investors' portfolio. From an economic point of view asset prices are the mechanism by which consumption and investment are allocated across time and states of nature. These decisions change according to the business cycle and the different sources of shocks that impact the economy. In this chapter we study the causes of asset market's comovements from a macroeconomic perspective. In particular we show that looking at stock-bond correlations helps to identify the nature of shocks that hit the euro area (EA hereafter) economy.

Figure 4.1.1 presents the evolution of the euro period equity and bond returns. Since the introduction of the common currency both bond and stock markets in the euro zone registered a high level of correlation giving support to the idea that the introduction of the common currency fostered integration among countries. However with the beginning of the sovereign debt crisis the behaviour of core and periphery bond yields started to move in opposite directions. This evidence is known as flight-to-quality in sovereign bond markets due to the increasing fiscal troubles of the periphery countries

[1]This chapter is based on Perego (2014).

and the relative increased fears of default. This evidence is plotted in the left-hand side of Figure 4.1.1. On the right-hand side we show the behaviour of the stock market. Notwithstanding the difference in the value of the two stock market indexes we observe that they moved in line during the whole period after the introduction of the euro even during both the financial crisis and the sovereign debt crisis. While the impact of the sovereign debt crisis it is easily detectable in the behaviour of sovereign bond markets, the identification of the causes of asset markets' co-movements before 2010 it is less obvious.

The first contribution of this chapter is to build an international general equilibrium model able to identify and explain how different shocks and macroeconomic dynamics impact on the euro area stock-bond correlation.

Many empirical works have explained the determinants of the stock-bond comovements for the euro zone in terms of macroeconomic variables. Among the others Kim et al. (2006) and Andersson et al. (2008) explain the role of variables such as inflation, GDP growth, market uncertainty as main drivers of the correlations. Perego and Vermeulen (2013), in the light of the recent sovereign debt crisis, highlight the role of relative imbalances between the core and the periphery of the euro zone and of variables such as balance of payments among the euro area asset markets movements' determinants. Recently, the work of Adrian et al. (2010) showed the crucial role of financial intermediaries' balance sheet in the pricing of both the cross-section as well as the time series of asset prices. In the euro area the balance sheets of banks were highly exposed to sovereign bonds that were used as a source of collateral. Moreover, the ECB yearly financial report (ECB, 2012) shows how the decrease in the integration on the sovereign bond market brought to a decrease in the integration also in the banking sector. Ultimately troubles on the banking sector translate into lower credit for the private sector and, in this way, they might impact the equity market performance.

General equilibrium models in the macro-finance literature have focused on the one hand on the term structure of bond interest rates and on the asset pricing of stock and bonds in a closed economy. Latest works on bond pricing are those of van Binsbergen et al. (2012) and Rudebusch and Swanson (2012)[2]. A good review of the stock-bond asset pricing literature is provided by Campbell et al. (2014). The first set of papers studies the bond premium and the relation with macroeconomic variables, the second explains the change in the stock-bond correlation in relation to monetary policy and

[2]For an exhaustive review of the literature see Rudebusch (2010).

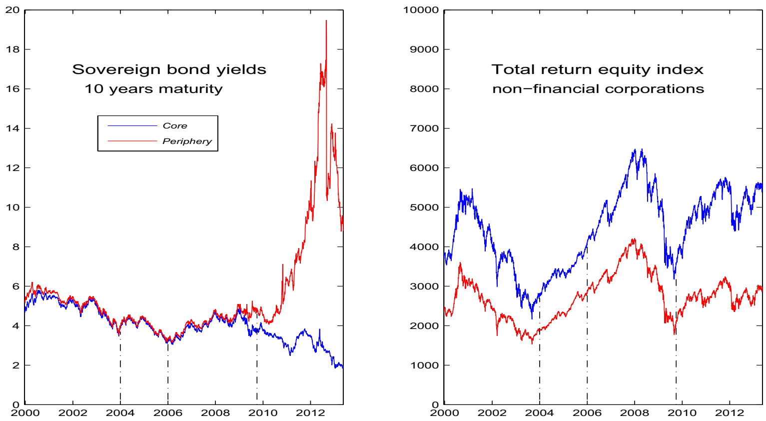
other macroeconomic variables. In both cases the international dimension of the correlations is neglected. On the other hand, the new literature on open economy financial macroeconomics focuses on the international dimension of asset markets. Coeurdacier and Rey (2011) provide an exhaustive review of the literature on the home bias in international capital markets. Closer to our approach is the branch of this literature dealing with the hedging properties of bond and equities. They find that bonds are better suited to hedge real exchange rate risk whereas equities non-tradable income risk. However, this set of models does not consider the role of financial intermediaries and the risk of default on sovereign bonds. Both dimensions proved to be crucial in the euro zone history.

The second contribution of this chapter is to introduce financial intermediaries into the open economy financial macroeconomics literature and to theoretically study their relation with asset markets.

We build a two-country real DSGE model with a banking sector and asset markets as this framework is the best equipped to study the transmission of shocks and the multiple linkages between the core and the periphery of the euro zone. On the modelling side we refer closely to Perego and Pierrard (2014). They develop a two-country model for a currency union including an international banking sector and allowing for endogenous default on government bonds. They look at the transmission of a sovereign default shock through the banking sector onto the real economy and study policy recommendations. We extend their model by including international equity markets as in Coeurdacier et al. (2007). This new framework allows for a comprehensive study of asset markets' dynamics and, additionally, to look at the impact of shocks originating in the equity market.

We find that the interaction between credit constraints in the banking sector and macroeconomic variables is a key driver of the time-varying stock-bond correlation. Constraints on bank's capital and collaterals determines a strong tightening of credit to firms and a pro-cyclical amplification of shocks. Moreover, the existence of credit constraints at the international bank level prompts more synchronization in asset markets' responses as there is a more homogeneous sharing of the effects of shocks between countries. We show that in the presence of credit constraints a sovereign risk shock reproduces the 2010-2012 facts on the euro area correlations. For the previous sample a productivity shock matches the negative stock-bond correlation during the years 2004-2006 while a financial expectation shock reproduces the positive correlation registered both during the dot-com and the subprime

Figure 4.1.1: Returns in the euro zone stock-bond markets



Notes. Stock market series are total return indexes on non-financial firms; bond series are DS benchmark 10 years index of yields to redemption. Countries belonging to the core are: Austria, Belgium, Finland, France and Germany. Whereas countries belonging to the periphery are: Greece, Ireland, Italy, Portugal and Spain. The series are aggregated at the core and periphery level by weighted average based on market capitalization for stock and government liabilities for bonds at the baseline values of 2002.

Data source: Datastream.

crisis period.

The remainder of the chapter is structured as follows. Section 4.2 presents the stylized facts on the EA stock-bond market; Section 4.3 details the model, Section 4.4 explains the calibration and Section 4.5 shows the dynamic simulations. Section 4.6 concludes.

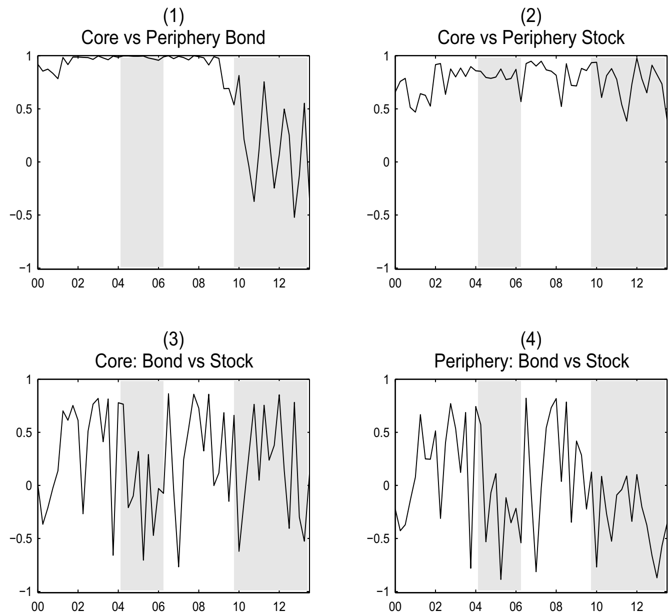
4.2 Stylized facts on the EA stock-bond markets

The behaviour of the stock market integration and the correlation of stock and bond returns have been studied in depth in the empirical financial literature. Regarding the euro area, the focus was in attesting the degree of integration between the different member countries and in understanding the portfolio diversification possibilities in the euro area asset markets. Kim et al. (2005) showes how the introduction of the common currency brought to the integration of euro area stock markets while Kim et al. (2006) points out how, since the introduction of the common currency, the correlation on the stock-bond market was time-varying and negative. Recently, the work of Perego and Vermeulen (2013) illustrates how the sovereign debt crisis impacted on the correlation in the sovereign bond market and, consequently, on the stock-bond markets' one. They find that the stock-bond correlation behaved differently in the core and in the periphery of the EA after the beginning of the sovereign debt crisis.

Figure 4.2.1 shows some stylized facts on the behaviour of sovereign bond and stock returns in the euro zone. We consider the 10 years yields to redemption index for sovereign bonds and the total return index for non-financial corporations for stocks. Since the beginning of the common currency union and up to 2009, we observe that the dynamics of sovereign bond yields in the core and in the periphery of the euro zone moved hand-in-hand. Both region's yields seem to be decreasing and converging towards the same value. This behaviour was interpreted as an indicator that the two area's sovereign bonds were perceived to be more and more safe and alike. After 2009, and more pronouncedly in 2010, the two region's yields started to diverge. In the core returns continued to decrease whereas in the periphery they rocketed. This evidence is what we refer to as flight-to-quality in the sovereign bond market. It shows that, since the beginning of the sovereign debt crisis, periphery sovereign bonds were perceived to be more risky and, for this reason, they were sold against the core, safer, ones. For what concerns the stock market, we observe that, during the whole euro area period, returns have been moving pretty much in line in the core and in the periphery. Notwithstanding the different crisis (financial first and sovereign then) the stock markets of the two regions were highly correlated: decreasing in the early 2000 after the dot-com crisis, increasing afterwards until the recent financial crisis with the consequent fall in the late 2007.

From these index series we compute the realized correlations between the stock-bond assets and the aggregated core-periphery markets. The behaviour of such correlations is presented in Figure 4.2.1. With the grey areas we highlight the change in the sign of the stock-bond correlations. We identify four sub-periods. The first and the third (in white) present a high correlations on the bond and stock markets and, further, a positive correlation on the core and periphery stock-bond markets. In the second sub-period the correlation on core and periphery stock-bond markets becomes negative notwithstanding the still high correlation on the bond and stock markets. For what concerns the last period we can clearly detect the decreasing correlation in the bond market, the high correlation in the stock market and a different regional pattern for the stock-bond correlations.[3] Before 2010 we can observe instead a time varying behaviour of the stock-bond correlations common to the two regions.

Figure 4.2.1: Realized correlations in the euro zone stock-bond markets



Notes. The realized correlations are computed on quarterly windows of the same data presented in Figure 4.1.1. They show the dynamic relations between the returns on stock and the yields on sovereign bond within the euro zone over the period 2000 to October 2013. The shaded areas highlight the change in the sign of the stock-bond correlations.

Previous studies conducted at the euro area level showed the same pattern.[4] However the way previous mentioned papers dealt with the correlation is somehow different. They focused on the correlation between price changes. We instead calculate the correlation between index of returns. The reason of the different approach is to use a correlation measure that is compatible

[3] These facts have been studied in detail by Perego and Vermeulen (2013).
[4] See for instance Kim et al. (2006).

with the one computed from the model's variables.[5] The two measures are however related. Stock market returns are made of a price component and of a dividend payout component. So we should expect the stock return index and the relative price index to move in line. Instead, on the bond market the relation between returns and prices is not linear. The bond's yield is the inverse to its price: as bond prices increase, bond yields fall. As a consequence, in terms of correlations, the only difference with respect to previous studies, as the ones of Kim et al. (2006) and Perego and Vermeulen (2013), comes from the stock-bond correlations that by construction present the opposite sign.

In Table 4.2.1 we present the average correlation per sub-period. Until 2010 there is an homogeneous market for stock and bonds within the two regions of the euro zone. The correlation in the bond market is almost unity while in the stock market it is very high. As the stock and bond markets within regions are integrated, the stock-bond correlations behave similarly in the two regions. In the period between 2000-2004 and 2007-2010 it is positive while in the period 2004-2007 it is negative. After 2010, following the disruption in the bond market, the stock-bond correlations do not behave similarly in the two regions any more. In the core the stock-bond correlation is positive whereas in the periphery it becomes negative.

The understanding of which mechanisms have contributed to determine the behaviour of these asset markets is the focus of the rest of the chapter.

Table 4.2.1: Correlation data

	2000-2004	2004-2007	2007-2010	2010-2012	2000-2012
corr($R^{b,p}$,$R^{b,c}$)	0.94	0.98	0.88	0.17	0.71
corr($R^{S,p}$,$R^{S,c}$)	0.74	0.82	0.82	0.73	0.77
corr($R^{b,c}$,$R^{S,c}$)	0.34	-0.08	0.44	0.28	0.22
corr($R^{b,p}$,$R^{S,p}$)	0.18	-0.24	0.28	-0.19	-0.02

$R^{b,j}$ is the gross return on sovereign bonds in country $j \in \{c, p\}$ and $R^{S,j}$ the gross return on equity.

[5] In the model the agents make decisions on the basis of changes in the returns from their assets rather than relative to changes in prices. This is because they hold one-period assets until maturity ruling out possible gains from buying and selling according to changes in prices.

4.3 Model

We develop an international business cycle model for the euro area. It consists of two regions, we call the first country/region as *core* and we denote it by c hereafter. We call the second country/region as *periphery* and we denote it by p hereafter. The model features an international banking sector, an equity market and an endogenous probability of default on sovereign debt. Households, in each region $j \in \{c, p\}$, work for the firms, consume and invest in deposits at the bank, in sovereign government bonds and in equity. Both the sovereign debt market and the labour market are segmented at the household's level, i.e. the household in country j may only hold debt from government j and work in country j. The segmentation of the bond market, though being stylized, is helpful to represent the high home bias in this market. The role of international holder of sovereign debt is left to financial intermediaries, in this way we reproduce the international exposure of bank's balance sheets to sovereign debt. The production side of the economy is composed of final and intermediate firms as well as by capital producers. Capital producers borrow from the international bank in the form of one-period loans, decide how to redistribute dividends to households and invest in the intermediate firm's capital. Final firm's combine the intermediate goods produced in the domestic and in the foreign country into a final good that is traded between regions. There exists one international bank located in country c. The bank plays an important financial intermediary role as it can provide credit to the private sector in a more efficient way than financial markets, given the presence of costs on the equity side. More specifically, the bank collects deposits from the j households, lends loans to capital producers' firms and buys one-period bonds from the government. The government expenditures are financed via lump-sum taxes from households or by public debt. Moreover, the government may default on its debt if the economy reaches a stochastic maximum level of sustainable debt to output. Finally, we assume that the two regions are perfectly symmetric except for a higher level of debt to output in the periphery country.

4.3.1 Households

In each country $j \in \{c, p\}$, the representative household may consume C_t^j, invest D_t^j in one-period bank deposits or b_t^j in one-period sovereign debt. Moreover households can invest in financial markets both in domestic and foreign equity $S_{i,t}^j$ issued by the respective firms-capital producers $i \in \{c, p\}$.

By investing in deposits the households obtain $R_{t-1}^{d,j}$, the predetermined gross return on deposits. The expected gross return on sovereign bond is $R_{t-1}^{b,j}$ while the actual net return is $R_{t-1}^{b,j} - \epsilon_t^j$, where $\epsilon_t^j \geq 0$ captures the share of outstanding sovereign debt lost by households because of – partial – sovereign default.

The expected return on equity holdings is given by the price at which households can sell the share $\rho_{s,t}^j$ bought in the previous period and the dividend payout div_t^j coming from the capital producers. $Q_{j,t}^i$ is the real exchange rate of country i when country j is taken as the numeraire. The household also supplies h_t^j hours to the firms and receives wages w_t^j. Moreover, it owns the firms located in j and receives their profits Υ_t^j. Finally, the household receives a lump-sum transfer $H_t^{h,j}$ from the government and must pay taxes T_t^j as well as a quadratic portfolio adjustment cost on sovereign debt represented by the parameter $\phi_b > 0$ in equation (4.3.1). This cost makes the households' portfolio choices less sensitive to interest rate differentials. Additionally, the households pay a cost related to their equity holdings represented by the parameter $\phi_s > 0$. The households, in order to minimize the sum of the squared costs associated to equity holdings, optimally choose to hold the same amount of c and p shares. For this reason we can interpret this cost as a way to mimic preferences for a diversified portfolio. If the shares' holdings deviate from the optimal reference value, the households bear an additional cost. The household's budget constraint is:

$$
\begin{aligned}
& C_t^j + D_t^j + b_t^j + \sum_i Q_{j,t}^i \rho_{i,t}^s S_{i,t}^j + \frac{\phi_s}{2} \sum_i Q_{j,t}^i \rho_{i,t}^s \left(S_{i,t}^j \right)^2 + \frac{\phi_b}{2} (b_t^j - \bar{b}^j)^2 \\
&= w_t^j h_t^j + R_{t-1}^{d,j} D_{t-1}^j + (R_{t-1}^{b,j} - \epsilon_t^j) b_{t-1}^j + \sum_i Q_{j,t}^i (\rho_{i,t}^s + div_{i,t}) S_{i,t-1}^j \\
&\qquad + \Upsilon_t^j + H_t^{h,j} - T_t^j. \qquad (4.3.1)
\end{aligned}
$$

Throughout the chapter, $\bar{z}$ represents the steady state of any variable z_t. The household's expected lifetime utility at date s is:

$$
\max E_s \sum_{t=s}^{\infty} \beta^{t-s} \left(\ln \left(C_t^j - \psi_n \frac{(h_t^j)^{\eta+1}}{\eta+1} \right) + \psi_d \ln D_t^j \right) \qquad (4.3.2)
$$

$0 < \beta < 1$ is the subjective discount factor, η is the inverse of the intertemporal elasticity of labour supply and $\psi_n, \psi_d > 0$ are parameters.[6] The household maximizes (4.3.2) subject to (4.3.1). It gives the following first order conditions (FOCs):

$$\psi_n (h_t^j)^\eta = w_t^j \ , \tag{4.3.3}$$

$$\lambda_t^j = \frac{\psi_d}{D_t^j} + E_t \beta \lambda_{t+1}^j R_t^{d,j} \ , \tag{4.3.4}$$

$$\lambda_t^j \left(1 + \phi_b (b_t^j - \bar{b^j})\right) = E_t \beta \lambda_{t+1}^j (R_t^{b,j} - \epsilon_{t+1}^j) \ , \tag{4.3.5}$$

$$Q_{j,t}^i \lambda_t^j (1 + \phi_s S_{i,t}^j) = E_t \beta \lambda_{t+1}^j (R_{i,t+1}^S) Q_{j,t+1}^i \ , \tag{4.3.6}$$

$$\lambda_t^j = \left(C_t^j - \psi_n \frac{(h_t^j)^{\eta+1}}{\eta+1} \right)^{-1} . \tag{4.3.7}$$

Equation (4.3.3) shows that the wage is equal to the marginal disutility of hours worked. Equations (4.3.4), (4.3.5) and (4.3.6) state that, at equilibrium, marginal costs are equal to expected marginal income from, respectively, deposits, sovereign bonds and equity. Equation (4.3.6) represents the FOCs for equity holding for country j households with respect to country $i \in \{c, p\}$, $i \neq j$ issuer. The expected real return on equity is:

$$E_t[R_{i,t+1}^S] = \frac{E_t[\rho_{i,t+1}^s] + E_t[div_{i,t+1}] + u_t^s}{\rho_{i,t}^s} . \tag{4.3.8}$$

These returns are defined as the change in price plus the dividend payout. u_t^s is an i.i.d. shock to the expected returns. An increase (decrease) of u_t^s mimics overly optimistic (pessimistic) expectations on equity returns. It

[6] The choice of a GHH utility function is motivated by the international framework. The absence of wealth effect on the labour supply helps to match a series of empirical regularities as explained by Garcia-Cicco et al. (2010), Raffo (2008) and Schmitt-Grohe and Uribe (2012). Moreover, the results of the chapter are not changed by using a different utility formulation (KPR for instance).

We introduce deposits in the utility function as in Enders et al. (2011) for steady state reasons. Nevertheless with this formulation deposits play the role of real value for cash. An increase in deposits increases the means of payments of the households and (ceteris paribus) increases their consumption.

can be interpreted as a noise component, a subjective belief, that makes expectations on future returns detach from their fundamental values.[7]

Comparing equations (4.3.5) and (4.3.6) we can analyse the relation between the sovereign bond and equity rates in the households' portfolio. Let us define $R_t^{nb,j}$ as the net return on sovereign bonds. As we assume that only the periphery country can default, net returns are respectively given by

$$R_t^{nb,p} = R_t^{b,p} - E_t[\epsilon_{t+1}^p] , \qquad (4.3.9)$$
$$R_t^{nb,c} = R_t^{b,c}. \qquad (4.3.10)$$

Abstaining from adjustment costs and price dynamics, the relation between the sovereign bond and equity rates is the following:

$$E_t[R_{i,t+1}^S] = R_t^{nb,j} + \lambda_t^j \phi_s S_{i,t}^j. \qquad (4.3.11)$$

Equation (4.3.11) shows that the two assets are not perfect substitute. There are two sources of differentiation: sovereign debt default and the cost associated to equity holdings. Changes in the amount of shares bought reduces the correlation between equity and sovereign returns. The more the shares held, the higher the return demanded by the households in order to hold such an asset. Analogously, periphery default on sovereign debt determines a wedge between the return on equity and periphery sovereign bonds.

4.3.2 Capital producers

The capital producers in country $j \in \{c, p\}$ have the choice of financing either via one-period loans from the bank or through asset markets in the form of equity. They may payout dividends, div_t^j, to the households or invest I_t^j in domestic firms. In turn, investment increases firms' capital stock K_t^j according to the following law of motion:

$$K_t^j = (1 - \delta)K_{t-1}^j + I_t^j, \qquad (4.3.12)$$

where $0 < \delta < 1$ is the capital depreciation rate. Capital provides a net real return r_t^j and capital producers pay a gross nominal interest rate $R_{t-1}^{l,j}$ on loans, as well as an adjustment cost on investment represented by the

[7]For a detailed description of the financial expectation shock see Section 4.5.

parameter $\phi_i > 0$.[8] If the capital producers decide to pay out dividends they face an adjustment cost represented by the parameter κ_d. As in Jermann and Quadrini (2012) the equity payout cost can be interpreted as a pecuniary cost as well as a way to model the speed of fund's adjustment when financial conditions change. In this model's specification of the cost, when κ_d is infinitely large capital producers have access to only one source of funds: bank loans. For smaller values, the capital producers can be financed both via (negative) dividend payouts and bank's loans. High values of κ_d oblige the capital producers to pay a high cost when they want to adjust the dividend payouts from their steady state value. Lower values allow more flexibility in the payout policy. The capital producers' budget constraint is:

$$div_t^j + I_t^j + \frac{\phi_i}{2}(I_t^j - \bar{I^j})^2 + \frac{\kappa_d}{2}(div_t^j - \bar{div^j})^2 + R_{t-1}^{l,j} L_{t-1}^j = L_t^j + r_t^j K_{t-1}^j. \quad (4.3.13)$$

As equity shares are held internationally, the capital producers are owned by the households of both the core and the periphery country. They maximize:

$$\max E_s \sum_{t=s}^{\infty} (\beta^{e,j})^{t-s} \; div_t^j$$

subject to (4.3.12) and (4.3.13). With β^e being the time varying weighted average of the discount factors of the core and periphery households, expressed in terms of the capital producers' domestic price index:

$$\begin{aligned} \beta^{e,c} &= \beta \left(S_{c,t}^c \left(\frac{\lambda_{t+1}^c}{\lambda_t^c} \right) + S_{c,t}^p \left(\frac{Q_{c,t+1}^p}{Q_{c,t}^p} \frac{\lambda_{t+1}^p}{\lambda_t^p} \right) \right), \\ \beta^{e,p} &= \beta \left(S_{p,t}^p \left(\frac{\lambda_{t+1}^p}{\lambda_t^p} \right) + S_{p,t}^c \left(\frac{Q_{c,t}^p}{Q_{c,t+1}^p} \frac{\lambda_{t+1}^c}{\lambda_t^c} \right) \right). \end{aligned}$$

As equity shares are held internationally the discount factor of capital producers accounts for the relative importance of each owner's marginal utility. The weights are set according to the time-varying amount of shares

[8] A convex adjustment cost on investment is common in the literature as it helps to match empirical behaviour of aggregate investment and prevents the investment demand curve to be perfectly elastic. For the early literature that assumes this cost see Gould (1968) and Lucas (1967) among others.

each household holds of one country's capital producers. The first order conditions for this problem read:

$$\lambda_t^{e,j} = E_t \beta^{e,j} \lambda_{t+1}^{e,j} R_t^{l,j} \ , \tag{4.3.14}$$

$$\lambda_t^{e,j} q_t^j = E_t \beta^{e,j} \lambda_{t+1}^{e,j} \left(r_{t+1}^j + (1-\delta) q_{t+1}^j \right) \ , \tag{4.3.15}$$

$$I_t^j = \bar{I}^j + \frac{1}{\phi_I}(q_t^j - 1) \ , \tag{4.3.16}$$

$$\lambda_t^{e,j} = \frac{1}{1 + \kappa_d (div_t^j - \bar{div}^j)} \ , \tag{4.3.17}$$

where $\lambda_t^{e,j}$ is the Lagrangian multiplier associated to the capital producers' budget constraint.

Equation (4.3.14) says that, at equilibrium, the marginal income from loans is equal to the expected marginal cost weighted by the households discount factor. Equation (4.3.15) defines the shadow value of capital, q_t^j, as the expected discounted value of the marginal profits of having one additional unit of capital. If $q_t^j < 1$, meaning that the shadow value of capital is smaller than the price of capital, equation (4.3.16) states that investments should decline, if $q_t^j > 1$ that investments should increase.[9] Furthermore, from equation (4.3.15), we see that the shadow value of capital increases when the expected future dividend payouts are lower than the actual ones.

4.3.3 Nonfinancial firms

In each country $j \in \{c, p\}$ firms are perfectly competitive. The intermediate j firm produces a good that is sold in the domestic country as well as in the foreign one. A final firm in each country combines the intermediate goods from the j and $-j$ countries into a final one.

Final firms

In each region the demand for goods is a composite of the home and foreign intermediate goods. The aggregate demand for country j is:

[9] This formulation of the investment equation follows Tobin's Q theory of investment (Tobin, 1969).

$$A^j = \left(\frac{A^j_j}{1-\alpha}\right)^{(1-\alpha)} \left(\frac{A^j_{-j}}{\alpha}\right)^{\alpha} , \tag{4.3.18}$$

where A^j_j and A^j_{-j} are respectively the demands of the final firm j for goods j and $-j$. $0 < 1-\alpha < 1$ is the degree of home bias or, alternatively, it can be interpreted as the index of country openness. We set this parameter to be $0 < \alpha < 0.5$ implying a certain degree of home bias. The composite final good can be used for consumption and investment by all the agents in the economy.[10] The optimal demand for each variety of the final good is given by the following first order conditions:[11]

$$A^c_{c,t} = (1-\alpha)\frac{1}{\phi^c_t} A^c_t , \qquad A^p_{p,t} = (1-\alpha)\frac{1}{\phi^p_t} A^p_t ,$$
$$A^c_{p,t} = \alpha\frac{1}{Q^p_{c,t}\phi^p_t} A^c_t , \qquad A^p_{c,t} = \alpha\frac{Q^p_{c,t}}{\phi^c_t} A^p_t .$$

The welfare based price index (for both regions) corresponding to these preferences is:

$$P^j_t = (p^j_{j,t})^{(1-\alpha)}(p^j_{-j,t})^{\alpha}. \tag{4.3.19}$$

Dividing by P^j, and by the law of one price, the price index can be simplified as:

$$\begin{aligned} 1 &= \phi^j_t \phi^{-j}_t , \\ Q^{-j}_{j,t} &= (\phi^j_t)^{\frac{2\alpha-1}{\alpha}} , \end{aligned}$$

with $\phi^j_t = \frac{p^j_{j,t}}{P^j_t}$ being the share of domestic produced goods' prices in the domestic price index and $Q^p_{c,t} = \frac{e_t P^p_t}{P^c_t}$ being the real exchange rate for the core country. The nominal exchange rate e_t is set to 1 as the two economies belong to the same currency union.

[10] We assume that the same Cobb-Douglas CES aggregator applies to the consumption bundles of all the agents as well as for investment. As a consequence the price index for consumption and investment is the same. For the choice of the CES function we follow Gali and Monacelli (2008).

[11] Optimal demands are the solution of the final firm maximization problem: $\{A^j_{j,t}, A^j_{-j,t}\}^{\infty}_{t=0}$ to maximize $P^j_t A^j_t - p^j_{j,t}A^j_{j,t} - p^j_{-j,t}A^j_{-j,t}$.

Intermediate firms

There is a competitive non financial sector in the economy which produces a tradable good under a Cobb-Douglass production function. The inputs are capital and labour rented respectively from capital producers and households. The maximization problem of the firms reads:

$$\max \Upsilon_t^j$$

$$\text{s.t. } \Upsilon_t^j = \phi_t^j Y_t^j - w_t^j h_t^j - r_t^j K_{t-1}^j , \quad (4.3.20)$$

$$Y_t^j = Z_t^j \left(K_t^j\right)^{\mu} \left(h_t^j\right)^{1-\mu} , \quad (4.3.21)$$

where Z_t^j represents total factor productivity and $0 < \mu < 1$ is the elasticity of output to capital. The first order conditions for this maximization problem equate the marginal productivity of factors with their marginal cost:

$$r_t^j = \mu \frac{\phi_t^j Y_t^j}{K_{t-1}^j} , \quad (4.3.22)$$

$$w_t^j = (1-\mu) \frac{\phi_t^j Y_t^j}{h_t^j} . \quad (4.3.23)$$

One source of aggregate risk in this model comes from the total factor productivity Z_t^j:

$$Z_t^j = \left(Z_{t-1}^j\right)^{\gamma_z} exp(u_t^z) , \quad (4.3.24)$$

that is represented as a stochastic autoregressive process with $0 < \gamma_z < 1$, and u_t^z i.i.d.

4.3.4 Banking sector

The banking sector is represented by an international and perfectly competitive bank *à la* Enders et al. (2011) augmented by credit frictions *à la* Perego and Pierrard (2014). The bank is located in the core but trades with all countries $j \in \{c, p\}$. It collects deposits D_t^j from households and can invest in sovereign bonds s_t^j as well as provide loans L_t^j to the firms in both regions. The bank maximizes its consumption, its profits, over the two regions.

The bank faces a capital requirement *à la* Enders et al. (2011) having to set aside a fraction $0 < \gamma < 1$ of loans as own capital. The bank can deviate from legal requirements ($x_t = 0$) but this is costly. The bank's balance sheet constraint is:

$$(1-\gamma)\sum_j Q^j_{c,t}L^j_t + \sum_j Q^j_{c,t}s^j_t = \sum_j Q^j_{c,t}D^j_t + x_t \,. \tag{4.3.25}$$

The bank budget constraint is:

$$\begin{aligned}
&\sum_j Q^j_{c,t}C^{b,j}_t + \sum_j Q^j_{c,t}R^{d,j}_{t-1}D^j_{t-1} + \sum_j Q^j_{c,t}L^j_t + \sum_j Q^j_{c,t}s^j_t + \Gamma_d\sum_j (D^j_t - \bar{D}^j) \\
&\quad + \frac{\Gamma_l}{2}\sum_j (L^j_t - \bar{L}^j)^2 + \frac{\Gamma_x}{2}(x)^2 + \frac{\Gamma_p}{2}\left(\frac{\sum_j Q^j_{c,t}(1-\epsilon^j_t)^\nu s^j_t}{\sum_j Q^j_{c,t}L^j_t} - \frac{\sum_j \bar{Q}^j_c \bar{s}^j}{\sum_j \bar{Q}^j_c \bar{L}^j}\right)^2 \\
&= \sum_j Q^j_{c,t}D^j_t + \sum_j Q^j_{c,t}R^{l,j}_{t-1}L^j_{t-1} + \sum_j Q^j_{c,t}(R^{b,j}_{t-1} - \epsilon^j_t)s^j_{t-1} + \sum_j Q^j_{c,t}H^{b,j}_t \,.
\end{aligned} \tag{4.3.26}$$

The bank pays a real return $R^{d,j}_{t-1}$ on deposits, it receives $R^{l,j}_{t-1}$ on loans and $R^{b,j}_{t-1}$ on sovereign bonds. Sovereign bonds are risky assets as government can default on it with a probability ϵ^j_t. The bank might receive a lump-sum transfer $H^{b,j}_t$ from the government. Moreover, the bank faces different types of costs as in Perego and Pierrard (2014): operational costs on deposits, captured by Γ_d; adjustments costs on loans, Γ_l, as in Guerrieri et al. (2012); and the cost of deviating from the legal requirement that, following Enders et al. (2011), we capture by $\Gamma_x > 0$. Finally the bank is subject to a collateral requirement cost $\Gamma_p(.)^2$ that, following Perego and Pierrard (2014), we call the collateral constraint. Banks normally use sovereign bonds as collaterals on the interbank market in order to collect funds to sustain the private credit supply. In this model we force the overall supply of loans to depend directly on the quantity, as well as on the quality, of the collateral sovereign bonds as we do not frame explicitly the interbank market. The parameter ν measures the riskiness of bonds and represents the haircut applied to them. In the case of a sovereign risk shock this cost introduces a demand for riskless bonds and determines the well known flight-to-quality in sovereign bond markets (more than obviously reducing the supply of credit to capital producers).

The bank utility is:

$$\max E_s \sum_{t=s}^{\infty} \beta^{t-s} (C_t^{b,c})^{\vartheta} (C_t^{b,p})^{1-\vartheta} \tag{4.3.27}$$

where ϑ is the share of consumption goods from country c in the utility that we set to 0.5 such that the bank consumes its profits equally in the two regions. The bank maximizes (4.3.27) with respect to (4.3.25) and (4.3.26). The first order conditions are:

$$\lambda_t^b = \vartheta \frac{(C_t^{b,c})^{\vartheta} (C_t^{b,p})^{1-\vartheta}}{C_t^{b,c}} \ , \tag{4.3.28}$$

$$Q_{c,t}^p = \frac{1-\vartheta}{\vartheta} \frac{C_t^{b,c}}{C_t^{b,p}} \ , \tag{4.3.29}$$

$$\lambda_t^b (Q_{c,t}^j - \Gamma_d + Q_{c,t}^j \Gamma_x x_t) = \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j R_t^{d,j} \ , \tag{4.3.30}$$

$$\begin{aligned} \lambda_t^b \Bigg(Q_{c,t}^j - \Gamma_p Q_{c,t}^j \left(\frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{\sum_j Q_{c,t}^j L_t^j} - \frac{\sum_j \bar{Q}_c^j \bar{s}^j}{\sum_j \bar{Q}_c^j \bar{L}^j} \right) \frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{(\sum_j Q_{c,t}^j L_t^j)^2} \\ + \Gamma_l (L_t^j - \bar{L}^j) + (1-\gamma) Q_{c,t}^j \Gamma_x x_t \Bigg) = \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j R_t^{l,j} \ , \end{aligned} \tag{4.3.31}$$

$$\begin{aligned} \lambda_t^b Q_{c,t}^j \left(1 + \Gamma_p \left(\frac{\sum_j Q_{c,t}^j (1-\epsilon_t^j)^{\nu} s_t^j}{\sum_j Q_{c,t}^j L_t^j} - \frac{\sum_j \bar{Q}_c^j \bar{s}^j}{\sum_j \bar{Q}_c^j \bar{L}^j} \right) \frac{(1-\epsilon_t^j)^{\nu}}{\sum_j Q_{c,t}^j L_t^j} + \Gamma_x x_t \right) \\ = \beta E_t \lambda_{t+1}^b Q_{c,t+1}^j (R_t^{b,j} - \epsilon_{t+1}^j) \ . \end{aligned} \tag{4.3.32}$$

Equation (4.3.29) shows that the ratio of consumption of the bank for the two regions depends on the ratio of relative price indexes. Equations (4.3.30), (4.3.31), (4.3.32) represent respectively the Euler equation for deposits, loans and sovereign bonds.

4.3.5 Government

The government consumption in each region $j \in \{c, p\}$, G^j, is financed via lump-sum taxes, T_t^j, from the households, as well as via public debt, B_t^j, according to:

$$G^j + H_t^{h,j} + H_t^{b,j} + (R_{t-1}^{b,j} - \epsilon_t^j)B_{t-1}^j = B_t^j + T_t^j \, , \quad (4.3.33)$$
$$T_t^j = \bar{T} + \tau(B_t^j - \bar{B}) \, . \quad (4.3.34)$$

Moreover, the government may transfer $H_t^{h,j}$ to the households and $H_t^{b,j}$ to the bank. Both for the tax rule and the transfer specification we follow Corsetti et al. (2013). As estimated by Bohn (1998), taxes react positively to the increase in debt such as to stabilize it. This implies that the government cannot finance public expenditure only via debt.[12] Equation (4.3.33) also shows that sovereign default may happen through the term $0 \leq \epsilon_t^j \leq 1$. Everything else equal, a strictly positive ϵ_t^j reduces the stock of sovereign debt in the next period. Finally we define public expenditures as a fixed fraction, G^j, of debt at any period.

Default

To determine the default rate ϵ_t^j we tightly refer to the methodology used by van der Kwaak and van Wijnbergen (2013) by introducing an exogenous fiscal limit for the economy. The intuition is that there is a maximum level of taxes that can be raised before the economy becomes politically unstable. This translates through equation (4.3.34) into a maximum level of sovereign debt-to-output ratio BY_t^{max} that the government is able to service. We moreover assume that this maximum *sustainable* level is stochastic and follows:

$$BY_t^{max} = \bar{BY}^{max} + \gamma_b(BY_{t-1}^{max} - \bar{BY}^{max}) + u_t^b \, , \quad (4.3.35)$$

where $0 < \gamma_b < 1$ is the autoregressive component, and u_t^b is a i.i.d. shock. This stochastic behaviour aims at capturing the uncertainty around political instability in the context of sovereign debt and taxation.[13]

Let us define $\tilde{B}_t^j$ as the level of debt in the economy when no default occurs:

[12] As the focus of the chapter is not on the fiscal dimension we use debt-smoothing lump-sum taxes rather than more complicated distortionary tax schemes.

[13] In reality, the maximum sustainable government debt level is not exogenous but depends on expected growth rates, on expected growth volatility or on the expected government ability to raise taxes (see for instance Collard et al. (2014)). But this is beyond the scope of this chapter.

$$G_t^j + R_{t-1}^{b,j}\, B_{t-1}^j = T_t^j + \tilde{B}_t^j\,. \tag{4.3.36}$$

If this level of debt-to-output $\tilde{B}_t^j/(4Y_t^j)$ is lower (resp. higher) than the maximum sustainable level BY_t^{max}, the government does not (resp. does) default. In other words, we define the default decision Δ_t as:

$$\Delta_t = \begin{cases} 0 & \text{if } \frac{\tilde{B}_t^j}{4Y_t^j} < BY_t^{max} \\ 1 & \text{otherwise} \end{cases} \tag{4.3.37}$$

This default process Δ_t is a step function that we approximate with the continuous normal cdf:

$$\epsilon_t^j = F\left(\frac{\tilde{B}_t^j}{4Y_t^j} - BY_t^{max}\ ;\ 0\ ,\ \sigma^2\right) \ = \ \Phi\left(\frac{\frac{\tilde{B}_t^j}{4Y_t^j} - BY_t^{max}}{\sigma}\right)\ , \tag{4.3.38}$$

where $\sigma > 0$ represents the variance and $\Phi(.)$ is the standard normal cdf. We see that when $\sigma \to 0$, then $\epsilon_t^j \to \Delta_t$. A reduction (resp. increase) in the maximum sustainable level of debt-to-output, through the stochastic shock u_t^b in equation (4.3.35), increases (reduces) the default rate in the economy. Similarly, a higher (resp. lower) debt-to-output ratio $\tilde{B}_t^j/(4Y_t^j)$ increases (resp. reduces) the default rate in the economy. Agents in the economy observe the current economic conditions and, as a consequence, they form expectations on default according to equation (4.3.38). If we assume that only the periphery country can default, the difference between the core and the periphery sovereign interest rate -abstracting from other general equilibrium dynamics- is given by a wedge that reflects the default expectations:

$$R_t^{b,p} = R_t^{b,c} + E_t[\epsilon_{t+1}^p]\,. \tag{4.3.39}$$

The spread between the core and the periphery interest rate on sovereign bonds is driven by default expectations reflecting low economic growth and high levels of debt (with respect to the fiscal limit) in the periphery country.

Default risk A stochastic shock (negative for instance) to the maximum sustainable level of debt increases default implying a change in the interest rate on bonds as well as a direct loss on the households and bank's portfolio.

This shock impacts for instance both on prices (interest rates changes) as on quantities (partial default on the amount of sovereign debt held by agents). To deal with the risk dimension of the shock we want to isolate the price effect from the quantity effect. In order to do so we assume that the government makes transfers to the households and the bank in order to compensate the loss:

$$\begin{aligned} H_t^{h,j} &= \epsilon_t^j b_{t-1}^j \,, \\ H_t^{b,j} &= \epsilon_t^j s_{t-1}^j \,, \end{aligned}$$

In this way we capture the effect of a change in the interest rate on bonds and abstract from the consequences of the direct wealth loss. The same specification has been used by Corsetti et al. (2013) and Perego and Pierrard (2014). This procedure is helpful to reproduce the sovereign debt crisis' dynamics in the euro area where only Greece effectively, partially, defaulted.

4.3.6 Closing the model

Asset market clearing conditions

The sovereign bond market clearing condition for country $j \in \{c, p\}$ is:

$$B_t^j = b_t^j + s_t^j \tag{4.3.40}$$

where b_t^j and s_t^j is the amount of bonds held respectively by the households and the bank.

The equity market clearing condition for country $i \in \{c, p\}$ issuing and country $j \in \{c, p\}$ holding is:

$$1 = S_{i,t}^j + S_{i,t}^{-j} \tag{4.3.41}$$

implying that there is a fixed amount of shares traded in the economy normalized to 1.

Good market clearing condition

Let's define the domestic demand for country j as:

$$A_t^j = C_t^j + C_t^{b,j} + I_t^j + G_t^j + \texttt{costs}_t^j \tag{4.3.42}$$

where $\texttt{costs}_t^j$ collects all adjustment and operative costs beared by households, capital producers and firms in country j. Moreover, $\texttt{costs}_t^c$ also includes the costs related to the bank.

The good market clearing condition for each region j reads:

$$Y_t^j = A_{j,t}^j + A_{j,t}^{-j} \tag{4.3.43}$$

By summing them up we obtain the resource constraint for the two-country economy:

$$\sum_j \phi_t^j Q_{c,t}^j Y_t^j = \sum_j Q_{c,t}^j A_t^j \tag{4.3.44}$$

stating that the total production has to be equal to the demand in the whole currency area.

4.4 Calibration

Table 4.4.1 presents an overview of the parameters of the model. Most of the values are widely used in the DSGE and sovereign default literature. The calibration refers to euro area stylized facts. Time is discrete and one period represents one quarter. We specify the two country model for the euro area distinguishing between the core and the periphery in terms of debt-to-output ratios. The periphery refers to the GIIPS (Greece, Ireland, Italy, Portugal and Spain) for which we assume a higher debt to GDP ratio with respect to that of the core. This is the only assumed asymmetry in the model although, in reality, there are additionally asymmetries between the core and the periphery of the EA. Most notably the size of the two regional economies.[14] However, we assume the same size for the core and periphery area in order to focus on the main asymmetry brought by differentials in debt levels. Unless otherwise specified we opt for the same parameter choice in the two country blocs.

[14] Data on the euro area period suggest that the core output accounts for about 63-67% of EA output and the periphery for the remaining 33-37%. Calibrating the model accounting for different sizes for the core and the periphery would change the steady state of the model but not the dynamics.

Table 4.4.1: Parameter values

Parameter	Value	Description
Households		
β	0.99	Discount factor
ϕ_b	0.001	Bond adjustment cost
ϕ_s	0.01	Stock adjustment cost
ψ_n	110	Weight of labour in (dis-)utility
ψ_d	0.05	Weight of deposits in utility
η	5	Inverse of the intertemporal elasticity of labour supply
Global bank		
ϑ	0.5	Elasticity of substitution between c and p consumption goods
γ	0.05	Bank capital ratio requirement
Γ_d	0.005	Deposit operating cost
Γ_l	0.05	Loan adjustment cost
Γ_p	0.5	Collateral requirement cost
Γ_x	1.50	Capital requirement cost
ν	8	Elasticity of haircut to default applied to government bonds
Production		
δ	0.025	Capital depreciation rate
ϕ_i	0.05	Investment adjustment cost
κ_d	11	Dividend adjustment cost
α	0.3	Index of openess
μ	0.3	Elasticity of production w.r.t. capital
Authorities		
τ	0.13	Elasticity of taxes w.r.t. debt
$\bar{G}^j/\bar{Y}^j$	0.20	Public consumption-output ratio objective
$\bar{B}^c/(4\bar{Y}^c)$	0.60	Debt-output ratio objective in the *core* country
$\bar{B}^p/(4\bar{Y}^p)$	0.85	Debt-output ratio objective in the *periphery* country
$\bar{BY}^{max}$	0.92	Maximum sustainable debt-output ratio
σ	0.015	Standard deviation of default pdf
Shocks		
γ_z	0.89	Autoregressive parameter for technological shock
γ_b	0.79	Autoregressive parameter for sustainable debt-output shock

4.4.1 Parameters governing the steady state

Taking the different Euler equations (4.3.4), (4.3.5), (4.3.6), (4.3.14), (4.3.15), (4.3.30), (4.3.31) and (4.3.32) at the steady state gives:

$$\begin{aligned}
\bar{R}^{d,j} &= \frac{1 - \mathtt{a}\,\psi_d}{\beta} = \frac{1-\Gamma_d}{\beta}\,,\\
\bar{R}^{l,j} &= \bar{R}^{b,j} = \frac{1}{\beta}\,,\\
\bar{R}_i^{S,j} &= \frac{1}{\beta}(1+\phi_s\bar{S}_i^j)\,,\\
\bar{r}^j &= \frac{1}{\beta} - 1 + \delta\,.
\end{aligned}$$

At steady state all the agents in the economy discount the future via the same discount factor β as $\bar{\beta}^e = \beta$. We assume no default at steady state, $\bar{\epsilon}^j = 0$, both for the periphery and the core and that $\bar{x} = 0$ implying no excess bank capital at steady state. We set $\Gamma_D = 0.005$ and $\beta = 0.99$ in order to have the annualized returns on loans and bonds of 4% and on deposits of 2%.[15] Additionally we set ϕ_s equal to 0.01 in order to obtain an annualized return on equity of 6%[16] given a steady state holdings of domestic as well as foreign shares of $\bar{S}_i^j = 1 - \bar{S}_i^{-j} = 0.5$. This value is consistent with the studies of ECB (2012) and Jochem and Volz (2011) on the intra-EA home bias in equity holdings assessing a degree of cross-border holdings around 40-60%. For what concerns the sovereign bond holdings in the euro zone, we follow Guerrieri et al. (2012) and we assume that 33% of sovereign debt is held by domestic household and the rest by the bank.[17]

Following Enders et al. (2011) we set the required bank capital ratio at $\gamma = 0.05$. Empirically the capital ratio for the major banks in the euro area is between 3% and 5%. Finally the size of the bank balance sheet is of 111% of yearly total output ($\bar{Y}^c + \bar{Y}^p$). This number is in line with the euro area

[15] These steady state values are set to match the empirical evidence for the 10 years bond's returns and the 5 years maturity loans' rate. This choice is made in order to have comparable maturities on the two assets, given the data availability.

[16] This value is in line with the annualized returns from the non-financial corporation equity index for EA countries.

[17] We do not have data on non-resident holdings of sovereign debt so we assume that it is mainly held by banks rather than foreign households. A different assumption would not change the implications of the model as long as the majority of the debt held by household is domestic.

data on bank balance sheet for loans to and holdings of securities issued by euro area residents.

The loans to physical capital ratio is set at around 1/3 and it pins down the households weight on deposits Ψ_d. Ψ_n, the disutility of labour parameter, is pined down by setting $\bar{h^j} = 0.2$ following the RBC literature implying that households work 20% of their time. We calibrate η, the parameter governing the shape of the labour disutility, in order to have a Frisch elasticity of 0.2 as it is in line with micro-based measures.[18] The production function is Cobb-Douglass with the capital share at 0.3; setting the depreciation rate at $\delta = 0.025$ implies $\bar{K}^j/\bar{Y}^j = 8.54$ and $\bar{I}/\bar{Y} = 0.21$ which is in line with the RBC literature and empirical observations. The consumption of households in total output is of 55% while the one of the bank of 2.3%. The consumption of the bank falls equally in the two regions as we impose $\vartheta = 0.5$. Finally, following the NOEM literature as in Gali and Monacelli (2008), we assume a bias for domestic goods and we calibrate $\alpha = 0.3 < 0.5$. The value selected is in the range of those used in recent macro-finance model. For a detailed description see for instance Coeurdacier et al. (2007).

On the fiscal side we distinguish between the core and the periphery in terms of debt-to-output ratios: we set the one of the periphery at 85%, at steady state, while the one of the core at 60%.[19] Public expenditures are set to 20% of GDP as in line with EA data. This implies that taxes-to-output are 22% of GDP for the core and 23% for the periphery where the difference is due to the different debt burden in the two regions that forces a higher taxation in the periphery. We set the maximum level of debt $\bar{BY}^{max}$ and the standard deviation of default, σ, in order to obtain an elasticity of default risk to debt of 0.1 around the steady state. This elasticity [20] is consistent with empirical stylized facts for the EA as shown in Perego and Pierrard (2014). The methodology used to calibrate the default process follows the one used by Corsetti et al. (2013). Finally we assume that only the periphery can default on its debt.

[18] MaCurdy (1981) and Altonji (1986) estimate the Frisch elasticity - determined from hours and wage fluctuations on an individual basis - to be in the range of 0 to 0.54.

[19] These values are in line with the IMF economic outlook for 2010.

[20] The elasticity of – yearly – default wrt. debt to output implied by the model is:

$$\texttt{elasticity}^j = \frac{4\Delta\epsilon_t^j}{\Delta X_{j,t}^b} = \frac{4}{\sigma}\,\phi\left(\frac{\bar{X}_j^b}{\sigma}\right),$$

where $\phi(.)$ is the standard normal pdf and $X_{j,t}^b = \frac{\bar{B}_t^j}{4Y_t^j} - BY_t^{max}$ with $\bar{X}_j^b$ its steady state.

4.4.2 Parameters governing the dynamics

This set of parameters does not affect the steady state but rather the dynamics of the model. Regarding consumption, we assume a logarithmic utility function for households and a linear one for the bank in order to account for the different degrees of risk aversion (higher for the households and null for the bank). As a sensitivity analysis we substitute the utility function used in the baseline model with a KPR formulation as of King et al. (1988). Correlation results are unchanged to the new utility specification. Moreover the results are also qualitatively consistent to changes in the value of the intertemporal substitution of consumption. However, the baseline formulation helps to better match empirical regularities, given the absence of wealth effect on the labour supply, and to have correlation results closer to the data estimates. As capital producers are owned by the households they do not have an explicit utility function. Adjustment costs on bonds, loans, and investments (ϕ_b, ϕ_d and ϕ_i) are standard in the literature of DSGE and their values are reported in Table 4.4.1.

In the bank specification we borrow the capital constraint from Enders et al. (2011) and set $\Gamma_x = 1.5$. For what concerns the collateral cost we set $\Gamma_p = 0.5$ and $\nu = 8$. For an exhaustive discussion on the role of those three parameters we address the interested reader to the discussion in Perego and Pierrard (2014).

On the capital producers' side, the adjustment cost on dividend payout is associated to the parameter κ_d. When κ_d is infinitely large capital producers have access to only one source of funds: bank's loans. For smaller values the capital producers can be financed both via dividend payouts and bank's loans. A similar cost is used by Jermann and Quadrini (2012). In the benchmark calibration we set κ_d such as to match the volatility of dividend payout for the EA over the period 1991-2013. In Section 4.5 we show how more flexibility on the dividend payout policy (lower values of κ_d) might have an impact on the correlations' dynamics.

Regarding the elasticity of the fiscal rule we follow Corsetti et al. (2013) and set the value of $\tau = 0.13$ that is a sufficiently high value to ensure that the debt remains bounded during the simulations.

In each country the sum of all the dynamic costs accounts for 1% of domestic output.

Shocks calibration

We calibrate the technology shock on EA data in order to match the volatility of output in the core and in the periphery for the period 1995Q1-2013Q4. The autocorrelation of the technology process is estimated to be 0.88 in the core and 0.89 in the periphery so that we calibrate the autocorrelation in the shock process, γ_z, to be 0.89 in both countries. We set the volatility of the technology shock, σ_z, to 0.004 in order to match the volatility of output, respectively of 0.013 and 0.011, in the core and in the periphery. Finally, the correlation between the shocks in the two regions is set to 0.5 as estimated by the author.

In order to calibrate the maximum sustainable level of debt shock we identify the part of the riskiness indicator for the periphery debt that is not explained by debt-to-output. As a riskiness measure we compute the sovereign bond yield spread between periphery countries and Germany. An alternative measure is the CDS on the underlying sovereign bonds. Unfortunately the data availability for this variable is limited to the period 2007-2012 that is when the sovereign debt shock is expected to be observed. For this reason we use yields in deviation from the benchmark risk-free asset (Germany's bonds) on the sample period 2000Q2-2013Q4 as a proxy for the CDS informations. We estimate a panel using as dependent variable the first difference of yield spread, $\Delta\, Yield$ and as independent variable the level of yield spread, $Yield$, the level of debt-to-output, $Debt$ as well as its first difference $\Delta\, Debt$. We additionally control for country fixed effects α_i. The shock we identify is the residual of the following panel regression[21]:

$$\begin{aligned} \Delta\, Yield_{i,t} = \beta_b\, \Delta\, Debt_{i,t} - \gamma\,(Yield_{i,t-1} - \beta_b\, Debt_{i,t-1}) + \alpha_i + u_t^b\,, \\ \text{for } i = \text{Greece, Ireland, Italy, Portugal, Spain;} \\ t = 2000q2, \ldots, 2013q3. \end{aligned} \tag{4.4.1}$$

Appendix 4.B explains that γ is related to γ_b, the persistence of the shock, by: $1 - \gamma = \gamma_b$. For instance for an estimate of $\hat{\gamma} = 0.211$ then $\hat{\gamma_b} = 0.789$. We calibrate consequently γ_b in equation (4.3.35) to 0.79 that is a close value to the one used by van der Kwaak and van Wijnbergen (2013), 0.8, for the same shock. Finally in order to calibrate σ_b we construct the variable maximum sustainable level of debt as explained in Appendix 4.B and compute its standard deviation. We set $\sigma_b = 0.1$ in the model such as to match the

[21] For details on the estimations and the choice of the panel model see Appendix 4.B.

relative standard deviation of the maximum sustainable level of debt with respect to output.

Finally the financial expectation shock is calibrated such as to match the EA volatility of the price-to-dividend ratio. We set $\sigma_s = 0.001$ accordingly.

4.5 Dynamic simulation

To simulate the model we take a first order approximation of the model's equations. Model correlations are computed from 50 simulations of the economy, each of 60 periods. The number 60 corresponds to the length, in terms of quarters, of the euro zone period data which we compare the model to. We look at the implications of a financial expectation shock, a technological shock and a sovereign risk shock for the international asset (equity and sovereign bond) markets. We will show that banking credit constraint (we will refer to them generally as credit constraint) play an important role for the behaviour of asset markets. In order to do so we simulate the benchmark model, as explained in Section 4.3, with a version without credit constraint. We do so by shutting down the collateral constraint and the cost on excess capital ($\Gamma_x = \Gamma_p = 0$). Moreover, we study the importance of capital producers' financing decisions for the correlations on asset markets. We compare for instance the previous models with a version characterized by low adjustment costs on dividend payouts ($\kappa_d = 1$ vs. the benchmark $\kappa_d = 11$).

Finally, we bring the model to the data. We show that it is able to quantitatively reproduce the asset markets' correlations during the euro period and in particular during the sovereign debt crisis. Additionally, in Appendix 4.C, we compare the model to standard business cycle stylized facts to attest its consistent performance with respect to reference macroeconomic variables' behaviours.

4.5.1 Financial expectation shock

We now investigate the case of a shock to the expected returns from equity.

Under the efficient market hypothesis (EMH), any fluctuation in stock prices is fully efficient as it reflects investors' expectations about future firm's profits. Recently however, part of the academic world started to doubt about the prevailing view that stock prices fluctuations are fully efficient. Behavioural economists started to attribute the imperfections in financial markets to a combination of cognitive biases such as overconfidence, overreaction, information bias, and various other predictable human errors in reasoning and information processing. Among the others, Shiller (2005) challenged the EMH theory by putting forward the idea that financial market are characterized by 'irrational exuberance' in the form of successive cycles of excesses of optimism and pessimism. He defines 'irrational exuberance' as a psychological contagion that spreads from person to person after news of a price increase occurs, bringing more investors to buy and effectively start the bubble. As a consequence, according to him, a large part of price movements during a bubble is caused by speculative purchases. Analogously, Adam et al. (2014) suggest that are self-reinforcing belief dynamics, triggered by fundamentals, that explain the most of US stock prices fluctuations. In their model if agents become optimistic, this causes an increase in actual stock prices, confirming agents' expectations and feeding a stock price bubble. In our model we do not aim at reproducing the dynamics leading to higher returns' expectations and the consequent increase in prices. We rather take this process as given and we introduce a positive shock on the returns' expectations such as to mimic these subjective irrational believes.[22] We assume this shock to be common to the core and the periphery of the EA as suggested by the similar behaviour of stock returns, Figure 4.1.1, and of price dividend ratios, Figure 4.5.1.

Figure 4.D.1 in Appendix 4.D presents the impulse response functions (IRFs hereafter) for the model with and without credit constraints. As for the previous shocks we will further investigate the role of more or less flexible dividend payout policy of the capital producers. By bringing the model to the data we compare the model's results with the correlations over the period 2000-2004 and 2007-2010.

Financial expectation shock in the data

The period between 2007-2010 is what we refer to as the financial crisis that started with a real estate bubble; the period 2000-2004 instead, on the one hand was characterized by the end of the dot-com bubble and, on the other hand, it was the converging period after the introduction of the common

[22] Although assuming an irrational shock in a framework characterized by rational agents might look contradictory, it is consistent with a theoretical framework á la Adam and Marcet (2011). In their model agents are 'internally rational' as they make fully optimal decisions by maximizing discounted expected utility under uncertainty, but at the same time they may not be 'externally rational' as they may not know the true stochastic process for the payoff of relevant variables that are beyond their control as prices.

currency.[23] In order to attest the presence in the data of such a period of high expected returns we look at the price-dividend ratio (PD henceforth) for an aggregate of EA core and periphery countries. PD ratios are usually used as measures of expected returns in the stock market.[24]

As we can notice, this ratio was high around the years 2000 and again in 2006-2008. However, the shock we identify as the financial expectation shock not only includes the rising part of the bubble but also its decline. For this reason we can compare the model's dynamics with the whole cycle of a bubble. In this perspective we observe that, for the dot-com period, PD ratio increased at the end of the '90 to burst until 2003; for the second period, the increasing time of PD ratios started in 2005 and the burst lasted until 2009. This behaviour of the stock markets, in both periods, have been regarded by scholars and media to be due to speculative bubbles.

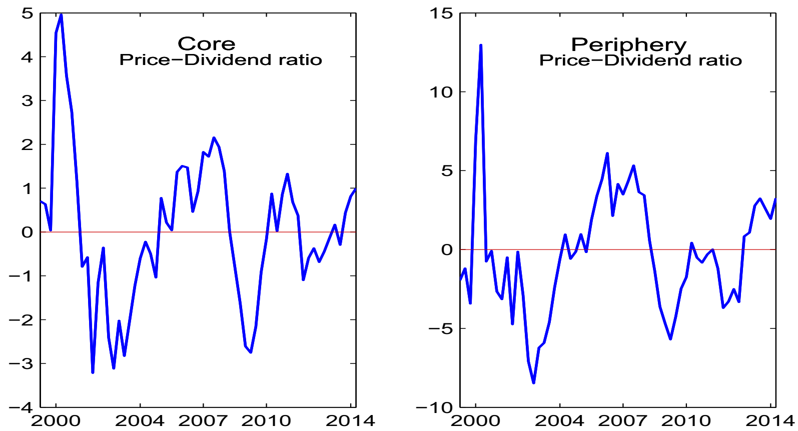
Model without credit constraints

Without credit constraints, a financial expectation shock has a very limited impact on rates and variables. On the equity side the shock drives up the stock price and, temporarily, the equity returns. This entails an increase in the capital producers' demand for loans driving up the interest rate. The bank, by arbitrage, demands a higher return on sovereign bonds in order to hold them and it accumulates excess capital. The increase in the interest rate on sovereign bonds determines an increase in the stock of debt and hence of taxation. As households foresee future taxation, they decrease consumption and savings both in sovereign bonds and in deposits. Output falls in both regions after a couple of periods as also investments slightly, but persistently, decrease. Table 4.5.1 shows the correlations. As the shock is assumed to hit the two regions in the same way it entails a one-to-one correlation between equity markets and a very high correlation in the sovereign bond one. In the absence of credit constraints, column (1) and (2), we notice that the cross asset correlation is almost null. This is due to the negligible change of sovereign bonds' interest rates as opposed to the change in equity returns. As we can notice, more flexible dividend payout do not change the results.

[23] For the concurrence of the two effects in this period we should be cautious in explaining it via a financial expectation shock. However, looking at the performance of the stock market in Figure 4.1.1, and at the realized correlations, we notice a strong similarity with the behaviour of the asset markets in the period 2007-2010.

[24] In the US stock market, for which this data is available, PD ratios comove almost perfectly with expected returns based on investors' surveys.

Figure 4.5.1: Price-Dividend ratio for core and periphery stocks



Notes. The figure plots the price-dividend ratio for the stock index in the core and the periphery against their HP-trends. Prices and dividends are expressed in real terms after being deflated by the domestic price consumption index. Core and Periphery series are geometric averages for the set of countries belonging to each region. Countries belonging to the core are: Belgium, Finland, France and Germany. Whereas countries belonging to the periphery are: Ireland, Italy, Portugal and Spain.

Data sources: Datastream and author's calculations.

This is not surprising as the shock affects directly the equity market ruling out the effectiveness of a different dividend payout policy.

Model with credit constraints

When we introduce credit constraints the impact of the shock amplifies. The capital constraint impedes the bank to be too leveraged (positive excess capital) and forces the bank to cut on part of the asset side. As a consequence of the capital constraint, the bank decreases loans and sovereign bonds in order to reduce the excess capital and the related cost. This drives up both loan and sovereign bond rates even more. On the production side it determines a stronger decrease in investments, capital and output. The fall in investment is driven by the fact that while households are overly optimistic, capital producers are not. As returns on equity increase, households are willing to buy more of this asset and reduce the other sources of investment (deposits and sovereign bonds). On the capital producers' side the higher lending rates and the expectations of future lower growth reduce loans' demand and investments (despite the fact that capital producers resort to internal financing via lower dividends).

At the same time, via collateral channel, a decreased loans' demand brings to a reduction in the demand of collaterals for the bank. As a consequence sovereign bond returns increase. On impact both the returns on equity and the interest rate on sovereign bonds raise determining a positive correlation. As soon as the effect of the shock ends, both rates decrease as households suddenly revise downwards their return expectations. This dynamics matches the correlation in the data both in the case of high and low adjustment costs on dividend payout as shown in Table 4.5.1 column (3) and (4).

Table 4.5.1: Correlation data vs financial expectation shock

	Data		Model			
	2000	2007	No credit constr.		Credit constr.	
	2004	2010	Bench. (1)	Flex. *div* (2)	Bench. (3)	Flex. *div* (4)
corr($R^{b,p}$,$R^{b,c}$)	0.94	0.88	0.94	0.95	0.99	0.99
corr($R^{S,p}$,$R^{S,c}$)	0.74	0.82	1	1	1	1
corr($R^{b,c}$,$R^{S,c}$)	0.34	0.44	0.002	0.004	0.54	0.52
corr($R^{b,p}$,$R^{S,p}$)	0.18	0.28	-0.002	-0.002	0.51	0.50

$R^{b,j}$ is the gross return on sovereign bonds in country $j \in \{c, p\}$ and $R^{S,j}$ the gross return on equity. 'Bench.' is the benchmark model calibrated as explained in section 4.4; 'Flex. *div*' is the model with a lower adjustment cost on dividend payout. The different model specifications are simulated after a positive shock to core and periphery equity returns' expectations.

4.5.2 Technology shock

Figure 4.D.2 in Appendix 4.D shows the effect of a positive technology shock to the core country. In the following we compare the model with and without credit constraints in the case of more or less flexible dividend payout policy of the capital producers. By bringing the model to the data we compare the model's results with the correlations over the period 2004-2007.

Technology shock in the data

The 2004-2007 period came between the burst of the dot-com bubble and the beginning of the real estate bubble whose burst turned into the recent financial crisis. The 2004-2007 period was characterized by a growing path for the euro zone GDP reflected in a good performance of the stock market as we can see from Figure 4.1.1. By looking at the correlation on the stock-bond market in this period, Figure 4.2.1, we observe a change in its time-varying behaviour with respect to the preceding and the following period. We read this change as an indication that something happened in this interval of time that drove, or became the main determinant of, the negative comovement. By introducing a positive technology shock in the model we manage to reproduce the correlation of this period. So, although we cannot precisely identify the nature of the shock that hit the economy in these years, we can have the suspicion that it was a technology shock. This suspicion is sustained in the data by looking at the growing path of GDP and at other, related, economic indicators.

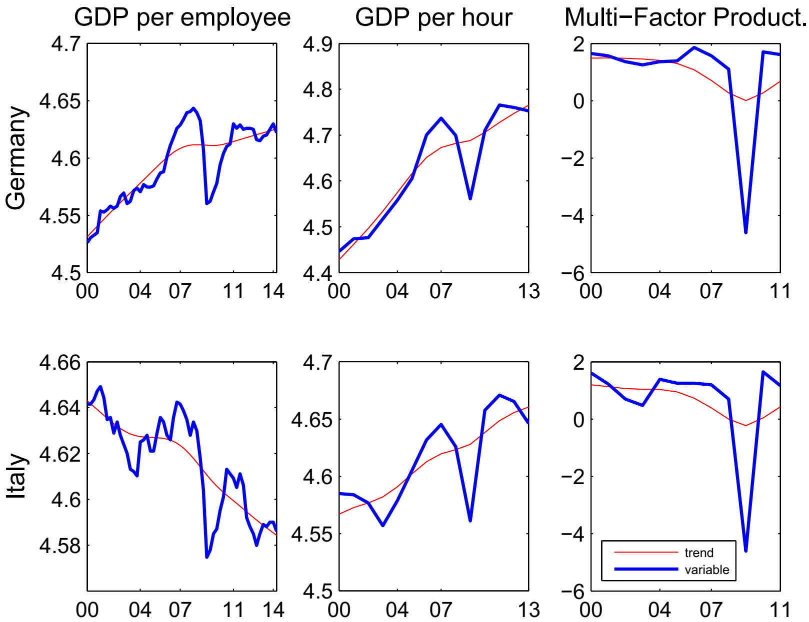
In Figure 4.5.2 we show the behaviour of GDP per person employed, GDP per hour and multi-factor productivity for Italy and Germany.[25] GDP per hour worked is a more reliable measure than GDP per employee and in particular captures labour productivity. Multi-factor productivity (MFP) additionally relates a change in output to several types of inputs. It is measured residually as that change in output that cannot be accounted for by changes in the combined inputs.

As we can see, in the period 2006-2007, all the GDP indicators show a higher than average productivity in both countries. As GDP measures do not adjust instantaneously to shocks we could infer that in the years preceding 2006, and up to 2007, there could have been a positive shock to productivity.[26] By looking at the MFP data we can see that between 2004 and 2007 productivity was above the trend providing additional evidence of a positive TFP shock in the period under consideration. However, we need additional rigorous empirical evidence to be able to properly identify this

[25] We consider Germany as the representative for the core countries whereas Italy for the periphery. Given the scarce availability of data for consistent samples over the different EA countries, we decided to show the behaviour of two representatives.

[26] The abrupt fall in all the indicators in 2009 should not be considered as a negative technology shock but rather as the consequence of the burst of the real estate bubble and the beginning of the financial crisis with its consequent reduction in credit and fall in production activities.

Figure 4.5.2: Indicators of a technology shock



Notes. The figure plots a selection of macroeconomic indicators for Germany and Italy. 'GDP per employee' refers to the GDP per person employed in the total economy; 'GDP per hour' refers to the manufacturing sector only and 'Multi-Factor Product.' shows the growth rate of multi-factor productivity for the whole economy. The series are plotted against their trends computed via Hodrick-Prescott filtering. Data on GDP per person is at quarterly frequency whereas the other two measures are at the annual one. *Data sources*: OECD statistics.

shock in the data.

Model without credit constraints

In the absence of credit constraints, that is when the bank's capital and collateral channels are not working, our model delivers the same dynamics as the international real business cycle model as of Backus et al. (1992). A positive productivity shock brings the marginal productivity of the factors of production to increase in the core country. Households work more, consume more and save more in the form of deposits. The bank provides more loans to the core capital producers driving down the loan interest rate. The shadow value of capital increases determining an increase in investments. Output increases and the real exchange rate, for the core, depreciates. In the periphery the relative change in prices determines an increase in output, labour and consumption as now core goods are cheaper. Moreover, households substitute consumption for savings decreasing the supply of deposits and driving up the interest rate. Investment in the periphery slightly increases as a consequence of the wealth effect brought about by the relative change in prices. The bank supplies less loans increasing the interest rate on periphery loans.

As of the equity market, in the core region capital producers payout, procyclically, more dividends and households buy more of domestic and foreign issued equity. The price of core shares increases and this drives the increase in the equity return. In the periphery, instead, capital producers payout negative dividends in an attempt to use internal resources to finance the higher investments as external resources (loans) are now more expensive. A negative dividend payout coupled with a fall in stock prices, as the periphery is not affected by the technology shock, determines a fall in equity returns. Finally, regarding sovereign bonds, as households in the core country enjoy more the effects of the productivity shock, they also increase the demand of domestic sovereigns driving down the interest rate. In the periphery, instead, the demand decreases determining a higher interest rate. Table 4.5.2, column (1), shows these dynamics in terms of correlations. If we allow capital producers to be more flexible in their dividend payout policy, column (2), we see that only the correlation on the equity market changes.[27] In the core, capital producers increase dividend payouts such as to further sustain the rise in the stock price and in the return on equity. In the periphery, capital producers payout even less dividends than in the previous case. This behaviour allows the capital producers to further self-finance their operations, increase investment and push up the stock price. In turn, this entails a lower decrease (and eventually a slight increase) in the periphery equity returns.

[27]In the model, a more flexible dividend payout policy is achieved by reducing the adjustment cost on dividends' parameter, κ_d, from 11 to 1.

Model with credit constraints

In the scenario without constraints the bank accumulates negative excess capital. After the positive technology shock the bank collects resources from the households (deposits) but does not provide enough loans to the firms. The unused resources translate into bank's consumption. The capital constraint forces the bank to avoid to be too indebted with no counterpart on the asset side of the balance sheet. It obliges the bank to match the asset side and the liability side of the balance sheet not allowing for a negative net position. Once we introduce the capital constraint, the bank keeps less unused resources for lending activities and provides more loans to the economy. In doing so the interest rate on loans decreases for the two regions providing an incentive for the capital's producers to be financed through the bank. As a consequence, in the periphery, dividend payout fall less and the demand of loans increases determining a more pronounced increase in investments. The stock price increases following the behaviour of investment and driving up the return on equity. Moreover, the augmented investments further sustain the output increase in both countries. Consumption, in both countries, increases as well. Via the collateral constraint, the bank demands also more sovereign bonds in order to support the private credit supply. Both core and periphery sovereign interest rates fall. On the equity market, the increase in investment drives a stronger increase in equity prices that is reflected in higher equity returns in both regions. Table 4.5.2, column (3), shows these dynamics in terms of correlations.

With credit constraint, on the one hand a positive technological shock in the core triggers a positive increase in equity returns both in the core and in the periphery; on the other hand, it determines an equal increase in the demand of sovereign bonds, as collaterals, that drives the interest rate on these assets down. As a consequence the correlation bond-stock is negative both in the core and in the periphery implying a certain degree of diversification for investor's portfolio. These results are not affected by increasing the flexibility of dividend payouts as shown in column (4). Capital producers in the periphery payout less dividends whereas those in the core payout more. These decisions determine a further (slight) increase in stock prices and equity returns. However, in the presence of credit constraint, allowing capital producers to decide their payout policy does not affect asset market's correlations. As a result, we conclude that the model with credit constraints is better able to reproduce the correlations as in the data with respect to the model without.

Table 4.5.2: Correlation data vs Technology shock

	Data	Model			
	2004-2007	No credit constr.		Credit constr.	
		Bench. (1)	Flex. *div* (2)	Bench. (3)	Flex. *div* (4)
corr($R^{b,p}$,$R^{b,c}$)	0.98	-0.75	-0.75	0.79	0.82
corr($R^{S,p}$,$R^{S,c}$)	0.82	-0.07	0.35	0.87	0.88
corr($R^{b,c}$,$R^{S,c}$)	-0.08	-0.19	-0.18	-0.11	-0.13
corr($R^{b,p}$,$R^{S,p}$)	-0.24	-0.29	-0.32	-0.06	-0.09

$R^{b,j}$ is the gross return on sovereign bonds in country $j \in \{c, p\}$ and $R^{S,j}$ the gross return on equity. 'Bench.' is the benchmark model calibrated as explained in section 4.4; 'Flex. *div*' is the model with a lower adjustment cost on dividend payout. The different model specifications are simulated after a correlated (positive) technology shock between the core and the periphery.

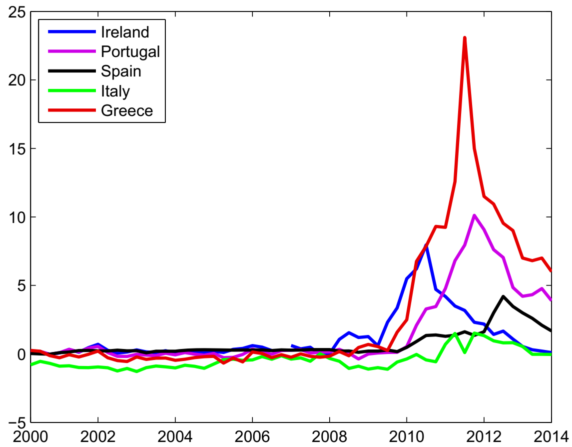
4.5.3 Sovereign risk shock

A shock to the maximum level of sustainable debt determines an increase in the default rate. The direct consequence is that agents demand a higher (gross) interest rate in order to compensate for the lower net return given by the expected higher default. On the government side, the debt level in the periphery increases as a consequence of the higher interest rate, given that, with default risk, the government does not enjoy a reduction in the stock of debt. As sovereign debt increases so do taxes given the debt-stabilizing tax rule. Figure 4.D.3 in Appendix 4.D shows the IRFs after a sovereign risk shock for the model with and without credit constraints. We will further investigate the role of more or less flexible dividend payout policy of the capital producers. By bringing the model to the data we compare the model's results with the correlations over the period 2010-2012.

Sovereign risk shock in the data

The period 2010-2012 was characterised by the sovereign debt crisis of the euro zone. Periphery countries experienced increasing troubles on their sovereign debt reflected in high interest rates as shown in Figure 4.1.1. The

Figure 4.5.3: Sovereign risk shock for EA periphery countries



Notes. The figure plots the residuals from the panel estimation on sovereign yields spreads that identifies the sovereign risk shock. The countries shown are: Greece, Ireland, Italy, Portugal and Spain. *Data sources*: Author's calculations.

main issues shaping the crisis were weak actual and potential growth, low competitiveness and large (and growing) debt-to-output ratios.[28] Prior to this crisis, the level of debt-to-output has been the main determinant of the interest rate demanded on sovereign bonds. However, during the sovereign debt crisis a big part of the riskiness was not explained by the level of debt-to-output. In order to identify this shock we regress the level of debt-to-output onto the sovereign bond yields' spreads vis-à-vis Germany as explained in Section 4.4 and in Appendix 4.B. The residuals are plotted in Figure 4.5.3.

As we can see, until 2010 the yields (or riskiness vis-à-vis Germany) were well explained by the previous level of risk as well as debt (residuals centred around zero). From 2010 the model does not fit the data as well as before meaning that something else was the driver of the risk. This is the shock we identify and that has its major impact between 2010 and 2012.[29]

[28] See for instance Petrakis et al. (2013).

[29] If we run the panel regression by splitting the sample before and after 2010 and compare the R^2, we see that it is much lower in the second sample. This provides additional

Model without credit constraints

Without credit constraints an increase in the maximum sustainable level of debt brings to a wealth loss for the periphery households via taxation. They decrease consumption of both domestic as well as foreign goods. Given the home biased composition of their consumption basket, the decrease in consumption in the periphery leads to a reallocation of relative prices with the appreciation of the core currency. The marginal productivity of factors of production falls, determining a decrease in labour and output. Furthermore, as the shadow value of capital falls, investments decrease which reduces capital. In the core, the change in relative prices brings employment, capital and output to increase. Also core consumption increases as foreign goods are relatively cheaper.

For what concerns the bank's related dynamics, loans' demand falls in both regions decreasing the interest rate. In the periphery, households decrease the supply of deposits and increase the holdings of sovereign bonds. In the core, households increase both deposits and the sovereign bond holdings. As the net return on sovereign bonds decreases, the bank decides to hold less of these assets on impact. However, as after impact the net return on sovereign bond increases, the bank decides to invest more in the periphery bonds driving an increase in its excess capital.

On the equity side, households in the periphery buy more of both domestic as well as foreign issued equity. At the same time capital producers payout more dividends both in the core and in the periphery. Such a behaviour in the periphery determines a faster disinvestment; in the core an attempt to keep a high price and return on equity. However, the price of equity falls in both regions as the expected discounted value of future dividends decreases. This, in turn, leads to a decrease in the return on equity in both regions, though more pronounced in the periphery country. Table 4.5.3, column (1), shows these dynamics in terms of correlations. In column (2) we see that allowing the capital producers to be more flexible on their payout policy changes the correlation on the equity market. Both in the core and in the periphery they payout more dividends for the reasons explained above. As a consequence the periphery stock price further falls whereas the core stock price increases. In turn, the positive increase in the core stock price drives a different dynamics of equity returns in the two regions: an increase in the core and a decrease in the periphery. All the reported effects are, however,

evidence of a change in the explanatory power of debt-to-output.

quite small without credit constraints.

Model with credit constraints

When credit constraints are introduced, the impact of the shock magnifies. The capital constraint impedes the bank to be too leveraged (positive excess capital) and forces the financial intermediary to cut on part of the asset side. As a consequence, the bank decreases the supply of loans. This in turn hampers the fall in investment in the periphery and leads core capital producers also to decrease investments. The consequent fall in capital in the two regions brings a fall in output, wages and labour supply in the periphery, and a short lasting increase in core output and employment. Real exchange rate dynamics drive the different behaviour. Nevertheless, as also core investments fall, output in the core is forced to decrease after the initial boost. Consumption falls more than before and this time also in the core country.

At the same time, the collateral constraint forces the bank to hold sovereign bonds as a collateral for the provision of credit to the private sector. The collateral requested not only accounts for the quantity of sovereign bonds held by the bank but also for their quality. For instance, a sovereign shock that decreases the quality of periphery collaterals, by increasing the default rate on sovereign bonds, forces the bank to hold more of these assets in order to make up for the loss in quality. This determines a flight to quality between the risky sovereigns (periphery bonds) and the riskless ones (core bonds).[30] Additionally, this behaviour drives a wedge in the return from deposits and sovereign bonds that induces the households to invest more in deposits than in sovereign bonds. Noteworthy, all the previous dynamics are consistent with the findings of Perego and Pierrard (2014).

For what concerns equity, the owners of the firms demand more equity payouts in order to sustain their consumption. Regardless of the increase in dividend payouts, equity prices fall reflecting the decrease in investments. As a consequence, the equity returns in the two regions decrease of almost the same amount.

[30] We refer to flight-to-quality in bond markets by comparing the level of the correlation before 2010, that was very high, to the one during the sovereign debt crisis that fell to approximately 0.2. The flight-to-quality in the sovereign bond market has been widely documented by media and scholars in the recent years. Among the others see for instance Barrios et al. (2009) for an analysis of core-periphery sovereign bond spreads.

Table 4.5.3: Correlation data vs Sovereign risk

	Data	Model			
	2010-2012	No credit constr.		Credit constr.	
		Bench. (1)	Flex. *div* (2)	Bench. (3)	Flex. *div* (4)
corr($R^{b,p}$,$R^{b,c}$)	0.17	0.16	0.15	0.28	0.25
corr($R^{S,p}$,$R^{S,c}$)	0.73	0.99	-0.85	0.99	0.99
corr($R^{b,c}$,$R^{S,c}$)	0.28	0.22	0.22	0.67	0.49
corr($R^{b,p}$,$R^{S,p}$)	-0.19	-0.60	-0.60	-0.14	-0.16

$R^{b,j}$ is the gross return on sovereign bonds in country $j \in \{c, p\}$ and $R^{S,j}$ the gross return on equity. 'Bench.' is the benchmark model calibrated as explained in section 4.4; 'Flex. *div*' is the model with a lower adjustment cost on dividend payout. The different model specifications are simulated after a negative shock to the maximum sustainable level of debt in the periphery.

The disruption of the sovereign bond market and the high correlation on the stock one ultimately impact in a different way on the core and periphery stock-bond correlations. In the core the correlation is positive. After a sovereign risk shock, on the one hand the interest rate on bonds is lowered by the flight-to-quality towards this asset; on the other hand, the equity returns decrease as firms are affected by a credit crunch that impacts negatively on investment and output. In the periphery the correlation turns instead to be negative as the sovereign returns spike whereas the stock returns decrease. As for the previous shocks, in the case of credit constraints, the capital producers' payout policy does not affect the correlations as we can see from column (3) and (4).

4.6 Conclusion

This chapter proposes a framework where to detect the sources of shocks that hit the euro area economy by looking at the correlation on the equity and sovereign bond markets. We explore the role of financial intermediaries, credit constraints and capital producers' dividend payout policy for the correlations on these markets. We show that credit constraints (i) amplify shocks and (ii) change the response of variables to the shocks being key for the behaviour of asset markets. Without credit constraints, asymmetric shocks in the union imply asymmetric impacts on the core and periphery asset markets. The existence of credit constraints at the international bank level prompts more synchronization in asset markets' responses and a more homogeneous sharing of the effects of shocks between countries. Capital producers' dividend payout policy can effect the behaviour of the stock market only in the case of unconstrained credit. This is not surprising as constraints on bank's capital and collaterals determine a strong tightening of credit to firms and a pro-cyclical amplification of shocks that leaves a small margin of manoeuvre to firms.

Finally, we show that the model with credit constraints is able to explain the stylized facts on correlations' behaviours in the EA stock and sovereign bond markets during the period 2000-2012. We find that a productivity shock can explain the negative relation between stock and bonds before the sovereign debt crisis whereas that a financial expectation shock can account for the positive one. After 2010, the heterogeneous behaviour of the core and periphery stock-bond markets can be reproduced by a sovereign risk shock to the periphery.

This chapter is a first attempt to introduce financial intermediaries in an otherwise standard open economy macroeconomic framework. Future research should focus more on the bank representation of leverage as well as on its regulation. Moreover, a closer look at the central bank's dimension and monetary policy would be worthy. Finally, it could be of interest to add to the dimension of asset markets by including bank and corporate debt in the model. On the firm side, introducing corporate debt and allowing for new issuing of equity would refine the capital choice of firms and add new insights to the corporate finance literature.

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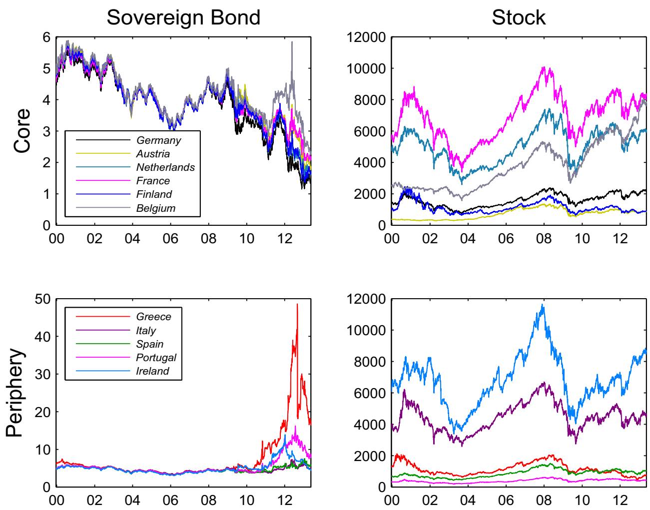
4.A Individual return series

In this appendix we present the disaggregated behaviour of sovereign bond and stock markets in the euro zone. The figure presents data from the year 2000 to October 2013. Legends for the individual countries refer to the rows.

Figure 4.A.1: Behaviour of core and periphery bond and stock returns



Notes. Stock market series are total return indexes on non-financial firms; bond series are DS benchmark 10 years index of yields to redemption.

Data Source: Datastream.

4.B Sovereign risk shock

In this appendix we present a detailed explanation of the methodology used to estimate the sovereign risk shock and we compare it with different panel specifications. Data for the yield series are taken from Datastream for the 10 years central government bonds. The $Yield$ series used in the estimations are computed as the difference of periphery country yields from the one of Germany. *Debt* data are expressed as percentage of output and are taken from the quarterly national account statistics from Eurostat. The periphery countries we consider are the GIIPS: Greece, Ireland, Italy, Portugal and Spain over the period 2000Q2-2013Q4.

4.B.1 Derivation of the panel formulation

From equation (4.3.39) we can see that the difference between the periphery and core returns on sovereign bonds depends on expectations of default. These expectations are themselves dependent on the changes in the level of debt-to-output and the stochastic maximum sustainable level of debt, equation (4.3.38). In the data we capture this relation by regressing the debt-to-output ratio of periphery countries to the yield spread between those countries and Germany, taken as the benchmark for the core. The residuals of this regression are the maximum sustainable level of debt (MSD). In other words, the stochastic MSD is the part of risk of sovereign bonds' yields unexplained by changes in levels of debt-to-output as expressed by the following relation:

$$Yield_{i,t} = \beta_b \, Debt_{i,t} + u_{i,t} \, ,$$

where

$$u_{i,t} = BY_t^{max} - \bar{BY}^{max}$$

from equation (4.3.35). We additionally assume that the MSD series follow the autoregressive process:

$$u_{i,t} = \gamma_b \, u_{i,t-1} + u_{i,t}^b$$

where $0 < \gamma_b < 1$ is the autoregressive component, and u_t^b is a i.i.d. shock. By substituting the $u_{i,t}$ definition into the Yield expression we obtain:

$$\begin{aligned} Yield_{i,t} &= \beta_b\, Debt_{i,t} + u_{i,t} \\ &= \beta_b\, Debt_{i,t} + \gamma_b\, u_{i,t-1} + u_{i,t}^b \\ &= \beta_b\, Debt_{i,t} + \gamma_b\, (Yield_{i,t-1} - \beta_b\, Debt_{i,t-1}) + u_{i,t}^b\,. \end{aligned}$$

By re-expressing variables in differences we obtain the final formulation as in equation (4.4.1):

$$\Delta\, Yield_{i,t} = \beta_b\, \Delta\, Debt_{i,t} - (1-\gamma_b)\,(Yield_{i,t-1} - \beta_b\, Debt_{i,t-1}) + \alpha_i + u_t^b$$

where α_i are country fixed effects. Notice that $(1-\gamma_b) = \gamma$ in equation (4.4.1). So by estimating $\hat{\gamma}$ we know $\hat{\gamma_b}$ that we interpret as the persistence parameter of the MSD shock. Finally, in order to calibrate the volatility of $u_{i,t}^b$, σ_t^b, we could reconstruct the series of the MSD as $u_{i,t} = Yield_{i,t} - \beta_b\, Debt_{i,t}$.

4.B.2 Alternative panel estimations

Table 4.B.1 presents the estimation results for equation (4.4.1) when controlling for different set of fixed effects.[31]

The specification in column (1) does not include fixed effects in order to get a preliminary idea of the sign of the coefficients, which indeed have the expected sign. In column (2) and (3) we include respectively, first only year and then also quarter fixed effects to control for time specific shocks common to all countries. The sign of the coefficients of interest remains unchanged. Then, in column (4) we include year and country fixed effects to control for any country specific factor affecting the change in the riskiness. Although this might appear the best specification in terms of explained variance, our final purpose is to use the error component as a proxy for exogenous riskiness shock. By including year (or even quarter) fixed effects, any time specific exogenous shock is absorbed by fixed effects, and thus removed from the error component. In contrast, we want the error term to capture also exogenous shock common to all countries, thus we remove year fixed effects from specification (4). Finally, in column (5) we show our

[31] The data sample has been cleaned from outliers by removing the top and bottom 1 percentile.

preferred estimation including only country fixed effects. The sign and the magnitude of coefficient do not change a lot, but the error component now (potentially) contains exogenous shock common to all countries.

Table 4.B.1: Alternative panel estimations

Variables	(1) Δ Yield	(2) Δ Yield	(3) Δ Yield	(4) Δ Yield	(5) Δ Yield
Δ Debt	0.0587**	0.0346**	0.0243**	0.0192*	0.0531**
	(0.0177)	(0.00986)	(0.00724)	(0.00864)	(0.0140)
Lag Yields	-0.145*	-0.173*	-0.168*	-0.227**	-0.211*
	(0.0581)	(0.0644)	(0.0651)	(0.0590)	(0.0792)
Lag Debt	0.00273	0.00177	0.00174	0.00954	0.0109
	(0.00291)	(0.00280)	(0.00279)	(0.00940)	(0.00946)
Country FE	no	no	no	yes	yes
Year FE	no	yes	yes	yes	no
Quarter FE	no	no	yes	no	no
Observations	260	260	260	260	260
R-squared	0.110	0.275	0.295	0.331	0.147
Number of i	5	5	5	5	5

Errors are cluster at country level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.C Business cycle statistics

In this appendix we compare the model's second moments with the cyclical properties of EA data. We simulate the model with a correlated technology shock between the core and the periphery and calibrated as explained in section 4.4. Table 4.C reports the standard deviations of sample moments that, as in section 4.5, are computed from 50 simulations of the economy, each of 60 periods. As with the data, the statistics in our simulations refer to Hodrick-Prescott filtered variables.

We compare the model with EA data on business cycle second moments.[32] In the specific, we refer to the ECB study of Agresti and Mojon (2001) where they present data for individual euro area countries for the period '70-'80 until 2000 for investment, output and consumption. In Data (1) of table 4.C we present their statistics by taking the average between countries belonging to the core and the periphery of the EA (except Ireland). Data on hours worked, 'N', are taken from Ohanian and Raffo (2011) on the period 1960-2010. As they only present an aggregate for euro area countries[33] we cannot disentangle the core and periphery statistics and we use one estimate for the two regions. In Data (2) we additionally provide statistics based on the author's calculations. Variables are logged and HP-filtered, except for Q that is only HP-filtered, with a 1600 smoothing weight. Data comes from the OECD economic outlook and covers the period 1995Q1-2013Q4. 'N' is hours worked and 'W' is compensation per employee divided by number of hours worked. 'Q' is the real exchange rate of the core with respect to the periphery. This variable has been created as the ratio between the consumption price index in the core and in the periphery.[34] [35]

As of model's simulations, we present moments for the benchmark model (with credit constraints) 'Bench.'; for a model without constraints, 'No credit

[32] Both for the model and for the data, standard deviations are always presented relative to the one of output in the domestic country.

[33] In detail they consider an average for France, Germany and Italy.

[34] The countries considered for the core region are France and Germany whereas those belonging to the periphery are Italy, Spain and Portugal.

[35] In Data (2) we find that the volatility of wages is higher than the one of hours worked. This is contradictory with the empirical estimates of the US business cycle as well as with national studies for EA countries (see for instance Bec et al. (2000), chapter 20, for a study on France). However, on the one hand these studies have been conducted on a different time period and on single countries rather than for an aggregate of the EA, on the other, the time period we consider could have strongly influenced the data given the recent financial crisis first and the sovereign debt crisis then.

Table 4.C.1: Individual country statistics

	France	Germany	Italy	Spain	Portugal
	Absolute standard deviations				
Y	0.0107	0.0155	0.0128	0.0108	0.0116
C	0.0075	0.0063	0.0099	0.0132	0.0141
I	0.0310	0.0382	0.0255	0.0392	0.0385
N	0.0069	0.0075	0.0054	0.0059	0.0068
W	0.0110	0.0120	0.0139	0.0187	0.0148
	Standard deviations relative to output				
C	0.7033	0.4034	0.7691	1.2225	1.2184
I	2.9038	2.4572	1.9848	3.6278	3.3314
N	0.6481	0.4805	0.4178	0.5457	0.5859
W	1.0283	0.7753	1.0843	1.7324	1.2830

This table presents the disaggregated behaviour of selected business cycle statistics for France, Germany, Italy, Spain and Portugal. Variables are log and HP-filtered. Data comes from the OECD economic outlook and covers the period 1995Q1-2013Q4. 'N' is hours worked and 'W' is compensation per employee divided by number of hours worked.

constr.' and for the benchmark model with low adjustment cost on dividends 'Flex. *div*'. Among the different model's specifications, 'Bench.' is the one that reproduces the closer the business cycle stylized facts in the two regions. As we can notice, the model delivers statistics consistent with the data although 'C' and 'I' are too volatile. This can be explained by the fact that we have a reduced representation of all the linkages and shocks that exist and hit the EA economy as the model was not constructed with this purpose. However it shows to behave qualitatively in line with the performance of models in the RBC literature although, for some variables, not quantitatively. These results are consistent through out the different model's specifications.

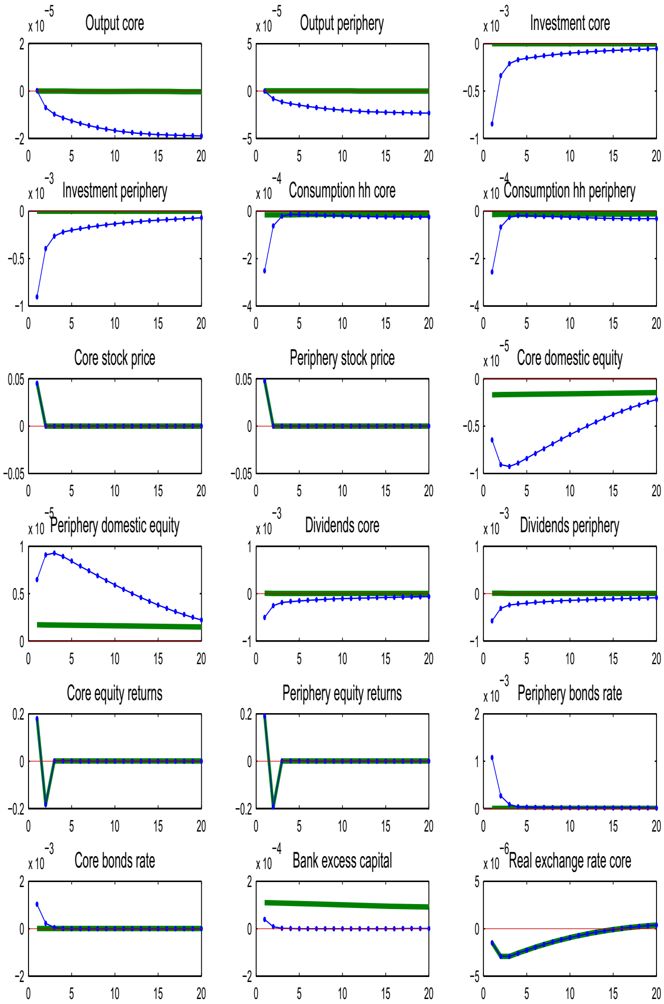
Table 4.C.2: Business cycle statistics

	Data		Model		
	(1)	(2)	Bench.	No credit constr.	Flex. *div*
			Standard deviations relative to output		
Core					
Y^c	1.00	1.00	1.00	1.00	1.00
C^c	1.00	0.45	1.51	2.12	1.61
I^c	2.83	2.58	8.5	4.47	7.6
N^c	0.78	0.45	0.45	0.46	0.45
W^c	-	0.77	0.21	0.21	0.21
Q^c	-	0.36	0.19	0.19	0.20
Periphery					
Y^p	1.00	1.00	1.00	1.00	1.00
C^p	1.05	0.87	1.57	2.13	1.64
I^p	3.05	2.49	8.6	4.46	7.5
N^p	0.78	0.31	0.46	0.45	0.45
W^p	-	1.13	0.21	0.21	0.20
			Correlation with output		
Core					
C^c	0.68	0.64	0.94	0.88	0.95
I^c	0.72	0.92	0.95	0.97	0.89
N^c	-	0.36	0.96	0.95	0.96
W^c	-	0.27	0.96	0.95	0.96
Q^c	-	0.23	0.45	0.42	0.41
Periphery					
C^p	0.69	0.77	0.95	0.87	0.94
I^p	0.62	0.91	0.95	0.97	0.90
N^p	-	0.08	0.96	0.96	0.96
W^p	-	0.47	0.96	0.96	0.96

We present the results for a correlated productivity shock in the core and in the periphery of the EA. We present moments for the benchmark model with banking frictions 'Bench.', without 'No credit constr.' and with low adjustment cost on dividends 'Flex. *div*'. Standard deviations and correlations are always presented relative to output of the domestic country. Data (1) is taken from Agresti and Mojon (2001) on the sample period '70-'80-2000. N^j, hours worked in Data (1), are taken from Ohanian and Raffo (2011) on the period 1960-2010 while W^j is not available for an aggregate of EA countries. Data (2) on the EA business cycle is taken from the OECD economic outlook at quarterly frequency for the period 1995Q1:2013Q4 and are based on author's calculations.

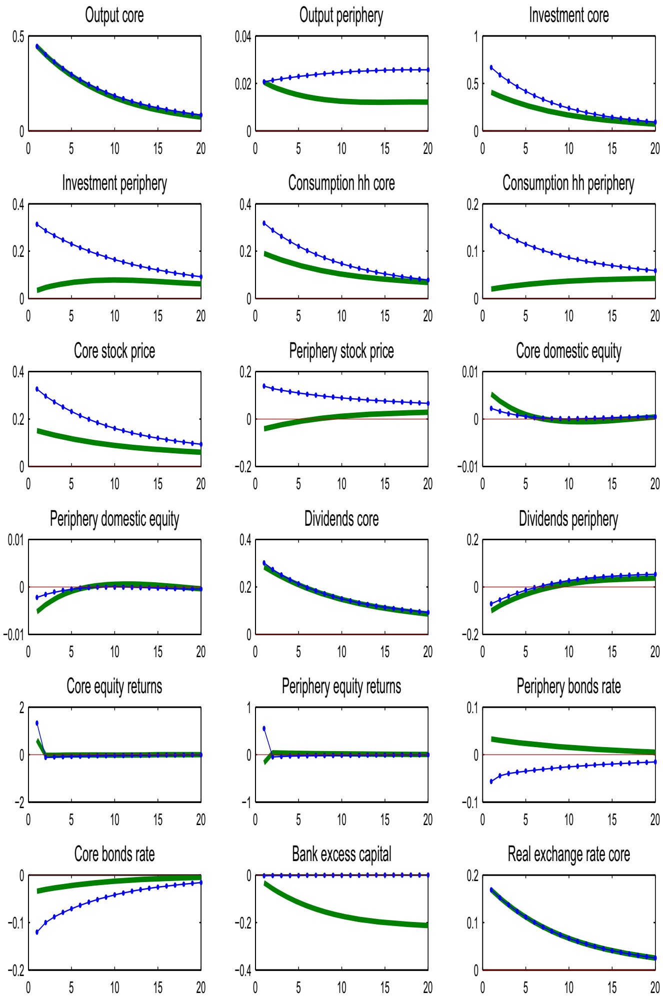
4.D Dynamic simulations

Figure 4.D.1: IRFs after a positive financial expectation shock.



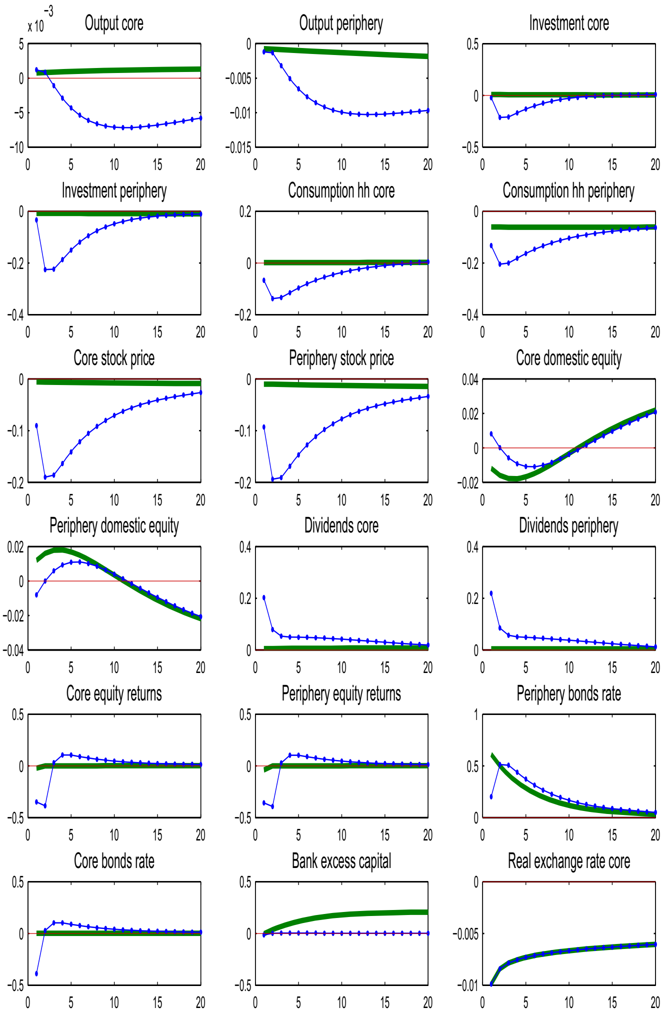
Notes. The shock is to the (union) equity market returns. IRFs show the benchmark model (dotted line) vs model without credit constraints (solid line). Results, in deviation from the steady state, are expressed respectively in percentage points for rates and in percent for the remaining variables.

Figure 4.D.2: IRFs after a positive technology shock in the core.



Notes. IRFs show the benchmark model (dotted line) vs model without credit constraints (solid line). Results, in deviation from the steady state, are expressed respectively in percentage points for rates and in percent for the remaining variables. 'Core domestic equity' stands for the equity of the core country held by core households. Analogously, 'Periphery domestic equity' stands for the equity of the periphery country held by periphery households.

Figure 4.D.3: IRFs after a negative maximum sustainable debt-output ratio shock in the periphery.



Notes. IRFs show the benchmark model (dotted line) vs model without credit constraints (solid line). Results, in deviation from the steady state, are expressed respectively in percentage points for rates and in percent for the remaining variables. 'Core domestic equity' stands for the equity of the core country held by core households. Analogously, 'Periphery domestic equity' stands for the equity of the periphery country held by periphery households.