

ESSAYS ON MACROECONOMICS AND MONETARY ECONOMICS

A Dissertation
submitted to the Faculty of the
Graduate School of Arts and Sciences
of Georgetown University
in partial fulfillment of the requirements for the
degree of
Doctor of Philosophy
in Economics

By

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Washington, DC
November 20, 2015

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ABSTRACT

The first chapter uses an event-study approach to analyze the impact of ECB's monetary policy decisions on the interbank money markets in countries maintaining a currency board with the euro. It compares the reaction of money markets in these countries to the response of the common Euro Area market. Similarities demonstrate the level of convergence of the economies, given their commitment to adopt the euro. Comparing the reaction of money market rates among countries, the chapter finds a sizable and significant response of Estonian and Lithuanian markets, while in Bulgaria the reaction is muted and sluggish. The results suggest that the level of financial integration and the dependence on foreign funding are key factors for the transmission of ECB's monetary policy shocks.

The second chapter examines the role of over-indebtedness and the process of deleveraging in driving the economy into a protracted recession. It develops a dynamic model of sectoral deleveraging within the framework of a New Keynesian model with nominal rigidities. A key contribution of the chapter is the analysis of debt reduction on a sectoral level. The chapter explores the deleveraging process and the transmission of the deleveraging shock between sectors, highlighting the key role of factor markets. Most importantly, it demonstrates that a multisectoral simultaneous debt deleveraging is particularly damaging to economic activity. Furthermore, the chapter confirms that structural reforms and highly accommodative monetary policy are effective tools for ameliorating the macroeconomics impact of deleveraging.

The third chapter examines the processes of leveraging and deleveraging that occurred in the Euro Area since the introduction of the euro. It highlights the key factors that instigated the credit expansion and accounts for debt dynamics before and after the crisis. The chapter relates the deleveraging effort of the private sectors to the associated shifts in spending behavior. Furthermore, adapting a standard public debt accounting framework, the chapter decomposes the evolution of private leverage into separate components and highlights their role in aggregate debt dynamics. The

approach demonstrates the central role of autonomous debt dynamics in shaping private leverage after the financial crisis.

INDEX WORDS: private debt, debt overhang, leverage ratio, deleveraging, Euro Area, monetary policy, monetary policy shocks, currency board

DEDICATION

This dissertation is dedicated to Petra for all her support and patience during the long process. To my mother, Ruska, my father, Georgi, and my brother, Dimitar, for always believing in me.

ACKNOWLEDGMENTS

I am very grateful to Guido Kuersteiner, Behzad Diba, and Matthew Canzoneri for their valuable advice and guidance. I thank the co-author of my second chapter, Ivan Lozev, for the great ease of our collaboration. I also appreciate the valuable comments of Nobuhiro Kiyotaki, Plamen Iossifov, and Mark Huggett. All errors are my own.

Many thanks,

Yordan G. Georgiev

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CHAPTER 1

ECB MONETARY POLICY SURPRISES AND THE INTERBANK MONEY MARKETS IN COUNTRIES TIED TO THE EURO

1.1 INTRODUCTION

A main area of research in empirical monetary economics concentrates on determining the transmission mechanism of monetary policy from the decision announcement to its impact on financial markets and the real economy. The final goal of monetary policy is to impact inflation and economic activity¹. However, an intermediate step in the transmission process is the reaction of financial markets to policy changes. A central bank aims at controlling short term interest rates as an instrument for achieving its long term goals. Familiarity with the channels of transmission and the magnitude of response of financial markets is crucial for fine-tuning the monetary policy decision process. The majority of academic research is centered on the monetary policy decisions taken by the central bank and the respective reaction of the domestic economy and markets. However, for small open economies, policy decisions of a neighboring country or a major trading partner can also have a substantial impact. A line of research analyzes the international transmission of monetary policy shocks using structural VARs. Cushman and Zha (1997) [46] examine the importance of US monetary policy for Canadian interest rates and conclude that contractionary US monetary policy shocks lead to small and brief increases in Canadian rates. Also, Kim (2001) [86] explores the reaction of G-7 countries to US shocks and highlights the leading role of financial markets in the transmission process. Canova (2005) [34] studies the transmission of US monetary policy shocks to eight Latin American countries and discovers that policy surprises significantly impact countries' macro-variables. Minea et al. (2009) [105] take a similar approach and investigate the reaction of Bulgarian macro-variables to ECB monetary policy shocks proxied by the 3-month EURIBOR rate, but their findings are inconclusive.

¹The legislation governing the mandate of the European Central Bank states explicitly that the only goal of the Bank is price stability. However, during the crisis, the mandate has been extended in order to cope with the threats to banks' soundness and countries' public finances.

Still, the monetary shock transmission mechanism in countries with restrictive monetary policy regimes remains an understudied area of research. In this paper, I investigate the short term response of interbank money markets in currency board countries tied to the euro to monetary policy changes made by the ECB. I employ two event-study approaches developed by Kuttner (2001) [90] and Cochrane and Piazzesi (2002) [39]. My analysis focuses on the magnitude of the instantaneous (next day) impact of the policy decision and, as a second step, on the speed of transmission of the exogenous shock until it is fully absorbed by the domestic banking sector. I concentrate on three countries: Bulgaria, Estonia, and Lithuania². They form a sub-sample of the countries that have pegged their national currency to the euro. As a consequence of their colonial history, several African countries have a currency board with the euro. However, in addition to the restrictive monetary policy regime, the group of countries I consider shares several other crucial characteristics: European Union membership, strong trading links with the Euro Area and financial system dominated by subsidiaries of major European financial institutions. Because of their political, economic, and financial ties to the Euro Area, policies implemented by the European institutions are expected to affect the three CEE countries.

Analyzing the nature and the magnitude of response of the financial sectors in these countries to ECB policies is of great importance to domestic authorities since any impact on the financial markets affects also the real economy. There are few papers studying the monetary policy transmission mechanism in the three countries. Vetlov (2004) [132] provides a detailed account of the Lithuanian monetary system, banking sector and economy and describes the environment shaping the shock transmission. However, the paper concentrates on the period before the creation of the euro and the integration of Lithuania in the European markets. Also, Lattemae et al. (2001) [93] provide a descriptive summary and a stylized structural model of the Estonian monetary transmission mechanism. The present paper offers an updated perspective on the current stance of the financial systems in the Baltic countries and their response to foreign monetary shocks. In a more recent work, Bredin et al. (2010) [28] analyze the instantaneous response of a group of developing countries to US monetary policy shocks, but their findings show virtually no response in the case of Bulgaria. Still, to the best of my knowledge, no other study employs similar techniques to analyze the three currency board countries of interest. The analysis provides a different perspective to the

²Estonia joined the Euro Area on January 1, 2011. However, for a period of twelve years, Estonia had a currency board with the euro and my analysis draws on this period. Also, Lithuania joined the common currency on January 1, 2015.

group of papers dealing with the transmission mechanism of monetary policy in countries with a currency board, concentrating on the first stage of the process - the reaction of financial markets to the shock.

To understand the nature of the connection that the currency board countries have with the euro and the European Central Bank as the institution that controls the anchor currency, the core features of the currency board institution are discussed.

1.1.1 CURRENCY BOARD REGIMES

The literature on fixed exchange rate regimes describes the advantages and disadvantages of establishing and maintaining a currency board. Liviatan (1993) [96] provides the historical background of currency boards. Currency Board Arrangements (CBA) developed as a form of monetary regime for British colonies. It served two purposes: maintain a stable exchange rate with the metropolitan state to facilitate trade and preserve revenue from seigniorage³. The local currency was backed by British pounds that were often deposited in the colonial central bank and earned interest. The system proved to be quite successful in the colonial period. Still, after gaining independence in the middle of the 20th century, the majority of colonies abandoned the currency board regime for political and symbolic reasons. However, after the fall of the Berlin Wall in 1989, the currency board once again gained popularity as a stable monetary regime for the young Eastern European democracies. A currency board regime is characterized by:

1. Fixed exchange rate against an anchor currency (or a basket of currencies). When selecting the anchor currency, the decision is based on multiple factors including the amount of the currency already in circulation in the economy, trading relationships with countries that use the currency and the level of inflation in the foreign country. Typical currencies of choice are the USD and the euro.
2. Foreign reserves maintained by the Central Bank that cover some form of a monetary aggregate and guarantee the free exchange of domestic and anchor currencies at the predetermined rate⁴.

³Seigniorage denotes central banks' profits generated from the difference between the value of a currency and the cost of physically printing the notes.

⁴The level of coverage and the monetary aggregate varies by country. Typically the monetary base and the reserves of the commercial banks in the Central Bank are covered with foreign assets.

3. Special legislation for establishing the board that prevents an easy exit by an executive fiat and contributes to the stability of the currency board institution.

One of the advantages of a currency board arrangement relative to more restrictive monetary regimes, namely dollarization, is that with a currency board the country continues to profit from seigniorage. However, unlike having a floating exchange rate, the Central Bank cannot freely print money. With a currency board, money creation is limited by the amount of foreign currency and reserves entering the economy. On the other hand, the Central Bank generates income from the difference between the interest earned on foreign reserves and the expense of maintaining the coins and notes in circulation. The foreign reserves that guarantee the convertibility of the domestic currency consist primarily of interest bearing foreign sovereign bonds and foreign currency reserves. The income from these assets exceeds the expense of maintaining the coins and notes in circulation, generating a profit that is remitted to the government after a small amount is deducted for operational expenses and the maintenance of the required reserves.

The introduction of a monetary policy arrangement as strict as the currency board is a hard political and economic move. According to theory, CBA is a favorable choice for a small open economy with sizable imports and exports as a portion of GDP (Liviatan, 1993 [96]). Historically, the regime has proven effective for fighting hyperinflation and subduing price growth. There are several long term and short term advantages of introducing a CBA. The country should experience a sharp and substantial reduction in inflation. In the long term, the CBA guarantees a more prudent fiscal policy with low budget deficits since the government cannot finance its spending through the central bank by an inflation tax and depreciation of the internal and external debt denominated in local currency. Foreign borrowing is the only source of public financing which is often hard, expensive and politically unpopular. Due to the conservative fiscal policy and the low level of inflation, the CBA creates confidence in consumers, producers and investors that promote trade, investment and growth.

The defining characteristic of the CBA, namely the fact that any monetary liability of the Central Bank should be issued against foreign assets, guarantees the independence of the Bank and practically eliminates political influence over its decisions. It prevents the direct monetarization of government's fiscal deficits. The legislative restrictions also forbid the support of insolvent banks which decreases the risk of moral hazard. In the three countries discussed, the Lender of Last Resort

(LOLR) function of the Bank is officially regulated by legislature only in Bulgaria, where the Central Bank is authorized to extend short term collateralized loans up to 3 months to commercial banks only in the case of a systemic risk for the banking system. In Estonia and Lithuania such provisions are not specified but could be potentially reviewed on a case by case basis since there are no official restrictions.

The convertibility characteristic of the CBA that historically has been limited to coins and notes in circulation now has been extended to other forms of Central Bank liabilities, including commercial banks' reserves. Historically, "classic" currency board arrangement did not include this provision⁵. However, with the development of the financial sector and the crucial role of banks for the functioning of the economy, the coverage and redemption of bank reserves is a feature that adds stability to the currency board institution. Bulgaria, Estonia and Lithuania introduced the currency board in different stages of their economic transition with the aim of achieving financial stability.

BULGARIAN CURRENCY BOARD

The introduction of the Bulgarian currency board followed a period of turbulent political events caused by a deep economic and banking crisis. It was instituted as a rescue measure imposed by the IMF and other foreign creditors. After the fall of the communist regime in 1989, Bulgaria experienced a period of instability that was marked by series of imprudent political decisions that led to an economic collapse and a short period of hyperinflation. The lack of effective reforms contributed to the decreasing competitiveness of many of the state-owned enterprises. To preserve the social peace, the government kept subsidizing the losing companies with public funds and loans from commercial banks. The accumulated massive budget deficit was monetized by the Central Bank, constantly depreciating the national currency. The crisis culminated in the winter of 1996. Driven by fear of widespread instability, depositors tried to collect their savings from banks and convert them into foreign currency, mainly U.S. dollars and Deutsche marks. The withdrawals depleted the foreign reserves of the Central Bank and led to the bankruptcy of 14 commercial banks that comprised 25% of the consolidated balance sheet of the banking sector (Nenovsky et al., 2002 [108]).

⁵The term "classic" refers to the currency boards of the British colonies in 19-th century.

With the technical expertise and assistance of the IMF, the Bulgarian currency board was introduced in June 1997. As in the other two Eastern European countries, the regime bears all the defining characteristics of a currency board outlined in the previous section. The newly-elected government created the legislative framework of the regime and reorganized the Bulgarian Central Bank, dividing it into three departments: Issue, Banking and Banking Supervision. The main functioning block of the CBA - the Issue Department - is responsible for issuing domestic currency backed by foreign assets. The balance sheet of the department contains the assets and liabilities of the Central Bank that guarantee the stability of the board (Table 1.1). The assets of the Issue Department include all the foreign reserves of the Bank. On the other hand, the liabilities consist of all the notes and coins in circulation, the reserves of commercial banks, the government fiscal reserves and the Banking department deposits. The inclusion of several items on the liability side enhances the convertibility of the local currency.

ESTONIAN CURRENCY BOARD

Estonia was the first Eastern European country to adopt a currency board on June 20, 1992. The decision was taken independently by the Estonian government without the imposition of the IMF or other creditors. The Currency Board Agreement was instituted to support the reestablishment of the national currency⁶. Authorities intended to guarantee the stability of the new currency by pegging it to a foreign nominal anchor. In light of the aspirations of the country to become part of the Western European community, Estonian government selected the Deutsche mark (later converted to the euro) for a reserve currency. Estonia made a direct transition from the common currency of the USSR to a national currency fully backed by foreign reserves. As a result, the newly formed National Central Bank never implemented a discretionary monetary policy.

The institutional organization of the CBA reflected authorities' strong commitment to achieve stability. The Law on the Security of the Estonian kroon that provided the legal framework for the functioning of the board guaranteed the three major building block of the CBA: fixed exchange rate with the Deutsche mark, 100% coverage of the currency board liabilities with gold and foreign assets and free convertibility of the domestic currency. When selecting the Deutsche mark for anchor currency, a strong consideration was given to both the stability of the German currency and also Estonia's aspirations to join the European Union (Nenovsky et al., 2002 [108]).

⁶From 1940 to 1992 the official national currency in Estonia has been the Russian ruble.

The Bank of Estonia consists of two departments - Issue and Banking. The excess reserves of the currency board are managed by the Banking Department and, according to legislation, can be used to provide liquidity to commercial banks in distress. The LOLR function was an important safety tool during the initial stages of development of the Estonian banking system when the Central Bank needed to induce confidence in the public by devising instruments to assist banks in the case of a major negative shock. With the liberalization of the sector and the penetration of major international financial institutions, the need for such safety instruments decreased.

LITHUANIAN CURRENCY BOARD

Historically and geographically Lithuania and Estonia share many common characteristics. They are neighboring Baltic states that gained independence after the fall of the Soviet Union. Both countries lacked a national currency and a Central Bank until the collapse of the USSR. However, the two countries opted for different approaches when introducing their new currencies. Estonia combined the introduction of the kroon with the creation of a currency board to support it. On the other hand, Lithuania originally opted for a Central Bank with a discretionary monetary policy. Lithuania introduced two new currencies. In May 1992, the government introduced a temporary currency - talonas that was on par with the ruble. A year later, in June 1993, the official currency - litas - was introduced (Nenovsky et al., 2002 [108]).

The Lithuanian Central Bank had variable success in managing inflation and avoiding a sharp depreciation of the new currency. Motivated by the persistency and stability of the Estonian CBA, the Lithuanian government started discussions for the introduction of a currency board. The idea was supported by the IMF, but actively opposed by the Central Bank, commercial banks and the industry. Disregarding the internal opposition, the government established the currency board on April 1, 1994. The reserve currency selected was the US dollar, a choice based on the high penetration of this currency in the country. Still, the choice of the reserve currency did not take into consideration the political and economic aspirations of the country to join the common European market. The reserve currency was changed to the euro on February 2, 2002. In 2004, the country entered the ERM II - the convergence monitoring mechanism that precedes the Euro Area membership.

1.1.2 BANKING SYSTEM

In addition to the features of the currency board arrangement, the characteristics of the banking sector also define the behavior of money market rates. Since the analysis centers on the short term response of money market rates to policy shocks generated by the ECB, the magnitude of impact is determined by the integration of the financial sector of the country into the European markets. According to the results, the level of integration of the banking sector and its dependence on foreign capital play a primary role in determining the speed and the magnitude of transmission of monetary policy shocks. A review of the banking sectors in the three countries shows similarities that can be traced back to their common socialist past and the successive transition to a market based economy. The presence of foreign bank subsidiaries in the domestic market increases the links between each country's banking system and the rest of Europe. The support of parent institutions and the indirect access to the international monetary markets amplifies the financial linkages and accelerates the shock transmission.

BULGARIAN BANKING SYSTEM

The current state of the Bulgarian banking system is the result of the evolution of the sector since the collapse of the communist regime in 1989. At the end of the communist era, the banking sector in Bulgaria consisted of few publicly owned banks. The fall of the regime marked the creation of regional and national private financial institutions operating with domestic capital. During the early 1990s, because of poor management, political pressures or criminal intent, commercial banks provided credit to individuals and enterprises that lacked the means to honor their obligations. The process culminated in the banking crisis of 1996. The Central Bank intervened on the market by recapitalizing banks while also monetizing the budget deficit of the central government. These actions lead to hyperinflation and a complete collapse. As a lesson from this painful experience, the new legislation establishing the currency board put special emphasis on controlling and regulating commercial banks. The Banking Supervision department of the Central Bank has the sole role of overseeing the banking sector. By imposing strict and conservative requirements, the Central Bank managed to rebuild depositors' confidence in the financial system.

After 1997, state-owned banks were privatized by strategic international financial conglomerates and the Central Bank allowed the creation of subsidiaries of foreign banks. There are 31 banks

operating in Bulgaria. According to the 2010 IMF Country Report [32], the Bulgarian financial market is dominated by the subsidiaries of large foreign banks from Italy, Austria, Greece and Hungary. The development of the sector over the last decade is impressive. The banking system has grown significantly since 1999. In the year 2000, total assets in the sector amounted to 9 773 million levs. Twelve years later, in 2012, total assets have reached over 79 413 million levs (Banks in Bulgaria, 2012 [12]). Compared to the other two countries in the sample, the banking sector in Bulgaria is considerably less concentrated. While the market has several main players, the five biggest institutions control around 57% of the sector and the three leading banks have only 16%, 12% and 11% market share, respectively. In contrast, in Estonia, Swedbank controls half of the market. In addition, locally owned Bulgarian banks control a sizable portion of the market and employ aggressive pricing strategies to attract clients. In 2008, EU bank subsidiaries accounted for 76% of the market and domestically owned banks controlled around 16%. By 2012, domestic institutions have gained position, increasing their share to 25% (Banks in Bulgaria, 2012 [12]). In comparison, close to 99% of the Estonian and 93% of the Lithuanian banking sectors are controlled by non-resident institutions.

The structure of banks' liabilities also differentiates the Bulgarian banking system from the two Baltic countries. The share of bank loans in total assets has grown consistently until it peaked at 84% in 2009. Since then, the share has been fluctuating around 82 - 83%. Similar to the other two countries, the Bulgarian housing market went through a period of rapid expansion. However, corporate loans continued to dominate banks' loan portfolios while the share of mortgage loans grew from 11% in 2005 to 14% in 2012. With relatively stable shares over the period, loans extended to corporate clients account for 57%, mortgages - 14% and consumer loans - 13% of banks' lending. Furthermore, the Bulgarian banking sector relies extensively on deposits from households and non-financial corporations to finance its operations, extracting profits from the net interest margin. According to the data, in 2012, 50% of the attracted funds by the banking system were from household deposits and another 30% were from corporate deposits. Funds attracted from residents amounted to over 80% of all the funds, making the system less dependent on foreign funding. In Estonia and Lithuania, domestic funds were insufficient to meet the swift credit expansion and additional financing was provided by parent banks from the European money markets. Instead, in Bulgaria, the credit boom was accompanied by a constant growth in deposits.

The Estonian financial system is dominated by privately owned commercial banks. It developed rapidly after the country gained independence and did not suffer any major crisis during the 1990s. The period after the fall of the communist regime was marked by the establishment of new institutions and the privatization of state owned banks. In the early 1990s, the Baltic state had as many as 42 banks. Subsequently, the number decreased after mergers and acquisitions. The process was precipitated by the Russian crisis in 1998 that generated some instability in the market. Private banks were taken over mainly by institutions from Sweden, Finland, and Denmark. As a consequence, all major financial institutions in Estonia are foreign owned and highly integrated into the EU markets (OECD, 2011 [53]). At the end of 2006, 99% of banks' assets were controlled by non-resident credit institutions. The sector is highly concentrated compared to Bulgaria and Lithuania - the two leading banks control 70% and the four largest banks control over 90% of the market.

In Estonia, the housing market played an important role in the development of the banking sector. The explosion of mortgage loans caused the current structure of lending where household mortgage loans account for 40% and real estate commercial loans comprise another 18% of all loans. Thus, around two thirds of banks' loan portfolio is invested in real estate. This should be contrasted to the other countries where lending to companies takes the leading share. The rapid expansion of credit, particularly mortgages, has been funded mostly by foreign borrowing in euro from the international financial markets through parent banks (IMF, 2009 [113]). To fill the gap between new deposits and loans, banks continually obtained funding from abroad. By 2007 the ratio of domestic deposits to bank loans was less than 50% and the share of institutional foreign borrowing amounted to 47% of liabilities. An additional motivation for using external funding to finance lending operations was the lower rates offered on the international money markets compared to the interest rates on deposits. As a consequence, the Estonian banking system became dependent on the international money markets to roll over its short term borrowing.

Lattemae (2001) [93] highlights that since the late 1990s the Estonian financial sector has developed strong connections with foreign markets. The banking sector attracted foreign resources indexed to the EURIBOR which creates a strong connection between foreign interest rates and the Estonian financial sector, keeping the domestic interest rates aligned with the foreign ones.

As part of the period of National Revival, the establishment of the Lithuanian banking system was considered integral for the country's economic sovereignty. Due to their common history, geography and economy, the development of the Lithuanian banking sector mirrors that in Estonia. The banking sector got consolidated through a process of privatization by foreign financial institutions. However, the progression was slower. Liberal regulations on capital requirements allowed the creation of multiple banks during the early stages. By 1993, there were 28 banks operating in the country. Still, a combination of unstable economic conditions, high inflation and poor regulations undermined the functioning of the system. By 1995, out of 27 registered commercial banks, only 12 actually operated. In December 1995, two large commercial banks controlling 17% of the market went bankrupt. The collapse did not develop into a banking crisis but undermined customer confidence. The event occurred less than a year before the Bulgarian banking crisis. Still, in terms of magnitude, the process was less severe. Nevertheless, after the bankruptcies, the government rapidly expanded the legal framework regulating the sector, aiming at protecting depositors and incriminating illegal behavior.

After a process of privatization, the banking system became dominated by subsidiaries of foreign banks controlling 93% of all assets. Swedish banks controlled 62% of the assets (Bank of Lithuania, 2012 [58]). In terms of structure and concentration, the Lithuanian banking system is analogous to the Estonian one. The same foreign institutions control both markets. The concentration in the sector is high: 60% of assets are managed by three banks and 80% by the largest five banks. The sector grew with the increase of the credit market. The loan portfolio of banks is increasingly oriented toward the fast growing real estate market in the country. During the boom years of 2003 - 2009, the share of mortgage loans increased from 20% to 33% (Bank of Lithuania, 2012 [58]). Still, similar to Bulgaria, in Lithuania loans to non-financial firms retain their dominant share in banks' portfolios, fluctuating over 50%.

The growth in the sector was swift. The expansion was funded by the presence of foreign capital in banks. During the boom period, the growth in deposits was vastly insufficient to cover the increase in lending and Lithuanian subsidiaries received massive funding from the international money markets through their parent banks. The high profit margins and the stable economy motivated parent banks to channel funds to their subsidiaries which they used for credit expansion. By 2008,

close to 50% of the liabilities in the system were to foreign entities. The percentage decreased slightly after the beginning of the crisis. However, unlike Bulgaria, both Lithuanian and Estonian banks rely heavily on funding from abroad to finance their operations since the domestic capital is not sufficient to fill in the gap between deposits and loans.

The remainder of the chapter is organized as follows. Section 1.2 reviews the literature on the derivation and effects of monetary policy shocks. Section 1.3 introduces the data and section 1.4 demonstrates that ECB governing council meetings are characterized by higher market volatility. Section 1.5 presents the methodology used in the analysis while section 1.6 discusses the results. Section 1.7 concludes.

1.2 LITERATURE REVIEW

The effects of monetary policy in a broader context have been studied extensively in the literature. Authors employ different techniques to isolate series of exogenous monetary policy shocks and handle endogeneity. A branch of the literature that gained popularity in the last two decades employs a structural vector autoregressive (SVAR) model that imposes identification restrictions to isolate the exogenous shocks from the residuals of the monetary policy rule. This approach has a number of shortcomings outlined by Rudebusch (1998) [118]. The isolation of the exogenous shocks relies on the assumption that the monetary policy decisions are caused by changes in a set of macro and financial variables. In theory, the inclusion of the variables in a system of equations should control for these changes and the remaining unexplained component of monetary policy should represent the orthogonal shocks. This approach has several limitations. First, for computational simplicity, the structure of the relationship is assumed to be linear, which is an oversimplification of the real-world mechanism. Furthermore, a major criticism of the method is its inability to incorporate all available information for the current state of the economy (Rudebusch, 1998 [118]). The structural VAR consists of a complex system of lagged variables and the inclusion of multiple covariates increases substantially the number of estimated coefficients. Even with monthly data, the series employed are often too short to guarantee the precise estimation of multiple coefficients. As a consequence, papers limit their analysis to 4 - 8 variables. The use of more than 10 covariates is not typical. Therefore, by employing the SVAR approach, researchers are forced to assume that all available information for the economy is contained within 4 to 10 macro and financial variables

which is clearly an oversimplification of the complexity of the economic system. The derived series of exogenous monetary policy shocks can represent a response to other information available to the market but not incorporated in the short list of variables forming the system. As a third drawback, it is a challenging task for researchers to determine the information available to the decision making body at the day of the meeting. Often, researchers use revised series which could differ from the pre-meeting estimates. Furthermore, it is a challenging task to track when individual time series become available⁷.

Since the SVAR approach suffers from several shortcomings, researchers have turned to alternative measures of exogenous policy shocks. Romer and Romer (1989) [116] attempt to identify monetary policy shocks through analyzing the minutes of the FOMC meetings. However, a potential drawback of this narrative approach is that shocks are identified subjectively by the author. A more robust identification methodology would incorporate a quantitative procedure for computing monetary policy shocks that also overcomes the weaknesses of the SVAR approach.

Krueger and Kuttner (1996) [89] study the ability of Federal Funds futures to forecast the Federal Funds rate. They demonstrate that the futures are an unbiased predictor of the Federal Funds rate and that any additional information only marginally improves the out-of-sample forecast. Rudebusch (1998) [118] introduces the idea of using the futures' market to isolate monetary policy shocks. This approach avoids the main drawbacks of the SVAR. Derivative traders, whose bets determine futures' prices, utilize all the up-to-date available information when pricing the futures. As a consequence, the set of information incorporated into futures' prices is broader than the set of macro variables employed by the SVAR. Therefore, using interest rate futures allows for the aggregation of all market information within one single measure - the futures-implied interest rate. Furthermore, futures' data do not suffer from a revision bias.

Soderstrom (2001) [124] describes a procedure for using futures' prices to extract market expectations about the Federal Funds rate and concludes that on the days before FOMC meetings the futures market is a good predictor of the interest rate after the meeting. Kuttner (2001) [90] develops further the procedure and decomposes the target interest rate changes into their expected and unexpected components. While expected target rate changes should have no impact on markets, the unexpected component should affect rates and asset prices. Kuttner (2001) [90] finds that

⁷For example, the inflation index is available with 1 month lag while industrial production has a 2 month lag.

an unexpected 1% increase in the Federal Funds target leads to a 79 basis points rise in 3-Month Treasury yields and a 32 basis points rise in 10-year Bond yields. Building on this methodology, Bernanke and Kuttner (2005) [21] study the effect of monetary policy on equity prices and discover that a positive Federal Funds target shock significantly reduces equity prices (with high-tech companies displaying the strongest reaction). In more recent work, Ammer, Vega and Wongswan (2010) [8] analyze the impact of US monetary policy shocks on domestic and foreign equities and obtain results consistent with Bernanke and Kuttner (2005) [21].

Aiming to differentiate the monetary policy surprise from other news that potentially can impact the market on the day of the policy announcement, some authors employ high frequency data to improve coefficients' estimation. Gurkaynak, Sack, and Swanson (2005) [75] and Fleming and Piazzesi (2005) [60] use 30-minute event windows to estimate the impact of policy surprises on bond yields. The results broadly confirm findings obtained using data with daily frequency. Furthermore, Faust et al. (2007) [57] use 20-minute windows to derive Federal Funds target surprises and trace their impact on exchange rates. They find that a 1% increase in Fed's target causes 1.23% appreciation of the dollar against the Euro and 0.66% appreciation against the British pound.

In addition to the methodology developed by Kuttner (2001) [90] that uses Federal Funds futures to derive monetary policy shocks, some researchers turn to longer-term interest rates to identify shocks. The argument is that longer maturities should provide a better measure of a policy surprise since they are less affected by the timing of the rate increase. If the Fed surprises markets by increasing the Fed Funds target earlier than expected, the Fed Funds futures will indicate a surprise while longer maturities should remain unchanged. Due to this argument, Ellingsen et al. (2003) [52] construct their shock series using the 3-Month Treasury bill rate, Rigobon and Sack (2004) [115] use 3-Month Eurodollar futures, and Bernanke and Kuttner (2005) [21] use 3-Month Eurodollar futures for a robustness check of their main measure. Similarly, Cochrane and Piazzesi (2002) [39] utilize the daily change in the 1-Month Eurodollar rate in the days of monetary policy meetings to derive shocks. The series of shocks that Cochrane and Piazzesi compute produce a sizable and significant impact on US government bond yields across all maturities with the effect decreasing for longer maturities. They demonstrate that a 1% monetary policy shock leads to 60 basis points change in the yields across maturities and explains more than 50% of the variability in yields around monetary policy meetings.

The results obtained using both the Kuttner (2001) [90] and Cochrane and Piazzesi (2002) [39] procedures for deriving monetary policy shocks are broadly consistent. Therefore, I construct series of monetary policy shocks using the two techniques in order to determine which one would produce better results in the context of the Euro Area. Both techniques for deriving monetary policy shocks using the financial markets are very intuitive and appealing. At any moment in time, traders employ all the available information they have to build their expectations for the Central Bank target rate. If the Governing Council makes a decision that is not fully predicted by agents, the unexpected component of the change is an exogenous shock that affects markets.

1.3 DATA

The focus of the paper is to trace the effects of ECB monetary policy on the interbank money markets in the three currency board countries. The magnitude of impact is of considerable importance to both financial market participants and the central authorities. It concerns also the broad public due to the linkages between the financial and real sectors. The interbank interest rates - the cost of uncollateralized borrowing of reserves with different maturities among banks - serve as the base for consumer lending rates. Therefore, changes in the interbank rates are transmitted to businesses and individuals - the final consumers of the banking product. An increase of banks' rates on consumer and commercial loans affects consumer demand, production and investment.

For the purposes of the analysis, I use multiple market interest rates of the Euro Area and the specific countries. In order to define monetary policy shocks using the methodology of Cochrane and Piazzesi (2002) [39], I use daily quotes of the 1-Month EURIBOR rate. I also use EURIBOR rates of longer maturities to evaluate the impact of monetary policy shocks on money markets. EURIBOR stands for Euro Interbank Offer Rate and it is the rate at which euro-denominated interbank term deposits are offered by one prime institution to another within the Euro Area⁸. EURIBOR is published every business day at 11:00 am Brussels time by the European Banking Federation (EBF) and the Financial Markets Association. The rate is computed from the quotes provided by a panel of Euro Area banks (currently 44 banks) from the member states. Thomson Reuters calculates and publishes the EURIBOR by collecting the quotes of the individual banks.

⁸The rate is quoted for spot ($T + 2$ days) settlement. A spot $T + 2$ days settlement means that if an amount has been contracted on day T , the actual transaction will be conducted in 2 days and the borrowing party will receive the money on day $T + 2$. For example, if a transaction is contracted on Monday, the delivery of the funds will happen on Wednesday.

The core of my analysis is based on the daily changes of money market rates in Bulgaria, Estonia, and Lithuania. I use daily data of interbank money market rates for SOFIBOR, TALIBOR, and VILIBOR. Detailed description of the data and their source is provided in Table 1.2. Most of the series are available for the entire period of analysis. Since the considered countries were socialist states without established financial markets, the banking sector there began to form at the beginning of the 1990s. Market indices and functioning interbank money markets appeared in the late 1990s and the early 2000s. For each country, there is over 9 years of data. The Estonian time series terminate in December 2010 when Estonia joined the Euro Area and the TALIBOR indices were discontinued. For my analysis, I consider only the currency board period for Estonia. In Bulgaria, the interbank money market rates - SOFIBOR - were established in February 2003 but for only a number of maturities. Six and twelve month rates were created in April 2009. Since the period coincides with the turbulence of the financial crisis, it is not surprising that the results I obtain for these two longer maturities are considerably less conclusive compared to the other countries.

The interbank money market rates in the currency board countries are constructed using similar methodology to the EURIBOR rates. The rates are quoted at 11.00 am local time⁹. The rates correspond to the prevailing interest rates of borrowing uncollateralized loans in domestic currency among banks. The rates are quoted for different maturities: from overnight to 12 months. In my analysis, I use maturities of 1, 3, 6, and 12 month in order to trace the impact across the short end of the yield curve. The market rates are produced based on the quotes provided by a panel of contributing domestic banks on a daily basis, similar to the EURIBOR rates with the exception that the EURIBOR rates are multinational.

1.4 GOVERNING COUNCIL MEETINGS AND MARKET VOLATILITY

This paper builds on the conjecture that international and domestic money markets react to the ECB Governing Council decisions. Any meeting can potentially surprise the market and produce a correction. Therefore, it should follow that meeting dates are characterized by higher market volatility. The data are reviewed in order to support this hypothesis. Wilhelmsen and Zaghini (2011) [133] produce a comprehensive cross country comparison studying the days of monetary policy meetings. Covering the period from 1999 to 2004, their sample includes the Euro Area

⁹Either Central European Time (CET +1) for the EURIBOR or Eastern European Time (EET +2) for SOFIBOR, TALIBOR and VILIBOR.

and thirteen emerging and developed economies that have an independent monetary policy. The authors show that meeting dates are associated with higher volatility of domestic money markets. I perform a similar analysis on the extended data covering the period from the introduction of the euro in January 1999 to August 2012. The results confirm the findings of Wilhelmsen and Zaghini (2011) [133] for the Euro Area with a small decrease in volatility across maturities. The difference can be interpreted as a demonstration that the market is becoming more effective in predicting the monetary policy stance of the ECB. Still, the main concern of the paper is whether domestic monetary markets in the currency board countries also exhibit higher volatility on ECB meeting dates. By denoting the day of the Governing Council meeting with t , I define a variable for the daily change in the market rate δ_t . Considering the timing of the official monetary policy announcement release and the publishing of the money market rates in each country, the market reaction to the meeting will be reflected in the quote on the following day. Therefore,

$$\delta_t^n = r_{t+1}^n - r_t^n \quad \text{for } n = 1, 2, 6, 12 \quad (1.1)$$

where r_t^n stands for the money market rate with maturity n (1, 3, 6, 12 months) on day t . I calculate the daily change for each maturity and for all countries (Bulgaria, Estonia and Lithuania) and the Euro Area. Since δ_t represents the change of the money market rate on a trading day, I calculate the average value of δ_t over the entire sample. Also, I compute the average value of δ_t over the subsample of ECB monetary policy meeting dates. If markets react to the monetary policy decisions, the change on meeting dates will be higher. Furthermore, I also consider the standard deviation of δ_t over the two samples. The results are summarized in table 1.3. They confirm that the volatility of money market rates on monetary policy meeting dates is considerably higher. SOFIBOR 6 and 12-Month rates are the only exceptions. However, as already discussed, the available data for the two maturities are very short (since 2009) and it is hard to draw any conclusions as the time period coincides with the financial crisis. Therefore, based on these results, I establish that the ECB meeting dates are atypical trading days of higher money market volatility in the three currency board countries.

1.5 METHODOLOGY

To derive historic series of ECB monetary policy shocks, I employ two identification techniques. The methodologies have been developed to study the impact of Fed’s monetary policy decisions in the US. Accounting for available data, I adapt the two techniques to the Euro Area setting and compute two series of monetary policy shocks. First, I employ the procedure suggested by Rudebusch (1998) [118] and developed in detail by Kuttner (2001) [90]. It relies on the assumption that futures’ prices incorporate all the information available to the market. In other words, if the decision making authority implements a policy that has been already predicted by investors, the change will have no impact on prices. The second approach I use follows the work of Cochrane and Piazzesi (2002) [39] that derive the surprise element of the decision by measuring the daily change in the 1-Month Eurodollar rate on meeting dates.

1.5.1 3-MONTH EURIBOR FUTURES SHOCK SERIES

In the US, the Fed conducts monetary policy by targeting the Federal Funds rate (an interbank money market rate). Kuttner (2001) [90] uses Federal Funds rate futures to isolate monetary policy shocks. The Federal Funds futures are derivative instruments whose settlement price is based on the average level of the Federal Funds rate over the relevant month and therefore can serve as an indicator of market’s expectations for Fed’s monetary policy stance in that month. Kuttner (2001) [90] decomposes the futures spot rate¹⁰ at day t of month m into the expected average federal funds rate for the month, based on the information available up to day t , and a risk premium (ξ)

$$f_{m,t}^0 = \mathbf{E}_t \frac{1}{d} \sum_{i \in m} r_i + \xi_{m,t}^0 \quad (1.2)$$

where $f_{m,t}^0$ is the Fed Funds futures spot rate on day t derived using the futures contracts maturing at the end of the current month (0); r_i stands for the effective market rate at a particular day and $\xi_{m,t}^0$ is the market risk premium at day t of month m . Based on this notation, Kuttner (2001) [90] derives a measure of the surprise element of monetary policy on an announcement day t

$$\Delta r_t^u = \frac{d}{d-t} \left(f_{m,t}^0 - f_{m,t-1}^0 \right) \quad (1.3)$$

¹⁰The interest rate that corresponds to the futures spot price at a particular day.

where the scaling factor $\frac{d}{d-t}$ accounts for the fact that Fed Funds futures are priced based on the arithmetic average of the Federal Funds rate over the month.

For the Euro Area, there are no equivalent market instruments that track the ECB policy rate. Still, there are interest rate futures that are strongly dependent on current market expectations for the path of the policy rate and can serve as close substitutes for the Fed Funds futures in the European context. Therefore, in the derivation of the shock series, I rely on the European EURIBOR futures market.

Futures that derive their value from EURIBOR and EONIA interest rates are traded at the EUREX Exchange in Frankfurt¹¹. Two existing financial products can potentially be used for the analysis: 1-Month EONIA futures or 3-Month EURIBOR futures. The 1-Month EONIA futures share many of the traits of the 30-Day Federal Funds futures used by Kuttner (2001) [90]. The futures are issued with 12 maturities - the current month and the 11 months that follow. At every given time, traders actively trade EONIA interest rate futures for a year ahead. The instruments are open for trade every business day from 8:00 am to 7:00 pm CET including on the last trading day. When the trading of the current month future ceases, a new future is created for the 11th closest month from that day. Futures are settled by a cash payment on the first exchange day following the final settlement day. The final settlement price is established on the final settlement day after 7:00 pm based on the compound average of the effective EONIA rates over the month.

The 1-Month EONIA futures bear the closest resemblance to the Fed Funds futures utilized by Kuttner (2001) [90] for deriving monetary policy shocks. Unfortunately, the EONIA based futures originated on January 27, 2003 - four years after the introduction of the euro. Using them could potentially lead to the loss of important information. Furthermore, comparing trading volumes, EURIBOR based futures are more actively traded by market participants. The larger number of transactions guarantees that the EURIBOR futures incorporate to a greater extent market's expectations for ECB's monetary policy. Traded on the same exchange, the 3-Month EURIBOR futures were first released on January 1999. The EUREX exchange issues contracts with four maturities per year for 10 years ahead. Futures mature in March, June, September, and December. The last trading day is *two* exchange days prior to the 3-rd Wednesday of the respective maturity

¹¹EONIA stands for Euro OverNight Index Average. It is the effective overnight reference rate for the euro. It is computed as a weighted average of all the overnight unsecured lending transactions initiated within the Euro Area on the interbank market by contributing banks. The rate is calculated by the European Central Bank using the same panel of contributing banks that determines the EURIBOR. EONIA is published by Thomson Reuters every work day before 7:00 pm.

month. Similar to the EONIA contracts, the EURIBOR futures are traded every business day from 8:00 am to 7:00 pm, except on the last trading day when transactions stop at 11:00 am CET. The difference in timing stems from the mechanism of calculating and publishing the two market rates - EURIBOR and EONIA. As already discussed, the settlement price of EONIA futures is derived from the compounded average of the reference rate over the month. Conversely, the EURIBOR futures final settlement price is based on the 3-Month EURIBOR rate published on that exact day. Since the EURIBOR is published daily at 11:00 am CET, all futures transactions terminate with the announcement of the official rate. The settlement of the contract is by a cash payment between the two parties.

Therefore, the 3-Month EURIBOR futures are the more actively traded interest rate derivatives and they offer longer time series, making them the preferred instrument for deriving ECB monetary policy shocks. In addition, Bernoth and Von Hagen (2004) [22] establish that the 3-Month EURIBOR futures are an unbiased predictor of ECB policy rate changes while Wilhelmssen and Zaghini (2011) [133] conclude that European money market rates behave in a similar fashion to the US ones, confirming that the Kuttner (2001) [90] procedure is applicable to the Euro Area environment.

A concern when using futures rates of longer maturity than the policy rate¹² is that changes in the futures-implied rate might reflect revisions in market expectations of the policy rate in future months and not a reaction to an unexpected change in the current month. However, Rigobon and Sack (2004) [115] argue that longer maturity futures are better predictors of the genuine surprise element in the policy rate change. The use of the 3-Month EURIBOR rate futures reduced the influence of timing shocks and instead picks up surprises in the level of the interest rate. Thus, the 3-Month EURIBOR rate futures are a reliable predictor of ECB's policy surprises and have been widely used (see Bredin et al., 2004 [27], Bredin et al., 2010 [28], Leon and Sebestyen, 2012 [94], Monticini et al., 2011 [107]).

Since I use 3-Month EURIBOR futures, I have to adapt Kuttner's methodology. The shock identification procedure assumes that futures prices reflect the expected interbank rate given the information available to the market plus a risk premium. The ECB Governing Council schedules meetings when it decides the monetary policy stance of the currency union. I denote with t the

¹²I derive monetary policy shocks using 3-Month EURIBOR futures while the ECB policy rate is a two-week REPO rate.

day of the meeting. Then, $f_{m,t-1}$ stands for the futures-implied 3-Month EURIBOR rate at the future's settlement day in month m quoted on the day before the meeting, $t - 1$. The 3-Month EURIBOR rate is strongly influenced by the ECB policy rate (r_m). It contains also a relatively small risk premium for credit risk ($\psi_{m,t-1}$). Therefore, the futures-implied rate is a combination of the expected official policy rate in effect on the 3-rd Monday of month m (r_m) (based on all available market information up to day $t - 1$ (Ω_{t-1})¹³) plus a credit risk premium due to the longer 3-month maturity ($\psi_{m,t-1}$) plus the futures risk premium specified by Kuttner (ξ_{t-1})¹⁴. The stated above can be written concisely as

$$f_{m,t-1} = \mathbf{E}_{t-1} [r_m | \Omega_{t-1}] + \psi_{m,t-1} + \xi_{t-1} \quad (1.4)$$

In the case of an unexpected change in monetary policy at time t , the futures' implied rate will react to the surprise. Once the information of the change is disseminated, investors react and alter the price based on their updated information set. This implies that Ω_t contains all the previous information until day $t - 1$ and the new information about the unexpected change. Notationally, if I denote the unexpected monetary policy shock with $\Delta r_t^{Kuttner}$, then

$$\Delta r_t^{Kuttner} = (\mathbf{E}_t [r_m | \Omega_t] + \psi_{m,t} + \xi_t) - (\mathbf{E}_{t-1} [r_m | \Omega_{t-1}] + \psi_{m,t-1} + \xi_{t-1}) = f_{m,t} - f_{m,t-1}$$

Therefore, by differencing future's prices on the day of the meeting and the previous day, I derive a shock for each individual meeting. Comparing the shock formula above to equation (1.3) from Kuttner(2001) [90], there is no scaling factor ($\frac{d}{d-t}$) since unlike the Federal Funds futures whose price depends on the average Fed Funds rate over a month, the 3-Month EURIBOR futures are priced based on the 3-Month EURIBOR rate at a particular day.

As highlighted in the procedure, shocks are derived only on dates of Governing Council meetings. The Council meets twice a month. In the period from January 1999 to November 2001, monetary policy was discussed during both meetings. However, since the end of 2001, a decision is made only during the first meeting. This meeting usually takes place on the first Thursday of the month.

¹³The notation Ω_{t-1} denotes the information set on day $t - 1$.

¹⁴The futures risk premium ξ_{t-1} exists since investors are risk averse and they bet on an uncertain event.

Since I analyze daily changes in futures prices, timing is of particular importance. After each meeting, at 1:45 pm CET the ECB press office publishes a release stating the monetary policy decision. The futures contracts are traded daily until 7:00 pm, which leaves enough time for the market to react to the policy decision. Therefore, by taking the difference between the closing and opening prices of the future on the day of the meeting, I derive the unexpected element of the decision. Following this approach, I might attain even more precise monetary policy shock estimates by narrowing the time window around the press office release. However, due to data limitation, this is the shortest time window I can consider¹⁵. Also, results using higher frequency data are broadly similar to the ones using daily data as mentioned in the literature review section. The methodology produces 3-Month EURIBOR futures shock series that I denote $\Delta r_t^{Kuttner}$.

1.5.2 PIAZZESI SHOCK SERIES

In addition to the Kuttner methodology, I estimate another series of monetary policy shocks employing the procedure developed by Cochrane and Piazzesi (2002) [39]. In the original work of Cochrane and Piazzesi (2002) [39], the authors compute unexpected changes in the Federal Funds target rate by employing the 1-Month Eurodollar rate. I adapt the procedure to the Euro Area setting by using the 1-Month EURIBOR rate. Shorter maturities appear too volatile for the purposes of the derivation. The technique builds on the assumption that changes in the 1-Month EURIBOR rate on meeting dates are caused only by the new information released after the meeting. There are no other significant events that can affect the rate during that day.

Plots of the ECB main refinancing rate and the 1-Month EURIBOR rate (the interest rate used to derive the shock series) demonstrate that while certain monetary policy decisions are fully predicted by the market, others take the market by surprise (Figures 1.1 and 1.2). For changes that have been expected by the market, the 1-Month EURIBOR rate adjusts well in advance and, at the day of the meeting, there is hardly any correction. However, there are instances when the EURIBOR rate drops/rises sharply after the announcement of the monetary policy decision. Cochrane and Piazzesi (2002) [39] concentrate their analysis only on the dates when the target interest rate is changed. Still, I assume that the market can be surprised both by the action and the inaction of the ECB Governing Council. If the market is expecting a change in the policy rate but such does not occur, there is a correction in the market rate. The market can be surprised by

¹⁵Bloomberg provides high frequency data only for the last three months.

the pro-active or inactive stance of the decision making body. Therefore, I use all meeting dates to derive monetary policy shocks.

The timing is crucial for the procedure. The EURIBOR rates are published every work day at 11:00 am CET by Thomson Reuters. The rate is an average of the quotes submitted by banks until 10:45 am. However, on the day of the meeting, the Governing Council releases a statement with its decision at 1:45 pm CET. Therefore, the 1-Month EURIBOR rate from the same day would not incorporate any information from the announcement. Any change due to new information will be reflected on the next day. Also, to avoid a possible timing error or last minute fluctuations due to speculations before the meeting, I follow Cochrane and Piazzesi (2002) [39] and I consider the 1-Month EURIBOR rate from the day before the meeting. Following the notation developed in the previous section, I denote with t the date of the Governing Council meeting. Then the 1-Month EURIBOR rate at day $t - 1$ will incorporate all available market information before the meeting, while the rate at day $t + 1$ will incorporate the updated information set with the monetary policy decision.

$$\Delta r_t^{Piazzesi} = r_{t+1}^1 - r_{t-1}^1 \quad (1.5)$$

where $\Delta r_t^{Piazzesi}$ stands for the value of the Piazzesi shock from the meeting on date t and r_{t+1}^1 is the 1-Month EURIBOR rate at day $t + 1$.

Over the period covered in the analysis, the Governing Council has met 197 times which produces two shock series of 197 observations each. Table 1.4 presents series' correlation. The 3-Month EURIBOR futures shock series are uncorrelated to the actual changes in the ECB target rate. However, one can expect that the direction of the monetary policy shock will often correspond to the direction of the actual target rate change which would entail a positive correlation coefficient. Therefore, the lack of correlation could suggest that in the context of the Euro Area, the 3-Month EURIBOR futures can be weaker predictors of monetary policy shocks. On the other hand, the Piazzesi shock series are positively correlated to the actual target rate changes as expected.

1.5.3 ROBUSTNESS OF THE SHOCKS

Conceptually, the derived shock series present exogenous changes in the monetary policy rate that are unrelated to past financial or macroeconomic data. If shocks are not exogenous but determined

by past information, using them in estimation can produce biased results due to endogeneity. In this section, I demonstrate that while actual changes in the ECB target rate are dependent on past events, the shock series are not and, thus, they carry an element of surprise. I establish that target rate changes respond to past developments in the EURIBOR market rates, bond yields and macro variables.

To analyze the dependence of the shock series on financial and macroeconomic data, I transform the monetary policy shocks to monthly frequency. The studied period spans 164 months while the Governing Council of the ECB has met 197 times producing shock series of 197 observations. Between January 1999 and November 2001, the Council convened twice a month and after that moved to a once a month meeting schedule. In order to convert the shocks into monthly series, I aggregate the shocks that have occurred during the same month. When the Governing Council has met twice during month m , producing shocks η_m^1 and η_m^2 , I sum them, i.e. $\eta_m = \eta_m^1 + \eta_m^2$. The new variable η_m represents the aggregate monthly shock.

In addition, I generate monthly data for changes in money market interest rates. I use daily frequency data and I compute the change in the rate from the first to the last day of the month, capturing the evolution of the rate over the month. I perform the procedure for all the EURIBOR maturities I use. I do not consider the money market rates of the currency board countries since it is highly unlikely that the ECB accounts for the developments in small countries outside the Euro Area in shaping its policy stance. I expand further the set of financial variables by introducing the government bond yields of four large Euro Area economies. The countries have been selected based on the significance of their economies for the currency union. The procedure for generating monthly data out of the daily yield quotes follows the one applied to the money market rates. The bond data are described in table 1.5.

In addition to financial variables, I consider macroeconomic variables from the four selected economies. These macrovariables are typically used in a SVAR system to derive monetary policy shocks: inflation rate, unemployment, and industrial production (Table 1.6). The data is not seasonally adjusted, since timing plays a critical role in the analyzed dependencies. Any filtering, such as seasonal adjustments, can remove important information from the data and produce unreliable results. As the macroeconomic data are in levels, I employ first differences. I test the effect of past developments in financial and macro variables on the shock series and target rate changes on a monthly frequency. By denoting with m the current month, the regression used is

$$\eta_m = \theta_0 + \theta_1 V_{m-n} + \varepsilon_m \quad (1.6)$$

where η_m is the value of the shock at month m and V_{m-n} is the lagged monthly difference of a macro or financial variable at month $m - n$ where $n = 1, 2, 3$. I consider three lags since coefficient estimates become smaller and less significant with the increase in the number of lags.

Reviewing the results in table 1.7, actual target rate changes depend significantly on past developments in financial variables, particularly EURIBOR rates and government bond yields. The response coefficient θ_1 is nearly 50 basis points for 1 percent increase in money market rates in the first lag of the 3 and 6-Month EURIBOR rates. The coefficient estimate θ_1 decreases with the number of lags, but continues to be significant even after three periods ($n = 3$). Past developments in bond yields have comparable effects. Even though the magnitude is smaller, the coefficients are significant. Results confirm that the actual target rate changes are not exogenous and are highly dependent on previous developments in financial markets. Furthermore, target rate changes respond to changes in inflation in the main economies: France (14.0 bps) and Germany (11.6 bps) (Table 1.8). They are also affected by changes in unemployment, particularly in France, Italy and the Netherlands.

Using the actual target changes as a base for comparison, the coefficient estimates of the shock series are considerably smaller and insignificant (Table 1.9). The estimated coefficients for the 3-Month EURIBOR futures shock series are small and insignificant. Similarly, the Piazzesi shock series produce small coefficient estimates. Only the EURIBOR coefficients are marginally significant, but still the response is much smaller compared to the response of the target rate changes. All other coefficients are small (below 5 basis points increase in the shock series for 1 percent increase in rates) and insignificant. The shock series are largely independent of past information. These findings confirm that the derived shock series satisfy the independence criteria and thus, can produce reliable estimates for the impact of ECB's monetary policy.

1.6 EMPIRICAL RESULTS AND DISCUSSION

1.6.1 RESPONSE OF EURIBOR RATES

Before computing the responses of interbank money market rates in the currency board countries, I evaluate how European rates are affected by the monetary policy shocks in order to obtain a base

for comparison. Comparing the responsiveness of money market rates in the three CEE countries to the European one provides a valuable insight of the level of convergence and financial integration of the currency board countries. The estimation procedure computes instantaneous effects and, thus, timing plays a crucial role. Money market rates are published at 11:00 am local time¹⁶. The market rate at time t - the day of the meeting - will reflect the available information before the announcement. To trace the shocks impact, I consider the change from day t to day $t+1$, estimating a linear regression over the sub-sample of meeting days.

$$\delta_t^n = \alpha_0 + \alpha_1 \eta_t + \varepsilon_t \quad (1.7)$$

As previously defined, the daily change of the market rate is δ_t^n and η_t is the shock variable ($\Delta r_t^{Kuttner}$, $\Delta r_t^{Piazzesi}$ and actual target rate changes). As argued in the preceding section, since the shock series are exogenous, there is no need to include additional regressors in the equation and the coefficient estimate of α_1 is unbiased. The linear model of equation (1.7) follows the approach of Kuttner (2001) [90] with the exception that I consider only the unexpected portion of the change since, as Kuttner demonstrates, the coefficient estimate of the expected element is insignificant. The results are summarized in table 1.10.

The shocks generate significant and sizable responses of the Euro Area money market rates. Even though the futures shocks produce a robust impact when applied to the US data, they are less conclusive for the Euro Area. Furthermore, the impact increases with the maturity of the money market rates which is inconsistent with the standard results in the literature. The estimation results support conclusively the use of the Piazzesi shock series to estimate the impact of monetary policy on money market rates. The explanatory power of the Piazzesi shock series is high - from 40% for 12 months maturity to 89% for 1 month. All the coefficients are large and highly significant. The instantaneous response of the 1-Month EURIBOR rate to a 1 percentage point monetary policy shock is 84 basis points. The instantaneous responses of longer maturities are in the range of 57 to 68 basis points. As expected, the impact of the actual target rate changes is small, even though significant across maturities.

¹⁶EURIBOR is published at 11:00 am CET, while SOFIBOR, TALIBOR, VILIBOR are published at 11:00 am EET (CET +1).

1.6.2 RESPONSE OF MONEY MARKET RATES IN CURRENCY BOARD COUNTRIES

Having obtained the shocks' impact on EURIBOR rates, I proceed to the primary goal of the paper - estimation of the response of money market rates in currency boards countries. The three currency board countries are members of the European Union and share a common exchange rate regime with the euro. I study whether the responses of their money markets to common monetary policy shocks are consistent among countries and relative to the EURIBOR rates. Using the linear regression model of equation (1.7), I estimate the impact of ECB's monetary policy shocks on countries' money market rates. The estimation results for different maturities of the money market rates in Bulgaria, Estonia and Lithuania are presented in table 1.11.

The results confirm that money markets in the currency board countries react to the ECB shocks. The responses of the Estonian and Lithuanian interest rates are comparable to the ones of the EURIBOR rates. The significance and the magnitude of impact are indicative for the degree of integration of these countries' banking systems into the European financial markets. The Estonian TALIBOR rates react significantly to the ECB shocks. For longer maturities of 6 and 12 months the responses are similar to the European ones, combined with a relatively high explained sum of squares for the regressions ranging from 0.14 to 0.21. The results confirm the degree of convergence of the Estonian banking sector and demonstrate the preparedness of the country to join the Euro Area on January 1, 2011.

The response of the VILIBOR rates is less significant, but the magnitude is comparable to the one of the Estonian money market rates. For the two shorter maturities of 1 and 3 months, the coefficient estimates are actually higher. On the other hand, the response of the Bulgarian money market is insignificant and erratic. Longer maturities react negatively to a positive shock, which is counter-intuitive. Also, the response of the 1 and 3-Month SOFIBOR rates is small and insignificant. However, as highlighted before, there are data restrictions with the 6 and 12-Month SOFIBOR rates. As the rate series originate in 2009, any results are contaminated by the severe financial crisis and are hard to justify. Concentrating on the results for the 1 and 3-Month SOFIBOR rates, it can be concluded that the Bulgarian money markets are largely independent in the short run from the European one. This finding is analyzed in further detail in the next subsection.

Comparing the results of the three countries through the prism of their EU membership and currency board regime leads to the conclusion that these two factors do not guarantee a convergence

in money market responses. The restrictive exchange rate regime is one but not the only factor that affects the short run behavior of rates. The structure and functioning of the banking system plays a crucial role. In the introduction of the paper, I detail the specific characteristics of the banking systems in the three CEE countries. The process of development of the banking sector in the three countries has several similarities due to common market size, location and socialist history. However, there are key differences that define the functioning of their interbank money markets. I advocate the response of money market rates is determined by several interlinked factors: ownership of the banking sector, loan structure and dependence on foreign funding to conduct domestic operations. A critical factor of difference between the three countries is the level of concentration of the sector. The Bulgarian banking system is comprised of a larger number of banks that interact on the market (Figure 1.3). Even though the observed tendency is for consolidation in the sector, the Bulgarian banking system is considerably less concentrated compared to the two Baltic states.

In all three countries, the subsidiaries of foreign financial conglomerates dominate the market. However, in the two Baltic states, the sector is led by a handful of institutions. In Estonia, the largest bank controls half of all the assets, while four banks manage 90%. In Lithuania, the market is a little less concentrated. Still, in both countries, domestically owned banks have insignificant shares: 1% in Estonia and 6% in Lithuania. In contrast, in Bulgaria over 20% of banks' assets are controlled by domestically owned institutions that have aggressive strategies to attract deposits from individuals and firms. Their market share has been growing during the years. In addition, the leading five Bulgarian banks manage around 50% of all the assets, while the largest one has about 16% market share. In this aspect, the banking sectors in the three currency board countries are quite different.

Closely related to the structure of the banking system, the source of funding for banks is another potential cause for the different responses among countries to the common ECB monetary policy shocks. After the consolidation of smaller institutions in the early 1990s and the privatization of state owned banks, the banking sector in the three CEE countries experienced a rapid expansion. Particularly since the beginning of the new century, total assets have been growing on average with more than 10% per year, reaching growth rates of over 40% during the boom years of 2005-2007 (Figure 1.4). After the beginning of the financial crisis, the growth has declined, maintaining total assets relatively stable.

According to figure 1.4 the banking sectors in the three countries are growing with comparable rates. Since 1999, the total assets of commercial banks have grown between 5 and 7 times. However, the starting point differs across countries. While Bulgaria suffered a severe economic and banking crisis at the end of 1996 that undermined consumers' confidence in banks, the Estonian economy has been going through a period of sustained and steady growth. Few years after the country's independence, domestic banks were privatized by international financial institutions, a process that occurred years later in Bulgaria. The transformation of the Lithuanian banking sector followed the Estonian one. The sector endured a lesser banking crisis at the end of 1995, a year before Bulgaria. Figure 1.5 presents the ratio of private banks' total assets to nominal GDP in each of the three countries. There is a sizable difference between Estonia and the two other countries. The Estonian banking sector reached 50% of country's nominal GDP by 1999. In Bulgaria, comparable size was reached in 2004, while in Lithuania in 2005, giving Estonia a substantial head start.

The fast growth of the Estonian banking sector is associated with the boom in the real estate market. The housing market underwent a swift expansion. Banks supported the process by providing abundant credit. Mortgage loans constitute the largest share of banks' loan portfolio in Estonia. Real estate related loans, both commercial and to households, are 60% of all loans - several times higher than in Bulgaria. The Estonian economy has been unable to fund with domestic deposits the massive annual growth of its banking sector. In order to support their lending operations, Estonian banks needed additional funds from abroad. To finance the gap, subsidiary banks borrowed heavily from international money markets through their parent banks. The borrowing conditions on the European markets further facilitated the process since the rates were lower compared to the deposit rates that banks had to pay their clients. As demonstrated in figure 1.6, foreign funding occupies a substantial share of banks' liabilities in the two Baltic countries.

The foreign funding of Lithuanian banks closely resembles the situation in Estonia. Still, the real estate share in lending did not grow as rapidly and commercial loans continue to dominate banks' portfolios. However, there is a defined distinction between the liabilities' structure of Estonian and Lithuanian banks and Bulgarian banks. In Estonia and Lithuania, the sector relies heavily on external financing. The portion of foreign funding in total liabilities fluctuates throughout the analyzed period, but it remains substantial in the two Baltic states. In Estonia, the ratio varies between 35 to 50%. In Lithuania, due to the banking crisis of 1995 that delayed the development of the sector, the ratio was originally lower than in Estonia. However, with the period of economic

boom and rapid lending expansion, by 2004 foreign borrowing from the international money markets became a major source of funding for domestic operations. Observing the similarities in the pattern of growth in figure 1.6 between Estonia and Lithuania, a possible explanation could be the common ownership of the main commercial banks by the same foreign financial institutions.

In contrast, the Bulgarian banking system did not become overdependent on foreign funding. The growth in credit was accompanied by a fast growth in domestic deposits. Even though the sector grew steadily during the analyzed period (Figure 1.4), banks met their needs primarily with domestic funds, without resorting extensively to the international financial markets. The ratio of foreign-to-total liabilities for Bulgarian banks remains below 20% during most of the period, never exceeding 30%. Figure 1.7 provides further evidence of the distinction between Bulgaria and the two Baltic countries. In Bulgaria, domestic deposits of individuals and firms form around 80% of banks' liabilities. The ratio decreases to 70% in 2008 and increases again after the beginning of the crisis. The aggressive strategy of commercial banks, both domestically owned and subsidiaries, to attract the available financial resources in the country have shaped the weaker dependence of the Bulgarian banking system on the international money markets. On the other hand, in Estonia and to a lesser extent in Lithuania, domestic deposits remain a modest source of funding even after the beginning of the crisis. Less than 50% of banks' funds in Estonia are from domestic deposits.

The outlined factors determine the high dependence of the two Baltic countries on the European money markets. In Estonia, banks rely heavily on parent institutions as a principal source of funding. The interbank money market is less active and follows closely the developments of the centralized European market. A change in the ECB policy has a direct impact on the subsidiary banks. In Bulgaria on the other hand, banks interact more actively on the interbank market. Domestic banks that do not have an easy access to parent funds borrow on it to satisfy their liquidity needs.

An alternative explanation for the different responses among countries is that the financial systems in the small transition economies are converging to the European market and the stage of convergence depends on the elapsed period of time. Estonia first introduced the currency board regime and did not suffer a major financial crisis. Lithuania followed within few years those processes and had a moderate banking crisis in 1995 when two banks went bankrupt. As a consequence, the banking sectors in these countries grew since the early 1990s. Bulgaria, on the other hand, suffered a severe economic and banking crisis in 1996 that led to multiple bankruptcies and a loss of consumer confidence. The introduction of the currency board and banks' privatization by stable international

financial institutions set the beginning of a period of growth. Still, Bulgaria might need time to reach the financial state of the Baltic countries. With the development of the banking system, domestic money market rates could converge to the European ones. However, this argument disregards the specifics of the Bulgarian banking system and singles out the level of development as the driving force behind the observed discrepancies in the estimated reactions to the common monetary policy shocks.

1.6.3 PERIOD OF TRANSMISSION

The results in the previous section demonstrated that the responses of money market rates differ across the three CEE countries. While in Estonia and Lithuania the next day impact is significant and similar to the impact on EURIBOR rates, in Bulgaria the findings are inconclusive. However, a relevant question is whether the Bulgarian money market does not respond to the ECB policy decisions or the transmission of the shocks is slow and cannot be detected on the next business day. I investigate this question by computing the impact over time. Let $\delta_t^{n,k}$ denotes the cumulative change in an interest rate of maturity n ($n = 1m, 3m, 6m, 12m$) that occurs over the span of k days after the decision announcement on date t . For example, $\delta_t^{3,4}$ denotes the cumulative change in the 3-month interest rate (3-month maturity) accumulated over 4 business days after the decision announcement¹⁷. I estimate the impact of monetary policy shocks on the money market rates over increasing intervals of time. The analysis is performed using the linear model specified in the previous section.

$$\delta_t^{n,k} = \alpha_0 + \alpha_1 \Delta r_t^{Piazzesi} + \varepsilon_t \quad (1.8)$$

Again, as monetary policy shocks are assumed to be exogenous, there is no need for the inclusion of additional covariates. I employ the Piazzesi shock series since they generate the most significant impact on money market rates across countries and, as already discussed in previous sections, can serve as a suitable instrument for quantifying ECB's monetary policy surprises in the context of the Euro Area. The results of the regressions are systematized in tables 1.12, 1.13 and 1.14.

As the results in the previous section demonstrated, the money market in Estonia is the most responsive to the shocks generated by the ECB. They are transmitted rapidly to the domestic

¹⁷The data I use consists only of business days. Assuming that the Governing Council meets on Thursday, a four day period after the meeting will represent the change in money market rates between that Thursday and the Wednesday of the following week.

banking system. The TALIBOR rates have absorbed the shocks by the 3-rd business day. The results confirm the dependence of the domestic banking sector on foreign funds and the higher degree of integration of the sector compared to the other two currency board countries. In Lithuania, the transmission occurs with a similar pace as in Estonia. On the 3-rd and 4-th days, the impact is clearly defined and the coefficients become significant. The coefficient estimates for Lithuania are larger than in the other two countries. A possible explanation is that the Lithuanian market is more volatile and changes induced by the ECB steer larger movements in rates. Still, findings confirm that the two Baltic states have similar banking systems with money market rates responding swiftly to ECB's monetary policy changes. However, Estonia's response is relatively faster, which can be viewed as an argument for Estonia's adoption of the euro at the beginning of 2011, while Lithuania remained part of the ERM II convergence mechanism until the end of 2014.

The next day response of Bulgarian money market rates across all maturities is small and insignificant. However, with the progress of time, the impact becomes more prominent. Estonia and Lithuania displayed a peak in their responses by the 3-rd or 4-th day. Longer time periods had smaller and less significant impact coefficients. In contrast, the findings for Bulgaria reveal a slower transmission process. It takes a week for the impact to become marginally significant. Still, the results are less definitive compared to the other two countries. An apparent issue is the data availability for the 6 and 12-Month SOFIBOR rates. Still, even for these maturities, coefficients increase in significance with the increase in the observed time period (the number of days after the ECB policy decision). While the next day response of the 6 and 12-Month SOFIBOR rates is small and puzzlingly negative, by the 7-th day, the response exceeds 50 basis points. The 1-Month maturity responds by 100 basis points on the 6-th day. For the 3-Month rate, the response is smaller. The results demonstrate that the Bulgarian market **does** respond to the shocks generated by the ECB, but unlike in the other two currency board countries, the response is manifested after a longer period. Therefore, the Bulgarian money market follows the trends of the European one. Still, due to the level of development of the sector and the active interbank market with multiple players, the rates respond sluggishly to exogenous shocks and have their own short term dynamics.

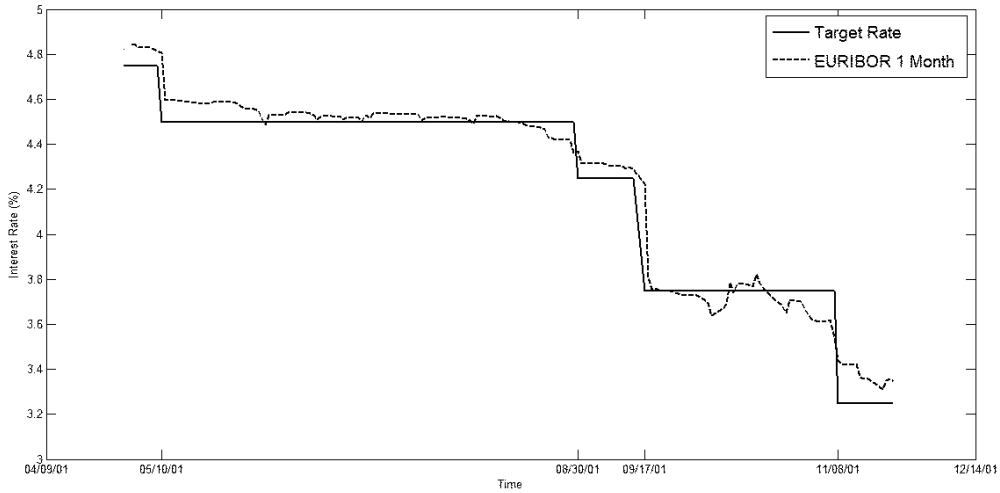
1.7 CONCLUSION

Economic theory states that a currency board regime practically eliminates the ability of a country to lead a discretionary monetary policy and instead it adopts the policy of the anchoring country. The dependence has been extensively researched. This paper analyzes empirically a particular aspect of the subject - the interaction between the monetary policy decisions of the anchoring country and the interbank money market in the currency board country. It examines first whether money markets in countries with a currency board regime are effectively reacting in a manner similar to markets in countries part of the common currency area. Such behavior can serve as an evidence of the level of convergence of these countries, especially considering their commitment to adopt the common currency in the future. Second, the paper also studies and compares the reaction to the monetary policy shocks across countries. It provides a potential explanation for the differences based on the structure of the banking sector in each country.

Drawing on the methodologies developed by Kuttner (2001) [90] and Cochrane and Piazzesi (2002) [39], I trace how the policy decisions made by the ECB Governing Council affect the interbank money markets in Bulgaria, Estonia, and Lithuania. My findings demonstrate that changes in the ECB target rates are transferred to the currency board countries. However, the speed and the magnitude of transmission depend on the level of integration of the country's banking system with the rest of Europe. Analyzing the history and structure of the banking systems in each country, I argue that an important factor in the transmission of ECB's shocks is the portion of foreign funding in the portfolio of domestic banks. Due to a heavy dependence on foreign financing, the Estonian money market behaves similarly to the European one. On the other hand, as a country with a less integrated banking sector and smaller reliance on foreign funds, Bulgaria is less responsive to ECB's policy shocks. Even though the shocks are transferred to the Bulgarian interbank money market over time, the immediate impact is insignificant.

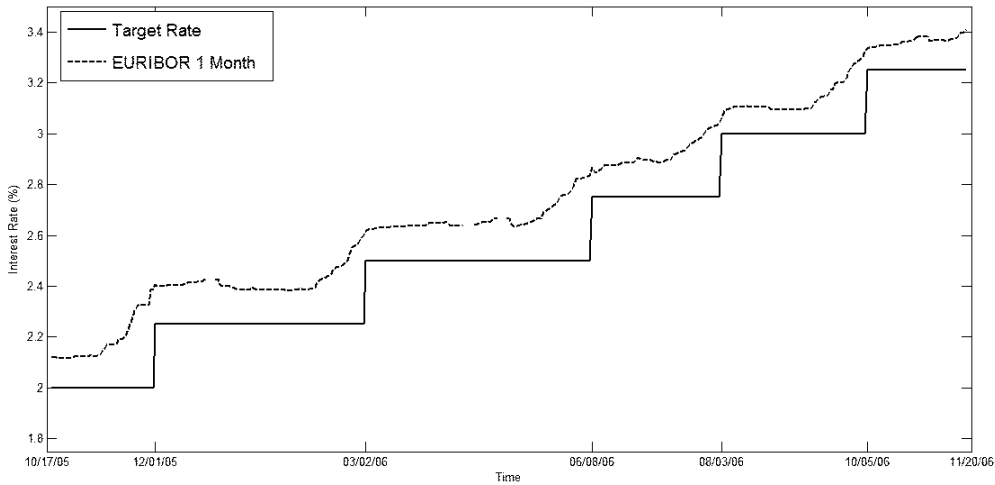
1.8 FIGURES

Figure 1.1: Unexpected Monetary Policy Decisions



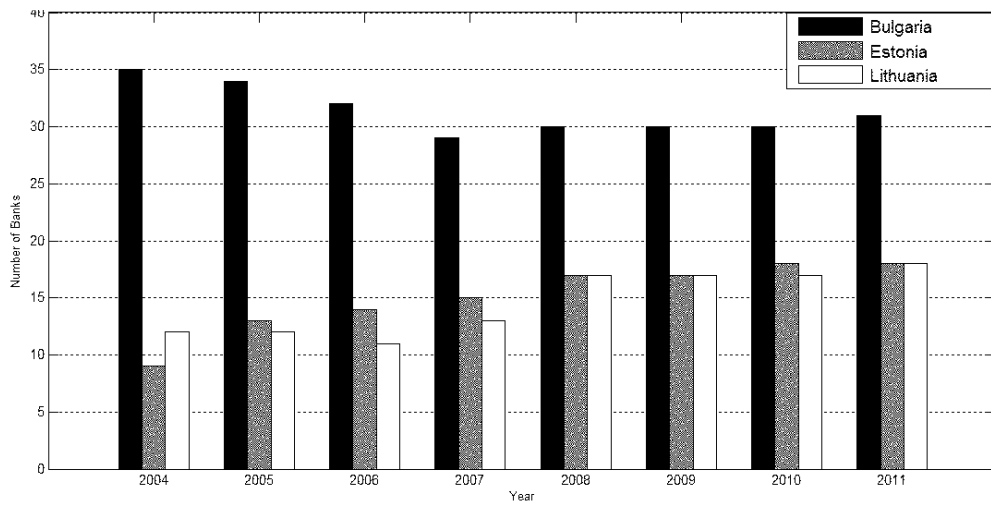
Note: The graph presents the path of the ECB main refinancing rate and the 1-Month EURIBOR. It demonstrates the large adjustment in the 1-Month EURIBOR in the case of a monetary policy surprise by the ECB. **Source:** Bloomberg and author's calculations.

Figure 1.2: Expected Monetary Policy Decisions



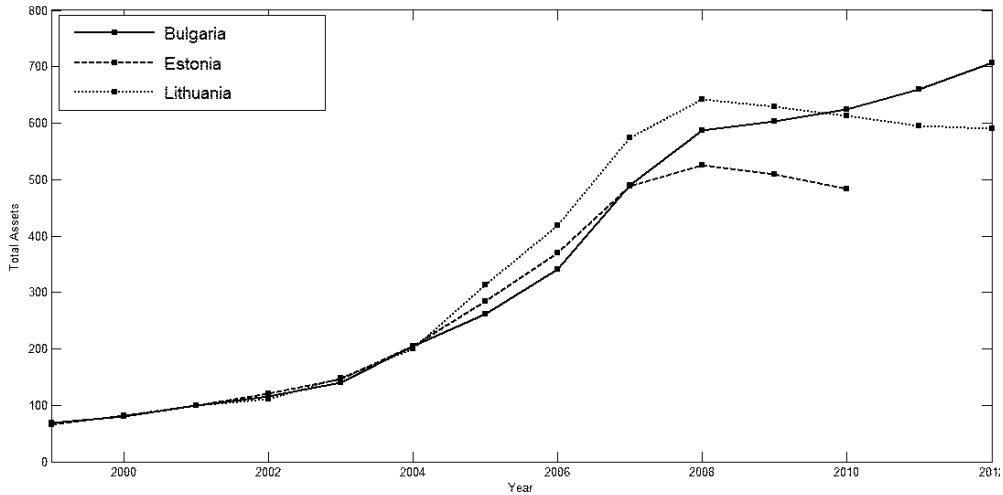
Note: The graph presents the path of the ECB main refinancing rate and the 1-Month EURIBOR. It demonstrates the lack of a major adjustment in the 1-Month EURIBOR when the monetary policy decision is expected. **Source:** Bloomberg and author's calculations.

Figure 1.3: Number of Banks



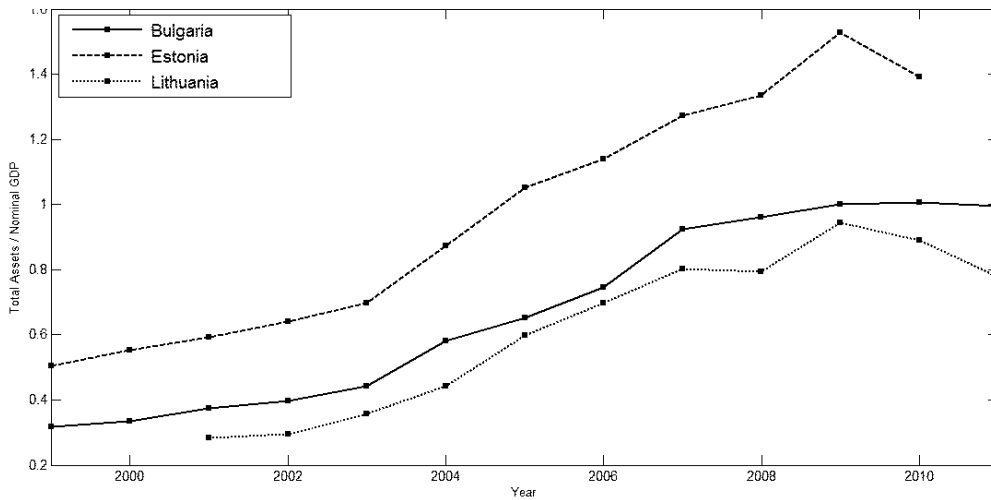
Note: The graph presents the number of private banks operating in the three CEE countries. **Source:** World Bank.

Figure 1.4: Expansion of Banks' Assets (Year 2001 = 100)



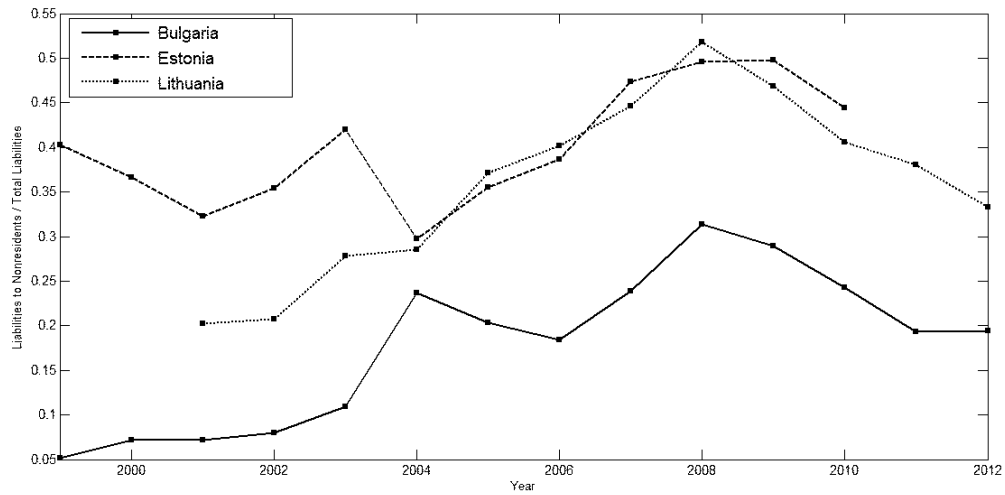
Note: The graph presents the expansion of private banks' total assets over the past decade. The asset level in 2001 has been normalized to a 100. **Source:** IMF International Financial Statistics.

Figure 1.5: Banks' Assets to Nominal GDP



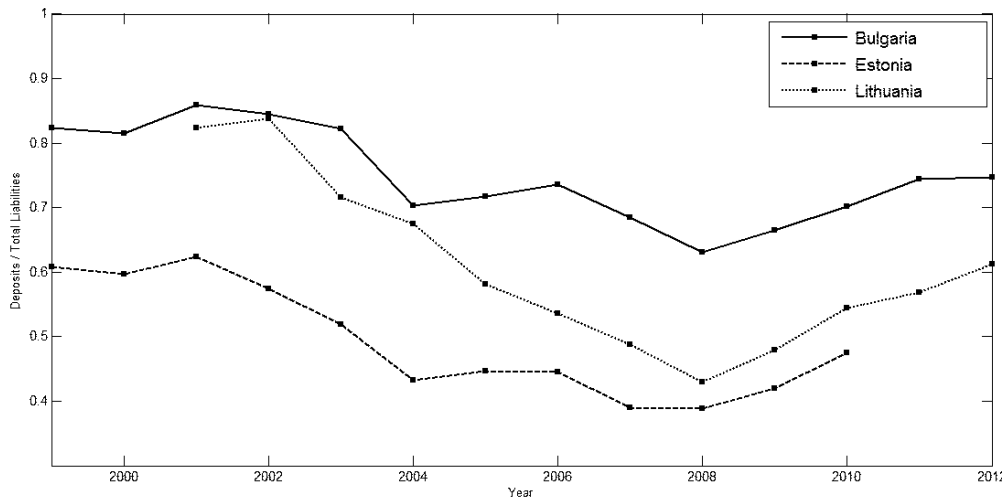
Note: The graph presents the ratio of private banks' total assets to nominal GDP in the three CEE countries. **Source:** IMF International Financial Statistics.

Figure 1.6: Structure of Banks' Liabilities to Non-Residents



Note: The graph presents the share of banks' liabilities to non-residents in total liabilities. **Source:** IMF International Financial Statistics.

Figure 1.7: Structure of Banks' Liabilities - Deposit Share



Note: The graph presents the share of household and corporate deposits in banks' liabilities. **Source:** IMF International Financial Statistics.

Table 1.1: Balance Sheet of the Issue Department of the Bulgarian National Bank

Liabilities	Assets
Notes and coins in circulation	Foreign reserves
Commercial banks reserves	
Government fiscal reserves	
Banking department deposits	

Note: The table presents the structure of the balance sheet of the Issue Department of the Bulgarian National Bank.

Table 1.2: Data Description of Money Market Rates

Variable	Country	Maturity	Period	Source
EURIBOR	Euro Area	1m, 3m, 6m, 12m	4 Jan. 1999-31 Aug. 2012	Bloomberg
SOFIBOR	Bulgaria	1m, 3m 6m, 12m	17 Feb. 2003-31 Aug. 2012 30 Apr. 2009-31 Aug. 2012	Bloomberg
TALIBOR	Estonia	1m, 3m, 6m, 12m	4 Jan. 1999-29 Dec. 2010	Bloomberg
VILIBOR	Lithuania	1m, 3m, 6m, 12m	2 Jan. 2001-31 Aug. 2012	Bloomberg

Note: The table provides a detailed description of money market rates data and sources.

Table 1.3: Average Daily Changes and Volatility of Money Market Rates

Rate		Average change				Standard deviation			
		1m	3m	6m	12m	1m	3m	6m	12m
EURIBOR	all dates	-0.08	-0.08	-0.08	-0.07	2.56	1.87	1.90	2.57
	meetings	-0.49	-0.36	-0.12	-0.09	5.31	4.48	4.46	5.38
SOFIBOR	all dates	-0.09	-0.09	-0.58	-0.63	6.32	5.84	3.37	5.44
	meetings	-1.81	-2.04	-0.30	-0.65	15.33	12.62	2.39	3.50
TALIBOR	all dates	-0.34	-0.36	-0.42	-0.42	7.15	7.21	7.21	7.39
	meetings	-0.60	-1.17	-0.69	-1.20	10.73	7.90	9.67	7.38
VILIBOR	all dates	-0.29	-0.33	-0.30	-0.27	9.70	7.10	6.18	6.41
	meetings	-2.72	-2.15	-1.81	-1.34	26.06	14.99	11.76	9.71

Note: The table presents the average daily change (in basis points) of money market rates over the entire sample of trading days (all dates) and over days of Governing Council meetings (meetings). The right portion of the table present the standard deviation of the daily rate changes over the entire sample and over meeting dates.

Table 1.4: Correlation of Shock Series and Actual Target Rate Changes

Variable	Correlation		
Target rate change	1		
$\Delta r_t^{Kuttner}$	-0.0211	1	
$\Delta r_t^{Piazzesi}$	0.6524	0.3156	1

Note: The table presents the correlation between the derived shock series and the actual target rate changes. Target rate changes correspond the actual change in the ECB policy rate.

Table 1.5: Data Description of Government Bond Yields

Country	Bond maturity	Period	Source
Germany	1y, 3y, 5y, 10y, 30y	4 Jan. 1999-31 Aug. 2012	Bloomberg
France	1y, 3y, 5y, 10y, 30y	4 Jan. 1999-31 Aug. 2012	Bloomberg
Italy	1y, 3y, 5y, 10y, 30y	4 Jan. 1999-31 Aug. 2012	Bloomberg
The Netherlands	1y	18 Jan. 2001-31 Aug. 2012	Bloomberg
	3y, 5y, 10y, 30y	4 Jan. 1999-31 Aug. 2012	Bloomberg

Note: The table provides a detailed description of government bond yields data and sources.

Table 1.6: Data Description of Macroeconomic Variables

Variable	Country	Period	Source
Inflation rate (HICP)	Germany, France, Italy, Netherlands	Dec. 1999- Aug. 2012	ECB SDW
Unemployment rate	Germany, France, Italy, Netherlands	Dec. 1999- Aug. 2012	EUROSTAT
Industrial production	Germany, France, Italy, Netherlands	Dec. 1999- Aug. 2012	IMF IFS

Note: The table provides a detailed description of macroeconomic variables and sources.

Table 1.7: Dependence of Target Rate Changes on Past EURIBOR Rates and Government Bond Yields

Lags	EURIBOR rates				German bond yields			French bond yields			Dutch bond yields		
	1m	3m	6m	12m	3y	5y	10y	3y	5y	10y	3y	5y	10y
1	37.7**	47.5**	48.3**	42.4**	23.8**	19.0**	13.3	20.9**	16.5**	11.6	23.3**	17.9**	11.3
2	26.2**	38.2**	37.8**	34.1**	19.8**	16.1	11.6	18.7**	15.1	10.0	21.0**	15.2**	9.3
3	21.5**	26.7**	31.7**	32.7**	25.8**	21.4**	13.0**	24.6**	18.2**	9.5	25.7**	18.0**	7.8

Note: The table presents estimates of the impact coefficient θ_1 in basis points (bps). The rows correspond to different lags, where the lag coefficient n represents the impact of a change in the value of a variable n months back on the present level of the shock. Individual columns correspond to different variables. “**” denotes a significant coefficient at the 5% level using Newey-West (1987) [109] standard errors.

Table 1.8: Dependence of Target Rate Changes on Past Developments in Macroeconomic Variables

Lags	Germany		France		Italy		Netherlands	
	HICP	Unempl	HICP	Unempl	HICP	Unempl	HICP	Unempl
1	7.7	-0.3	10.7	-13.5**	10.4	-0.7	5.9	-4.1
2	11.6	-1.0	14.0**	-14.0	9.9	5**	5.0	-7.0
3	2.1	2	9.3**	-14.8**	4.2	-1.4	4.0	-9.5**

Note: The table presents estimates of the impact coefficient θ_1 in basis points (bps). Variables HICP and Unempl stand for inflation rate and unemployment in each country. The rows correspond to different lags, where the lag coefficient n represents the impact of a change in the value of a variable n months back on the present level of the shock. Individual columns correspond to different variables. “**” denotes a significant coefficient at the 5% level using Newey-West (1987) [109] standard errors.

Table 1.9: Dependence of Shock Series on Past EURIBOR Rates

Lags	EURIBOR futures shock series				Piazzesi shock series			
	EURIBOR rates				EURIBOR rates			
	1m	3m	6m	12m	1m	3m	6m	12m
1	-2.2	-3.9	-3.5	-3.4	10.2**	9.2**	10.6**	9.9**
2	-1.4	-2.2	-2.5	-2.4	4.7**	6.9**	7.6**	7.3**
3	-3.0	-2.9	-3.7	-3.6	2.3	3.1	2.9	3.2

Note: The table presents estimates of the impact coefficient θ_1 in basis points (bps). Rows correspond to different lags, where the lag coefficient n represents the impact of a change in the value of a variable n months back on the present level of the shock. Left portion of the table presents the estimates for the 3-Month EURIBOR futures shocks series and the right portion - for the Piazzesi shock series. Individual columns correspond to different EURIBOR maturities. “**” denotes a significant coefficient at the 5% level using Newey-West (1987) [109] standard errors.

Table 1.10: Response of EURIBOR Rates to Shock Series

Maturity	3m EURIBOR shocks		Piazzesi shocks		Target changes	
	α_1	R^2	α_1	R^2	α_1	R^2
1m	48.1 (3.68)	0.15	83.9 (18.45)	0.89	18.8 (4.25)	0.30
3m	51.3 (4.99)	0.24	67.6 (13.59)	0.81	13.8 (3.54)	0.23
6m	64.6 (6.41)	0.39	59.4 (11.69)	0.63	12.4 (3.79)	0.18
12m	82.8 (6.85)	0.44	56.8 (7.94)	0.40	11.5 (3.56)	0.11

Note: The table presents the estimates of the impact coefficient α_1 in basis points. Terms in brackets refer to coefficients' t-statistics using Newey-West (1987) [109] standard errors. The sample contains 197 observations.

Table 1.11: Response of Money Market Rates to Piazzesi Shock Series

Maturity	SOFIBOR		TALIBOR		VILIBOR	
	α_1	R^2	α_1	R^2	α_1	R^2
1m	11.5 (0.89)	0.001	69.0 (3.61)	0.16	122.6 (1.15)	0.08
3m	10.5 (1.65)	0.001	56.7 (3.27)	0.20	67.6 (1.07)	0.08
6m	-3.7 (-0.39)	0.002	58.4 (3.33)	0.14	51.3 (1.09)	0.07
12m	-12.0 (-1.07)	0.01	54.1 (2.81)	0.21	40.7 (1.07)	0.07

Note: The table presents the estimates of the impact coefficient α_1 in basis points. Terms in brackets refer to coefficients' t-statistics using Newey-West (1987) [109] standard errors. The sample size for the Estonian interbank money rates (TALIBOR) is 177 due to the adoption of the euro on January 2011; for Lithuanian rates (VILIBOR) sample size is 153 because the rates are quoted since January 2001; for Bulgarian rates (SOFIBOR) the sample size is 115 for 1 and 3 month maturities and 40 for 6 and 12 month maturities.

Table 1.12: Speed of Transmission of ECB Monetary Policy Shocks in Estonia

TALIBOR								
Period of days	1m		3m		6m		12m	
	α_1	R^2	α_1	R^2	α_1	R^2	α_1	R^2
1 day	69.00 (3.61)	0.16	56.76 (3.27)	0.20	58.41 (3.33)	0.14	54.15 (2.81)	0.21
2 days	79.59 (4.11)	0.17	71.53 (4.69)	0.18	68.37 (4.17)	0.17	71.64 (3.57)	0.21
3 days	86.43 (4.04)	0.13	82.77 (5.67)	0.17	74.33 (4.74)	0.14	78.82 (4.04)	0.17
4 days	88.59 (4.16)	0.14	75.66 (4.21)	0.13	72.23 (4.50)	0.12	83.52 (3.73)	0.14
5 days	89.65 (4.13)	0.09	76.71 (4.27)	0.09	72.34 (4.50)	0.08	83.22 (3.65)	0.09
6 days	66.28 (1.84)	0.04	52.02 (1.43)	0.02	48.47 (1.37)	0.01	57.40 (1.40)	0.03

Note: The table presents the estimates of the impact coefficient α_1 in basis points. The estimated coefficients correspond to the impact of a monetary policy shock generated using the Cochrane and Piazzesi (2002) [39] methodology on the cumulative change in money market rates over increasing periods of time (1 to 6 days). Terms in brackets refer to coefficients' t-statistics using Newey-West (1987) [109] standard errors. Sample size of the regressions is 177.

Table 1.13: Speed of Transmission of ECB Monetary Policy Shocks in Lithuania

VILIBOR								
Period of days	1m		3m		6m		12m	
	α_1	R^2	α_1	R^2	α_1	R^2	α_1	R^2
1 day	122.60 (1.15)	0.08	67.66 (1.07)	0.08	51.32 (1.09)	0.07	40.79 (1.07)	0.07
2 days	141.12 (1.42)	0.11	114.60 (2.33)	0.19	72.90 (1.80)	0.13	155.78 (2.74)	0.41
3 days	190.00 (2.02)	0.16	121.12 (2.61)	0.19	75.17 (2.47)	0.12	173.37 (2.67)	0.42
4 days	212.09 (2.11)	0.16	133.28 (2.84)	0.16	102.91 (2.97)	0.16	173.42 (2.74)	0.26
5 days	212.31 (2.01)	0.14	114.52 (2.47)	0.11	77.71 (2.02)	0.07	147.42 (1.92)	0.16
6 days	212.31 (1.95)	0.13	107.12 (2.29)	0.07	74.06 (2.10)	0.06	145.34 (1.75)	0.14

Note: The table presents the estimates of the impact coefficient α_1 in basis points. The estimated coefficients correspond to the impact of a monetary policy shock generated using the Cochrane and Piazzesi (2002) [39] methodology on the cumulative change in money market rates over increasing periods of time (1 to 6 days). Terms in brackets refer to coefficients' t-statistics using Newey-West (1987) [109] standard errors. Sample size of the regressions is 153.

Table 1.14: Speed of Transmission of ECB Monetary Policy Shocks in Bulgaria

Period of days	SOFIBOR							
	1m		3m		6m		12m	
	α_1	R^2	α_1	R^2	α_1	R^2	α_1	R^2
1 day	11.54 (0.89)	0.00	10.52 (1.64)	0.00	-3.69 (-0.39)	0.00	-12.06 (-1.07)	0.01
2 days	33.28 (2.92)	0.01	19.76 (2.57)	0.00	-3.09 (-0.37)	0.00	-3.14 (-0.23)	0.00
3 days	44.48 (2.48)	0.02	21.59 (2.26)	0.00	-2.14 (-0.16)	0.00	7.52 (0.34)	0.00
4 days	65.08 (3.02)	0.03	36.83 (2.65)	0.00	27.61 (0.83)	0.03	13.58 (0.46)	0.01
5 days	86.16 (3.08)	0.03	45.13 (2.20)	0.01	25.59 (0.66)	0.02	30.79 (0.65)	0.03
6 days	100.01 (2.65)	0.04	51.45 (2.14)	0.01	28.57 (0.80)	0.03	30.61 (0.67)	0.03
7 days	123.89 (2.53)	0.04	67.76 (2.19)	0.02	51.91 (1.19)	0.03	52.38 (0.87)	0.04

Note: The table presents the estimates of the impact coefficient α_1 in basis points. The estimated coefficients correspond to the impact of a monetary policy shock generated using the Cochrane and Piazzesi (2002) [39] methodology on the cumulative change in money market rates over increasing periods of time (1 to 7 days). Terms in brackets refer to coefficients' t-statistics using Newey-West (1987) [109] standard errors. Sample size of the regressions is 115 for 1 and 3 month maturities and 40 for 6 and 12 month maturities.

CHAPTER 2

SECTORAL DEBT DELEVERAGING IN AN ENVIRONMENT OF NOMINAL RIGIDITIES

2.1 INTRODUCTION

The 2008 financial crisis has caused a prolonged economic slump that still continues to weigh on economic activity in the Euro Area. A widely accepted view is that the profile of weak recovery following the crisis is caused by the large stock of debt accumulated during the boom period that continues to act as a drag on private demand. These dynamics are not without a precedent in economic history. In the past, high levels of private debt have triggered deep recessions followed by prolonged periods of anemic growth. Fisher (1933) [59] argues that the Great Depression in the US has been caused by the combination of high household debt and price deflation. In addition, Koo (2008) [87] asserts that the "lost decade" in Japan is the result of over-leveraged private balance sheets that have prevented the private sector from expanding demand.

The decade leading to the 2008 financial crisis witnessed the accumulation of a massive stock of private debt across the developed economies and the formation of global imbalances. Authors have motivated the sizable accumulation of debt with the extended period of favorable economic conditions leading to the crisis and also the continuous deepening of financial markets that promoted an easier access to credit. In the years leading to the crisis, a combination of factors - low interest rates, lax lending standards, a boom of exotic financial products, and an abundant supply of capital from emerging economies - all fueled a continuous rise in private leverage.

2.1.1 THE CREDIT BOOM: FACTS AND CAUSES

In the decade leading to the financial crisis, private balance sheets grew rapidly. A stable macroeconomic environment and ample global liquidity led to the expansion of the financial sector. Credit growth was also assisted by the relatively accommodative monetary policy stance of central banks across the developed world.

Several main factors facilitated the process of rapid leveraging observed before the crisis in developed economies. First, an extended period of consistent, non-inflationary economic expansion caused an excess of confidence that developed into complacency. It was expected that globalization and improvements in technology would maintain the pace of economic growth into the future (Carney, 2015 [35]). As the developed world enjoyed a continuous steady growth and low stable inflation, agents' willingness to take on risk increased which pushed asset valuations upward. Second, advances in financial engineering further facilitated the access to credit. Financial innovations and the creation of complex instruments for sharing and hedging risk gave agents the deceptive assurance that risks have been largely eliminated which motivated a continuous fall in lending standards. Financial institutions offered loans to a broad base of clients that would not be able to access credit under the previous stricter lending criteria. Third, the credit boom in the developed economies was facilitated also by the steady supply of capital from emerging markets - the global savings glut (Bernanke, 2005a [18]). Large amounts of money were channeled to the advanced economies where they circulated in search for investment opportunities.

Concentrating on the Euro Area, the expansion of credit was driven by the rapid financial deepening observed globally in both advanced and emerging economies. However, there was one additional factor. The introduction of the euro in 1999 intensified the financial market integration between member states. It eliminated exchange rate risk and supported expectations of faster peripheral convergence (Obstfeld, 2013 [110]). Due to the common currency, sovereign yields and lending rates across the monetary union converged in spite of the different economic fundamentals in individual countries. In search of higher returns, banks from the Eurozone core economies directed capital to the Eurozone periphery that was perceived as a low risk investment because of the common currency. However, in reality, the inflow of capital into the Eurozone periphery concentrated risk there and intensified the debt problem.

The inflow of funds from the core to the periphery maintained nominal interest rates low and relaxed the access to credit, boosting domestic demand and prompting higher inflation relative to the core economies. On its turn, higher price growth decreased further real interest rates and promoted borrowing, pushing the saving rate down. Investment in the periphery increased, generating asset price bubbles¹. Growing asset prices loosened further collateral constraints of borrowers and supported higher demand. As a result, driven by both strong demand and ample supply, credit

¹Most notably, Spain and Ireland experienced housing booms in which house prices grew substantially.

grew rapidly in the Euro Area and private debt expanded well above past historic levels (Figure 2.1).

2.1.2 THE MINSKY MOMENT: A SHIFT IN CONFIDENCE

The long stretch of continuous economic expansion and moderate inflation before the 2008 financial crisis encouraged overoptimistic expectations of future buoyant growth. Optimism and a false sense of safety among lenders increased their risk tolerance. In addition, as lenders loosened their lending criteria, borrowers increased their disposition to take on a larger amount of debt anticipating that asset prices will continue growing². As a consequence, the private sector accumulated a massive amount of debt compared to the pre-boom period.

However, the burst of the housing bubble in the US was the turning point that precipitated a collapse in both borrowers' and lenders' confidence and a reevaluation of borrowing limits. With the onset of the financial crisis, agents swiftly reevaluated the sustainability of the existing stock of debt through the prism of less buoyant income growth expectations and asset valuations. Typical for a financial crisis, this outturn has been examined previously by Minsky (1986) [106]. Thus, the sudden change in agents' attitude towards leverage is often referred to as a Minsky moment, a term coined by Paul McCulley. The term depicts the abrupt realization that the favorable conditions that justify the accumulation of a large stock of debt are no longer present and, in reality, agents have amassed a significant debt overhang. The sudden change in the risk profile of debt restricts agents' ability to roll over and service their obligations. As a consequence, the perception of higher risk materializes in the form of higher interest rate spreads and more restrictive bank lending standards that limit the supply of credit to the economy and inflate debt servicing costs.

Consistent with these patterns, the 2008 financial crisis affected lenders' risk appetite, increasing the required risk premium. Furthermore, banks' lending standards tightened in response to the new more unstable environment. As a result, borrowers were urged to readjust their balance sheets. The speed and intensity of the deleveraging process in individual European countries depended on the initial level of debt overhang and the flexibility of the national economy. Still, across the entire continent, the deleveraging process decreased aggregate demand and depressed economic activity. The impact of the reduction in debt demonstrated the "paradox of deleveraging" as described

²This can be seen as an example of Minsky's Ponzi finance where a loan can be refinanced only if the price of the underlying asset continues to increase.

by Minsky (1986) [106], according to which the process of debt reduction, while optimal for the individual, can instigate a recession.

2.1.3 DELEVERAGING AND ECONOMIC ACTIVITY: LESSONS FROM THE DATA

Since the 2008 financial crisis that caused a deep recession, an increasing number of authors have explored the nexus between debt overhang and economic activity present in the data. The literature can be split broadly into *inter-country* analysis that considers a cross-section of countries and *intra-country* analysis that concentrates on separate regions within a country. Both branches of research provide similar findings. Empirical data confirm that higher levels of leverage increase the vulnerability of the economy in an event of a systemic shock. The key rationale is that, following the Minsky moment, agents with higher outstanding stock of debt need to deleverage more aggressively in order to reach a lower sustainable level of debt. As more funds are allocated for the repayment of debt, the deleveraging process causes a drop in consumption and investment that slashes domestic demand. Production responds to the contraction in demand and also decreases.

Exploring past recessions, Jorda, Schularick and Taylor (2011) [85] analyze episodes of financial crises in cross-country data and discover two important tendencies. First, on average, financial crises are more severe than cyclical recessions. Second, a higher amount of debt accumulated during the boom period causes a larger downturn afterwards. A recession preceded by a larger accumulation of debt is deeper and also the recovery path is more prolonged. Demand remains subdued for an extended period of time while over-indebted agents deleverage. In their work, Glick and Lansing (2010) [67] arrive to similar conclusions. Countries that have experienced the largest increase in household leverage during the credit boom exhibit the most severe decline in consumption. The unwinding of excess debt is achieved via higher savings that can cause a significant drag on consumption. Furthermore, the severity of the recession is determined by the degree to which the pre-crisis growth was fueled by unsustainable borrowing. Taylor (2012) [126] also finds a significant relationship between the credit growth during the boom and the subsequent collapse in GDP. His analysis confirms that following a credit boom, the period of recovery is lengthier compared to a cyclical recession. Furthermore, Taylor (2012) [126] emphasizes that the ratio of public debt to GDP before the crisis has a material impact on the subsequent economic slowdown. Countries with larger fiscal space (i.e. lower sovereign debt) are able to implement larger fiscal stimulus programs and also cover bank losses and prevent bankruptcies, counteracting the fall in private demand.

An empirical paper by the IMF summarizes these main findings. Igan et al. (2013) [79] highlight that economic downturns preceded by a larger run-up in gross household debt are associated with a significantly larger contraction in economic activity, both in terms of size and length. Igan et al. (2013) [79] analyze data from a sample of 24 OECD countries over the period 1980-2011. They find that the consumption lost in 2010 relative to the pre-crisis trend is larger in economies that experienced a faster increase in the gross household debt-to-income ratio over the period 2002-2006. For each 10 percentage points rise in household debt prior to the crisis, the subsequent loss in consumption is 2.6 percentage points. In addition, household deleveraging is more pronounced after a period of rapid growth in household debt. The household debt-to-income ratio declines by an average of 5.4 percentage points following a high-debt burst. In contrast, the debt-to-income ratio does not decrease in a low-debt recession. These findings explain the sizable contraction in economic activity observed after the 2008 financial crisis and the intense household deleveraging that followed.

Empirical analysis of intra-country data leads to comparable results. Mian and Sufi (2012) [102] and Mian, Rao and Sufi (2013) [103] use US county level data to explore the causal effects of household debt. They conclude that household leverage has a major role in explaining the drop in consumption during the Great Recession. Performing a similar analysis on Spanish provincial data, Jauch and Watzka (2012) [83] find a positive link between mortgage debt levels pre-crisis and the rise in provincial unemployment during the crisis. The authors explain their findings with the different propensity to consume of debtors and creditors. Because of it, the drop in debtors' consumption is not fully offset by an increase in creditors' consumption.

Further analysis using more granular data reinforces these conclusions. Baker (2015) [11] uses comprehensive financial information for 150 000 American households over the period 2008-2013 to evaluate the role of debt in dampening US consumption during the Great Recession. The data cover household debt, assets, income and consumption. Baker (2015) [11] confirms that the increase in household debt is an important determinant of the severity of the US recession following the financial crisis. In addition, the author finds that the elasticity of consumption with respect to income among high-debt households is significantly higher compared to low-debt households. Households' consumption behavior can be explained with the existence of an optimal debt-to-income ratio targeted by households. Thus, highly-indebted households decrease their consumption in order to attain this optimal level of leverage. The findings of Baker (2015) [11] are consistent with our

modeling framework. Borrowers and lenders in the model are assumed to differ in their propensity to consume while debt accumulation is guided by an optimal "safe" level of debt.

While the empirical literature concentrates disproportionately on the nexus household debt - economic activity, there is also work that explores corporate sector deleveraging. This is of particular relevance since in many European countries the corporate sector has expanded substantially its leverage, even more so than the household sector (Figure 2.1). Ahearne and Wolff (2012) [6] explore the process of corporate deleveraging in Europe. Episodes of corporate balance sheet adjustments reveal that corporate deleveraging impacts severely investment, corporate savings, and wages. Corporate deleveraging drives domestic demand down through a sizable drop in investment. More importantly, corporate deleveraging has a large negative income effect as it is associated with persistent periods of wage moderation. Ruscher and Wolff (2012) [119] find similar results using a sample of developed economies. According to their paper, corporate balance sheet adjustments are long lasting and have significant effects on investment and wages. Corporate balance sheet adjustments impact not only the investment channel but also the income channel. Driven by the need to consolidate their balance sheets, corporations cut their labor and intermediate costs. Higher corporate savings to pay off debt are partially achieved by lowering wages which affects household income. Therefore, corporate deleveraging is achieved by slashing investment and increasing savings on the back of falling labor costs.

2.1.4 A STEP FURTHER: THE EFFECTS OF SECTORAL DELEVERAGING

As the previous subsection discusses, countries that have experienced a larger increase in private debt suffer a weaker economic growth throughout the crisis. Going a step further, Lo and Rogoff (2015) [97] explore the importance of both the overall debt level in the economy and its composition among sectors. They elaborate on the shock amplification mechanisms that exist across sectors. Private defaults can create contingent liabilities for the government. Additionally, if households are over-indebted, this will prompt a drop in demand that can worsen corporate debt sustainability. A Minsky moment can affect borrowers' disposition to maintain high levels of debt which impacts demand and generates a feedback loop among sectors. High levels of leverage in the financial sector have also negative effects on the rest of the economy as they limit the supply of credit. Furthermore, the financial channel of shock transmission is of key importance for the economy, as

a deterioration of the economic environment manifests itself in higher borrowing rates and stricter lending standards that suffocate the economy.

Bornhorst and Arranz (2014) [26] also focus on sectoral indebtedness. The authors establish that the negative impact of over-indebtedness is present on a sectoral level for household debt and consumption and corporate debt and investment. Most importantly, Bornhorst and Arranz (2014) [26] conclude that the negative impact of debt in one sector depends also on the level of indebtedness in the other sectors of the economy. Their analysis asserts that the confluence of debt in multiple sectors exacerbates the contraction of economic activity during the crisis. The negative impact of debt on economic growth is intensified if more than one sector is over-indebted. High corporate and high household debt on their own are associated with weakening GDP growth. However, the negative impact is amplified if both sectors have an unsustainably high debt. Consequently, countries where all sectors are highly indebted are most severely affected by the crisis (as evident from the Euro Area peripheral economies). Bornhorst and Arranz (2014) [26] confirm that feedback loops among sectors intensify the economic downturn in the case of a simultaneous deleveraging. The impact is particularly severe when all sectors in the economy - both private and public - deleverage simultaneously. Economic activity remains depressed since no sector expands its balance sheet. The modeling framework we develop explores these dynamics in details and rationalizes the results.

2.1.5 THEORETICAL PAPERS ON DELEVERAGING

The deleveraging process evident in the data and its large economic impact has motivated the creation of theoretical models that study over-indebtedness. If the severity of the crisis is affected by the amount of debt in the system, then a simplified model that fails to account for these interactions would not be able to generate the observed macroeconomic dynamics. Recent papers attempt to model the drivers behind the slowdown observed during the financial crisis, concentrating on the deleveraging cycle. Midrigan and Philippon (2011) [104] develop a model that rationalizes the empirical evidence that output and employment have declined more in regions that experienced a larger increase in household leverage. They construct a cash-in-advance economy in which credit can be used as a substitute for fiat money. In the model, a fall in consumption is generated by a decrease in the supply of credit that tightens households' cash-in-advance constraints, triggering a recession. The drop in households' borrowing capacity is achieved through a permanent exogenous

reduction in the collateral constraint parameter³. The exogenous shock to the ability to borrow leads to a decline in non-durable and durable consumption in line with the US data. The decline in durable consumption is much more pronounced in the model (similar to the data) due to the higher intertemporal substitution for durables.

Hall (2011) [76] also highlights the role of tightening household borrowing constraints for explaining the financial crisis. The author develops a model that includes two types of heterogeneous agents (borrowing constraint and unconstrained households) and also financial frictions in the form of a wedge between the interest rates of savers and borrowers. Hall (2011) [76] demonstrates the impact of higher debt servicing costs and larger financial frictions on economic activity: unemployment in the modeled economy increases and consumption of indebted households falls. Similar to Midrigan and Philippon (2011) [104], in Hall (2011) [76] investment in housing and consumer durables is particularly affected.

Guerrieri and Lorenzoni (2011) [74] study the impact of a deleveraging shock in a closed economy using a Bewley-Aiyagari-Hugget style model. Similar to other authors, Guerrieri and Lorenzoni (2011) [74] explore the transition of the economy from a regime of easy credit to one of tighter credit by subjecting households to an exogenous reduction in their borrowing limit. As agents use a fraction of their capital as collateral, an exogenous increase in the parameter defining the collateral requirement restricts agents' ability to borrow. The credit crunch generates a recession that is triggered by the combination of debt repayments and higher precautionary savings. Over-indebted agents decrease spending and increase the supply of labor. In aggregate, in the Guerrieri and Lorenzoni (2011) [74] model a tightening of the credit limit that reduces households' debt-to-GDP ratio by 10% causes a 1% drop in output on impact.

Eggertsson and Krugman (2012) [51] also model an exogenous reduction in households' debt limit. In their paper, the deleveraging process is a key driver of the economic slowdown. However, while in Guerrieri and Lorenzoni (2011) [74] borrowing and lending among agents are motivated by idiosyncratic shocks, in Eggertsson and Krugman (2012) [51] borrowing is the result of different preferences among agents. Borrowers discount the future more heavily than savers. The formulation chosen in Eggertsson and Krugman (2012) [51] allows for a simpler and more tractable solution of

³Household borrowing in the Midrigan and Philippon (2011) [104] model is limited to a fraction of the value of their housing stock.

the model. Due to these advantages, in building the framework of our model, we draw on the paper of Eggertsson and Krugman (2012) [51].

2.1.6 OBJECTIVES AND CONTRIBUTIONS OF THE PAPER

In its most synthesized form, the credit cycle can be split into three phases. First, there is a period of over-optimism, during which debtors borrow aggressively piling up unsustainable amounts of debt. Second, a Minsky moment takes place and agents abruptly realize that the accumulated debt is excessive. Lastly, a lengthy period of deleveraging commences that lasts for an extended period of time. The present paper explores the later two phases of the process - the economic impact of a fall in credit availability and the transition of the economy to an environment of tight credit. In addition, the paper identifies the main forces at work during the deleveraging process and their impact on economic activity. The analytical framework of our paper draws extensively on the work of Eggertsson and Krugman (2012) [51]. We analyze debt reduction in the framework of a small-scale New Keynesian model with nominal rigidities.

As empirical results demonstrate, a proper analysis of private sector indebtedness has to account for the fact that debt is not allocated symmetrically across sectors. Countries differ in the evolution of sectoral debt before the crisis⁴. In several European economies, the rapid expansion of private debt is attributed largely to either the household or the corporate sectors. Cuerpo et al. (2013) [44] examine debt overhang on a sectoral level in the EU member states and conclude that while some European countries have amassed an unsustainable stock of debt in the household or corporate sectors, other countries have both sectors over-indebted. Therefore, the magnitude and speed of the deleveraging process in individual countries depend not only on the level of initial private debt overhang, but also on the distribution of debt across sectors. In particular, an identical level of private debt can be due to either a large over-indebtedness in one sector or a relatively even distribution of debt across sectors. This affects the size of the needed balance sheet adjustment in each sector and the respective impact on economic activity. To account for sectoral indebtedness, we expand the Eggertsson and Krugman (2012) [51] model and introduce two distinct types of leverages agents - borrowers and entrepreneurs. In this richer framework, we are able to differentiate the effects of deleveraging on the economy depending on which sector adjusts its stock of debt. Furthermore,

⁴In the exposition, a sector refers to the standard EUROSTAT division of the domestic economy into household, corporate, financial, and public sectors.

our modeling framework allows us to reproduce the damaging effects of a multisector simultaneous debt reduction as outlined in Bornhorst and Arranz (2014) [26].

As the economic impact of debt reduction varies across sectors, our model explores how the deleveraging of a particular sector affects other sectors and the total economy. By modeling two types of leveraged agents, we explore the process of simultaneous deleveraging. Since sectors in the economy are closely interconnected, the expenditure of one feeds directly into the income of the other. As deleveraging imposes a spending cut, it affects other sectors. Furthermore, debt reduction also forces lenders to decrease their asset holdings because debt represents both a liability and an asset for different economic agents. With its structure, our model incorporates all these dynamics and traces how the deleveraging shock is transmitted across sectors.

To achieve these goals and model sectoral deleveraging, our model expands on the baseline specification of Eggertsson and Krugman (2012) [51] in three key directions. First, as discussed, we incorporate explicitly two leveraged sectors in the model by introducing two types of leveraged agents - borrowers and entrepreneurs. Leveraged agents differ in the source of their income. While household borrowers are endowed with labor and earn wage income, entrepreneurs own and invest in capital that they rent to firms. In this specification, borrowers denote the household sector while entrepreneurs - the corporate (non-financial corporations) sector in the economy. By modeling explicitly the two private sectors, we examine the paths of consumption and investment and their reaction to the deleveraging shock. A second addition we make to the Eggertsson and Krugman (2012) [51] baseline is that we introduce productive capital into the model. Firms employ two inputs - capital and labor - in a Cobb-Douglas production function for producing consumption and investment goods. Third, unlike in Eggertsson and Krugman (2012) [51], we simulate the non-linear version of the model instead of log-linearizing the system, allowing for richer dynamics. The non-linearity of the system we simulate generates the amplification effect in the case of a simultaneous debt reduction which is one of the main findings of the paper.

Lastly, in the baseline model specification of Eggertsson and Krugman (2012) [51], the deleveraging shock is achieved through a sudden reduction in the borrowing limit of indebted agents. Still, the precise dynamic path and the time horizon of deleveraging remains uncertain since in their model the complete deleveraging occurs in one period - "short term". In contrast, in our model, the deleveraging process is carried out over several periods determined endogenously based on the optimal deleveraging decisions of borrowers and entrepreneurs. This is achieved by linking agents'

individual level of debt to the interest rates they pay. Our specification builds on an extension of the Eggertsson and Krugman (2012) [51] baseline model and is also employed by Benigno, Eggertsson and Romei (2014) [14]. Under the modeling design we use, borrowers are not at the corner of their borrowing constraint but instead choose their optimal level of debt, taking into account that the higher level of debt corresponds to a higher "risky" borrowing interest rate.

2.1.7 MAIN FINDINGS OF THE PAPER

In a frictionless environment, deleveraging should have no impact on real economic activity. Prices and rates adjust freely to facilitate the adjustment process and relative price movements operate as shock absorbers. The real interest rate falls to maintain demand unaltered, by motivating economic agents who hold assets to increase consumption and investment. Thus, following the deleveraging shock, adjustment is achieved through a sharp fall in the real interest rate that stimulates savers to increase consumption. In broad terms, the real interest rate serves as an intertemporal price that governs borrowing and lending. As over-indebted borrowers are urged to reduce their debt, their spending contracts as a larger share of income gets allocated to pay off debt. As a result, the lower demand for loans drives the real interest rate down. Since in a closed economy, the debt of some agents is an asset for others, the real interest rate has to fall enough to motivate lenders to pick up the slack in consumption by spending their savings.

However, without fully flexible markets, the presence of nominal and real rigidities prevents the optimal adjustment of prices and rates, causing a drop in output. Any constraint or rigidity that impedes the adjustment mechanism prolongs and deepens the economic contraction. Our baseline model specification incorporates price rigidities⁵. The presence of nominal rigidities slows price adjustments, depresses aggregate demand and causes a contraction in output. In addition, falling prices open the door for Fisherian debt dynamics (Fisher, 1933 [59]). As debt is denominated in nominal units, deflation increases the real burden of debt and urges borrowers to deleverage more aggressively. Falling prices practically transfer wealth from borrowers to lenders, further reducing demand. This dynamic reinforcing mechanism aggravates the recession and amplifies the drop in output.

⁵In Appendix A.6, we introduce also a zero lower bound (ZLB) on the nominal deposit rate.

Modeling the deleveraging process, our analysis points to several key conclusions. First, for comparable levels of debt overhang in the household and corporate sectors, the corporate deleveraging has a modestly larger negative impact on economic activity which is driven by the fact that investment is much more responsive during a period of debt reduction. The drop in investment is several times larger in magnitude compared to the fall in consumption. The collapse in investment can be explained by the fact that during a recession incentives to invest plummet as the factors of production already in existence are underused. Thus, new investment is low since production is already well below capacity.

A second key prediction of the model is the amplification of the economic downturn in the case of a simultaneous deleveraging of more than one sector. This result is consistent with the empirical findings of Lo and Rogoff (2015) [97] and Bornhorst and Arranz (2014) [26]. The intuition is straightforward: over-indebted sectors allocate a larger portion of their income to pay off debt, trying to reduce it to a sustainable level. This causes a drop in consumption and investment. Other sectors in the economy have to pick up the slack in demand left by the deleveraging sector. If more sectors are deleveraging simultaneously, there is less capacity in the economy to counteract the drop in demand and respectively the economic contraction is larger.

As discussed, while the liabilities of borrowers are assets for lenders, the demand lost from deleveraging agents is not fully offset by lenders when the economy has rigidities that prevent the free adjustment of prices and rates. The level of structural rigidities in the economy affects the smooth completion of the adjustment process. Due to nominal and real rigidities and the Taylor rule, rates and prices fail to adjust enough to motivate creditors to absorb the additional savings in the economy and maintain total demand. In countries suffering from debt overhang, the transition to the new equilibrium passes through the reallocation of capital and labor from losing to profitable enterprises. Hence, the speed of adjustment depends on the flexibility of labor and product markets. The negative impact that rigidities have on the depth and magnitude of the economic contraction presents a strong case for structural reforms geared towards reducing them. We demonstrate that structural reforms geared towards decreasing nominal rigidities ameliorate the negative impact of the deleveraging process. A faster and more efficient price adjustment allows the economy to maintain higher levels of consumption and investment.

In addition, monetary policies can be used to alleviate the contraction in economic activity accompanying the debt reduction effort of the private sector. Monetary easing reduces the interest

rate burden of borrowers and also the interest rate that savers receive on their deposits, motivating them to expand consumption. A proactive Central Bank that is highly responsive to any deviation of the economy from the steady state strengthens agents' confidence and generates self-fulfilling expectations that decrease the negative impacts of private deleveraging.

The remainder of the chapter is organized as follows. Section 2.2 introduces the model and discusses the deleveraging shock. Section 2.3 describes the model parametrization, while section 2.4 discusses the simulation results and the transmission dynamics. Under a plausible parameterization of the model, we explore the interactions between the deleveraging sectors. In section 2.5 we consider the roles of structural reforms and monetary policy in alleviating the negative impact of deleveraging. Section 2.6 concludes.

2.2 MODEL

We model the implications of sectoral debt reduction on economic activity: the impact on output, consumption, investment and prices. As mentioned in the introduction, we expand the model of Eggertsson and Krugman (2012) [51] by introducing heterogeneous borrowers, productive capital, and an endogenously determined deleveraging process. For the actual deleveraging impulse - the Minsky moment - we follow Eggertsson and Krugman (2012) [51] and model it as an unexpected shift in the optimal level of debt for each sector. The Minsky moment hits the financial system and alters the risk profile of borrowers, increasing endogenously their interest rate risk premium⁶. The spread between the lending rates and the deposit (policy) rate in the model depends on the amount of outstanding debt of each borrower over the "safe" level. Therefore, a drop in the "safe" level of debt widens interest rate spreads which limits agents' ability to roll over and service their obligations, forcing them to reduce their debt.

Following the Minsky moment, leveraged households face higher borrowing costs which incentivizes them to repay part of their debt over time. The risk premium on loans depends on the financial intermediators' view on the sustainable level of debt that borrowers can service. The core driving force behind the deleveraging shock in the model is the notion that lenders' perception of the "safe" level of leverage is subject to change over time. While during extended periods of

⁶The risk premium in the model has the form of interest rate spreads between the deposit (risk-free) rate and borrowing rates.

economic growth agents are willing to take a more relaxed stance on debt, this position is bound to change and the change is often sudden and unexpected.

In broad terms, the model consists of three types of households: savers, borrowers and entrepreneurs. Consumption goods in the economy are produced by a continuum of monopolistically competitive firms that employ labor and capital as inputs in their production function. The risk-free nominal interest rate in the economy i_t^d is set by a Central Bank using a Taylor rule. In addition, the model contains price rigidities a la Calvo⁷. The model is specified with the aim of achieving a tractable and transparent mechanism of private debt deleveraging. With this goal, we abstract from modeling a fully developed financial and government sectors. The details of the model are presented below.

2.2.1 HOUSEHOLDS

We model a continuum of households of measure 1. The model has three types of households with shares:

- χ_b - borrowers
- χ_s - savers
- χ_e - entrepreneurs

where

$$\chi_b + \chi_s + \chi_e = 1$$

All types of households consume a continuum of goods of measure 1 that are imperfect substitutes. Consumption goods are aggregated using a Dixit-Stiglitz aggregator with an elasticity of substitution determined by the parameter θ , giving producers market power and the ability to set prices⁸. Based on the Dixit-Stiglitz consumption aggregator, a consumption bundle C_t^i is given by

⁷In Appendix A.6, we add nominal interest rate rigidities - a zero lower bound on i_t^d - as an extension to the baseline model in order to trace how this friction adds to the gravity of the crisis.

⁸The assumption that individual consumption goods are imperfect substitutes and firms are able to set prices allows for the introduction of nominal price rigidities that have an important role for the dynamics of the model.

$$C_t^i = \left[\int_0^1 c_t^i(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}$$

where $i = s, b, e$ refers to the type of household and $c_t(j)$ is the quantity of good j consumed by the household in period t . If we denote with P_t the corresponding aggregate price index, its form is

$$P_t = \left[\int_0^1 p_t(j)^{1-\theta} dj \right]^{\frac{1}{1-\theta}}$$

where $p_t(j)$ is the price associated with good j . Households allocate their consumption expenditure among different goods with the objective of maximizing utility. As the utility function is strictly increasing in consumption, this corresponds to maximizing the consumption bundle C_t for any given level of total expenditure. The optimal allocation of household consumption gives the demand equation for each individual good j . The consumption amount of each individual variety $c_t(j)$ relative to the total aggregate consumption bundle C_t depends on the ratio of the individual price $p_t(j)$ to the aggregate price index P_t ⁹.

$$c_t^i(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} C_t^i$$

where again $i = s, b, e$ refers to the type of household and j denotes the individual variety. We now turn to the optimization problems of the individual household types.

BORROWERS

Consistent with the empirical literature discussed in the introduction (Jauch and Watzka, 2012 [83] and Baker, 2015 [11]), borrowers in the model are more impatient. Therefore, by construction, borrowers have a higher propensity to consume out of current income, which is achieved through a lower discount factor β_b ($0 < \beta_b < 1$). Borrowers have to borrow to sustain their desired level of consumption. Since borrowers discount the future more heavily, they have a positive stock of debt in the steady state. The utility function of a representative borrower is

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_b^t \left[u^b(C_t^b) - v^b(h_t^b) \right] \tag{2.1}$$

⁹Detailed derivations are provided in Appendix A.1.

where \mathbb{E}_0 denotes the standard expectations operator; β_b is the intertemporal discount factor and C_t^b is the consumption bundle of the continuum of goods produced by firms. The function $v^b(\cdot)$ measures the disutility of labor and h_t^b stands for hours worked.

Borrowers are subject to the following budget constraint

$$P_t C_t^b + (1 + i_{t-1}^b) B_{t-1} = P_t W_t h_t^b + B_t - P_t T_t^b \quad (2.2)$$

where B_t is nominal debt; P_t is the aggregate price index associated with the consumption bundle C_t^b ; W_t denotes the real wage paid per hour worked and T_t^b are lump-sum taxes (lump-sum transfers) paid/received by borrowers. Borrowers receive labor income from firms and pay taxes (or receive transfers) to the government. Current income each period is used for consumption and to service debt obligations taken in the previous period. Furthermore, each period borrowers decide on the amount of new borrowing they will take.

The nominal risk-free rate in the model is presented by the interest rate on deposits i_t^d . While all depositors face the same deposit rate i_t^d , the rate each borrower faces i_t^b depends on his **individual level** of debt. The borrowing interest rate on loans i_t^b is higher than the interest rate paid on deposits. The spread between the deposit and borrowing rates is the premium that borrowers pay to banks and it depends on the individual level of debt each borrower holds¹⁰. While in equilibrium the level of nominal debt held by each borrower is the same, this assumption impacts the first order optimality conditions of borrowers. The relation between the deposit and borrowing interest rates has the form

$$(1 + i_t^b) = (1 + i_t^d) (1 + \omega_t) \quad (2.3)$$

The interest rate spread stems from the information asymmetry that exists between lenders and borrowers and is denoted by the term $\omega(\cdot)$. It can be justified with the costs associated with financial intermediation that banks bear. We provide more details on the derivations of the spread function later in the paper. The interest rate spread $\omega(\cdot)$ depends on borrowers' individual level of real debt $\frac{B_t}{P_t}$ relative to the "safe" level of debt b^j . Therefore,

¹⁰In assuming that the interest rate spread ω_t depends on the **individual level** of debt of each borrower, we follow Eggertsson and Krugman (2012) [51] and Benigno, Eggertsson, and Romei (2014) [14]. This setting differs from Curdia and Woodford (2010) [45] where the spread depends on the aggregate level of debt.

$$\omega_t = \omega\left(\frac{B_t}{P_t}, b^j\right) \quad \text{for } j = \text{high}, \text{low}$$

We assume that the derivative of the function $\omega(\cdot)$ with respect to the first argument is positive and it is negative with respect to the second argument. We also assume that $\omega(\cdot) > 0$ for every t .

Since the borrowing interest rate is higher than the deposit rate, banks that perform the role of financial intermediaries in the model earn profits. We follow Eggertsson and Krugman (2012) [51] and Benigno, Eggertsson, and Romei (2014) [14] and assume that all profits are rebated lump-sum to savers who own the banks.

Borrowers select consumption, borrowing, and hours of work to maximize utility (2.1) given their flow budget constraint (2.2) and the borrowing rate equation (2.3). In the model, borrowers internalize the fact that the borrowing rate they face is dependent on the amount of debt they hold. In other words, each agent's borrowing cost is affected by his individual debt decision. Therefore, when selecting their optimal amount of debt, borrowers take into account debt servicing costs.

For a representative borrower, combining the first order optimality conditions with respect to consumption C_t^b and nominal debt B_t , the following Euler equation is derived

$$u_c^b(C_t^b) = \beta_b (1 + i_t^b) \frac{u_c^b(C_{t+1}^b)}{\Pi_{t+1}} \left[1 + \frac{\omega_b\left(\frac{B_t}{P_t}, b^j\right) B_t}{1 + \omega_t} \frac{1}{P_t} \right]$$

where $u_c^b(\cdot)$ denotes the first derivative of the utility function with respect to consumption and $\omega_b(\cdot)$ denotes the first derivative of the spread function with respect to nominal debt B_t . The Euler equation of the borrower represents the inter-temporal trade-off between today's consumption and tomorrow's consumption. In addition, the optimal supply of labor implies that the marginal rate of substitution between labor and consumption equals the real wage

$$W_t = \frac{v_h^b(h_t^b)}{u_c^b(C_t^b)}$$

SAVERS

As the name suggests, savers do not need to borrow to meet their consumption. Instead, they hold deposits and collect the interest on them. To ensure that in a steady state savers will hold a positive amount of deposits that will be lent to borrowers, we assume that $0 < \beta_b < \beta < 1$, i.e.

savers discount the future less heavily than borrowers. In addition, in the model, savers own firms and financial intermediaries (banks) whose profits add to their income.

As in the case of borrowers, a representative saver maximizes his present discounted lifetime utility.

$$\max_{C_t^s, h_t^s, D_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t [u^s(C_t^s) - v^s(h_t^s)]$$

subject to the budget constraint

$$P_t C_t^s + D_t = P_t W_t h_t^s + (1 + i_{t-1}^d) D_{t-1} + \int Z_t^s(i) di + \int V_t^s(i) di + P_t F_t^s - P_t T_t^s$$

Using consistent notation, C_t^s denotes the consumption bundle; h_t^s are hours worked; D_t is the volume of nominal deposits held by savers; i_t^d is the nominal interest rate on deposits; and T_t^s are lump-sum taxes (transfers). In addition, since in the model savers own firms and banks, V_t^s accounts for the profits from retail firms while Z_t^s reflects profits from banks. Also, F_t^s is the income from stealing distributed among savers¹¹.

As savers hold deposits and do not borrow, they face no other constraint except the budget constraint. Therefore, savers' optimal choices are governed by the standard Euler equation

$$u_c^s(C_t^s) = \beta (1 + i_t^d) \frac{u_c^s(C_{t+1}^s)}{\Pi_{t+1}}$$

which is the inter-temporal trade-off between today's and tomorrow's consumption. The left-hand side of the Euler equation is the marginal benefit of consuming today, while the right-hand side stands for the marginal utility foregone by not saving one's income to be consumed in the next period. In addition, similar to borrowers, the marginal trade-off between consumption and labor is given by

$$W_t = \frac{v_h^s(h_t^s)}{u_c^s(C_t^s)}$$

ENTREPRENEURS

Entrepreneurs are introduced into the model to proxy the investment behavior of non-financial corporations in the economy. As discussed in the introduction, during the credit boom preceding

¹¹A detailed explanation of the concept of "stealing" and its role in the financial intermediation process is provided in a separate subsection on financial intermediation.

the financial crisis, both the household and corporate sectors experienced a rapid increase in debt. The onset of the crisis revealed the need for an aggressive deleveraging in both sectors and the subsequent balance sheet adjustment caused a sharp and sizable decrease in private investment that contributed to the fall in output. The model aims at incorporating these empirical observations and capturing these dynamics. In the model, we make the assumption that entrepreneurs have access to investment opportunities while savers can only invest in deposits offered by banks. This motivates lending and borrowing.

Similar to borrowers, entrepreneurs need to borrow to finance their consumption and investment. However, they are not endowed with labor. Instead, entrepreneurs accumulate capital that does not enter into their utility function, but generates income when rented out to firms for production. The entrepreneurs hold capital and rent it to firms at the rental price $P_t R_t^K$. In addition, in the model, entrepreneurs' investment in new capital is subject to an investment adjustment cost $\Phi(\cdot)$ that affects their optimal choice of investment¹².

A representative entrepreneur maximizes his discounted lifetime utility¹³

$$\max_{C_t^e, b_t^e, K_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_e^t [u^e(C_t^e)] \quad (2.4)$$

subject to a budget constraint and the standard law of accumulation of capital

$$P_t C_t^e + P_t I_t + (1 + i_{t-1}^e) B_{t-1}^e + P_t \Phi(I_t) = P_t R_t^K K_t + B_t^e - P_t T_t^e \quad (2.5)$$

$$K_t = I_t + (1 - \delta) K_{t-1} \quad (2.6)$$

The notation is consistent with the other two agent types in the model. C_t^e is the consumption bundle; B_t^e is the amount of nominal debt; i_t^e is the borrowing interest rate for entrepreneurs; and T_t^e are lump-sum taxes (transfers). Also, K_t is the capital stock owned by entrepreneurs, I_t denotes the investment bundle, and R_t^K is the real rental price of capital. As already defined, $\Phi(\cdot)$ is the investment adjustment cost.

¹²The size of the investment adjustment cost affects the extent to which entrepreneurs will adjust their spending by cutting investment. If the adjustment cost is close to zero, i.e. $\Phi(\cdot) \rightarrow 0$, then investment will be reduced substantially. If the adjustment cost is very high, i.e. $\Phi(\cdot) \rightarrow \infty$, then any adjustment will be achieved by a reduction in consumption.

¹³Notice that since entrepreneurs are not endowed with labor and hold only capital, there is no disutility from labor in their utility function.

Similar to borrowers, the interest rate faced by each entrepreneur depends on the **individual level** of debt that the entrepreneur holds. Therefore, entrepreneurs are not price takers with respect to the borrowing cost i_t^e . They internalize that their level of debt affects the interest rate they pay. Therefore, this affects their individual borrowing decision. This is reflected in the equations governing the interest rate of entrepreneurs.

$$(1 + i_t^e) = (1 + i_t^d) (1 + \omega_t^e) \quad (2.7)$$

$$\omega_t^e = \omega^e \left(\frac{B_t^e}{P_t}, b^{e,j} \right) \quad \text{for } j = \textit{high, low}$$

where $\omega^e(\cdot)$ is the interest rate spread between the borrowing and deposit rates and $b^{e,j}$ is the optimal "safe" level of debt for entrepreneurs.

Entrepreneurs choose consumption, borrowing and capital to maximize their utility (2.4) given their budget constraint (2.5), the law of motion of capital (2.6), and the interest rate and wedge equations (2.7) which leads to the following Euler equation

$$u_c^e(C_t^e) = \beta_e u_c^e(C_{t+1}^e) \frac{1 + i_t^e}{\Pi_{t+1}} \left[1 + \frac{\omega_b^e \left(\frac{B_t^e}{P_t}, b^{e,j} \right) B_t^e}{1 + \omega_t^e P_t} \right]$$

Since entrepreneurs also hold and invest in capital, their optimization problem is enhanced by an additional optimality condition - a no-arbitrage condition - that relates the interest rate for entrepreneurs to the return on capital

$$(1 - \delta) [1 + \Phi_K(I_{t+1})] = [1 + \Phi_K(I_t) - R_t^K] \frac{1 + i_t^e}{\Pi_{t+1}} \left[1 + \frac{\omega_b^e \left(\frac{B_t^e}{P_t}, b^{e,j} \right) B_t^e}{1 + \omega_t^e P_t} \right]$$

2.2.2 FINANCIAL INTERMEDIATION

An important element of the model is the presence of endogenously determined spreads between the deposit and borrowing interest rates. As discussed in the previous section, the spread functions $\omega(\cdot)$ and $\omega^e(\cdot)$ depend on agents' individual level of debt relative to a "safe" level. In the previous section, we introduced the spread functions. Here we provide further details on the financial intermediation process and derive the functions. The derivations in this section follow closely Eggertsson and Krugman (2012) [51] where also agents' individual level of debt affects the interest rate that they

face¹⁴. This assumption allows borrowers to internalize the fact that they hold debt above the optimal "safe" threshold. Thus, in the case of over-indebtedness, interest rate spreads widen and trigger a process of deleveraging.

We assume that in addition to households and firms, the modeled economy is comprised of a continuum of banks with the sole function of accepting deposits from savers $D_t(j)$ and supplying loans to borrowers and entrepreneurs $B_t(j)$ and $B_t^e(j)$. The activity of the financial intermediaries (banks) in the model is quite simple. Banks raise liquidity from savers at the risk-free nominal deposit interest rate i_t^d and lend to borrowers at the higher rates i_t^b and i_t^e . For simplicity, we assume that there are banks that lend only to either borrowers or entrepreneurs. Per our set up, loans and deposits are paid back in full (principal and interest) in the next period, i.e. we use one period loans and deposits. Let us consider a "bank" as the life of a single loan contract. Then bank's profits $Z_t(j)$ earned from this contract are denoted by

$$Z_t(j) = \frac{D_t(j)}{P_t} - \frac{B_t(j)}{P_t} - \Gamma_t\left(\frac{B_t(j)}{P_t}, b^j\right) + \mathbb{E}_t \Omega_{t,t+1} \left[(1 + i_t^b) \frac{B_t(j)}{P_{t+1}} - (1 + i_t^d) \frac{D_t(j)}{P_{t+1}} \right] \quad (2.8)$$

where $\Omega_{t,t+1}$ is a stochastic discount factor and $\Gamma(\cdot)$ is the cost associated with financial intermediation. We employ the modeling assumption of Eggertsson and Krugman (2012) [51] and postulate that the financial intermediation cost is increasing in the level of real debt $\frac{B_t(j)}{P_t}$ and its deviation from the "safe" debt level b^j ¹⁵. The functional form of $\Gamma(\cdot)$ is

$$\Gamma_t\left(\frac{B_t(j)}{P_t}, b^j\right) = \tilde{\kappa} \frac{B_t(j)}{P_t} + \Xi \left(e^{\frac{B_t(j)}{P_t} - b^j} \right)$$

where $0 < \tilde{\kappa} < 1$ and $\Xi > 0$. The intermediation cost function is convex and strictly increasing.

Based on Eggertsson and Krugman (2012) [51], we also make the simplifying assumption that bank profits from the loan contract are distributed back to bank's owners in period t when the loan is issued. As a consequence, the bank holds enough assets to only pay off the depositors in the next period $t + 1$. This assumption implies that

¹⁴Eggertsson and Krugman (2012) [51] adopt the basic structure of a loan contract from Curdia and Woodford (2010) [45]. However, they modify Curdia and Woodford (2010) [45] by imposing that the borrowing interest rate spread is increasing in borrower's own level of debt instead of aggregate debt. Benigno, Eggertsson, and Romei (2014) [14] follow the modelling approach taken by Eggertsson and Krugman (2012) [51] and make the same assumption.

¹⁵As in Eggertsson and Krugman (2012) [51], the intermediation cost is motivated by the presence of "bad borrowers" who pose for good borrowers, "steal" away their loans and do not pay them back. For more details, please refer to Eggertsson and Krugman (2012) [51].

$$(1 + i_t^b)B_t(j) = (1 + i_t^d)D_t(j)$$

which can be rewritten as

$$D_t(j) = \frac{(1 + i_t^b)}{(1 + i_t^d)}B_t(j)$$

Substituting this relationship in the equation for bank's profits (2.8) and also using the functional form of $\Gamma(\cdot)$ produces

$$Z_t(j) = \frac{(1 + i_t^b)}{(1 + i_t^d)} \frac{B_t(j)}{P_t} - \frac{B_t(j)}{P_t} - \left[\tilde{\kappa} \frac{B_t(j)}{P_t} + \Xi \left(e^{\frac{B_t(j)}{P_t} - b^j} \right) \right]$$

Note the last term of the profits equation (2.8) drops out because, given the assumption that $(1 + i_t^b)B_t(j) = (1 + i_t^d)D_t(j)$, the expression in square brackets becomes 0.

Banks have the objective of maximizing their profits by choosing the amount of loans they provide. Differentiating with respect to $B_t(j)$ the expression above, we obtain that

$$\left(\frac{(1 + i_t^b)}{(1 + i_t^d)} - 1 \right) = \tilde{\kappa} + \Xi \left(e^{\frac{B_t(j)}{P_t} - b^j} \right) \quad (2.9)$$

However, if we turn to the interest rate differential between i_t^b and i_t^d as specified in equation (2.3), then

$$(1 + i_t^b) = (1 + i_t^d)(1 + \omega_t)$$

$$\omega_t = \left(\frac{(1 + i_t^b)}{(1 + i_t^d)} - 1 \right) \quad (2.10)$$

Therefore, the functional form of the interest rate spread is derived from the optimality conditions of the bank. By combining equations (2.9) and (2.10), it follows that

$$\omega_t \left(\frac{B_t}{P_t}, b^j \right) = \tilde{\kappa} + \Xi \left(e^{\frac{B_t(j)}{P_t} - b^j} \right)$$

where $0 < \tilde{\kappa} < 1$, and $\Xi > 0$. Introducing the notation $\kappa = \tilde{\kappa} + \Xi$, the interest rate spread can be written as

$$\omega_t \left(\frac{B_t}{P_t}, b^j \right) = \kappa + \Xi \left(e^{\frac{B_t(j)}{P_t} - b^j} - 1 \right)$$

A closer observation of the derived functional form of $\omega_t(\cdot)$ reveals some of its properties. The spread function is continuous, differentiable and strictly convex. The interest rate spread functions in Eggertsson and Krugman (2012) [51] and Benigno, Eggertsson, and Romei (2014) [14] all share these properties. When the real stock of debt corresponds to the “safe” level (which holds in the deterministic steady state we compute), the interest rate spread is equal to κ . Therefore, κ is the spread between the deposit and borrowing interest rates in the steady state. That spread increases in the case of a debt overhang when real debt exceeds the “safe” threshold. The parameter Ξ controls the extend to which the spread widens in response to the debt overhang¹⁶.

Following an identical reasoning, we derive the interest rate spread of entrepreneurs. Making the simplifying assumption that some banks lend only to borrowers and others only to entrepreneurs, we go over the same steps for a bank that lends to entrepreneurs to obtain the functional form of $\omega^e(\cdot)$ which is

$$\omega_t^e\left(\frac{B_t^e}{P_t}, b^{e,j}\right) = \kappa^e + \Xi^e \left(e^{\frac{B_t^e(j)}{P_t} - b^{e,j}} - 1 \right)$$

2.2.3 FIRMS

On the supply side, the model incorporates monopolistically competitive firms that use labor and capital supplied by households through competitive factor markets to produce goods. We assume there is a continuum of firms of measure 1 and each firm is producing each variety of the consumption good. Firms employ a Cobb-Douglas production function of the form

$$y_t(j) = k_t^\alpha(j) l_t^{1-\alpha}(j)$$

Based on the structure of household demand (i.e. the Dixit-Stiglitz consumption aggregator), the demand for each good j produced by firms is¹⁷

$$y_t(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} Y_t$$

¹⁶The form of $\omega_t(\cdot)$ is similar to the functional form of the risk premium specified in Schmitt-Grohe and Uribe (2003) [69] that examines the relationship between the interest rate faced by domestic agents and the aggregate level of foreign debt of a country. Their authors calibrate the parameter Ξ to match the volatility of the current-account-to-GDP ratio.

¹⁷For a detailed derivation of the demand equation faced by each firm, refer to Appendix A.2.

All firms are driven by the objective of maximizing their profits. Therefore, they select optimal allocations of inputs to achieve this goal. Firms maximize profits each period t by solving the optimization problem

$$\max_{l_t(j), k_t(j)} [p_t(j)y_t(j)] - [P_t W_t l_t(j) + P_t R_t^K k_t(j)]$$

s.t.

$$y_t(j) = k_t^\alpha(j) l_t^{1-\alpha}(j)$$

The first term in square brackets is the total revenue a firm earns from production and the second term is the total cost. The optimization problem of profit maximization implies a problem of cost minimization. In every period t , a firm decides on the optimal allocations of labor and capital that minimize its costs for any given level of production. Analytically, this is presented as

$$\min_{l_t(j), k_t(j)} P_t W_t l_t(j) + P_t R_t^K k_t(j)$$

s.t.

$$k_t^\alpha(j) l_t^{1-\alpha}(j) = \bar{y}$$

The optimality condition derived from this minimization problem characterizes the relationship between firms' optimal demand of capital and labor in the production process. The optimal allocations of capital and labor used by firms depend on the prices of the two inputs.

$$W_t l_t(j) = \left(\frac{1-\alpha}{\alpha} \right) R_t^K k_t(j) \tag{2.11}$$

In the model, firms are subject to price rigidities. We assume Calvo pricing and impose that firms can readjust prices each period with probability $(1 - \gamma)$ where $0 < \gamma < 1$. In this setting, each firm that adjust its price chooses the same price P_t^* that maximizes the present discounted value of its profits under the assumption that the selected price will remain in place. We make the simplifying assumption that firms are owned by savers and we use their discount factor to discount future profits. The problem faced by firms when setting the price P_t^* can be written as¹⁸

¹⁸The detailed derivations of Calvo pricing are provided in Appendix A.3.

$$\max_{P_t^*} \mathbb{E}_t \sum_{T=t}^{\infty} \left\{ (\gamma\beta)^{T-t} \left[\frac{u_c^s(C_T^s) P_t}{u_c^s(C_t^s) P_T} \right] \left[P_t^* y_T(j) - \left(\frac{1}{\alpha} \right)^\alpha \left(\frac{1}{1-\alpha} \right)^{1-\alpha} (P_T W_T)^{1-\alpha} (P_T R_T^K)^\alpha y_T(j) \right] \right\}$$

s.t.

$$y_T(j) = \left[\frac{P_t^*(j)}{P_T} \right]^{-\theta} Y_T$$

The solution of the optimal pricing problem above yields a relationship between the general price index P_t and the optimal price selected by firms that are able to adjust their prices P_t^*

$$\frac{P_t^*}{P_t} = \frac{\frac{\theta}{\theta-1} \sum_{T=t}^{\infty} (\gamma\beta)^{T-t} u_c^s(C_T^s) \left(\frac{P_T}{P_t} \right)^\theta Y_T \left(\frac{1}{\alpha} \right)^\alpha \left(\frac{1}{1-\alpha} \right)^{1-\alpha} W_T^{1-\alpha} R_T^{K,\alpha}}{\sum_{T=t}^{\infty} (\gamma\beta)^{T-t} u_c^s(C_T^s) \left(\frac{P_T}{P_t} \right)^{\theta-1} Y_T} \quad (2.12)$$

Furthermore, Calvo pricing implies a law of motion of the general price index that has the form

$$P_t = \left[(1-\gamma) (P_t^*)^{1-\theta} + \gamma P_{t-1}^{1-\theta} \right]^{\frac{1}{1-\theta}}$$

and can also be rewritten as

$$\left(\frac{P_t^*}{P_t} \right) = \left[\frac{1 - \gamma \Pi_t^{-(1-\theta)}}{1 - \gamma} \right]^{\frac{1}{1-\theta}} \quad (2.13)$$

Lastly, introducing an index of price dispersion denoted by $\Delta_t \equiv \int \left(\frac{p_t(j)}{P_t} \right)^{-\theta} dj$, we can obtain the law of motion

$$\Delta_t = (1-\gamma) \left(\frac{P_t^*}{P_t} \right)^{-\theta} + \gamma \Delta_{t-1} \Pi_t^\theta \quad (2.14)$$

The three equations (2.12), (2.13), and (2.14) determine the path of prices in the model.

2.2.4 AGGREGATION

To complete the characterization of the model, we equate supply and demand in each market. The total aggregate consumption in the economy is the sum of the consumption of savers, borrowers and entrepreneurs weighted by their respective shares, i.e. $C_t = \chi_s C_t^s + \chi_b C_t^b + \chi_e C_t^e$ and also for each variety we have $c_t(j) = \chi_s c_t^s(j) + \chi_b c_t^b(j) + \chi_e c_t^e(j)$. Since we model a closed economy, the total output of firms is distributed among consumption, investment, and government expenditure G_t . This can be written as

$$Y_t = C_t + \chi_e (I_t + \Phi(I_t)) + G_t$$

Investment I_t enters also in the standard law of accumulation of capital $K_t = I_t + (1 - \delta) K_{t-1}$ where the depreciation rate is denoted by δ .

Turning to the labor market, in equilibrium the total labor employed by firms equals the sum of the labor provided by borrowers and savers. Therefore, $L_t = \chi_s h_t^s + \chi_b h_t^b$. Also, looking at production, the Cobb-Douglas production function employed by each firm has the form $y_t(j) = k_t^\alpha(j) l_t^{1-\alpha}(j)$. Taking into account the downward sloping demand faced by firms $y_t(j) = \left[\frac{p_t(j)}{P_t}\right]^{-\theta} Y_t$ and the fact that by construction both factor markets in the model are competitive with only one variety of capital and labor, we can derive that

$$Y_t \Delta_t = (\chi_e K_t)^\alpha L_t^{1-\alpha}$$

where $\Delta_t \equiv \int \left(\frac{p_t(j)}{P_t}\right)^{-\theta} dj$ is the index of price dispersion as specified before.

Also, from the optimizing behavior of firms (2.11), we obtain the relationship

$$W_t L_t = \left(\frac{1-\alpha}{\alpha}\right) R_t^K (\chi_e K_t)$$

As a next step, we turn to agents' budget constraints and introduce the notation $b_t = \frac{B_t}{P_t}$ and $b_t^e = \frac{B_t^e}{P_t}$. We derive a link between income, spending and real debt for borrowers and entrepreneurs

$$b_t = C_t^b - W_t h_t^b + T_t^b + (1 + i_{t-1}^b) b_{t-1} \Pi_t^{-1}$$

$$b_t^e = C_t^e + I_t + \Phi(I_t) - R_t^K K_t + T_t^e + (1 + i_{t-1}^e) b_{t-1}^e \Pi_t^{-1}$$

The model is closed with the specification of a monetary policy rule used by the Central Bank. The nominal risk-free interest rate in the economy i_t^d follows the Taylor rule¹⁹

$$i_t^d = i^d + \phi_\Pi (\Pi_t - 1) + \phi_Y \ln \left(\frac{Y_t}{\bar{Y}}\right)$$

¹⁹In Appendix A.6, we consider a zero lower bound restriction on the nominal interest rate i_t^d that changes the Taylor rule formula to $i_t^d = \max \left\{ 0, i^d + \phi_\Pi (\Pi_t - 1) + \phi_Y \ln \left(\frac{Y_t}{\bar{Y}}\right) \right\}$.

2.2.5 DEFINITION OF EQUILIBRIUM IN THE MODEL

Definition: An equilibrium is a sequence of prices $\left\{i_t^d, i_t^b, i_t^e, \omega_t, \omega_t^e, W_t, R_t^K, \frac{P_t^*}{P_t}, \Pi_t, \Delta_t\right\}_{t=0}^{\infty}$ and a sequence of policy rules $\left\{b_t, b_t^e, C_t^b, C_t^s, C_t^e, h_t^b, h_t^s, Y_t, I_t, K_t, C_t, L_t\right\}_{t=0}^{\infty}$, such that in every period t the following conditions are satisfied:

- households' optimality conditions
- firms' optimality conditions
- market clearing conditions
- and also the Taylor rule holds.

2.2.6 SUMMARY OF EQUILIBRIUM CONDITIONS

Due to its complexity, the model can not be solved analytically. Therefore, to analyze the impact of a deleveraging shock on economic activity in the model we use numerical simulations. To perform the simulations, we need to make assumptions about the functional forms of $u^i(\cdot)$, $\nu^i(\cdot)$ and $\Phi(\cdot)$.

Household preferences are characterized by the isoelastic utility function

$$u^i(C_t^i) = \frac{(C_t^i)^{1-\xi^i}}{1-\xi^i}$$

where $i = b, s, e$. Similarly, the disutility from labor has the form

$$\nu^i(h_t^i) = \frac{(h_t^i)^{1+\varepsilon^i}}{1+\varepsilon^i}$$

Both functional forms are standard in the literature.

Next, the capital adjustment cost is given by

$$\Phi(I_t) = \frac{1}{2}\zeta \left[\frac{I_t}{K_{t-1}} - \delta \right]^2 K_{t-1}$$

Substituting the law of accumulation of capital $I_t = K_t - (1 - \delta)K_{t-1}$ into the equation above, we express the adjustment cost as a function only of capital

$$\Phi(K_t) = \frac{1}{2}\zeta [K_t - K_{t-1}]^2 \frac{1}{K_{t-1}}$$

In addition, for computational simplicity, we rewrite the Calvo pricing relationship (2.12). We denote the infinite sum in the numerator with PN_t and in the denominator with PD_t . Then equation (2.12) can be expressed as

$$\frac{P_t^*}{P_t} = \frac{\frac{\theta}{\theta-1}PN_t}{PD_t}$$

where both PN_t and PD_t are defined recursively as

$$PN_t = u_c^s(C_t^s)Y_t \left(\frac{1}{\alpha}\right)^\alpha \left(\frac{1}{1-\alpha}\right)^{1-\alpha} W_t^{1-\alpha} (R_t^K)^\alpha + \gamma\beta\Pi_{t+1}^\theta PN_{t+1}$$

$$PD_t = u_c^s(C_t^s)Y_t + \gamma\beta\Pi_{t+1}^{\theta-1}PD_{t+1}$$

The above specifications complete the list of equations that form the system and allows for the model to be simulated numerically. The non-linear model is comprised of 24 endogenous variables and 24 equations. The list of endogenous variables is

$$\left\{ i_t^d, i_t^b, i_t^e, \omega_t, \omega_t^e, b_t, b_t^e, C_t^b, C_t^s, C_t^e, h_t^b, h_t^s, Y_t, W_t, \frac{P_t^*}{P_t}, PN_t, PD_t, \Pi_t, \Delta_t, I_t, R_t^K, K_t, C_t, L_t \right\}$$

Also, the full list of equilibrium conditions of the model are presented below in a systemic way.

The interest rates of borrowers and depositors are related through

$$(1 + i_t^b) = (1 + i_t^d)(1 + \omega_t) \tag{2.15}$$

where the borrowers' interest rate spread has the form derived in the section on financial intermediation

$$\omega_t = \kappa + \Xi \left(e^{b_t - b^j} - 1 \right) \tag{2.16}$$

where b^j denotes the "safe" level of debt. Similarly, the interest rate of entrepreneurs relates to the deposit interest rate through

$$(1 + i_t^e) = (1 + i_t^d)(1 + \omega_t^e) \tag{2.17}$$

and the interest rate spread for entrepreneurs is

$$\omega_t^e = \kappa^e + \Xi^e \left(e^{b_t^e - b^{e,j}} - 1 \right) \quad (2.18)$$

and $b^{e,j}$ denotes the "safe" level of debt for entrepreneurs.

On the demand side, the Euler equation of borrowers is

$$\frac{1}{(C_t^b)^{\xi_b}} = \beta_b \frac{(1 + i_t^b)}{\Pi_{t+1}} \frac{1}{(C_{t+1}^b)^{\xi_b}} \left[1 + \frac{\Xi^e e^{b_t - b^j}}{1 + \kappa + \Xi (e^{b_t - b^j} - 1)} b_t \right] \quad (2.19)$$

the Euler equation of savers has the standard form

$$\frac{1}{(C_t^s)^{\xi_s}} = \beta \frac{(1 + i_t^d)}{\Pi_{t+1}} \frac{1}{(C_{t+1}^s)^{\xi_s}} \quad (2.20)$$

and the Euler equation of entrepreneurs is

$$\frac{1}{(C_t^e)^{\xi_e}} = \beta_e \frac{(1 + i_t^e)}{\Pi_{t+1}} \frac{1}{(C_{t+1}^e)^{\xi_e}} \left[1 + \frac{\Xi^e e^{b_t^e - b^{e,j}}}{1 + \kappa^e + \Xi^e (e^{b_t^e - b^{e,j}} - 1)} b_t^e \right] \quad (2.21)$$

In addition, there is a no-arbitrage condition that relates the entrepreneurs' interest rate to the return on capital

$$\begin{aligned} (1 - \delta) + \zeta \left(\frac{K_{t+1}}{K_t} - 1 \right) + \frac{1}{2} \zeta \left(\frac{K_{t+1}}{K_t} - 1 \right)^2 = \\ = \left[1 + \zeta \left(\frac{K_t}{K_{t-1}} - 1 \right) - R_t^K \right] \frac{1 + i_t^e}{\Pi_{t+1}} \left[1 + \frac{\Xi^e e^{b_t^e - b^{e,j}}}{1 + \kappa^e + \Xi^e (e^{b_t^e - b^{e,j}} - 1)} b_t^e \right] \end{aligned} \quad (2.22)$$

Households' optimization determines also the supply of labor. The labor supply of borrowers is

$$W_t = (h_t^b)^{\varepsilon_b} (C_t^b)^{\xi_b} \quad (2.23)$$

and the labor supply of savers is

$$W_t = (h_t^s)^{\varepsilon_s} (C_t^s)^{\xi_s} \quad (2.24)$$

Optimal price setting using Calvo pricing is characterizes by the following three equations:

$$\frac{P_t^*}{P_t} = \frac{\theta}{\theta - 1} \frac{PN_t}{PD_t} \quad (2.25)$$

where the recursive definition of PN_t is

$$PN_t = \frac{1}{(C_t^s)^{\xi_s}} Y_t \left(\frac{1}{\alpha}\right)^\alpha \left(\frac{1}{1-\alpha}\right)^{1-\alpha} W_t^{1-\alpha} (R_t^K)^\alpha + \gamma\beta\Pi_{t+1}^\theta PN_{t+1} \quad (2.26)$$

and the recursive definition of PD_t is

$$PD_t = \frac{1}{(C_t^s)^{\xi_s}} Y_t + \gamma\beta\Pi_{t+1}^{\theta-1} PD_{t+1} \quad (2.27)$$

In addition, aggregate prices follow the process

$$\left(\frac{P_t^*}{P_t}\right) = \left[\frac{1 - \gamma\Pi_t^{-(1-\theta)}}{1 - \gamma}\right]^{\frac{1}{1-\theta}} \quad (2.28)$$

and the index of price dispersion $\Delta_t \equiv \int \left(\frac{p_t(i)}{P_t}\right)^{-\theta} di$ has the following law of motion

$$\Delta_t = (1 - \gamma) \left(\frac{P_t^*}{P_t}\right)^{-\theta} + \gamma\Delta_{t-1}\Pi_t^\theta \quad (2.29)$$

Total consumption in the model is the sum of the consumption of individual agent types

$$C_t = \chi_s C_t^s + \chi_b C_t^b + \chi_e C_t^e \quad (2.30)$$

Goods markets in the economy clear as real output equals aggregate demand

$$Y_t = C_t + \chi_e \left[I_t + \frac{1}{2}\zeta \left(\frac{I_t}{K_{t-1}} - \delta\right)^2 K_{t-1} \right] + G_t \quad (2.31)$$

The standard law of accumulation of capital is

$$K_t = I_t + (1 - \delta) K_{t-1} \quad (2.32)$$

Agents' real debt is described by the flow budget constraint of borrowers

$$b_t = C_t^b - W_t h_t^b + T_t^b + (1 + i_{t-1}^b) b_{t-1} \Pi_t^{-1} \quad (2.33)$$

and the flow budget constraint of entrepreneurs

$$b_t^e = C_t^e + I_t + \frac{1}{2}\zeta \left(\frac{I_t}{K_{t-1}} - \delta\right)^2 K_{t-1} - R_t^K K_t + T_t^e + (1 + i_{t-1}^e) b_{t-1}^e \Pi_t^{-1} \quad (2.34)$$

The labor market in the model also clears

$$L_t = \chi_s h_t^s + \chi_b h_t^b \quad (2.35)$$

Aggregate supply is determined by the Cobb-Douglas production function

$$Y_t \Delta_t = (\chi_e K_t)^\alpha L_t^{1-\alpha} \quad (2.36)$$

and the relationship between labor demand and capital demand is

$$W_t L_t = \left(\frac{1-\alpha}{\alpha} \right) R_t^K (\chi_e K_t) \quad (2.37)$$

The model is closed with the monetary policy rule of the Central Bank - Taylor rule.

$$i_t^d = i^d + \phi_\Pi (\Pi_t - 1) + \phi_Y \ln \left(\frac{Y_t}{\bar{Y}} \right) \quad (2.38)$$

2.2.7 STEADY STATE

Based on the full system of equilibrium conditions, we characterize the steady state of the economy. We consider a steady state where the equilibrium level of debt is equal to the optimal "safe" level. Here we provide some of the core calculations for the estimation of the steady state. The remaining steps are described in Appendix A.4.

In the steady state prices are stable and therefore we set $P_t = P_{t-1} = P_t^*$, $\Pi_t = \frac{P_t}{P_{t-1}} = 1$ and $\frac{P_t^*}{P_t^*} = 1$. Using the savers' Euler equation (2.20) and imposing a steady state, we derive that

$$i^d = \frac{1}{\beta} - 1$$

Also, using the Euler equation of borrowers and assuming that $\bar{b} = b^j$ ²⁰, we derive that

$$\frac{1}{\Xi} \left[\frac{\beta}{\beta_b} - 1 - \kappa + \Xi \right] = 1 + b^j$$

The above identity can be satisfied by any combination of values of the exogenous parameters κ , Ξ and b^j . However, since in the parametrization of the model the values of κ and b^j are calibrated to target the steady state interest rate spread and the debt level, the above equation helps to determine the value of the parameter Ξ when κ and b^j are given

²⁰We assume that the steady state level of debt corresponds to the "safe" level of debt b^j determined by banks which is exogenously provided to the model.

$$\Xi = \frac{1}{\bar{b}^j} \left(\frac{\beta}{\beta_b} - 1 - \kappa \right)$$

The parameter κ is selected to target the steady state interest rate spread based on the equation

$$(1 + i^b) = \frac{1}{\beta} \left(1 + \kappa + \Xi \left(e^{\bar{b}-b^j} - 1 \right) \right)$$

where the last term is 0 since $\bar{b} = b^j$. Then, for any value of i^b , we can back out κ

$$\kappa = (1 + i^b) \beta - 1$$

and from equation (2.16) and the assumption that $\bar{b} = b^j$, we can conclude that the steady state spread is κ

$$\bar{\omega} = \kappa$$

Similarly, from the Euler equation of entrepreneurs and assuming that $\bar{b}^e = b^{e,j}$ it follows that

$$\Xi^e = \frac{1}{b^{e,j}} \left(\frac{\beta}{\beta_e} - 1 - \kappa^e \right)$$

and κ^e can be selected to target a steady state interest rate i^e . Therefore, the value of i^e can be freely selected and then κ^e is backed out

$$\kappa^e = (1 + i^e) \beta - 1$$

and from (2.18)

$$\bar{\omega}^e = \kappa^e$$

Combining the equilibrium conditions of the model, we fully characterized the steady state. A detailed strategy for calculating the steady state and all the derivations are presented in Appendix A.4.

2.3 CALIBRATION

To carry out the numerical simulation of the non-linear model, we specify the model's deep parameters. The objective of the calibration is not to reproduce a specific event, but rather to capture the

effects of deleveraging produced by the model that are quantitatively relevant under a reasonable parametrization. The baseline parameters of the model are provided in Table 2.1. The time period is a quarter.

The calibration of the model parameters follows Eggertsson and Krugman (2012) [51]. To achieve lending and borrowing at the steady state, borrowers and entrepreneurs discount the future more heavily than savers which implies that $\beta_e = \beta_b < \beta$. The discount factor $\beta = 0.995$ is selected to yield an annual risk free interest rate of 2% in the final steady state. The discount factors of the other two types of agents are selected to be $\beta_b = \beta_e = 0.96$. The depreciation rate of capital targets an annual rate of 24% as in Eggertsson and Krugman (2012) [51]. Also following their paper, we specify the value of the Calvo coefficient of price rigidity at $\gamma = 0.9$. The elasticity of labor supply of borrowers and savers is set to $\varepsilon = 3.03$. The consumption elasticity of substitution is set to 1 for all agent types, i.e. $\xi_s = \xi_e = \xi_b = 1$. In addition, we use Eggertsson and Krugman (2012) [51] to set the steady state annual interest rate on loans to 8% for both borrowers and entrepreneurs. This pins down the values of the parameters $\kappa = 0.0149$ and $\kappa_e = 0.0149$.

In determining the initial level of debt, we follow Cuerdo et al. (2013) [44] and assume that it equals to 80% of annual GDP. Since our goal is to evaluate and compare the macroeconomic impact of deleveraging when only one or both private sectors are reducing their leverage, we assume that both sectors have an identical initial stock of debt. This is a simplifying assumption that facilitates comparability and makes the analysis more transparent. The steady state level of debt after the deleveraging effort, i.e. the new "safe" level of debt, is set to 65% of GDP for both agent types. The size of the deleveraging shock (i.e. the reduction in the "safe" level of debt) is analogous to the one in Cuerdo et al. (2013) [44].

It is important to detail the derivation of the parameters Ξ and Ξ_e . Based on the steady state calculations, the values of the two parameters are determined from the steady state level of debt. However, in a simulation, the model transitions from a high debt equilibrium to a new low debt equilibrium. In the first period of the simulation, the model is pushed towards the new low debt steady state by an exogenous reduction in the "safe" level of debt. Since period one, the model is moving towards the new steady state. Therefore, the saddle path that leads to the new steady state is defined by the parameters that describe the new equilibrium. Consequently, we use the values of Ξ and Ξ_e that correspond to the new low "safe" level of debt.

The share of each household type is set to produce a reasonable drop in output, consumption and investment. Furthermore, the entrepreneurs' share χ_e corresponds to the average ratio of business investment to GDP in the Euro Area. Borrowers are 30% of the total, while entrepreneurs are set to 20%²¹. Finally, the Central Bank monetary policy rule in the model has the form of a Taylor rule. We choose that the policy response to inflation deviations ϕ_Π is 1.5, while the response to output deviations ϕ_y is 0.125. Both coefficients are standard in the literature (Schmitt-Grohe and Uribe, 2012 [70]; Gali, 2008 [64])²².

2.4 DELEVERAGING SIMULATION

Using the parametrization specified above, we simulate the non-linear system of equations²³. The deleveraging shock is introduced into the system as an unexpected fall in the risk attitude of lenders. The sustainable level of leverage suddenly drops and the model gradually transitions from a high debt steady state to a low debt one. The unexpected drop in lenders' risk tolerance places the modeled economy out of equilibrium at the start of the simulation. Mechanically, we initialize the model at the high debt equilibrium and at period 1, we push it towards the low debt equilibrium by exogenously reducing the "safe" levels of debt b^j and/or $b^{j,e}$. The exogenous deleveraging shock leaves one or both types of leveraged agents over-indebted. As the initial stock of debt is higher than the new "safe" level, this translates into a debt overhang for the affected sector(s). After the introduction of the exogenous shock, the model converges to its new steady state where agents' debt levels are again aligned with the new lower "safe" debt threshold. After the realization of the initial shock, the model is deterministic. Agents have a perfect foresight. Even though this is a strong assumption, Hall (2011) [76] affirms that perfect-foresight models provide a good account of the mechanisms at play in a dynamic model once the initial stress is realized.

We examine the process of adjustment of agents' balance sheets and trace the impact of deleveraging on the variables in the model. A core aspect of the paper is the analysis of the transmission of the deleveraging shock between the household and corporate sectors. We investigate the existing

²¹The average share of business investment in GDP for the Euro Area over the last 20 years is 20.2%.

²²When enriching the model in Appendix A.6 by introducing a zero lower bound on the nominal interest rate set by the Central Bank, the inflation coefficient ϕ_Π is too low for the model to converge. To resolve the problem, we increase the responsiveness of the Central Bank to deviations in inflation. The value of the policy response coefficient is increased from 1.50 to 1.74, i.e. $\phi_\Pi = 1.74$.

²³The simulation of the model is performed using Dynare - a software package for the solution of DSGE models (WWW.DYNARE.ORG).

links between sectors and how debt overhang in one sector affects negatively the other and the total economy. Model simulation results establish that a leading channel of transmission of the deleveraging shock is through input factor markets. The fall in demand accompanying the initial response of the over-indebted sector to the deleveraging shock has a negative impact on production. Consequently, the demand for factors of production also suffers. This second round effect harms the other sector. Since aggregate demand falls, the demand for factors of production also drops, shrinking wages and return on capital which are the sources of income for individuals. The fall in factors' demand and the corresponding fall in capital return and wages has a direct impact on agents' ability to consume and service their debt obligations.

The environment of weak demand affects sectoral income. The hit on disposable income aggravates the fall in consumption and investment and deepens the crisis. In addition, depressed aggregate demand and falling wages also drive prices down through the fall in marginal costs, creating deflation²⁴. Since the stock of debt is in nominal terms, any fall in prices leads to a wealth transfer from borrowers to lenders, intensifying the need for deleveraging. The Fisherian dynamics of nominal debt naturally appear in the model and reflect the problem faced by several peripheral Euro Area economies. We describe in further details the deleveraging process when either borrowers or entrepreneurs or both sectors have to cope with debt overhang.

2.4.1 BORROWERS' DELEVERAGING

Figure 2.2 presents the transitional dynamics of the model when borrowers experience a debt overhang²⁵. After the "safe" level of debt for borrowers is reduced exogenously, the risk premium that borrowers have to pay spikes up. As leveraged agents internalize the higher cost of borrowing they need to pay, borrowers embark on a process of deleveraging that suppresses their consumption until the new lower steady state level of indebtedness is achieved. Aggregate consumption falls 1% below its steady state level driven by the lower spending of indebted agents. Following the initial shock, in the first four quarters of the simulation, output also falls 1.8% below its steady state level. In the closed economy, the plunge in demand translates directly into a lower production which damages factor demand for the two production inputs: labor and capital.

²⁴Final good prices fall after factor prices due to the modeled price rigidities.

²⁵Figures A.1 and A.2 in appendix A.5 present the path of all the endogenous variables in the model in the quarters following the borrowers' deleveraging shock.

Since stagnant production needs less capital as input, investment reacts sharply downwards in the model in spite of the presence of adjustment costs. Consistent with empirical data, the fall in investment is several times larger compared to the drop in consumption and, at its trough, investment falls 6.2% below its steady state level. As factor demand drops following the initial deleveraging shock, wages and return on capital have to decline for aggregate factor markets to clear. The decrease is quite large - around 10% for both factor prices. The reduction in wages can be traced back also to the increased supply of labor by borrowers who attempt to boost their income while deleveraging. On the other hand, the return on capital is determined by the no-arbitrage condition, i.e. it depends on the real interest rate and on the capital adjustment costs. As factor prices fall, final goods prices follow suit, causing a period of deflation that lasts for more than three years.

As the economy plunges into a recession, the Central Bank reduces the riskless deposit interest rate in the short run to combat the negative output gap and price deflation. The reduction of the policy rate serves two objectives. First, it decreases leveraged agents' debt servicing costs, thus assisting the deleveraging process. Second, the drop in the deposit (risk-free) interest rate stimulates savers' consumption and discourages saving. In addition, while borrowers are increasing their supply of labor in the model, savers cut on their work hours as the drop in wages increases the relative value of leisure. Savers' willingness to cut on labor and increase consumption is supported also by the fact that all interest rate spread income earned by banks is transferred to them, further boosting their disposable income at the expense of the leveraged borrowers.

The slowdown in economic activity affects also the other type of leveraged agents - entrepreneurs. The fall in the return on capital R^K decreases entrepreneurs' disposable income. They react by adjusting consumption and investment downwards. Cutting on current investment allows for a smaller decrease in consumption and assists entrepreneurs' consumption smoothing. However, the second-round negative effect on demand is substantial. The decrease in entrepreneurs' income, coupled with an effort to preserve consumption, cause entrepreneurs to accumulate more debt in the initial phase of the deleveraging process. As they accumulate more and more debt, it becomes costlier to finance current consumption through external financing. Furthermore, entrepreneurs experience an initial spike in the real debt burden they face due to price deflation which affects negatively their spending capacity. An additional expense for entrepreneurs is the investment adjustment cost that they have to incur when decreasing investment in response to the economic contraction. In

summary, the second round effects of the deleveraging effort of borrowers impact the other indebted sector and their combined reaction leads to a sizable reduction in economic activity.

2.4.2 ENTREPRENEURS' DELEVERAGING

Figure 2.3 presents the case when entrepreneurs suffer from debt overhang²⁶. Entrepreneurs' debt deleveraging has a sizable negative impact on investment. As the interest rate spread increases, it becomes costlier for entrepreneurs to finance investment externally. At the same time, savers are stimulated to consume more and work less, while borrowers try to smooth consumption, but as leverage builds up, they also need to scale down demand. The rest of the model dynamics are broadly similar to the case of borrowers' deleveraging with some notable differences. Entrepreneurs' deleveraging is more detrimental to aggregate economic activity. Economic output falls by 2% from its steady state level compared to a 1.8% drop in the case of borrowers' debt overhang. The difference in the size of the impact is more pronounced when turning to investment - a 12% fall from the steady state level compared to a 6.2% fall when borrowers are deleveraging.

The widening of the entrepreneurs' interest rate spread triggers a deep drop in current investment. The reduction in investment is motivated by the decreased demand for productive capital. Investment in capital is affected by the recession that reduces investment incentives as factors of production remain underused and production is below capacity. Furthermore, the higher interest rate premium on credit pushes up the required return on capital (and hence marginal costs) above its steady-state level in the medium run. As final goods' prices depend on the weighted average of future marginal costs, inflation picks up amid the protracted recession episode. The risk premium shock can be viewed as a negative supply shock, because it raises the cost of productive capital.

2.4.3 TWO SECTOR SIMULTANEOUS DELEVERAGING

When both private sectors suffer a debt overhang and need to deleverage simultaneously, the model dynamics remain similar to the two previously discussed cases. In a closed economy model, the simultaneous debt reduction carried out by a large share of economic agents has a detrimental impact on aggregate demand. In spite of the accommodative stance of monetary policy, the remaining agents in the economy are not able to pick up the large slack in aggregate demand. As the number of agents

²⁶Figures A.3 and A.4 in appendix A.5 present the path of all the endogenous variables in the model in the quarters following the entrepreneurs' deleveraging shock.

that need to reduce leverage increases, there is a limited capacity in the rest of the economy to fill in the gap in domestic demand. As a result, the negative impact of the simultaneous deleveraging is augmented.

Figure 2.4 demonstrates the negative effect of a simultaneous debt reduction in comparison to the sum of individual sectors' deleveraging. It outlines the dynamics of six variables: output, aggregate consumption, investment, capital, inflation and the deposit (riskless) interest rate. The plots compare the macroeconomic impact of the deleveraging shock when both private sectors reduce debt simultaneously to the arithmetic sum of the impacts of the two sectors reducing debt separately. Figure 2.4 reveals that while the initial impact of the deleveraging impulse is comparable, the magnitude of the contraction augments through time in the case of a simultaneous deleveraging. Therefore, the aggregate impact on the economy is larger when more than one sector reduce debt concurrently. The sizable downturn is caused by the second round effects that reinforce the negative impact of the initial shock. When both sectors cut consumption and investment aggressively, the remaining economic agents are unable to compensate for the fall. Lower demand translates into lower factor demand and respectively lower income in the subsequent periods, intensifying the initial shock.

Going a step deeper, the interplay of nominal and real rigidities open the output gap during the period of debt deleveraging. The non-linear nature of these frictions determine the non-additivity of the impulses. Both capital adjustment costs and interest rate premia (two of the "imperfections" in the model) are convex functions and therefore, marginal costs increase with the size of the shock. When two sectors deleverage simultaneously, i.e. two shocks are jointly simulated, the second sector's deleveraging shock affects the economy when it is below its steady state. At that point, marginal costs are higher. This makes the transition to the new equilibrium more costly. The point is evident from the higher inflation rate in the case of a two sector deleveraging - higher costs lead to higher prices. Monetary policy, on the other hand, is still linear and does not recognize the higher adjustment costs when the two sectors deleverage simultaneously. The riskless interest rate is higher in the joint deleveraging case in order to counteract the increase in inflation that picks up as a response to the higher costs of economic adjustment. The higher policy interest rate further impedes consumption and stimulates savings, exacerbating the recession.

A policy conclusion from this analysis is that when the economy is facing a large shock and/or multiple shocks that augment on each other, monetary policy needs to be more accommodative.

Monetary authorities should refrain from increasing nominal interest rates up too quickly in order to allow for a faster output recovery.

The gravity of the macroeconomic impact in the case of a multisectoral deleveraging is a core result of the model. As more sectors in the economy are facing deleveraging pressures, the potential impact of debt reduction is more damaging for the economy. This result is driven by the internal amplification mechanism of the model where second round effects are reinforcing the initial shock. In particular, the findings of the paper draw on the non-linearity of the model that provide more comprehensive dynamics of the deleveraging process.

2.5 POLICY ANALYSIS

In the previous section, we presented the core mechanisms governing the deleveraging process and how they impact the total economy. The simulation results demonstrate that a relatively small reduction in debt has a sizable impact on real variables and prices. The drop in economic activity is particularly severe when more than one sector reduces its debt. Given the contraction in output, it is important to consider policies that can reduce the negative impact of the deleveraging shock and assist the economy in its adjustment to the new steady state. In this section, we analyze the effectiveness of structural reforms and monetary policy in ameliorating the economic downturn caused by the deleveraging shock.

2.5.1 STRUCTURAL REFORMS: REDUCTION IN PRICE RIGIDITIES

Figure 2.5 compares the impact of the deleveraging shock between the baseline specification and a scenario characterized by lower price rigidities: γ is decreased with 10% from 0.9 to 0.816. Lower price rigidities provide firms with larger flexibility to adjust their prices in response to the fall in aggregate demand following the deleveraging shock. By cutting prices, firms manage to maintain higher production volumes compared to the baseline. In addition, because of lower prices, economic agents are able to allocate portion of their income to debt repayment without decreasing real demand as steeply. Still, lower price rigidity has also a negative impact on borrowers as the real stock of debt of borrowers increases through debt deflation. More flexible prices cause a higher deflationary environment after the deleveraging shock is applied. However, assisted by the accommodative monetary policy, the positive effects of lower prices on demand outweigh the short lived

period of debt deflation. The preservation of real demand and final production assists the demand for factors of production which is higher compared to the baseline. The second round effects in the model are muted and the economy transitions faster to the new steady state (Figure 2.5). As factor markets are the drivers of the shock transmission, higher price flexibility ameliorates the impact on factors' demand and respectively diminishes the effect of the deleveraging shock.

Simulation results demonstrate that rigidities make deleveraging relatively more painful. The optimal reaction of the economy to the fall in demand is a downward adjustment in prices. When working properly, this mechanism allows for the maintenance of a stable level of real demand and employment. In the presence of rigidities, firms are unable to adjust prices as fast. As a consequence, firms reduce their demand for capital and labor.

Model simulation results confirm the important role of structural reforms aimed at reducing nominal rigidities and allowing for faster economic adjustments. As economic theory reiterates, the decrease in rigidities improves economy's ability to recover after a negative shock. In several European economies, the surge in credit has been accompanied by a construction boom and a sizable concentration of capital in the non-tradable sector. As a result, the economic recovery needs to go through a large sectoral reallocation of capital and labor (Cuerpo et al., 2013 [44]). Rigidities hinder this process prolonging the observed economic downturn and reforms that reduce them will speed up the transition.

2.5.2 STRUCTURAL REFORMS: MORE ELASTIC LABOR SUPPLY

Following the financial crisis, Europe has been plagued by a chronically high unemployment that has been explained by the rigidity of its labor market. While the model specification does not include labor market frictions in the form of nominal wage rigidities, it is an interesting exercise to explore whether the elasticity of labor supply would have a palpable impact on the economic response to the deleveraging shock. Given the detrimental effects of high unemployment on both the household income in the short term and the production capacity of the economy in the long term, we model the effects of a labor market reform that alters households' supply elasticity of labor. We simulate a scenario where the elasticity of labor is increased by reducing the model parameters ε_b and ε_s (both parameters are reduced from 3.03 to 1.51). The variables' path is presented in figure 2.6.

Due to the sizable price rigidity incorporated into the model, labor is largely demand driven. Still, the higher elasticity of labor supply impacts the simulation results. As one can expect, labor contracts by more in the scenario relative to the baseline, but as a consequence, wages are not as severely affected. The response of factor markets to the initial demand shock determines the second-round effects of depressed factor income on economic activity. Elastic labor supply facilitates the deleveraging because both factors of production - labor and capital - react to the shortage in demand. To substitute for the more elastic labor, investment does not fall by as much. Still, the short term fall in income due to the drop in labor affects consumption in the first ten quarters that decreases below the baseline. To equate factor markets, i.e. the higher capital-to-labor ratio in the more elastic labor supply case, wages do not need to fall down by as much as in the baseline. Higher wages and capital accumulation as a result of the more elastic labor supply affect positively the disposable income of both consumers and entrepreneurs, thus moderately improving aggregate demand and speeding the recovery.

2.5.3 MONETARY POLICY REFORM: RESPONSIVENESS OF THE CENTRAL BANK

In the model, the Central Bank reacts to the depressed economic environment following the deleveraging shock by lowering the monetary policy rate (the deposit rate i^d). The degree of Central Bank responsiveness to the negative economic shock impacts the recovery period. Simulations demonstrate (Figure 2.7) that a more proactive monetary policy stance supports a faster economic recovery, ameliorating the impact of the deleveraging shock. Figure 2.7 compares the baseline to a scenario where the coefficients of the Taylor rule are increased by 100%: ϕ_{π} is increased from 1.5 to 3 and ϕ_y from 0.125 to 0.250. Simulation results outline two findings. The impact of the deleveraging shock is muted, while at the same time, the fall of the policy rate is less severe. The model is forward looking and fully deterministic after the initial shock. Therefore, agents are able to incorporate the pro-active policy reaction of the Central Bank into their behavioral decisions. In the scenario with higher coefficients, deflation is not as severe at the beginning of the stress which ameliorates the impact of real debt deflation on borrowers. Both consumption and investment fall by less.

In the first period of the simulation after the deleveraging shock has been applied, the more proactive behavior of the Central Bank drives the real interest rate in the economy lower compared to the baseline. While in the baseline prices in the first period fall three times more, the drop in the

policy rate is less than two times larger. As a result, in the more responsive monetary policy case, the real rate becomes more negative which reduces the initial impact of the deleveraging shock on domestic demand as savers are stimulated to spend more. The lower contraction in demand limits the fall in production and respectively factor prices. This ameliorates the second round effects and the economy converges faster to the new steady state. Looking past the first period of the simulation, as the economic downturn in the baseline is larger, the marginal costs related to capital are higher while the economy adjusts to the new steady state. Since the inflation rate depends on the path of marginal costs, inflation in the baseline simulation pick ups which assists the Central Bank and reduces the real interest rate. Therefore, following the first period, real rates in the baseline simulation are actually lower for 40 quarter. However, as the proactive stance of the Central Bank in the more responsive monetary policy case limits the initial impact of the delevergaing shock, for the remained of the simulation the economy does not require low real rates to promptly converge to the new steady state.

As the model is deterministic and economic agents have full information of the reaction function of the monetary authority, households expect that the Central Bank will be highly proactive to return the economy back to equilibrium. Having that security, agents decrease demand by less compared to the baseline. However, this limits the fall in prices and respectively the wealth transfer from borrowers to lenders through the channel of debt deflation. As a result, the fall in demand is smaller compared to the baseline and the system transitions faster to the new equilibrium. The simulation results build an argument in favor of the proactive monetary policy stance many central banks took during the financial crisis.

2.6 CONCLUSION

The paper studies the implications of private debt overhang - a pressing problem in many developed economies since the 2008 financial crisis. To perform our analysis, we develop a formal model of sectoral deleveraging within the framework of a classical New Keynesian model and we explore the implications of a protracted period of debt reduction. A novelty of the model is that it simulates the deleveraging process when either the household or corporate sectors or both have accumulated debt above the equilibrium level. A sudden revision of the sustainable level of debt causes a prolonged

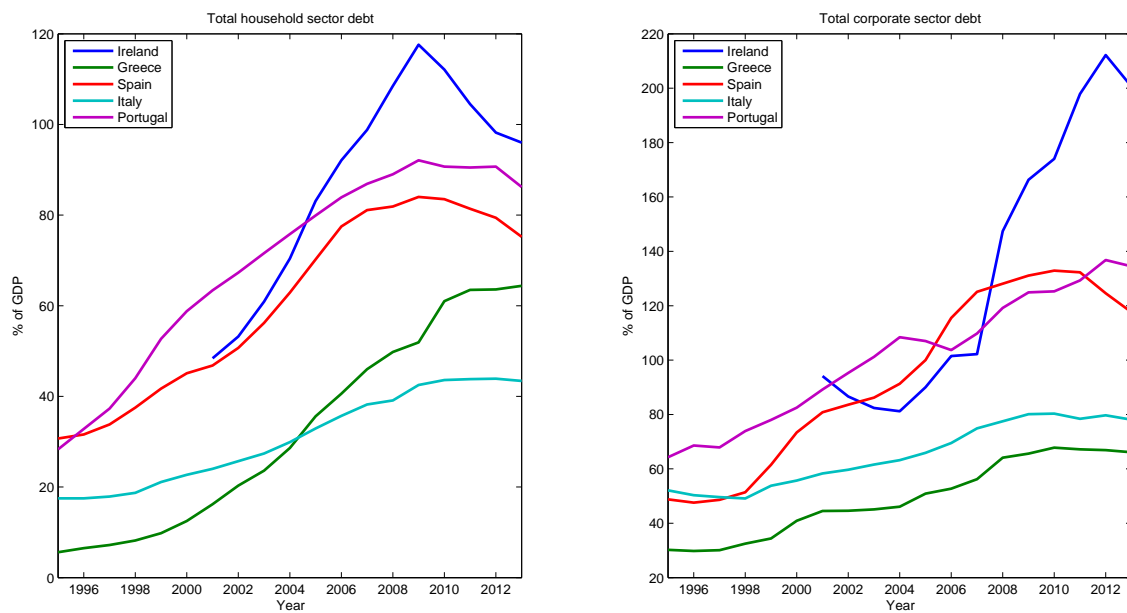
period of debt reduction accompanied by a drop in demand. Individual sectors engage in rebuilding their balance sheets until they achieve the new steady state level of debt.

As observed empirically, sectoral debt reduction has a significant negative impact on economic activity through the contraction of consumption and investment. For a short period of time, impact is further amplified by debt deflation. Due to the presence of sizable price rigidities in the economy, the deleveraging shock affects also employment as the fall in domestic demand translates into a fall of the demand for factors of production. Falling income from both labor and capital is in the core of the shock amplification mechanism of the model. While the initial impetus to pay off excessive debt weakens demand, the second round effect of shrinking income intensifies the contraction in spending. Furthermore, it spreads the negative shock to other sectors in the economy.

A core feature of the model is its ability to replicate the detrimental effects of a simultaneous sectoral deleveraging on economic activity as found in the empirical data. While empirical research has emphasized that the effects of deleveraging are intensified when other sectors in the economy try to reduce their debt, this paper is the first (to our knowledge) to explore the issue analytically in the framework of a New Keynesian model. Our analysis demonstrates that the simultaneous deleveraging of both household and corporate sectors is more damaging than the sum of individual sectors' deleveraging. This fact can be rationalized by the presence of convex capital adjustment costs and risk premia. In addition, within the framework of a closed economy, any reduction in spending by a group of agents has to be picked up by the remaining agents in the economy. As during simultaneous debt deleveraging a large portion of economic agents restrict their consumption and investment, there is less scope for remaining agents to fully offset the drop in domestic demand.

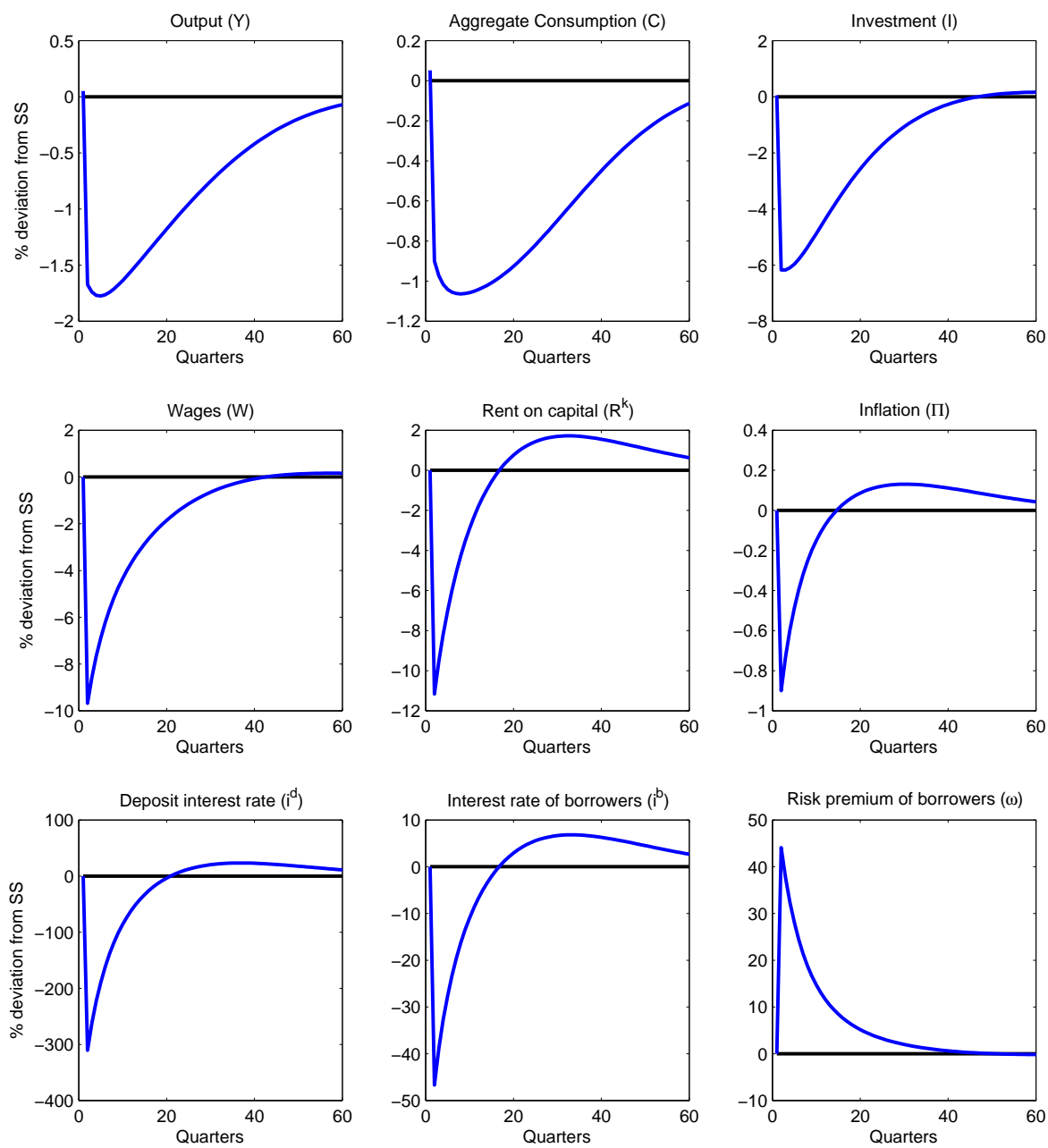
Having demonstrated the effects of the deleveraging process, we establish the key role of structural reforms in achieving a less severe economic downturn. Structural reforms that reduce economic rigidities contribute to a faster rebalancing process. Measures aimed at reducing nominal and real rigidities through labor and product market reforms are crucial for attenuating the impact of private sector deleveraging on economic activity and unemployment.

Figure 2.1: Private Sector Debt Accumulation



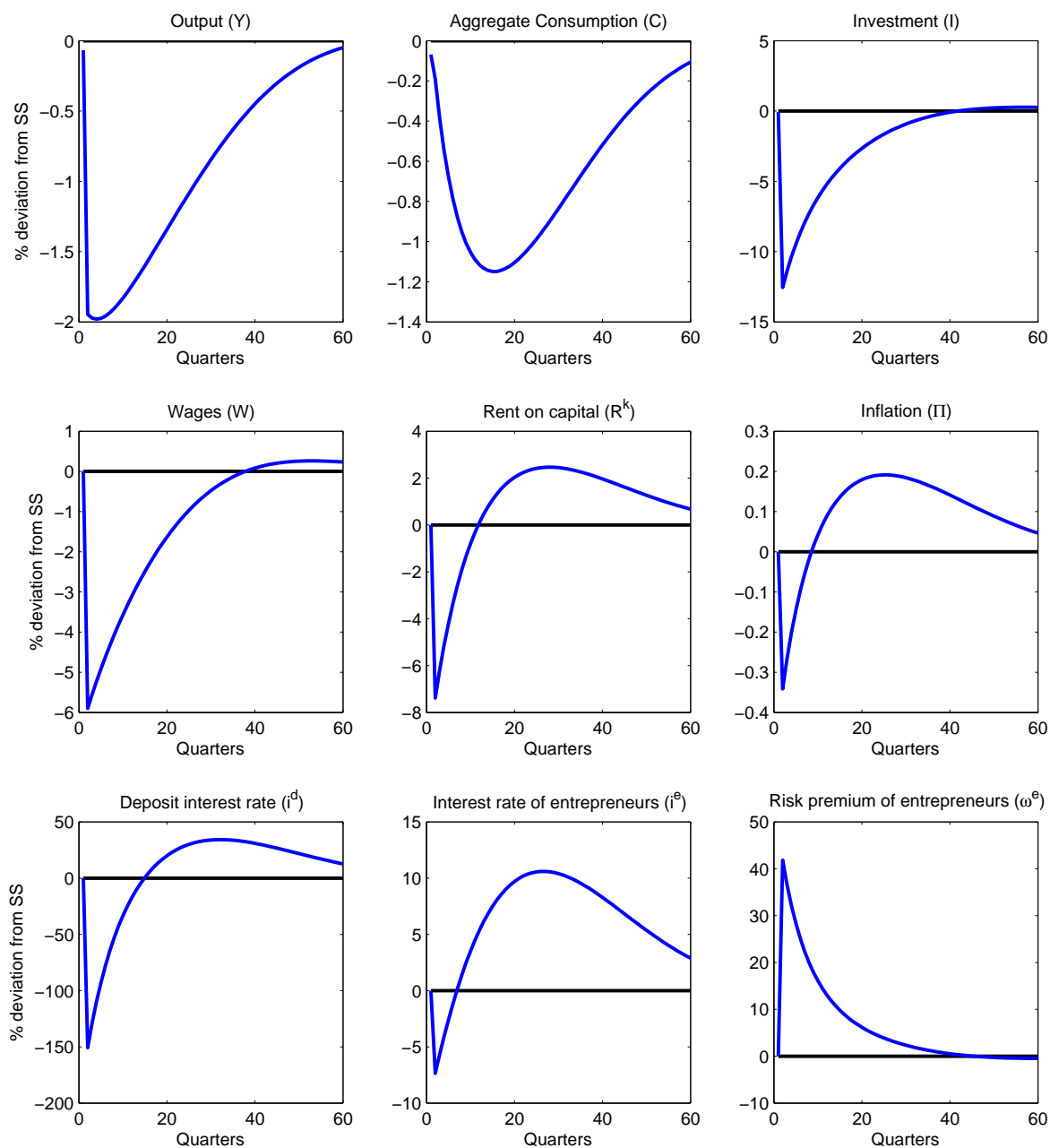
Note: The graph presents the expansion of household and corporate leverage since 1995. **Source:** EURO-STAT National Sector Accounts and author's calculations.

Figure 2.2: Economic Impact of Borrowers' Deleveraging



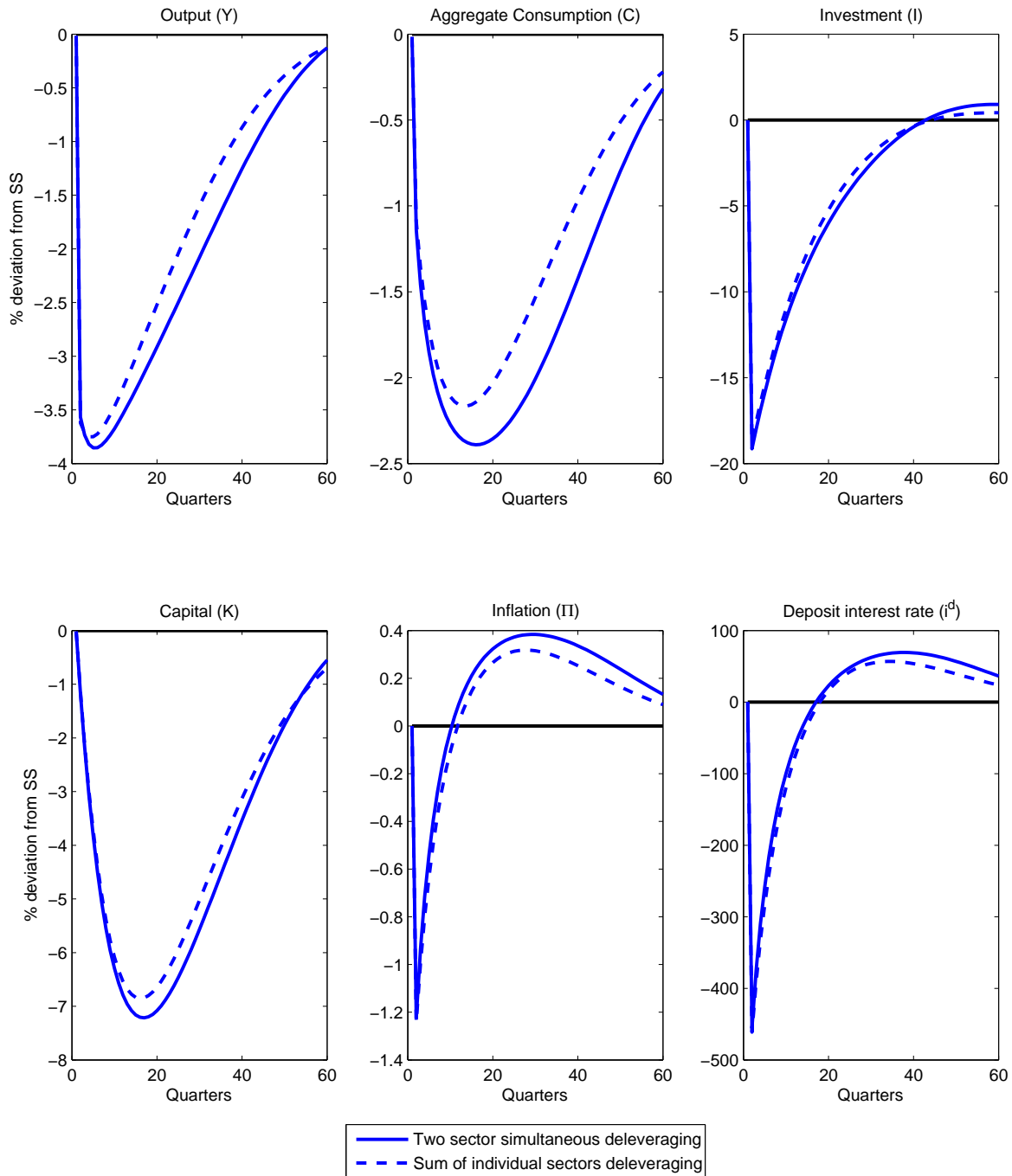
Notes: Responses of economic variables following a deleveraging shock to borrowers. In the simulation, the real debt of borrowers decreases to the new "safe" level. The plots cover the first 15 years of the simulation. All variables are presented in percentage point deviations from the steady state.

Figure 2.3: Economic Impact of Entrepreneurs' Deleveraging



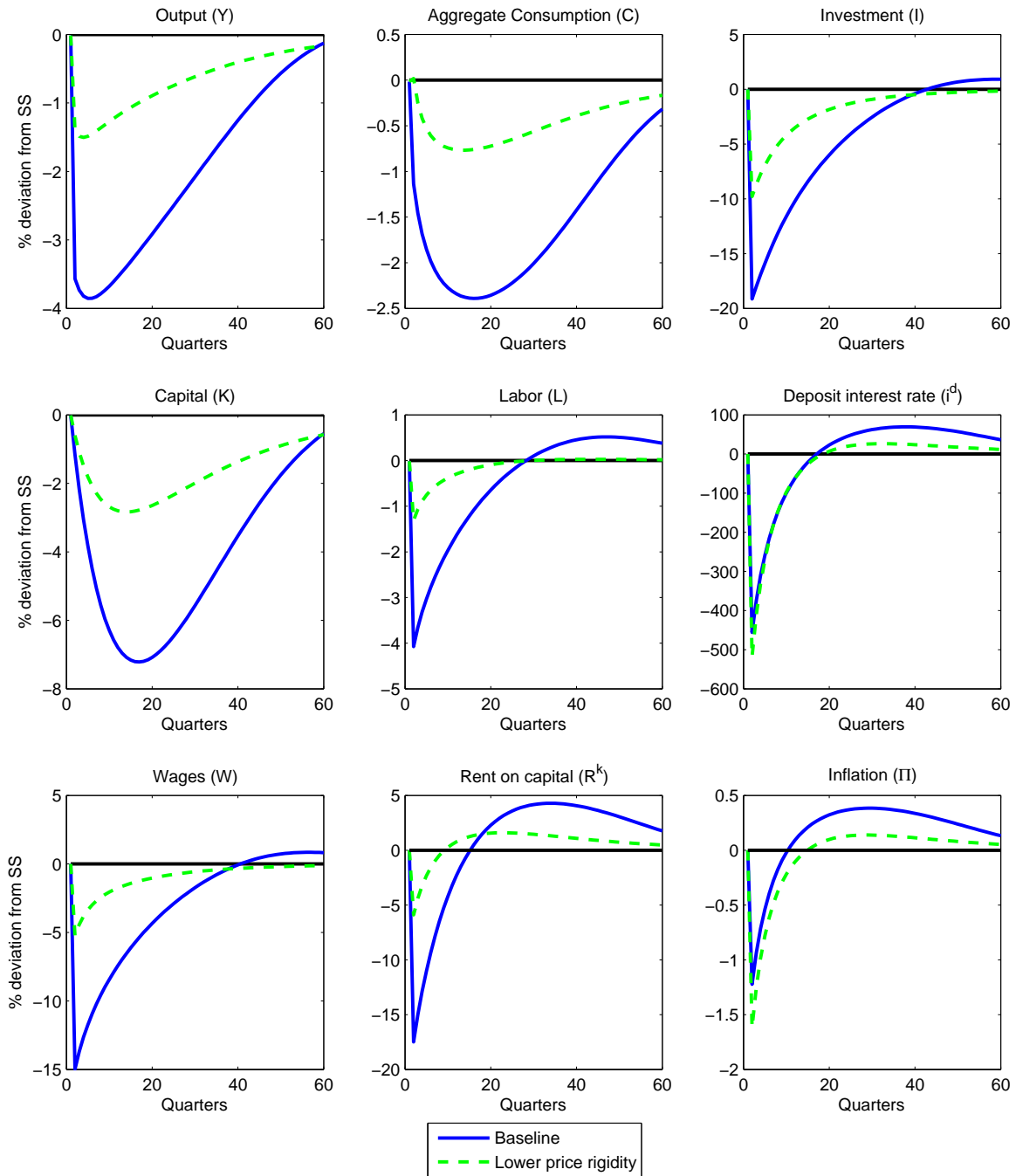
Notes: Responses of economic variables following a deleveraging shock to entrepreneurs. In the simulation, the real debt of entrepreneurs decreases to the new "safe" level. The plots cover the first 15 years of the simulation. All variables are presented in percentage point deviations from the steady state.

Figure 2.4: Two Sector Simultaneous Deleveraging and the Role of Non-Linearity



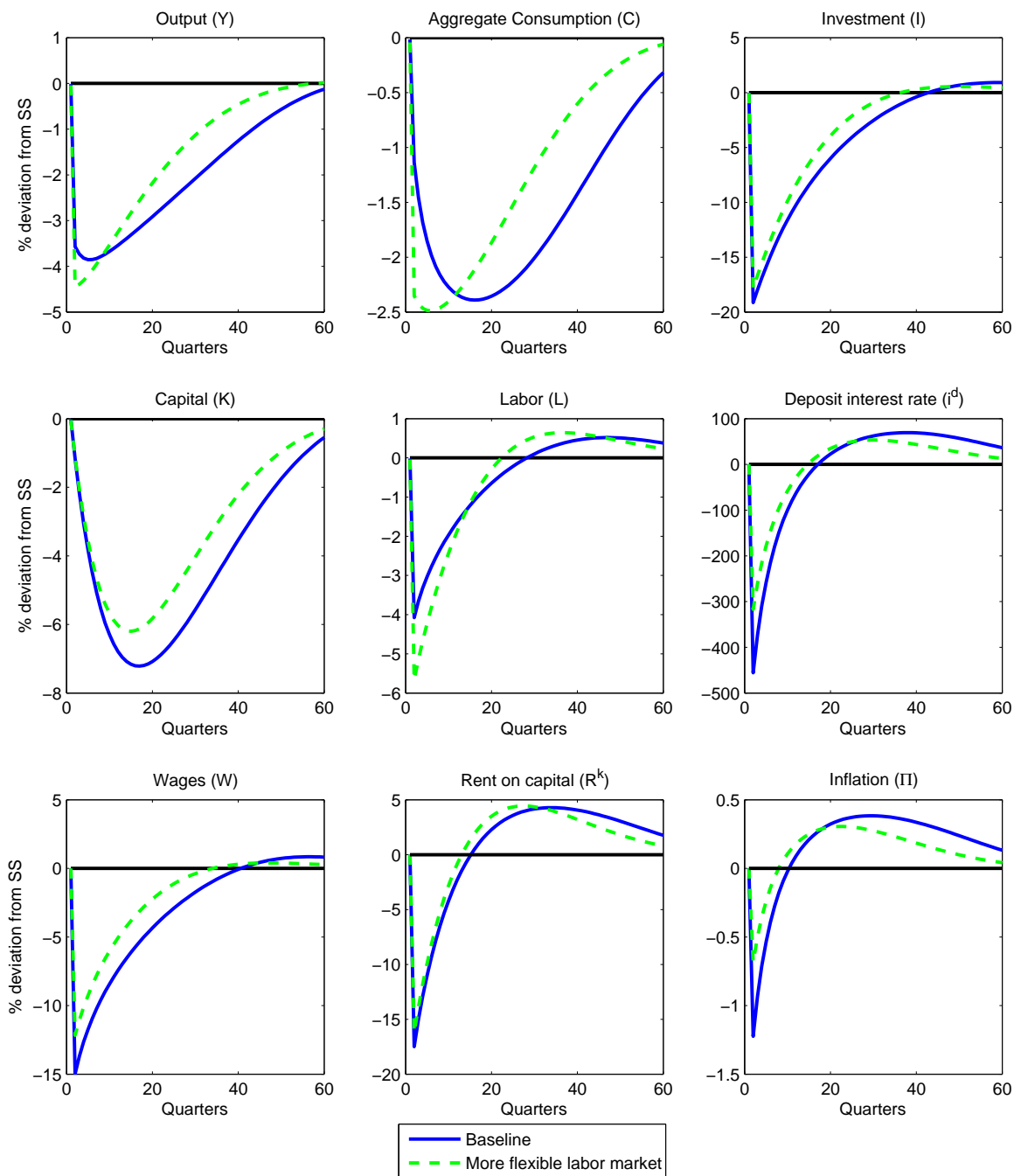
Notes: Responses of economic variables in the case of a two sector simultaneous deleveraging. The plots cover the first 15 years of the simulation. All variables are presented in percentage point deviations from the steady state. The continuous lines denote the series in the case of a simultaneous deleveraging. The dashed lines are the sum of the impacts when individual sectors are deleveraging.

Figure 2.5: The Role of Structural Reforms: 10% Reduction in Price Rigidities



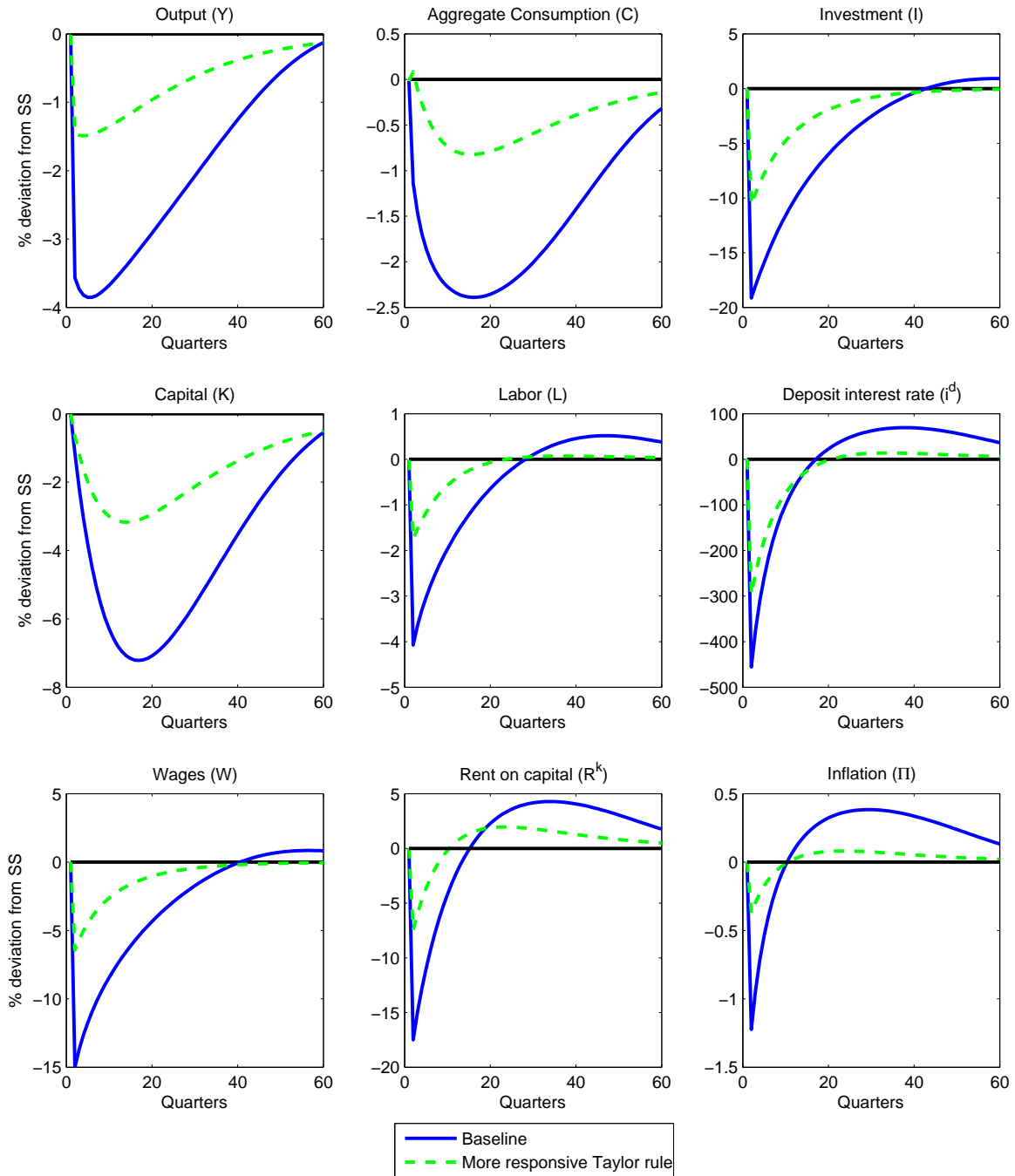
Notes: Responses of economic variables in the case of a two sector simultaneous deleveraging and 10% reduction in price rigidities. The plots cover the first 15 years of the simulation. All variables are presented in percentage point deviations from the steady state. The continuous lines denote the series in the baseline case. The dashed green lines denote the series in the scenario with more flexible prices.

Figure 2.6: The Role of Structural Reforms: 50% Increase in the Elasticity of Labor Supply



Notes: Responses of economic variables in the case of a two sector simultaneous deleveraging and a 50% increase in the elasticity of labor supply. The plots cover the first 15 years of the simulation. All variables are presented in percentage point deviations from the steady state. The continuous lines denote the series in the baseline case. The dashed green lines denote the series in the scenario with a more elastic labor market where ε_b and ε_s are both reduced with 50%.

Figure 2.7: The Role of Monetary Policy: More Responsive Central Bank Reaction Function



Notes: Responses of economic variables in the case of a two sector simultaneous deleveraging and more responsive Central Bank reaction function. The plots cover the first 15 years of the simulation. All variables are presented in percentage point deviations from the steady state. The continuous lines denote the series in the baseline case. The dashed green lines denote the series in the scenario with a more responsive Taylor rule where the coefficients have been increased by 100% (ϕ_{Π} is increased from 1.5 to 3 and ϕ_y from 0.125 to 0.250).

Table 2.1: Core Parameters of the Model

Parameter	Description	Value	Target or Source
α	Share of capital in production	0.3	Standard
β	Saver's discount factor	0.995	Annual risk free rate of 2%
β_b	Borrower's discount factor	0.96	Eggertsson and Krugman (2012)
β_e	Entrepreneur's discount factor	0.96	Eggertsson and Krugman (2012)
δ	Depreciation rate	0.06	Eggertsson and Krugman (2012)
γ	Calvo coefficient of price rigidity	0.9066	Eggertsson and Krugman (2012)
θ	Elasticity of substitution	6	Philippopolous (2013)
κ	Portion of stolen loans	0.0149	S.S. interest rate spread
κ_e	Portion of stolen loans	0.0149	S.S. interest rate spread
Ξ	Debt overhang - spread relation	0.007356	Interest rate spread
Ξ_e	Debt overhang - spread relation	0.007356	Interest rate spread
ξ_b	Consumption Elasticity of substitution	1	Standard
ξ_s	Consumption Elasticity of substitution	1	Standard
ξ_e	Consumption Elasticity of substitution	1	Standard
ε_b	Elasticity of labor supply	3.03	Standard
ε_s	Elasticity of labor supply	3.03	Standard
ζ	Coefficient of capital adjustment	20	Fall in investments
χ_b	Share of borrowers	0.30	Fall in output and consumption
χ_e	Share of entrepreneurs	0.20	Fall in output and investments
χ_s	Share of savers	$1 - \chi_b - \chi_e$	Fall in output and investments
b^j	"Safe" borrower's debt	2.93069	Debt equals 65% of annual output
$b^{e,j}$	"Safe" entrepreneur's debt	2.93069	Debt equals 65% of annual output
ϕ_Π	Policy response to inflation deviations	1.5	Gali (2012)
ϕ_y	Policy response to output deviations	0.125	Gali (2012)

Note: The table presents the core deep parameters of the model and their respective sources.

CHAPTER 3

PRIVATE SECTOR LEVERAGING AND DELEVERAGING DYNAMICS IN THE EURO AREA

3.1 DRIVERS OF THE LEVERAGING PROCESS

The past decade was characterized by a significant increase in credit. Few global trends played a major role in the expansion. As the financial sector gained importance in the global economy, economic agents increased their leverage on the back of an enhanced access to credit, low borrowing costs, and optimistic expectations for future economic growth and asset valuations.

Over the last four decades, since the early 1970s, the system of tight financial controls has been liberalized substantially on a global scale. Justified by the efficient market theory, multiple steps have been taken to deregulate the financial sector. The process of financial **liberalization** that originated in the United States and Great Britain has initiated a continuous trend towards financial deepening and has facilitated the creation of a globally-integrated financial market (Crotty, 2009 [43]). The financial liberalization encompassed series of measures aimed at reducing the barriers to capital mobility. The deregulation of financial markets domestically and internationally included the elimination of interest rate caps and the introduction of a free cross-border capital mobility. It also involved an easing of banking supervision and lower standards of prudential regulation (Buiter and Rahbari, 2012 [30]). While pioneered by developed economies, the push towards financial liberalization has been broad-based: countries in all income groups and all regions introduced reforms that promoted internal and external capital mobility (Abiad et al., 2008 [2]). Epstein and Jayadev (2007) [84] motivate the observed deregulation of financial markets with the political response to the low real rates of return on financial capital during the 1970s.

Hand in hand with financial deregulation, the expansion of the financial sector has been assisted also by a wave of **financial innovation**. Theoretically, the process of financial innovation permits the accumulation of higher levels of debt due to the more efficient allocation of risk across agents. New financial instruments are designed to remove large concentrations of risk from the balance sheets of financial institutions and to distribute the risk among a large number of individual

investors who should be better equipped to handle it. By allowing for risks to be split and then traded, financial innovation serves the purpose of dispersing these risks. Therefore, in theory, the proliferation of complex financial instruments bridges the gap between the market and the ideal Arrow-Debreu world by expanding the set of state-contingent securities, which should fortify the stability of the financial system.

However, in spite of its theoretical appeal, the growth in securitization preceding the financial crisis was less successful in distributing risk among investors. Instead, it abused a regulatory arbitrage. Financial institutions managed to decrease their effective capital requirements through the use of off-balance sheet vehicles and instruments: asset backed conduits and structured investment vehicles. Acharya et al. (2009) [3] highlights the shift of financial activity from more tightly regulated financial products and entities to more loosely regulated ones, which encouraged the development of the "shadow banking" system. As a result, risk remained concentrated within the financial institutions and it was further magnified by the overleveraging that the newly engineered instruments allowed for (Acharya and Richardson, 2009 [4]). Bean (2010) [13] indicates that in the period between 2000 and 2007, there was a marked expansion in the issuance of asset backed securities, collateralized debt obligations, and credit default swaps. Still, the risks that securitization was intended to mitigate remained largely in the banking sector as banks bought structured products originated by other banks, thus increasing the fragility of the financial system to negative macroeconomic shocks.

Another problem of the newly introduced financial products was their complexity which gave rise to opacity. The presence of asymmetric information among market participants and the high degree of complexity of the new financial environment prevented both regulators and investors from forming an accurate position on the instruments' risks and exposures. The opacity of the financial system, combined with high levels of debt, increased the susceptibility of the economy to negative shocks. As a result, during the financial crisis, the fall in the value of the underlying assets caused a large uncertainty about the value of the derived securities (Blanchard, 2009 [23]).

The rapid growth in credit observed before the financial crisis was assisted also by an extended period of economic stability in the western world - **the Great Moderation**. The 2000s were characterized by a stable and sustained economic growth, low inflation and sizable cash flows across countries and sectors. Coric (2012) [42] demonstrates that both advanced and developing economies experienced a significant reduction in GDP growth volatility, confirming that the Great Moderation

was a worldwide phenomenon¹. The drop in output volatility has been explained by Cabanillas and Ruscher (2008) [33] with the reorientation of production towards services, the reduction in the correlation between employment and productivity and the computerization of inventory management. In the Euro Area, output growth volatility declined substantially over the past three decades. The fall in output volatility was also accompanied by a convergence of volatility levels across countries.

Households witnessed a continuous rise in disposable income and asset prices. According to Bean (2010) [13], the positive developments encouraged an unusually low perception of risk among agents. Higher risk appetite and low funding standards shifted both credit demand and supply curves outwards. Buitier and Rahbari (2012) [30] explain the increase in debt with its attractiveness to both lenders and borrowers during periods of steady asset price appreciation. Debt provides lenders with a stable and predictable (in good times) stream of relatively high returns. Moreover, securitized products sold by banks were frequently rated very low risk. As a result, during expansion, lending in a high growth environment seems a low risk and high return investment. On the other hand, through debt borrowers are able to purchase assets and profit from price appreciation over time without having the cash needed for the initial purchase of the assets which is very attractive in periods of rapid asset appreciation.

The benign economic environment before the crisis generated overoptimistic expectations for future economic growth. Low macroeconomic volatility and persistent income growth promoted high risk taking that fueled financial markets. Witnessing rapid asset price appreciation and stable income growth, lenders and borrowers alike projected that observed trends will continue into the future, which proved to be wrong (Blanchard, 2009 [23]). The increase in indebtedness was stimulated also by the fall in real interest rates and the resulting search for higher yields. The "**savings glut**" caused by the high saving in China, commodity exporters and other emerging markets drove long term interest rates down (Bernanke, 2005b [19]). Capital from these countries was channeled into assets in the advanced economies, leading to excess liquidity and low yields.

While the inflow of capital kept long term interest rates low, an extra **loose monetary policy** pushed down on short term rates, fueling the credit expansion. Taylor (2009) [127] confirms that in the 2000s, the actual monetary policy rate set by the US Fed was consistently below the one determined by the Taylor rule. Such large and persistent deviation between the two rates has last

¹While GDP growth volatility reduced across countries, the length of the moderation period varies. The reduction in GDP growth volatility in advanced economies took place earlier compared to developing economies.

been observed in the 1970s. Taylor (2009) [127] concludes that the lenient monetary policy is one of the driving forces behind the credit expansion and the housing boom in the US. At the same time, in the Euro Area, the deviations from the Taylor rule vary in size among countries as the common ECB monetary policy is applied to the individual member states that differ in inflation and output growth. Still, the central trend is that countries with larger deviations from the Taylor rule (for example Spain) experienced larger asset price booms. Therefore, the perception of low market risk, combined with massive capital inflows from emerging markets and loose monetary policy, boosted both the demand and the supply of credit in advanced economies.

Concentrating on the Euro Area, the introduction of the common currency had a pivotal role in the leveraging process. The creation of the Eurozone - a unified financial market that offered perfect capital mobility among member states without an exchange rate risk - instigated a large flow of capital from the core to the periphery of the union² (Buiters and Rahbari, 2012 [30]). Searching for higher yields, banks from the core economies invested aggressively in Southern Europe. Koo (2011) [88] emphasizes that German banks directed large amounts of capital to the Euro Area peripheral economies, fueling housing bubbles in those markets.

Gros (2012) [72] relates the capital flows from the North to the South of the monetary union to the structure of the financial markets in the savings-rich Northern Euro Area countries where the majority of private savings are managed by banks and other highly regulated intermediaries (insurance companies, pension funds, etc.). These institutions have a strong home bias to invest within the Euro Area because regulation imposes limits on their non-euro denominated assets due to the fact that investments within the Euro Area are immune to exchange rate risk. Therefore, there is a high propensity for excess savings from the North of the Euro Area to be invested elsewhere in the monetary union where they can receive higher return. The inflow of funds from the core economies led to a substantial improvement in the terms of borrowing in the periphery. By joining the common currency, economies enjoyed a sharp reduction in the borrowing rates of both the private and public sectors. Between 2001 and 2008, the yields of Irish, Spanish, or Greek 10-year bonds rarely exceeded German ones with more than 25 basis points in spite of the considerable difference in fundamentals (figure 3.1).

²Using a common categorization of the Euro Area countries, I denote Belgium (BE), Germany (DE), France (FR), the Netherlands (NL), and Austria (AT) as core members. Ireland (IE), Italy (IT), Greece (EL), Spain (ES), Cyprus (CY), and Portugal (PT) are periphery members and Estonia (EE), Slovenia (SI), Slovakia (SK), Lithuania (LT), and Latvia (LV) are CEE members.

To certain extent, the massive capital flow from the core to the periphery of the monetary union is an expected phenomenon. It is a natural result of the convergence process among countries with different levels of economic development (Holinski et al., 2012 [78]). In the presence of integrated financial markets³, countries with lower per capita income attract foreign investments due to the expectation that higher productivity growth and respectively higher economic growth will generate above average rates of return on capital. Higher expected productivity of invested capital serves also as an assurance that the accumulated foreign liabilities can be paid-off in the future.

However, while economic convergence is a natural phenomenon, the eradication of exchange rate risk and overoptimistic expectations of higher future income growth contributed to a "bad convergence" process as defined by Smaghi (2011) [123]. Countries in the Euro Area experienced the accumulation of sizable macroeconomic and financial imbalances. Alberola et al. (2012) [80] stress the role of loose financial conditions and investors' complacent attitude in the sharp credit expansion observed in the Euro Area periphery. Domestic and external debt-to-income ratios increased rapidly. As long as borrowed funds are channeled into production-enhancing investments, the build up of debt is sustainable as it contributes to future production and income growth. However, in the Euro Area, large part of the borrowed funds was directed towards consumption and the non-tradable sector (mostly housing) which has a limited impact on the supply capacity of the economy and fails to boost productivity (Alberola et al., 2012 [80]). The weak investment in the tradable sector in the Euro Area periphery is emphasized also by Giavazzi and Spaventa (2010) [66]. Lane and Pels (2012) [92] reiterate that excessive optimism and inadequate countercyclical policies contributed to the spike in consumption and caused asset price bubbles.

The build up of high debt in the Euro Area creates instability also due to the nature of the capital flows in the monetary union. Koo (2011) [88] outlines that a distinct feature of the monetary union is the strong pro-cyclicality of its capital flows. During an expansion, funds flow into the high growth economies, exacerbating the build-up of imbalances. However, with the onset of the crisis, financial flows retreat to the "safe heavens" least affected by the financial distress. The pro-cyclical movements amplify the economic cycle. According to Koo (2011) [88], for a country experiencing

³Vernengo and Perez-Caldentey (2012) [131] study the continuous process of financial integration in Europe that accompanied the creation of the monetary union. Since the late 1980s and early 1990s (following the Single European Act of 1987), most European countries embarked on a path of financial liberalization, lifting capital controls, deregulating interest rates and adopting the European directives. As reflected by the Chinn-Ito index that measures the openness in capital account transactions, the openness of the financial systems of individual European countries has increased continuously throughout the 1990s, reaching full liberalization after the adoption of the euro.

a boom, the optimal policy is to limit the inflow of foreign funds and prevent the unsustainable build-up of imbalances. However, such policy is impossible to implement within the union. Similarly, when faced with a balance sheet recession, countries are struggling to stimulate private investment and consumption due to massive capital outflows.

As highlighted, the effects of the lengthy period of low market volatility and moderation experienced by the European economies were enhanced by the free capital mobility present in the Euro Area. Blanchard (2009) [23] explains the sizable accumulation of debt in the Euro Area with the benign economic environment and the relaxed attitude towards risk. In many peripheral countries, investments in capital and labor across sectors did not match the composition of sustainable demand. With the beginning of the financial crisis, the misplaced and optimistic expectations of future growth gave way to a collapse in asset prices and a fall in aggregate demand and economic activity (Gros and Alcidi, 2011 [73]). Originating in the financial sector, the crisis led to balance sheet recessions in many of the European economies.

The remainder of the chapter is organized as follows. Section 3.2 elaborates on the process of debt accumulation and the magnitude of debt overhang in the Euro Area. Section 3.3 traces the ongoing balance sheet adjustments aimed at reducing the debt burden of the private sector. Section 3.4 decomposes the leverage dynamics of the household and corporate sectors, implementing a novel approach, while section 3.5 examines the macroeconomic impact of the deleveraging process. Section 3.6 summarizes the findings and highlights some policy recommendations and section 3.7 concludes.

3.2 THE PROCESS OF DEBT ACCUMULATION AND THE SIZE OF DEBT OVERHANG

Multiple factors have affected the stock of debt in the Euro Area during the boom period. As discussed in the previous section, credit demand and supply were shaped by a long period of volatility moderation, a liberalization of the financial markets and an abundant inflow of capital. However, in order to assess the evolution of private indebtedness in the Euro Area, an accurate and comprehensive definition of debt should be employed. There are potential arguments for the use of both gross or net debt where net debt is measured as the difference between agents' total stock of debt and total stock of assets. Economic analysis suggests that net debt (net wealth) drives agents' consumption decisions⁴ (Benito et al., 2007 [16]). However, as observed during the recent financial

⁴A relevant example supporting this theory is the US housing boom. On the basis of the continuous increase in housing prices, US households raised their consumption by accumulating more debt. Their

crisis, accounting for assets has several shortcomings when discussing sustainable debt dynamics. Asset prices fluctuate substantially throughout the cycle. A financial boom can push asset prices sky high before they fall sharply during the burst. The main drawback of netting assets out of debt is that debt by its nature is not state-contingent, while asset prices are. During periods of financial distress, assets are not a reliable source of funding for paying-off debt. In addition, Borio (2010) [25] stresses that during crises assets' liquidity may reduce abruptly. Therefore, assets cannot be readily converted into means of payment that can be used to service debt obligations. Particularly in the context of a liquidity constraint, assets are not a reliable source of funding (Tirole, 2011 [129]).

Due to asset price volatility, assets can appreciate significantly during good times, while collapse in a downturn. Therefore, a measure that includes assets can be very volatile. It can register sustainable debt dynamics during an asset price boom, masking the build-up of sizable imbalances (Buiter and Rahbari, 2012 [30]). Still, as soon as a crisis hits, such measure will reveal a sharp deterioration. As assets are becoming illiquid during periods of financial distress, disposable income plays a primary role when determining indebtedness. While the private sector possesses assets that can be liquidated to pay-off debt, there are problems with illiquidity and maturity mismatch between assets and liabilities. Drehmann et al. (2011) [49] discuss the importance of using gross debt and income when evaluating debt sustainability. They demonstrate that the ratio of gross debt to income, i.e. **leverage**, is the most successful early warning indicator for an unsustainable build-up of debt⁵. It benchmarks the growth of credit relative to economic activity. Therefore, during a crisis, gross debt is the main measure of indebtedness and current disposable income is the most reliable measure of debt servicing capacity.

A potential alternative to the measure of gross debt is a broad measure of net debt that subtracts the most liquid asset holdings - currency and deposits - from the total stock of debt⁶. This broad measure of net debt is immune by and large to the liquidity shortcomings discussed above. As data confirm, the household sector holds a large portion of its financial assets in the form of bank deposits. In most Eurozone countries, the net measure of household debt is negative, demonstrating behavior can be motivated by the fact that their net wealth over the period was increasing with the rise in house prices.

⁵In the present paper, gross debt for each sector is defined as the sum of end of period amount outstanding of debt securities and loans.

⁶The measure of net debt for each sector is computed as the difference between the end of period stock of gross debt and the stock of deposits and currency owned by the sector.

that in aggregate household's deposits exceed loans from the banking sector. Still, due to the rapid credit growth experienced in the CEE and peripheral economies, the measure of household net debt turns positive during the boom. The broad measure of net debt presents very similar dynamics compared to gross debt⁷. The findings are consistent with Buiter and Rahbari (2012) [30] that establish that using both the broad measure of net debt and gross debt produce similar qualitative and quantitative results. Therefore, the two alternative measures of debt confirm the considerable increase in indebtedness observed in the Eurozone member countries before the crisis.

As discussed, the gross debt to income ratio is an early warning indicator for the accumulation of unsustainable debt dynamics. On one side, a long list of empirical and theoretical research has demonstrated that the credit-to-income ratio increases over time with the advancement of the financial system: the long-term trend of financial innovation is related to long-term economic growth (Levine, 2005 [95]). However, periods of rapid credit growth can cause an unsustainable expansion of leverage. Financial institutions' ability to screen potential borrowers and manage risk is limited. Therefore, sharp credit expansion may conceal sub-prime lending and financial instability.

The stock of gross debt has increased rapidly before the financial crisis. During the expansion, the leverage ratios of the two non-financial private sectors have reached an all time high in most of the Euro Area countries. Figures 3.2 and 3.3 depict the level of leverage reached in 2009. The gross debt-to-income ratio differs across countries in the monetary union. For the household sector, countries can be broadly divided into three groups. With the exception of the Netherlands, core member countries have relatively low household leverage - well below 100%. On the other hand, in the Eurozone periphery, households' stock of debt is larger compared to disposable income, particularly in Ireland, Spain, Cyprus and Portugal. The high leverage is the direct result of the rapid credit expansion experienced there in the early 2000s. Looking at the new CEE member states, the leverage ratio of the household sector is well below the Eurozone average. Estonia is the only country where the households' debt-to-income ratio approaches values close to the older Euro Area members. Still, credit growth in those countries has been among the fastest due to the rudimentary state of their financial systems at the beginning of the period.

⁷Figures B.3 and B.4 in Appendix B.1 compare the dynamics of the two measures of debt since the year 2000.

Turning to the corporate sector, conclusions are similar⁸ (Figure 3.3). The leverage ratio in the core members is lower compared to the periphery with the exception of Belgium. The ratio of gross corporate debt to entrepreneurial income⁹ is particularly high in Ireland, Spain, and Portugal. A result that stands out when reviewing both figures is that private sector indebtedness in Greece is close to the Euro Area average. This could appear inconsistent with the sizable economic downturn that Greece experienced since the beginning of the crisis. However, the primary problem of Greece has been public and not private debt overhang. The CEE member states have a moderate corporate leverage. However, due to an intensive credit boom, Estonia and Slovenia have surpassed the average levels of corporate indebtedness in the Eurozone. Paired with the underdevelopment of their financial systems, the large stock of accumulated debt is a source of vulnerability for the two economies.

Figure 3.4 traces the evolution of gross household debt and the leverage ratio since the year 2000¹⁰. During the pre-crisis period, gross debt continuously increases in all member states except Germany. Both the stock of nominal debt and the leverage ratio increase throughout the Eurozone. Credit expands significantly in the CEE and peripheral economies and in the Netherlands. As data confirms, the path of gross debt and leverage both share similar dynamics. In spite of the economic boom experienced across the union, the growth rate of credit consistently surpasses the growth of disposable income. This can be rationalized by the large capital inflows and high risk appetite. The growth in nominal income motivates borrowing and contributes to the sizable increase in leverage. However, a rise in debt without a comparable increase in income may cause vulnerabilities since in periods of financial distress and market illiquidity, income remains the primary measure of debt servicing capacity. A steady growth in the leverage ratio exposes agents to negative shocks that can

⁸The corporate sector is comprised of public non-financial corporations and national and foreign-controlled private non-financial corporations whose economic operations are predominantly in the country. Residency of corporations and their inclusion in the national accounts is determined by their place of incorporation (EUROSTAT European system of national accounts, 2013 [56]). Due to attractive corporate tax rates, some Euro Area countries boast a large number of multinational corporations. In particular, Ireland and Belgium have a high concentration of multinational corporations. The series of gross corporate debt used in the paper include inter-company corporate debt with non-resident affiliates which is considerable for multinational corporations. Therefore, the levels of corporate debt in Ireland and Belgium are quite large due to the size of the multinational corporations relative to their national economies. As a result, the high level of corporate leverage in the two countries is not fully comparable to the other Eurozone states (Cussen and O’Leary, 2013 [47]). Still, the EUROSTAT series of gross corporate debt are the officially reported statistics and are used by both researchers and policy makers (de Rougemont and Winkler, 2013 [117]).

⁹The entrepreneurial income account is a standard ESA2010 corporate sector account that corresponds to current corporate profits before distribution and income tax.

¹⁰The euro is officially introduced in 1999. I analyze the evolution of debt since the following year - 2000.

severely damage their ability to meet their obligations without a sharp reduction in consumption and investment.

Even though corporate leverage evolves more dynamically compared to household leverage due to the higher volatility of entrepreneurial income, the positive trend of growth during the pre-crisis period is preserved (Figure 3.5). In core Euro Area economies, a steady growth in income reduced the leverage ratio in spite of a continuous increase in gross debt. On the other hand, in peripheral countries and CEE members, the period between 2000 and 2007 was marked by a large increase in corporate leverage. The process manifests itself clearly in CEE countries - Estonia, Slovenia, Lithuania, Latvia - where financial integration and the entry of foreign banks into the domestic market stimulated corporate borrowing. Even though entrepreneurial income rose in these countries, the increase in debt surpassed the increase in income.

Favorable economic conditions and capital inflows raised debt across the monetary union. The leveraging process was led by the peripheral economies that built-up large imbalances (Gros, 2012 [72]). Placing the expansion of credit in a context, the increase in debt that occurred between 2002 and 2009 is comparable to the initial stock of debt at the beginning of the decade. Figures 3.6 and 3.7 account for the change in leverage between 2002 and 2009. There are clear outliers in both sectors. Ireland is a leader. While the large increase in corporate leverage in Ireland can be partially justified by the large number of multinational corporations in the country, the increase in household leverage is also substantial due to the housing boom. Household leverage expanded significantly also in Estonia, Latvia, Lithuania, Cyprus, Spain and Greece. Among core Euro Area economies, the Netherlands is the only country that experienced a marked increase in household leverage. Turning to corporate leverage, it increased most significantly in Spain, Estonia, Slovenia and Latvia. Results demonstrate that the European integration has instigated a large credit expansion in the CEE members.

The rapid rise in leverage is of primary importance for financial stability. As most of borrowing is collateralized, debt is explicitly linked to asset prices. During an asset price boom, lending explodes both in nominal terms and also relative to agents' income, pushing leverage up. Still, the rise in leverage is a potential sign of the build-up of unsustainable debt. In its foundation, debt is serviced from income. However, during an asset price boom, borrowing is justified by higher asset prices. Then the process of leveraging enters into a self-enforcing cycle where credit growth props demand and boosts economic growth and asset prices. Stable growth, on its turn, encourages optimistic

expectations for future economic activity and asset appreciation. Rising asset prices support higher collateral which in turn leads to higher borrowing. However, the resulting decoupling between the growth rates of income and credit leaves economic agents more vulnerable to unexpected negative economic shocks.

In the event of an economic downturn, higher credit translates into higher debt servicing and repayment costs which suppresses spending. Several authors - Eggertsson and Krugman (2012) [51], Guerrieri and Lorenzoni (2011) [74], and Midrigan and Philippon (2011) [104] - have analyzed theoretically the role of debt overhang on economic activity. Furthermore, Georgiev and Lozev (2015) [65] study debt overhang on a sectoral level. Private sectors that have experienced rapid debt accumulation are more susceptible to a crisis. However, the problem is not limited to private sector debt. Public sector debt also plays a role in exposing the national economy to negative shocks. Taylor (2012) [126] emphasizes that the ratio of public debt to GDP before a crisis has a material impact on the subsequent economic slowdown. Countries suffering from a large public indebtedness do not possess the fiscal space to implement significant fiscal stimulus programs nor to cover bank losses and prevent bankruptcies. Moreover, the creditworthiness of the state is transferred to the private sector. Thus, high public debt can raise borrowing costs across the economy.

3.3 THE DELEVERAGING PROCESS

The period before the financial crisis was characterized by a rapid increase in credit across the private sector. The sizable accumulation of debt boosted asset prices in several Euro Area countries. Gros and Alcidi (2011) [73] motivate the creation of construction bubbles in Spain and Ireland with the inflow of foreign capital to peripheral countries. With the financial crisis, high asset prices deflated, damaging agents' confidence and prompting a deleveraging process. While the financial crisis was triggered by the burst of the US housing market, the high integration of the global financial system spread the shock originated in the US to Europe (Goodhart, 2014 [68]). The financial crisis caused an abrupt shift in agents' risk attitude. Not only agents' risk appetite, but also their risk perception deteriorated dramatically. During the boom period, Eurozone peripheral economies enjoyed a stable economic expansion fueled by capital inflows. The growth rate of output surpassed nominal interest rates in those countries, making the debt dynamics manageable (Gros,

2012 [72]). However, with the economic slowdown and the spike in interest rate risk premiums, debt levels resulted much less sustainable, making refinancing harder.

Eggertsson and Krugman (2012) [51] refer to the rapid deterioration in agents' risk attitude that accompanied the financial crisis as a "Minsky moment". The abrupt realization of the accumulated excess in leverage and high asset prices prompts a long-lasting increase in interest rate risk premiums and tightens lending standards. The shift in agents' behavior affects also financial markets' liquidity. The difficulty of servicing a sizable amount of debt relative to current income triggers a widespread sale of assets that brings asset prices down and reduces market liquidity. In addition, the deleveraging of the financial sector itself limits the supply of credit to the economy and renders bank financing more expensive.

Theoretically, an increase in leverage should not pose a substantial economic risk under certain assumptions. According to Bernanke (2000) [17], since debt of some agents is an asset for others, the leverage level is irrelevant for the total economy as long as borrowers and lenders have comparable consumption and investment behavior. Therefore, the observed accumulation of debt can be treated as a transfer of assets among agents without significant macroeconomic effects. However, as past crises demonstrate, the characteristics of debtors and lenders matter. A possible explanation for the importance of leverage is that borrowers have larger propensity to consume and invest out of income compared to lenders¹¹. Therefore, the deleveraging need depends on agents' balance sheet positions. In case agents are severely indebted and their assets and income are shrinking, they decrease spending aggressively to pay-off debt. In these circumstances, market rigidities and imperfections and precautionary savings on the part of lenders impede less indebted entities to step in and pick up the slack in private demand.

Following the burst of a debt-financed asset price bubble, asset prices collapse while liabilities remain, leaving sectoral balance sheets strained. Realizing the presence of a debt overhang, borrowers commence to repair their balance sheets by increasing savings on the back of a fall in consumption and investment. These trends are analyzed for the household and corporate sectors in individual Euro Area countries. As historical data demonstrates, the deleveraging process is long-

¹¹Using granular financial data for 150 000 American households, Baker (2015) [11] finds that the elasticity of consumption with respect to income among high-debt households is significantly higher when compared to low-debt households. Furthermore, higher marginal propensity to consume out of current income for borrowers is assumed in theoretical papers that study the economic impact of deleveraging: Eggertsson and Krugman (2012) [51] and Benigno, Eggertsson and Romei (2014) [14].

lasting because borrowers strive to reduce a stock variable - the amount of outstanding debt - by changing a flow variable - increased savings.

The deleveraging process is long-lasting and has detrimental consequences for economic growth if the debt overhang is high and requires a sizable adjustment of agents' balance sheets. Nevertheless, judging the deleveraging need of an individual sector is a complex task that should account for multiple factors: the quality and maturity of the financial system, the structure of the market, the type of the economy. Empirical studies have attempted to compute an optimal level of debt for the private sectors (Cechetti et al., 2011 [36] and Cuerpo et al., 2013 [44]). Results however are not robust. Authors often agree, for the Euro Area countries in particular, that a potential benchmark for a sustainable level of debt is the leverage ratio in the early 2000s when there is a broad consensus that financial excesses were absent (Buiter and Rahbari, 2012 [30]). This is the stance taken by Cuerpo et al. (2013) [44] and the European Commission Macroeconomic Imbalances Procedure [122].

After the large accumulation of debt before the financial crisis, leverage is expected to revert back to lower historical averages. The pre-boom levels of the debt-to-income ratio mark the potential extent of the deleveraging need. The expected deleveraging can be compared to previous episodes of balance sheet recessions. The current crisis, in spite of its size and reach, bears the traits of previous financial recessions (Koo, 2011 [88]). Buiter and Rahbari (2012) [30] study a sample of over 30 deleveraging episodes that occurred during the last century. In the eight years prior to a crisis, the debt-to-GDP ratio increases by an average of 30 percentage points, while in the subsequent eight years, it diminishes by 15-20 percentage points, validating the notion of mean reversion.

Figures 3.8 and 3.9 demonstrate the current size of debt overhang of the household and corporate sectors if leverage should return to its 2001 level¹². The graphs display the percentage points change that will bring the leverage ratio back to its pre-boom level. Even though some deleveraging has taken place since the beginning of the financial crisis, particularly in the corporate sector of the CEE member states, debt-to-income ratios are well above their pre-boom levels in many of the Euro Area countries. The Netherlands, Cyprus and Ireland are outliers for the household sector. However, continuous deleveraging pressures may be experienced also by Greece, Spain and the Baltic countries. Similarly, the corporate sectors in Belgium and the peripheral economies - Ireland, Spain,

¹²I follow Buiter and Rahbari (2012) [30] in selecting the year 2001 as a guide for the deleveraging needs in individual countries. The year is chosen on the basis of stable economic and financial dynamics prevalent during that period.

Italy, Cyprus and Portugal - have increased their leverage substantially. In the core economies, the deleveraging need is smaller with the exception of Belgium. However, as mentioned before, Belgium has a large number of multinational corporations which raises the stock of corporate debt. Therefore, there is a clear distinction between the corporate deleveraging needs in the core and in the periphery of the Euro Area.

Since the onset of the financial crisis, the corporate sectors in the CEE member states managed to carry out a sizable readjustment. With the exception of Slovakia, the present deleveraging needs in these economies are moderate. However, due to the very low level of financial development at the beginning of the period, leverage in the CEE members needs to increase in the future. This is presented implicitly by the white bars in figure 3.9. The negative white bars account for the ongoing process of financial and economic convergence between the CEE member states and the rest of the monetary union. The corporate sectors in Estonia, Slovakia, Lithuania, and Latvia have to increase their debt in order to narrow the gap with the more mature economies in the union. However, the process of convergence must be achieved gradually in order to prevent the appearance of new credit bubbles.

Based on figure 3.8, the household gross debt-to-income ratio has to decrease on average by 43 percentage points in order to return to its 2001 level. The 2001 level is a less pertinent benchmark for the new Euro Area members (particularly the Baltic states) due to the economic transition of the ex-socialist economies. However, for the Southern European countries, the needed adjustment is considerable. Assuming a subdued economic growth in the medium term, it will take over a decade for the household sectors in those countries to deleverage. Similar conclusion can be drawn for the corporate sector. In several peripheral countries, gross debt has increased dramatically: Ireland, Spain, Greece, Cyprus and the new member states. Across countries, the leverage ratio must decrease on average with more than 102 percentage points if using the 2001 benchmark. Nevertheless, the ongoing economic and financial conversion among old and new member states has to be considered when judging the deleveraging needs.

3.3.1 DELEVERAGING EFFORT AFTER THE ONSET OF THE CRISIS

After the onset of the financial crisis, there is a clear shift in the spending behavior of both the household and corporate sectors reflected in their net lending/net borrowing accounts. Net lending/net borrowing is the final balancing item of the non-financial sectoral accounts. It corresponds to the

difference between sector's income and its spending on consumption and investment. It also equals the amount available to the sector for the purchase of financial assets. A positive level of net lending signifies that the sector is financing other sectors, accumulating financial assets or reducing liabilities. On the other hand, a negative level of net lending (i.e. net borrowing) demonstrates that the sector is funding a portion of its consumption and investment from other sectors, increasing its financial liabilities. Figure 3.10 summarizes the average leveraging or deleveraging effort of the household sector during the financial boom (2001 - 2007) and after the onset of the crisis (2008 - 2013)¹³. There is a marked shift in the saving and borrowing behavior. For the household sector, as expected, countries that experienced the fastest growth in leverage before the crisis underwent the most radical adjustment. According to figure 3.10, before 2007, the household sector had the atypical role of a net borrower in the new CEE Euro Area members as well as in Ireland and Greece. In Spain, net lending was also much lower relative to the core economies, implying large consumption and investment. On the other hand, after the crisis, the red bars demonstrate a drastic change in consumption and investment in these economies, where financial deficits turned into surpluses and the household sector assumed its typical role of a net lender to the rest of the economy. Greece is the only exception. Still, net borrowing there has also contracted.

Similar conclusions can be drawn for the corporate sector (Figure 3.11)¹⁴. Fast credit growth during the pre-crisis period can be linked to a larger adjustment effort in the crisis. Corporates deleveraged more aggressively compared to households. Attempting to fix their balance sheets, firms increased drastically their saving. New CEE member states and peripheral economies led the effort. The shift was particularly acute in the CEE Euro Area members, Spain, Ireland and Greece. As discussed in detail in subsequent sections, the size of the adjustment caused a considerable economic contraction in those countries due to the large drop in aggregate demand.

¹³Applying a standard public sector methodology, I define the deleveraging effort of both private sectors - household and corporate - as the corresponding net lending/net borrowing account augmented by gross interest payments. Data is sourced from the EUROSTAT non-financial National Sector Accounts. Interest payments on the existing stock of debt are added back since they are non-discretionary expenses for the sector and thus, are not representative of the actual deleveraging intentions. The series are divided by income to be standardized across countries.

¹⁴The evolution of the net lending/net borrowing account for the household and corporate sectors throughout the period is presented in Appendix B.1: figures B.5 and B.6. The conclusions are identical to the ones obtained from figures 3.10 and 3.11.

3.3.2 TRENDS ACCOMPANYING THE SHIFT FROM NET BORROWING TO NET LENDING

The increase in saving of the private sector depresses aggregate economic activity. Ruscher and Wolff (2012) [119] study 35 historic episodes of corporate balance sheet adjustment. They argue that corporate deleveraging is traditionally achieved by reducing investment and increasing saving (similar to the household sector that reduces consumption and investment). The decrease in investment leads to a fall in domestic demand. In addition, Ruscher and Wolff (2012) [119] calculate that employees' compensation as a share of gross value added of the corporate sector decreases by nearly 5 percentage points and the increase in corporate savings corresponds closely to the decrease in wages¹⁵. Epstein and Jayadev (2007) [84] provide a potential explanation to these findings, arguing that labor income is most affected by the corporate deleveraging since the liberalization of financial markets in the last decades has facilitated capital mobility across countries, giving larger bargaining power to capital over labor.

Analyzing first the household sector, figure 3.12 links the evolution of net lending of the household sector to changes in final consumption and investment. Being the final balancing item in the system of national accounts, net lending corresponds to the difference between household disposable income and household final consumption and investment¹⁶. Figure 3.12 demonstrates an increase in net lending after the onset of the crisis that is achieved through sizable shifts in consumption and investment. There are two distinct trends. After the 2007 financial crisis, both consumption and investment decrease as a share of disposable income in the countries experiencing deleveraging pressures. In all peripheral economies and the new CEE members, investment decreased steadily (red line)¹⁷. It is important to emphasize that the graph depicts not only a fall in the nominal amount of investment that could be related to falling income during the crisis, but also a fall in

¹⁵Gross value added or GVA refers to the value of output produced by a sector minus the value of intermediate goods used in the production process. Costs of intermediate goods are measured as the difference between the change in final product inventories and the costs of purchasing goods and services needed for production. Gross value added is a measure of the contribution that individual sectors make to GDP (Francois et al., 2007 [63]).

¹⁶Based on the taxonomy of the System of National Accounts (ESA 95), net lending/net borrowing is the residual item after subtracting final private consumption and gross capital formation from gross disposable income. There are also terms for adjustments and transfers that are disregarded in the current presentation since they are usually small. Using abbreviations, $NLB = (GDI - C) - GCF$ and $GS = GDI - C$, where GDI stands for gross disposable income; C - final consumption; GCF - gross capital formation; and GS - gross savings. As the corporate sector has no final consumption, the relevant equation for the corporate sector is $NLB = GDI - GCF$.

¹⁷A large portion of household investment is residential investment. The fall in investment is driven by the combination of falling house prices and lower housing demand after the peak years before the crisis.

the actual share of investment in disposable income. Households refrain from investing and allocate their funds towards either servicing debt obligations or accumulating precautionary savings.

In addition, final household consumption decreases as a share of disposable income around the beginning of the crisis¹⁸. Ireland, Spain, Cyprus and the Baltic states experience a drop in the share of consumption relative to income. The consumption share of income falls more significantly during the first 2-3 years following the crisis. After this period, it gradually recovers to nearly pre-crisis levels. On the other hand, consumption as a share of income tends to increase in the core Euro Area members which can be explained by consumption smoothing. Due to depressed economic activity and falling income, households in countries experiencing smaller deleveraging pressures choose to allocate larger share of their income to maintain their pre-crisis level of consumption.

Turning to the corporate sector, data reveal that corporate balance sheet adjustments are achieved by a reduction in spending: wages, capital investment and profit distribution. Examining episodes of corporate deleveraging in Germany and Japan, Ruscher and Wolff (2012) [119] point out that while in Germany corporate savings increased predominantly through falling compensation of employees, in Japan, wages remained relatively stable during the initial stage of deleveraging and the adjustment occurred through shrinking shareholders' returns (distributed profits). Figure 3.13 traces the evolution of the main spending items of corporations and links them to the net lending of the sector. The graph displays compensation of employees, distributed profits and gross fixed capital formation as a share of gross value added¹⁹. An evaluation of the trends in the Euro Area economies reveals that while before the crisis the investment share has been rising, after 2007 it has decreased in all countries (red line). In addition, in actively deleveraging economies - Estonia, Ireland, Greece, Spain, Portugal, Lithuania, Latvia - the adjustment has been partially achieved through shrinking compensation of employees (black line)²⁰. The decrease in wages is particularly significant in the Baltic countries where salaries have been steadily increasing before 2007 due to

¹⁸Note that the share of household consumption in disposable income in figure 3.12 has been reduced by 75% for tractability. While the reduction affects the level, it does not impact the outlined trends.

¹⁹Again, gross value added (GVA) of the corporate sector has the standard definition of total output minus intermediate costs of production. Spending items of the corporate sector are presented as a share of gross value added instead of gross disposable income (as done for the household sector) due to the structure of the National Sector Accounts. The main spending items of the household sector are consumption and investment, both of which are funded from disposable income. Therefore, household disposable income is the appropriate denominator for the ratios. On the other hand, for the corporate sector, both employee compensation and distributed profits are deducted from gross value added to obtain gross disposable income. Therefore, for corporates, gross value added is the preferred denominator variable.

²⁰Note that in figure 3.13 the share of employee compensation in gross value added has been reduced by 25% for tractability. While the reduction affects the level, it does not impact the outlined trends.

convergence. Examining the share of distributed profits in GVA, dynamics differ among countries (blue dashed line). It falls in Estonia, Greece, Spain and Latvia, while it rises in Ireland, Cyprus (until 2010) and Lithuania. Therefore, based on figure 3.13, corporate deleveraging is achieved through higher savings on the back of a large cut in investment in fixed capital and a drop in employees' compensation and distributed profits. The fall in investment is the main driver of the shift in net lending. Still, falling wages and profits also account for a sizable portion of the adjustment. These trends are most apparent in the actively deleveraging Baltic states and Ireland.

The mechanics of the deleveraging process uncover the high degree of interconnectedness between sectors. The shrinking share of employee compensation that corporations spend affects directly the income of the household sector. In addition, the fall in investment and consumption translates into a drop in aggregate demand. Since one agent's spending is another agent's income, the balance sheet repair of an entity depresses others' income and asset prices. The negative effects of sectoral deleveraging on other sectors and the economy as a whole are analyzed theoretically in Georgiev and Lozev (2015) [65]. By building a model of sectoral deleveraging within the framework of a New Keynesian general equilibrium model, the authors explore how the deleveraging impulse of a sector affects the income and, subsequently, expenditure of other sectors. As Buiter and Rahbari (2012) [30] point out, the "paradox of thrift" emerges where the rational actions of individuals faced with an unsustainable stock of debt create negative income and demand externalities to others in the economy. The deleveraging effort of overindebted agents reduces consumption and investment and thus, contracts the effective demand for output. As a consequence, during a deleveraging episode, aggregate expenditure and income are depressed.

Because of the sectoral interconnectedness, the impact of the balance sheet consolidation has to be analyzed not only through the investment channel (i.e. the fall in investment and consumption), but also the income channel (i.e. the fall in income) that has second round effects on private demand. The adjustment achieved through higher saving leads to lower spending on goods and services and respectively - lower income from production. The shortfall in demand can be counteracted only if other agents with less affected balance sheets (possibly the government or the rest of the world) step in to fill in the gap. Bornhorst and Arranz (2014) [26] estimate that sectoral deleveraging is most harmful when several sectors - private non-financial, financial and public - need to deleverage simultaneously. In these circumstances, aggregate demand can enter into a downward spiral. Furthermore, large scale deleveraging across sectors is detrimental to the economy since a significant

fraction of capital and labor becomes idle and should be channeled to other productive uses which requires lengthy and painful structural adjustments (the creation of new enterprises, reallocation and requalification of workers, etc.)

3.4 DECOMPOSITION OF DEBT DYNAMICS

The balance sheet adjustment is a long lasting process that severely affects economic activity and aggregate demand. Still, the final objective - reduction in leverage to a more sustainable level - is achieved by the interaction of two separate phenomena: agents' effort to reduce debt and the autonomous dynamics of the existing stock of debt. With a sizable stock of existing debt, changes in interest rates, real income growth and inflation play a significant role in the evolution of leverage. The autonomous debt dynamics can facilitate the intentional deleveraging effort of individuals or can obstruct it. Under certain conditions, debt dynamics can be strong enough to render any deleveraging efforts ineffective. Such example is the peak of the Great Depression when autonomous debt dynamics made deleveraging unfeasible.

With a significant stock of existing debt, any change in the nominal interest rate or inflation and real income growth will have a direct impact on the leverage ratio even if agents' borrowing is zero. Since agents adjust their expenditure gradually, autonomous debt dynamics can have a defining role in altering the leverage ratio. If the nominal interest rate exceeds the growth rate of real income and inflation, agents can preserve the leverage ratio constant or decrease it only by maintaining their spending subdued for an extended period of time, which depresses aggregate demand. Therefore, the evolution of leverage depends on both agents' borrowing behavior and autonomous debt dynamics. This holds true especially during deleveraging episodes when agents face a large stock of debt. In many countries and sectors, the balance sheet adjustment is obstructed by falling income and prices. Deflation increases the real burden of debt and tightens agents' budget constraints. Thus, the denominator shrinks, pushing the leverage ratio upward.

I explore the observed changes in the leverage ratios of the household and corporate sectors in the Euro Area member states. Adapting a standard public debt accounting framework, I decompose the changes in leverage into separate components and measure their contributions to aggregate dynamics. Concentrating on the public debt-to-GDP ratio, several authors employ this decomposition approach. Analysis of public debt dynamics has been carried out by Hall and Sargent (2010)

[77] and Aizenman and Marison (2011) [7] for the US, Buitier (1985) [29] and Das (2011) [48] for the UK, and Abbas et al. (2011) [1] for a broader set of countries. A common theme across these papers is that changes in interest rates and the growth rate of GDP play a significant role in the evolution of the public debt-to-GDP ratio over time. The fall in the debt-to-GDP ratio across advanced economies observed after the World War II is largely due to the positive difference between nominal GDP growth and interest rates. The ratio fell in spite of the fact that seldom governments ran primary balance surpluses.

A recent study of Mason and Jayadev (2014) [98] applies the public debt methodology to explore the evolution of US household leverage since 1929. Their analysis demonstrates that autonomous debt dynamics have impacted the path of US household leverage over the last decades. Similar to their work, the present analysis applies the standard public debt accounting framework to the household and corporate sectors in the Euro Area countries. By decomposing the private sector leverage during the boom and bust periods, I separate the shifts in agents' borrowing from autonomous debt dynamics. In highly indebted countries, the intentional effort of agents to pay-off their debt is outweighed by the autonomous debt dynamics. Even as agents slash borrowing, falling prices and income increase the leverage ratio. The further need to deleverage triggers a larger cut in expenditure that additionally reduces income in a self reinforcing cycle.

When a sector seeks to deleverage, its capacity to reach the new leverage target depends on its autonomous debt dynamics²¹. Analytically, the leverage ratio in period t can be expressed as

$$\frac{B_t}{P_t Y_t} = \frac{(1 + i_t) B_{t-1}}{(1 + \tilde{\pi}_t) P_{t-1} (1 + g_t) Y_{t-1}} + \frac{D_t}{P_t Y_t} = \frac{(1 + i_t) B_{t-1}}{(1 + \tilde{\pi}_t + g_t) P_{t-1} Y_{t-1}} + \frac{D_t}{P_t Y_t}$$

where B_t is the nominal stock of gross debt of the sector; P_t is the price level; Y_t is a measure of real income; D_t is the nominal primary balance of the sector²²; i_t is the effective nominal interest rate on the stock of outstanding debt; $\tilde{\pi}_t$ is the inflation rate; g_t is the corresponding growth rate of income Y_t ²³. Note that after the second equal sign in the expression above, the term $g_t \tilde{\pi}_t$ has been omitted since it is a product of two small numbers.

²¹Mason and Jayadev (2014) [98] refer to the autonomous debt dynamics as Fisher dynamics. This term originates from the work of Irving Fisher [59] on debt deflation.

²²The nominal primary balance corresponds to the primary deficit in the case of the public sector.

²³As presented, the equation is a simplification of the complex structure of private sector debt. In reality, private debt has a complicated maturity structure. Similarly, the effective nominal interest rate i_t is combining a large set of interest rates on debt with different risk and maturity profiles. Still, the analysis does not attempt to explain the changes in interest rates that can be caused among other things by the changing maturity composition of debt. Instead, it explores the observed effective interest rate path relative to the

$$\left[\frac{B_t}{P_t Y_t} \right] = \left[\frac{D_t}{P_t Y_t} \right] + \frac{(1 + i_t)}{(1 + \tilde{\pi}_t + g_t)} \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right]$$

Therefore, using the formula, any change in the leverage ratio can be expressed as

$$\Delta \left[\frac{B_t}{P_t Y_t} \right] = \left[\frac{B_t}{P_t Y_t} \right] - \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right] = \left[\frac{D_t}{P_t Y_t} \right] + \frac{(1 + i_t)}{(1 + \tilde{\pi}_t + g_t)} \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right] - \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right]$$

$$\Delta \left[\frac{B_t}{P_t Y_t} \right] = \left[\frac{D_t}{P_t Y_t} \right] + \frac{(i_t - g_t - \tilde{\pi}_t)}{(1 + \tilde{\pi}_t + g_t)} \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right]$$

which is approximated by

$$\Delta \left[\frac{B_t}{P_t Y_t} \right] \approx \left[\frac{D_t}{P_t Y_t} \right] + (i_t - g_t - \tilde{\pi}_t) \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right]$$

A change in the leverage ratio can be attributed to either the primary balance of the sector or the autonomous debt dynamics that combine the impact of the nominal interest rate, the inflation rate and the growth rate of real income.

$$\Delta \left[\frac{B_t}{P_t Y_t} \right] \approx \left[\frac{D_t}{P_t Y_t} \right] + \left\{ i_t \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right] - g_t \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right] - \tilde{\pi}_t \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right] \right\} \quad (3.1)$$

3.4.1 VARIABLE DEFINITIONS

The derivations above demonstrate that any change in the debt-to-income ratio can be analyzed in terms of the independent contributions of primary balance, interest rate, real income growth and inflation. The set up incorporates the implicit assumption that changes in inflation are transferred directly to nominal income but not to the nominal interest rate. Therefore, the Fisher equation does not hold in the short run. Since inflation is fully passed onto nominal rates only in the medium term, it is included as an independent determinant affecting the leverage ratio. The assumption follows a body of empirical work that confirms that nominal interest rates do not fully incorporate changes in inflation (Cooray, 2002 [41]).

The variables used in the analysis are defined below²⁴.

path of the growth rate of nominal income. The form of the equation and variables' definitions are standard in the literature.

²⁴All variables are sourced from the EUROSTAT National Sector Accounts.

Gross debt - gross debt is defined as the sum of the end-of-period stock of total debt securities (F33) and loans (F4) from the sectoral financial balance sheet. The definition of the variable is the same for both the household and corporate sectors. Identical definition of debt is used by the European Commission (EC, 2012 [122]). (In ESA 95 notation, gross debt is $F33 + F4$.)

Household gross adjusted disposable income - household gross disposable income is adjusted for the interest paid on debt. Since income is a measure of the debt servicing capacity of the sector and interest spending is part of debt servicing, I add interest spending back, obtaining the level of household income before debt payments. This adjusted measure should be a better guide of what is the full debt servicing capacity of the household sector. I also make standard adjustments for expenses and revenues related to pension funds. (In ESA 95 notation, adjusted disposable income is $B6G + (D8received - D8paid) + D41$.)

Corporate gross adjusted entrepreneurial income - entrepreneurial income measures firms' income before investor allocations and reinvested earnings²⁵. Entrepreneurial income denotes firms' funds available to service debt. Similar to the household sector, entrepreneurial income is augmented with gross interest payments. Gross interest payments include both net interest payments (D41) and FISIM allocations²⁶. Gross interest is the full amount of interest paid by the sector on its debt. (In ESA 95 notation, adjusted entrepreneurial income is $B4G + D41G$.)

Primary balance - following Mason and Jayadev (2014) [98], I define primary balance as the change in the gross liabilities of the sector minus gross interest payments (D41G). The variable is computed from changes in the stock of gross debt from one period to the next. Given this definition, defaults and re-evaluations will appear as a primary balance. The variable will reflect also asset sales over the period²⁷. The definition is identical for both sectors.

Imputed effective interest rate - interest rate is derived directly from the sectoral accounts instead of banking surveys. The effective interest rate represents the gross interest payments for the period divided by the stock of debt at the beginning of the period. It corresponds to the

²⁵The entrepreneurial income account is a standard ESA2010 account provided by EUROSTAT. The entrepreneurial income account is a balancing item that corresponds to current profits before distribution and income tax.

²⁶Financial intermediation services indirectly measured (FISIM) is an indirect measure of the value of financial intermediation services provided but not explicitly charged by financial institutions as the price of these services is incorporated in interest rates.

²⁷Based on the definition, any measurement error will also be contained in the primary balance term.

average interest paid by the sector on its current stock of debt and it is not the marginal rate on new borrowing.

Inflation rate - inflation is computed as the rate of change of the GDP deflator for individual Euro Area members.

Growth rate of real income - is the growth rate of the adjusted disposable income (for the household sector) or adjusted entrepreneurial income (for the corporate sector) minus the inflation rate.

3.4.2 EMPIRICAL FINDINGS

Autonomous debt dynamics are governed by the paths of three variables: interest rate, growth rate of real income and inflation. Given the presence of an existing stock of debt, whenever the interest rate paid on debt surpasses the growth rate of nominal income, the autonomous debt dynamics drive the leverage ratio upward. Figure 3.14 reveals the average difference between the growth rate of nominal income and the effective interest rate for Euro Area countries before and after the financial crisis. There is a marked shift in the spread between nominal income growth and effective interest rate between the two periods. These differences have affected agents' borrowing behavior. In core Euro Area economies - Belgium, Germany, the Netherlands and France - the effective household nominal interest rate consistently exceeds the growth rate of nominal income both before and after the crisis. Therefore, in these economies, the household sector experienced negative autonomous debt dynamics in the period before 2008. The negative spread discouraged the fast accumulation of debt in these countries. In the years following the financial crisis, the negative autonomous debt dynamics remained. In particular, the negative spread widened in Belgium, France and the Netherlands²⁸. Similar trends are observed also in Italy and Portugal that can be explained by the large initial stock of private debt. On the other hand, vibrant economic activity before 2008 in the peripheral and CEE Euro Area members maintained nominal income growth above the effective interest rate. The positive spread was highest in the CEE countries - Estonia, Slovakia, Latvia and Lithuania - where the average difference between the growth rate of nominal income and the effective interest rate is above 5% in the period before the crisis. In these countries, fast economic

²⁸The evolution of the effective interest rate and the nominal income growth for the household and corporate sectors is presented in figures B.7 and B.8 of Appendix B.1. The graphs present the positive spread between income growth and interest rates that provoked higher borrowing during the boom period.

growth during the boom period contributed to high credit demand that further boosted income, supporting the leveraging cycle.

Mechanically, the positive spread between the growth rate of nominal income and the effective interest rate observed in the peripheral and CEE economies before 2008 should lead to a reduction in the leverage ratio as long as the household sector does not accumulate new debt. In reality, over the same period, the household sector in these countries expanded its leverage as the boost to agents' confidence due to high income growth and the respective pick up in borrowing surpassed the positive effects of the autonomous debt dynamics. This is confirmed by the empirical results presented in table 3.1. The positive intercept β_0 demonstrates that the average change in the leverage ratio has been positive over the period which is consistent with the observed rise in debt. More importantly, the significant positive coefficient for the dummy variable accounting for periods of positive autonomous debt dynamics β_1 reveals that household leverage has been expanding in spite of the positive autonomous debt dynamics. The estimated value is even higher when limiting the sample to the peripheral and CEE Euro Area member states. As mentioned above, in these economies, the large positive spreads between nominal income growth and interest rates instigated a process of rapid leveraging that outweighed the autonomous debt dynamics.

Since the onset of the financial crisis, the spreads between interest rates and nominal income growth have reversed, as figure 3.14 demonstrates, opening the door to negative autonomous debt dynamics. On one side, the combined effects of falling credit demand and unprecedented monetary policy easing have brought rates down throughout the Eurozone²⁹. However, the fall in economic activity was large enough to overcompensate for the fall in rates. Household income plummeted after the crisis (most visibly in 2009 and onwards), setting off dangerous autonomous debt dynamics in the most affected economies. Concentrating on the peripheral and CEE countries in figure 3.14, there has been a sizable shift of over 10 percentage points between the average positive spreads observed before the crisis and the large negative spreads after 2008. This sharp reversal has a twofold impact on leverage. By damaging borrowers' confidence, it causes a period of active deleveraging. However, simultaneously, the autonomous debt dynamics act in the opposite direction, pushing the leverage ratio upward.

²⁹Even though interest rates have fallen after the crisis, credit rationing and higher lending standards have been limiting the supply of credit.

Figure 3.15 presents similar dynamics for the corporate sector. However, due to lower effective interest rates compared to the household sector, the spread between nominal growth rates and effective interest rates is positive in most of the Euro Area during the boom phase. Except for Germany, Ireland and Italy, on average the corporate sector enjoyed positive debt dynamics before the financial crisis. After the onset of the crisis, income fell sharply in 2009 in most member states which on average caused negative debt dynamics in the post financial crisis period. Still, corporate income recovered relatively fast in the CEE countries and in Ireland as non-financial corporations in these countries carried out the adjustment faster.

The empirical results of the analysis of corporate leverage are presented in the last two columns of table 3.1. Again, means are estimated over the full sample of Euro Area countries and also the non-core economies. The estimated intercept β_0 is positive in both cases, reflecting that on average the corporate leverage ratio has increased over the analyzed period. Still, the coefficient estimate for periods of positive debt dynamics β_1 is negative and significant which implies that the autonomous debt dynamics have contributed to a reduction in leverage. The results differ from the household sector where the intentional leveraging efforts of agents was strong enough to completely overtake the autonomous debt dynamics. The last column in table 3.1 demonstrates that the average increase in corporate leverage observed in the peripheral and CEE countries is markedly higher than in the core Euro Area economies.

Going a step further, figures 3.16 and 3.17 relate changes in the leverage ratio to the contribution of autonomous debt dynamics. White bars depict the aggregate impact of interest rate, inflation and real income growth. Concentrating on the household sector, before the financial crisis, autonomous debt dynamics had visible impact on the leverage ratio in Belgium, Germany, the Netherlands, and Portugal where the two series were closely related. In contrast, in the peripheral economies and particularly in the CEE members, household borrowing substantially outweighed the positive effect of autonomous debt dynamics. In Baltic countries, autonomous debt dynamics were counteracted by a robust credit demand that fueled a substantial debt expansion and caused a rapid increase in leverage. Similar developments were observed also in Ireland, Greece, Spain, Cyprus, Slovakia and Slovenia. However, with the onset of the financial crisis, a shift occurs and autonomous debt dynamics take a central stage in the evolution of leverage. The growth rate of real income plummets in 2009 across the Euro Area that obstructs the deleveraging effort of the private sector.

The outlined trends in figure 3.16 are summarized by the regression results in table 3.2. As the second column of table 3.2 demonstrates, autonomous debt dynamics had no significant effect on the evolution of the leverage ratio before the crisis. The coefficient estimate of -0.56 is not significant. In addition, the negative sign confirms the results from table 3.1 that before the financial crisis changes in household leverage were defined by agents' leveraging effort that dominated the positive effect of autonomous debt dynamics. However, since the onset of the financial crisis, autonomous debt dynamics dictate the evolution of household leverage. This is implied by the positive and significant coefficient estimate for the interaction variable ($\beta_3 = 0.97$). Peripheral and CEE economies are the drivers behind this trend as columns 2 and 3 demonstrate. While in non-core Euro Area economies leverage before the crisis develops diametrically different from the path defined by autonomous debt dynamics (statistically significant coefficient of -0.97), in core economies autonomous debt dynamics govern the shifts in leverage (statistically significant coefficient of 1). After the onset of the crisis, autonomous debt dynamics become a significant determinant of the path of the leverage ratio also in the peripheral and CEE economies (statistically significant coefficient of 1.41) while there is no significant change for the core economies.

For the corporate sector, the picture is relatively similar. As table 3.1 demonstrates, autonomous debt dynamics have a significant role in shaping the corporate leverage ratio throughout the analyzed period. Before the financial crisis, autonomous debt dynamics dictate the evolution of leverage in the core Euro Area economies: Belgium, Germany, France, the Netherlands, Austria. To certain extent they affect also the leverage ratio in Italy and Portugal where the initial stock of debt is large. In Baltic countries and the fast growing peripheral economies - Spain and Ireland - changes in leverage are influenced by the credit boom. Still, the last column of table 3.2 confirms that on average for the Euro Area, autonomous debt dynamics have affected significantly the level of corporate leverage throughout the period. Their role has increased further since the beginning of the crisis. Thus, in the period since 2007, a large portion of the change in corporate leverage can be attributed to autonomous debt dynamics.

The individual elements of autonomous debt dynamics provide additional insight: figures 3.18 and 3.19. For both sectors, the growth rate of real income is the primary component that determines autonomous debt dynamics before and after the financial crisis³⁰. The figures demonstrate the

³⁰Other perspective of the decomposition of autonomous debt dynamics into sub-components is presented in figures B.9 and B.10 of Appendix B.1. There, instead of looking at the change in levels through time, the plots present the actual levels.

change in the level of autonomous debt dynamics and the contribution to that change coming from individual shares: interest rate, income growth and inflation. As the two figures establish, the income growth share accounts for a large portion of the changes in autonomous debt dynamics. Before the crisis, expanding income led to positive debt dynamics in spite of rising interest rates. On the other hand, after the crisis, the fall in income is the leading factor that affected autonomous debt dynamics. Regardless of the massive injection of market liquidity by central banks that drove interest rates down, the drop in income was large enough to generate a sharp reversal in autonomous debt dynamics. In addition, falling inflation is playing a role in Ireland, Greece, Portugal and the Baltic states. Therefore, after the financial crisis, the key drivers that caused the negative autonomous debt dynamics are the economic contraction and deflationary pressures while falling interest rates have been pushing in the opposite direction.

3.5 MACROECONOMIC IMPACT OF DELEVERAGING

The need to reduce leverage following a credit boom defines the gravity and length of the economic downturn accompanying a balance sheet recession. Analyzing past deleveraging episodes, Reinhart and Rogoff (2010) [112] confirm that balance sheet recessions are deeper and more protracted when compared to recessions with no debt overhang. Thus, the build-up of debt during the period of rapid expansion has a macroeconomic cost following the bust. Previous episodes of deleveraging have generally been associated with a weak economic performance (IMF, 2009 [81]). Buiters and Rahbari (2012) [30] summarize 18 episodes of financial crises accompanied by deleveraging in a database covering 86 countries from 1960 to 2006. According to their paper, historic episodes of deleveraging are long-lasting and debt reduction severely affect output, aggregate demand and employment. The effect of deleveraging on real GDP is large - in the first two years following a financial crisis, output falls on average by 10% relative to a pre-crisis trend and it fails to close the gap in subsequent years. Therefore, the financial crisis leads to an extended period of weak economic activity. Consumption has very similar dynamics to output which can be expected considering its sizable share in GDP. On the other hand, the fall in investment is more than three times larger³¹.

³¹Developing a theoretical model of deleveraging, Eggertsson and Krugman (2012) [51] also account for the larger drop in investment relative to output. They calibrate their model using US data from the recent financial crisis and target a fall in investment over three times larger than the fall in GDP. A substantially larger fall in investment relative to output is obtained also in the sectoral model of deleveraging developed by Georgiev and Lozev (2015) [65].

In addition, the current account moves into a surplus, but the improvement is due primarily to import compression instead of a pick up in exports. The gain in net exports is achieved through depressed domestic demand and falling standard of living.

Turning to the present downturn in the Euro Area, the observed path of macroeconomic variables follows broadly previous balance sheet recessions. There is a clear trend, Euro Area countries that have experienced rapid credit expansion are suffering a more severe economic contraction. A distinction can be drawn between the decline in real GDP observed in core Euro Area economies and in peripheral and CEE members. Figure 3.20 shows the deviation of real GDP from a pre-crisis linear trend³². Due to the global scale of the crisis, all Euro Area countries have been impacted by it. Still the decline varies across member countries. Core economies that experienced a low leverage growth in the years before 2007 have endured a relatively minor fall in output (solid red line). Three years after the financial crisis, real GDP in core Euro Area economies deviated around 5% from the pre-boom trend. The gap increases to 10% by year six. The results are close to the averages computed by Buiter and Rahbari (2012) [30]. Looking at individual countries, the deviations from trend observed for Austria, Belgium and France are close to 9%, which is double the number estimated for Germany (4.6%). Since the Netherlands has the highest stock of private debt among the core Euro Area economies, it experienced also a relatively larger economic slowdown. Table 3.3 contains the deviation of real GDP from trend for individual Euro Area countries.

While the deviation from trend for core Euro Area economies is comparable to historic averages, the peripheral and CEE member countries have suffered a severe recession (dashed and dotted lines in figure 3.20). The average gap between real GDP and linear trend for the two country groups falls in the lower quartile of the distribution of previous balance sheet recessions. Most severely affected

³²The loss in output following the financial crisis is estimated relative to a pre-boom linear trend. Using a log transformation of real GDP over the period 1990 - 2004, I calculate a linear trend. In case of shorter series, the first available data point is used. As using data from the peak of the boom can distort the results, the last year over which the linear trend is computed is 2004. The estimated trend is applied to the actual value of the log of real GDP in year 2008. Therefore, the trend value in period $t + 1$ is computed as the sum of the previous period estimated value and the trend itself: $Y_{t+1}^{trend} = Y_t^{trend} + Trend$ and $Y_{2008}^{trend} = Y_{2008}^{observed}$. Deviations of the actual series from the estimated linear trend are computed in percents using the formula (it is similar to the calculation of output gap)

$$Deviation_t = 100 * \left(\frac{Y_t^{observed} - Y_t^{trend}}{Y_t^{trend}} \right)$$

By construction, the deviation from trend in year 2008 equals 0. The mechanics for computing the deviations of real private consumption and private investment are identical. Figures B.11, B.12, and B.13 in Appendix B.1 present log transformations of the actual series of real GDP, real private consumption and real private investment and the calculated trends.

by the crisis were Greece, Ireland, Spain, and the Baltic countries. The deviation from trend for Greece and Ireland is over 30% which can be explained to a certain extent by the fast pre-boom GDP growth in the two countries. At the same time, the gap for Baltic countries is over 25%.

The slowdown in private consumption across country groups approximates the slowdown in output. Figure 3.21 illustrates the average deviations of output, consumption and investment from trend across country groups³³. Similar to real GDP, the deviation of private consumption is smallest for core Euro Area economies. By the end of the six year period, it is below 10%. Again, Germany has the smallest gap to trend, followed by Austria, Belgium and France. On the contrary, Baltic economies experience a massive dip in consumption over the first two years of around 15%. Comparing the size of the gap to trend, the deviation of real consumption is smaller compared to output. This is observed for both core and peripheral Euro Area members³⁴. For CEE countries, the deviation of real GDP is smaller after the second year which can potentially be explained by net trade. In addition, figure 3.21 demonstrates the collapse of private investment across the Eurozone. As in previous episodes of balance sheet recession, the fall in investment is around three times larger than the fall in output. Core economies undergo the smallest decrease in investment. Still, by the sixth year, the deviation from trend is over 15%. Germany is the only country that is close to trend for investment. Peripheral countries and CEE Euro Area members experience sizable declines. In Estonia, Latvia, Slovenia and Ireland the deviation from trend is around 60%. The data reveals a slight uptick in investment in 2011, but the common trend across countries is one of a continuing decline. It is disconcerting that unlike in previous recession episodes, more than 6 years after the crisis, the difference between actual data and pre-crisis trends is widening. No country in the monetary union has been able to recover from the crisis.

Summarizing the impact on the real economy from the private sector balance sheet adjustment, private consumption, investment and output have fallen sharply after the crisis in the most affected economies. The observed deviations of macrovariables from their long-term linear trends are consistent with previous episodes of balance sheet recession described by Buiter and Rahbari (2012) [30]. Core countries have been less affected by the financial crisis and the gap to trend for them gravitates around the averages computed by Buiter and Rahbari (2012) [30]. The Netherlands is

³³The deviations of output, consumption, and investment from pre-boom linear trends for individual Euro Area members are presented in figures B.14, B.15 and B.16 of Appendix B.1.

³⁴Similar results are obtained by Georgiev and Lozev (2015) [65]. In their model of sectoral deleveraging, the fall in aggregate consumption is smaller than the fall in output. The larger contraction in output is caused by the collapse of private investment.

the only exception where the large stock of private debt impacts negatively economic growth. The deviation of Dutch consumption, investment, and output from trend compares to the one in Spain. On the other hand, peripheral and CEE economies undergo a deep recession and their experience corresponds to the lower quartile of the distribution of past balance sheet recessions. Nevertheless, it is important to underline that no country shows signs of returning to its long-run trend of growth six years after the financial crisis. As data reveals, the balance sheet recession could lead to a new lower long-run rate of economic growth.

Analyzing the macroeconomic contraction following the financial crisis and comparing it to the credit expansion observed during the boom phase, it can be concluded that core Euro Area member states are less affected by the financial crisis since there has been a smaller build-up of debt. Recent research relates the size of debt overhang to the decline in economic activity. In series of papers, Mian, Rao, and Sufi (Mian, Rao and Sufi, 2013 [103] and Mian and Sufi, 2011 [101]) explore micro-level US county data and present strong empirical evidence that the size of pre-crisis liabilities affects the level of economic activity after the crisis. They establish a connection between debt overhang and the post-crisis decline in consumption, employment and broader economic activity. In a similar analysis of Spanish provincial data, Jauch and Watzka (2012) [83] confirm a positive link between the pre-crisis level of mortgage debt and the rise in provincial unemployment during the crisis. Furthermore, cross-country empirical analysis also supports the existence of a link between debt overhang and the slowdown in economic activity. Igan et al. (2013) [79] study data from a sample of 24 OECD countries over the period 1980-2011. They find that the consumption lost in 2010 relative to a pre-crisis trend is larger in economies that experienced a faster increase in household leverage over the period 2002-2006.

Figure 3.22 establishes a negative relationship between the level of private leverage achieved in 2009 and the post crisis deviation of real GDP from trend for Euro Area member states. The build-up in debt before the crisis translates in a larger contraction afterward. There are two outliers on the graph. However, their economic performance can be explained by the idiosyncratic characteristics of the two countries. Luxemburg has a massive stock of private debt but it has not experienced a very large economic contraction since the small country hosts various multinational companies. The size of the private indebtedness there is exaggerated as part of the private debt is to subsidiaries and other related entities. The other outlier - Greece - has a relatively small stock of private debt but a massive stock of public debt that has provoked the collapse in economic activity.

Figure 3.23 takes a different perspective and considers the link between the speed of credit expansion and the deviation of real GDP from trend for Euro Area countries. The graph explores the notion that rapid credit growth is associated with an unsustainable build-up of debt and the issuance of subprime loans. As in figure 3.22, a similar trend is observed. Euro Area members that experienced the fastest increase in private debt relative to GDP are undergoing the deepest recessions. The scatter plot demonstrates that the relationship is well defined with no large outliers. The economic contraction in Greece again appears large (36%) relative to the increase in credit (80%), but this can be explained by its large stock of public debt.

While figures 3.22 and 3.23 strongly suggest the presence of a link between credit expansion and the economic downturn, an empirical analysis is needed to confirm the relationship³⁵. To allow for a cross sectional analysis, the sample of countries is extended to include OECD members. In the theoretical model of deleveraging developed in Georgiev and Lozev (2015) [65], the size of output contraction is affected by the degree of debt overhang - the difference between the current level of debt and an “optimal” sustainable level. Two factors can influence the size of debt overhang: the total level of debt and the speed of credit expansion. The intuition behind is that while some countries have a large stock of private debt, that stock has been maintained over a long period of time which makes it more sustainable when compared to a country that has moved rapidly from a state of low private debt to a state of high debt over a short period of time. Therefore, an empirical analysis of the effect of private debt on economic activity has to account for both the absolute level of debt but also the speed of debt accumulation. In addition, after the onset of the crisis, the presence of a large debt overhang affects lenders’ willingness to extend loans and increases interest rate risk spreads. This has an additional negative impact on economic activity as it inhibits new borrowing and obstructs the rolling over of existing debt.

Table 3.4 presents the estimation results of assessing the role of private debt on economic activity following the recent financial crisis. Three nested specifications are considered where the dependent variable is the deviation of real GDP from the pre-boom linear trend. As a first specification, the deviation from trend is regressed on the ratio of debt-to-GDP in 2009 and the change in the interest rate during the crisis³⁶. The two regressors explain around 67% of the variability in the

³⁵Figures B.1 and B.2 in Appendix B.1 replicate scatter plots 3.22 and 3.23, extending the sample to the OECD member countries. Similar trends are observed.

³⁶The lending rate to the private sector would be the optimal interest rate to be used in the regression analysis since it corresponds to the borrowing interest rate modeled in Georgiev and Lozev (2015) [65]. However, due to data limitation, lending rates are substituted with 10Y government bond yields. The reasoning

real GDP gap across countries. Estimates have the expected negative sign - higher stock of private debt before the crisis causes a larger economic downturn. Similarly, as the interest rate risk spreads widen, economic output contracts. Still, as discussed above, not only the level of private debt but also the speed of credit expansion can affect the degree of debt overhang. The second specification reflects this fact and adds a variable that reflects the increase in gross private debt relative to the initial stock of debt in 2002. The addition of the variable improves the explanatory power of the regression. The coefficient estimate for the variable that measures the speed of credit expansion is statistically significant and with the expected sign³⁷. The estimate confirms that a faster build-up of debt during the expansion causes a larger debt overhang and triggers a more intense deleveraging after the onset of the crisis.

As a third specification, a variable is added that interacts private debt in 2009 to a dummy that has a value of 1 if the public debt-to-GDP ratio in 2009 is above a 60% threshold. The interaction variable aims to account for the drag on economic activity caused by the simultaneous debt overhang of the private and public sectors. In addition, as highlighted by Taylor (2012) [126], if the public sector has a high stock of debt at the beginning of the crisis, it has a limited ability to fund an expansionary fiscal policy. While the estimated coefficient has the expected negative sign, it is not significant at the 10% level. A potential explanation is that several of the core Euro Area economies that were relatively less affected by the crisis had large stocks of public debt. On the other hand, many of the peripheral and CEE Euro Area members had small stocks of public debt before the crisis. Thus, the impact of high public debt can be harder to derive from the data and the lack of significance of the coefficient estimate should not be over-emphasized.

The results of the cross-sectional analysis confirm the significance of debt overhang in triggering the deleveraging process that causes a prolonged drag on economic activity. Not only the stock of private debt but also the speed of credit growth are significant determinants of debt overhang. In addition, the widening of interest rate spreads during the crisis further strains demand. These three factors account for over 70% of the variation in real GDP relative to trend. These findings are consistent with previous empirical analyses that use both macro and micro-level data.

is that sovereign bond yields are a lower bound for the borrowing rates that private agents face. Therefore, a rise in bond yields usually causes an increase in private borrowing rates.

³⁷All regression specifications are computed using a standard OLS estimator and a heteroskedasticity robust White estimator. The variance of the coefficients does not change significantly and the coefficient estimates remain significant when using both estimators. The presented adjusted R^2 and the BIC statistics in Table 3.4 are computed using the standard OLS estimator.

3.6 SUMMARY OF FINDINGS AND POLICY OBSERVATIONS

With the beginning of the financial crisis, the overindebted household and corporate sectors initiated a process of deleveraging. The organized effort of the private sector to pay down debt had a direct negative impact on private demand. The macroeconomic effects of the crisis are most severe if more than one sector needs to deleverage simultaneously (Bornhorst and Arranz, 2014 [26]). In a situation when the private sector is rebuilding its balance sheet, the optimal policy of the public sector is to step in and pick up the slack in aggregate demand. Eggertsson and Krugman (2012) [51] demonstrate this theoretically by deriving that fiscal multipliers are higher than one in a period of private sector deleveraging. Furthermore, higher fiscal multipliers during a period of economic downturn are estimated empirically by Auerbach and Gorodnichenko (2012) [9]. Ideally, fiscal stimulus has to be introduced at the beginning of the crisis and should be maintained throughout the duration of the private sector deleveraging. Once the private sector has achieved a lower sustainable level of debt, the government can switch to a policy of fiscal surpluses.

However, there are two major obstacles faced by Euro Area member states in their attempt to counteract the negative effects of the balance sheet recession. First, the large public debt of peripheral Euro Area economies that quickly expanded after the beginning of the crisis limited their ability to borrow from the international financial markets at reasonable interest rates in the years 2011-2012. Yields have stabilized only after the resolved intervention of the European Central Bank. Furthermore, European regulations are strictly against expansionary fiscal policies leading to high public budget deficits. Second, because of the common currency, domestic and international investors can purchase government bonds issued by any Euro Area country without taking on exchange rate risk. As a consequence, Koo (2011) [88] argues that countries undergoing an active deleveraging of the private sector and having a large pool of private sector savings are losing capital to the core Euro Area economies that are regarded as "safe heavens". The capital outflows are an additional barrier for public policy since governments cannot take advantage of private savings' surpluses to fight the balance sheet recession.

Considering the present rate of economic growth and the sluggish process of deleveraging observed in many peripheral Euro Area economies, the reduction of current debt levels will take several years and will generate a continuous drag on aggregate demand. A potential solution is a more organized effort to clear the balance sheets of financial institutions through debt restructuring

and write-offs. Even though in the short term the measures will hurt lenders and can place further strain on public finances, past experience and theoretical work demonstrate that debt forgiveness could be less painful than the alternative (Igan et al., 2013 [79]). The creation of Eurozone-wide mechanisms to support struggling banks may be a step in the right direction.

Without debt forgiveness, it is questionable whether successful deleveraging can be achieved through higher real growth rates, especially considering the current economic trends. Refraining from excessive leveraging, future growth rates are expected to be modest. In addition, several other factors have negative effects on Eurozone growth. Unfavorable demographics are straining the social and health systems and place a burden on public finances. In addition, many of the peripheral Euro Area countries have distorted and dysfunctional labor markets (Buiter and Rahbari, 2012 [30]). Government policies should be directed towards resolving some of these problems. A possible area of improvement is the present immigration policy of the Euro Area.

3.7 CONCLUSION

Since the creation of the Euro Area, favorable global economic conditions and continuous financial liberalization triggered large financial inflows to the poorer economies in the monetary union. With no exchange rate risk and larger return on capital, peripheral economies became attractive to investors and enjoyed decreasing borrowing rates. Low borrowing costs, easy access to credit, and optimistic expectations for future economic growth caused a rapid increase in leverage across the Euro Area, particularly in the periphery. The CEE economies that recently joined the union also underwent an explosion in lending when western banks entered their underdeveloped financial sectors. However, the rapid expansion of private liabilities left agents vulnerable to negative shocks and they were severely affected by the financial crisis that started in 2008. Facing crumbling asset prices, widening interest rate risk premiums and market illiquidity, agents started to rebuild their balance sheets by reducing spending. Reviewing the deleveraging process in individual Euro Area countries, there is a clear evidence that countries with larger debt overhang have been the ones most active in reducing their leverage.

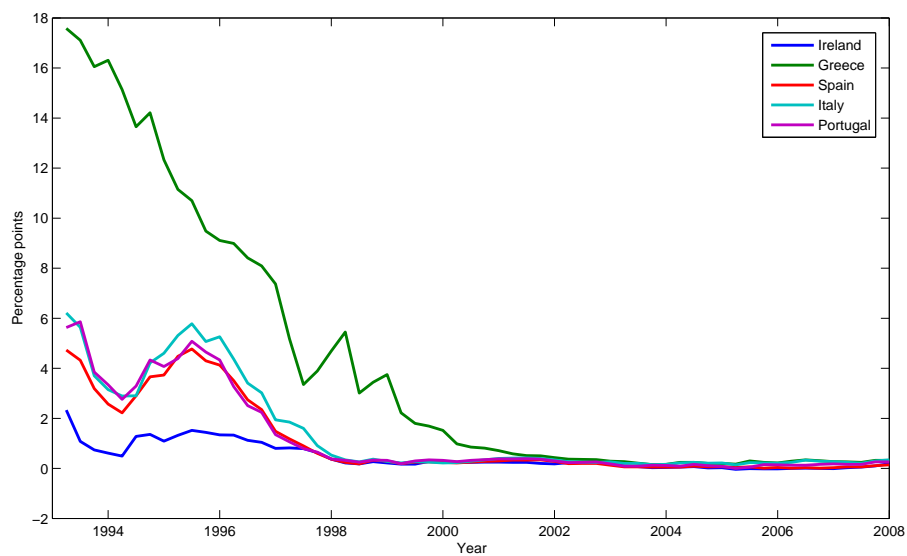
Nevertheless, while debt reduction is a rational reaction for overindebted agents, it requires a long-lasting reduction in aggregate expenditure. As a first round effect, deleveraging initiates a contraction in investment and consumption that translates into a fall in output. The data shows that

countries that have experienced the most intensive growth in leverage during the boom period are also the ones suffering the most severe contraction in demand. However, the expenditure channel is half of the story. The drop in demand affects negatively production and the corporate sector reacts by cutting wages and capital investment, driving down the prices of the two factors of production. The process is intensified if the corporate sector is also suffering from debt overhang and needs to rebuild its balance sheet. EUROSTAT National Sector Accounts demonstrate that several of the Euro Area economies are deleveraging through a decrease in employees' compensation and rent on capital. The fall in labor and capital income further affects demand. As a consequence, the income channel intensifies the economic contraction during the balance sheet recession.

The present economic downturn is unprecedented in recent history. Still, private leverage in many of the Euro Area member countries continues to be high. Any increase in the historically low interest rates can be damaging given the large stock of outstanding debt. Furthermore, due to the global scale of the crisis, it is hardly possible for the Euro Area economies to grow out of debt as in previous periods. A potential solution to the problem is a large scale debt restructuring. Reforms and debt to equity conversion can be an answer to the current situation. In addition, the European Central Bank should continue to maintain an active monetary policy stance in battling the build up of deflationary pressures. However, the role of the Bank is very limited without a collective legislative effort to decrease the debt burden.

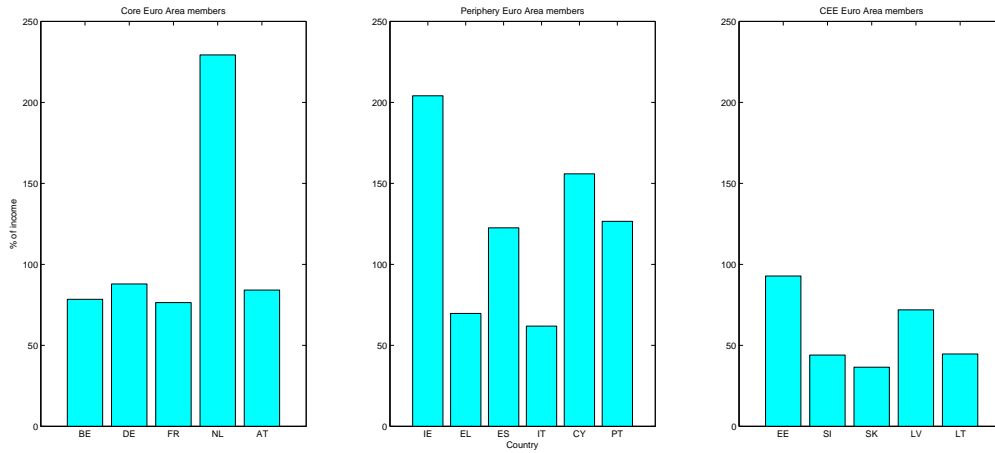
3.8 FIGURES

Figure 3.1: Compression of Sovereign Yield Spreads



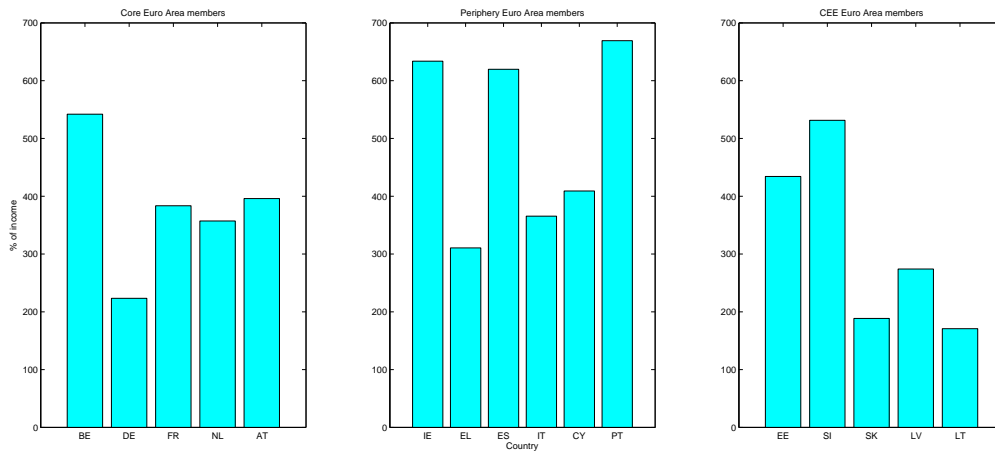
Note: The graph presents the compression of long term bond yields across Euro Area members during the period leading to the introduction of the euro. Lines denote the percentage point spread between the 10Y sovereign bond yield of individual countries and the 10Y German Bund yield. **Source:** EUROSTAT and author's calculations.

Figure 3.2: Household Sector Leverage Ratio Reached in 2009



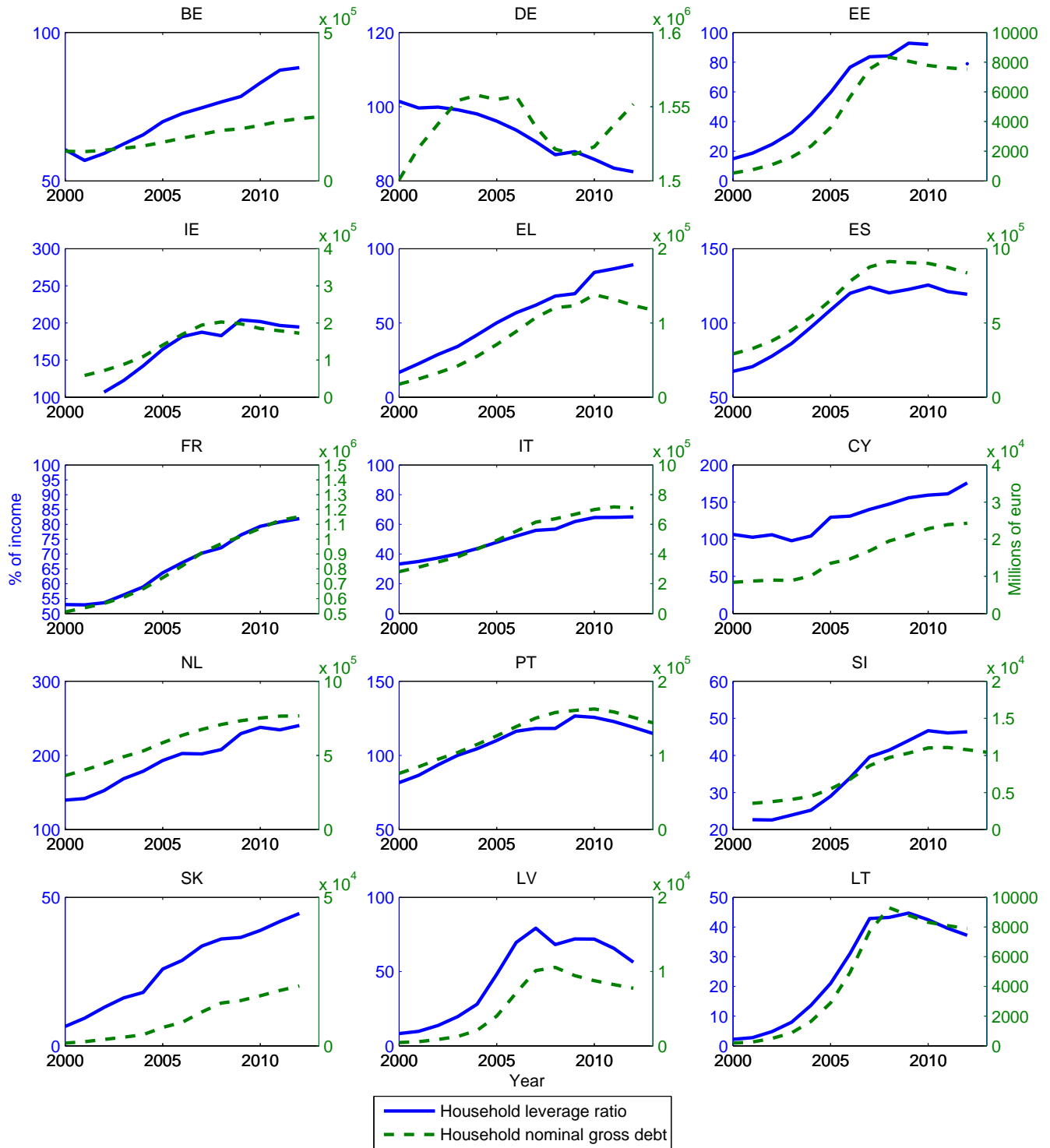
Note: The graph presents the level of the household sector leverage ratio (i.e. the ratio of gross debt to disposable income) reached at the end of 2009. Leverage is presented as a percentage of disposable income. Countries are split into core, periphery, and CEE members according to the grouping detailed before. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.3: Corporate Sector Leverage Ratio Reached in 2009



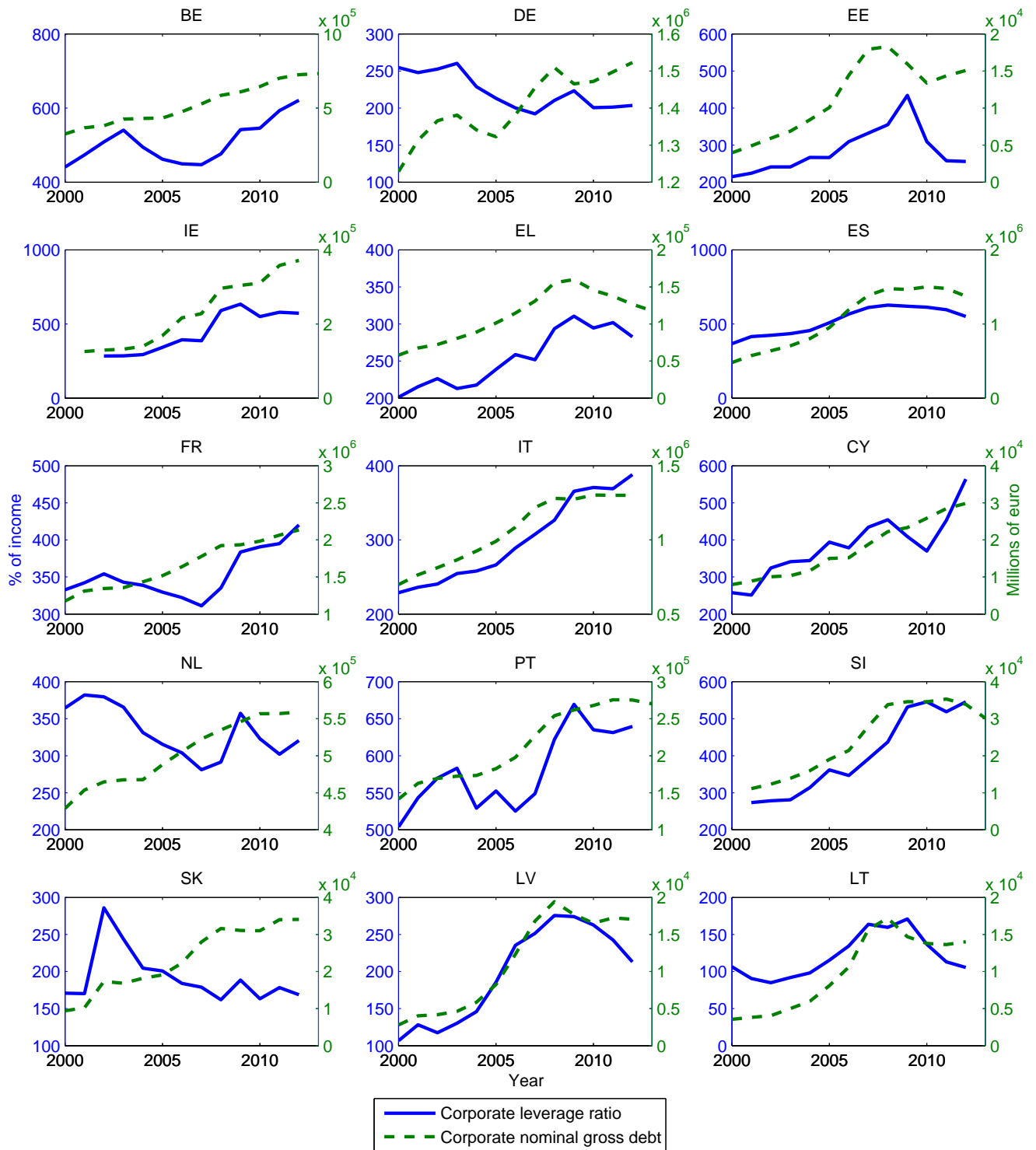
Note: The graph presents the level of the corporate sector leverage ratio (i.e. the ratio of gross debt to income) reached at the end of 2009. Leverage is presented as a percentage of entrepreneurial income. Countries are split into core, periphery, and CEE members according to the grouping detailed before. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.4: Evolution of Gross Debt and the Leverage Ratio of the Household Sector



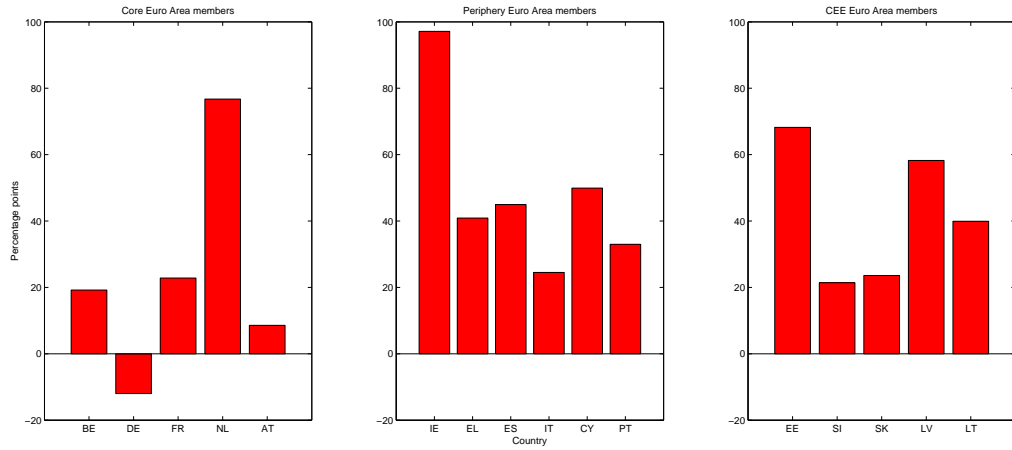
Note: The graph presents the evolution of gross debt of the household sector and the leverage ratio over the period 2000 to 2013. The leverage ratio defined as gross debt divided by nominal disposable income is presented in percentage points. Gross debt is in millions of euro. Each individual plot corresponds to a member country. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.5: Evolution of Gross Debt and the Leverage Ratio of the Corporate Sector



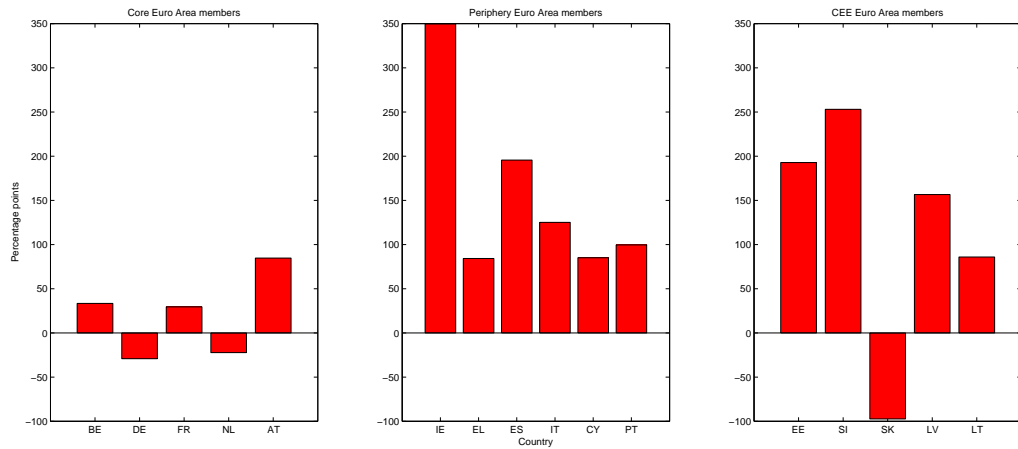
Note: The graph presents the evolution of gross debt of the corporate sector and the leverage ratio over the period 2000 to 2013. The leverage ratio defined as gross debt divided by nominal entrepreneurial income is presented in percentage points. Gross debt is in millions of euro. Each individual plot corresponds to a member country. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.6: Household Sector Percentage Points Change in Leverage Between 2002 and 2009



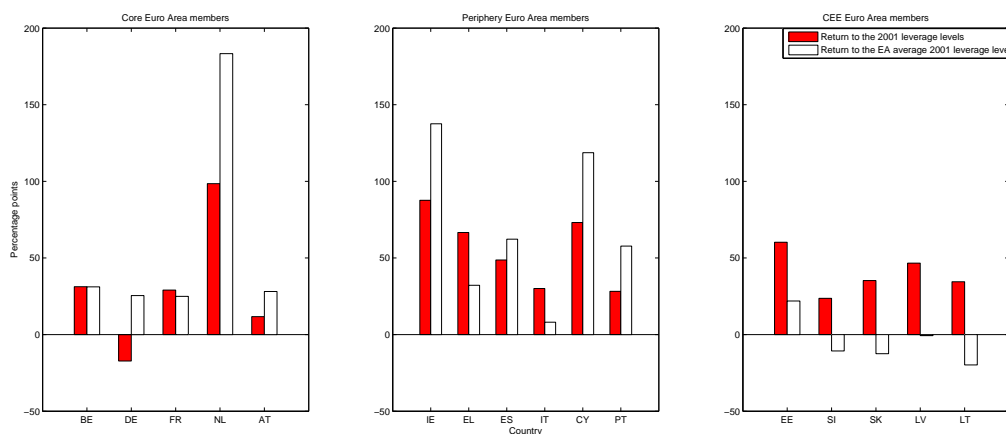
Note: The graph presents the change between the household leverage ratio at the end of 2002 and 2009 in percentage points. Countries are split into core, periphery, and CEE members. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.7: Corporate Sector Percentage Points Change in Leverage Between 2002 and 2009



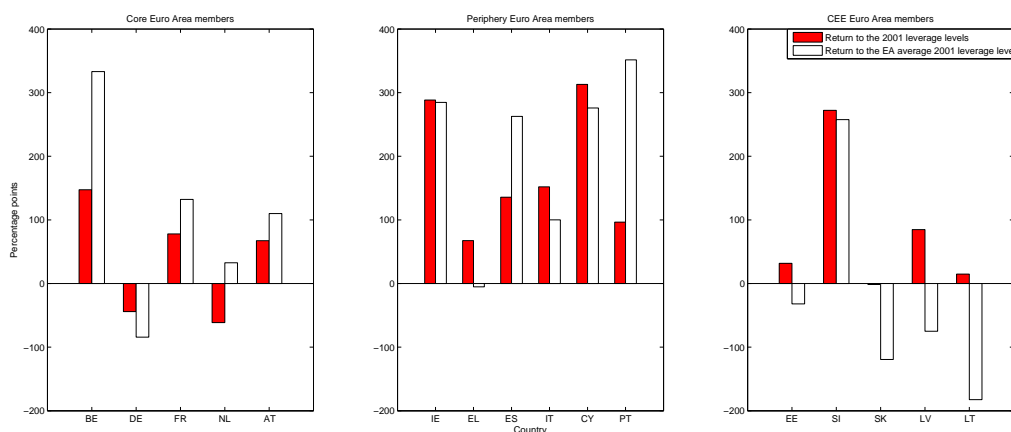
Note: The graph presents the change between the corporate leverage ratio at the end of 2002 and 2009 in percentage points. Countries are split into core, periphery, and CEE members. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.8: Percentage Points Change in Household Leverage Required to Return to 2001 Levels



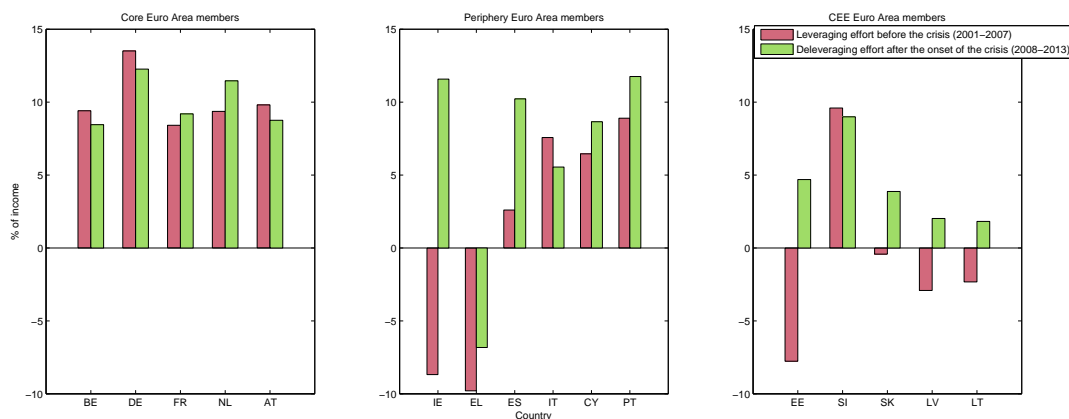
Note: The graph demonstrates the percentage points reduction in the household leverage ratio that will bring it back to its 2001 level. Bars correspond to the difference between the observed levels of leverage in 2013 and 2001. Red bars measure the percentage points decrease in leverage needed to bring the debt-to-income ratio back to the country specific 2001 level, while white bar present the percentage points reduction that will bring household leverage to the average level for the Euro Area in 2001. Countries are split into core, periphery, and CEE members. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.9: Percentage Points Change in Corporate Leverage Required to Return to 2001 Levels



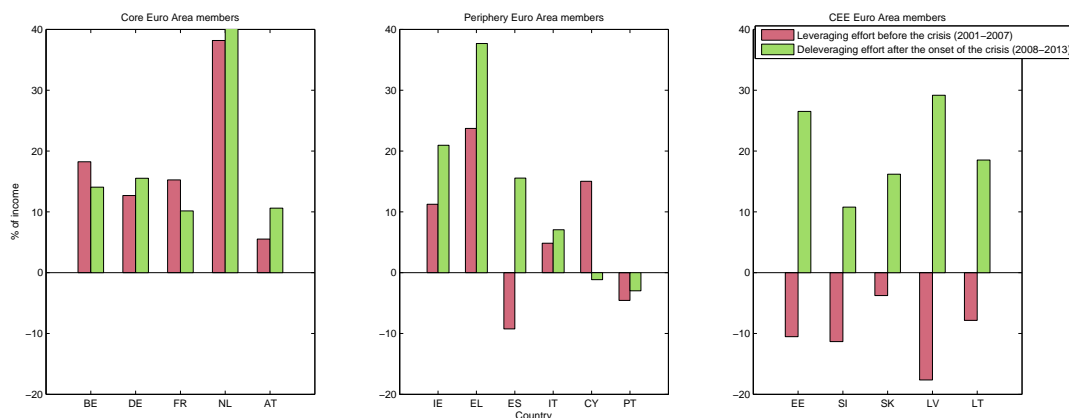
Note: The graph demonstrates the percentage points reduction in the corporate leverage ratio that will bring it back to its 2001 level. Bars correspond to the difference between the observed levels of leverage in 2013 and 2001. Red bars measure the percentage points decrease in leverage needed to bring the debt-to-income ratio back to the country specific 2001 level, while white bar present the percentage points reduction that will bring corporate leverage to the average level for the Euro Area in 2001. Countries are split into core, periphery, and CEE members. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.10: Average Household Leveraging and Deleveraging Effort Before and After the Financial Crisis



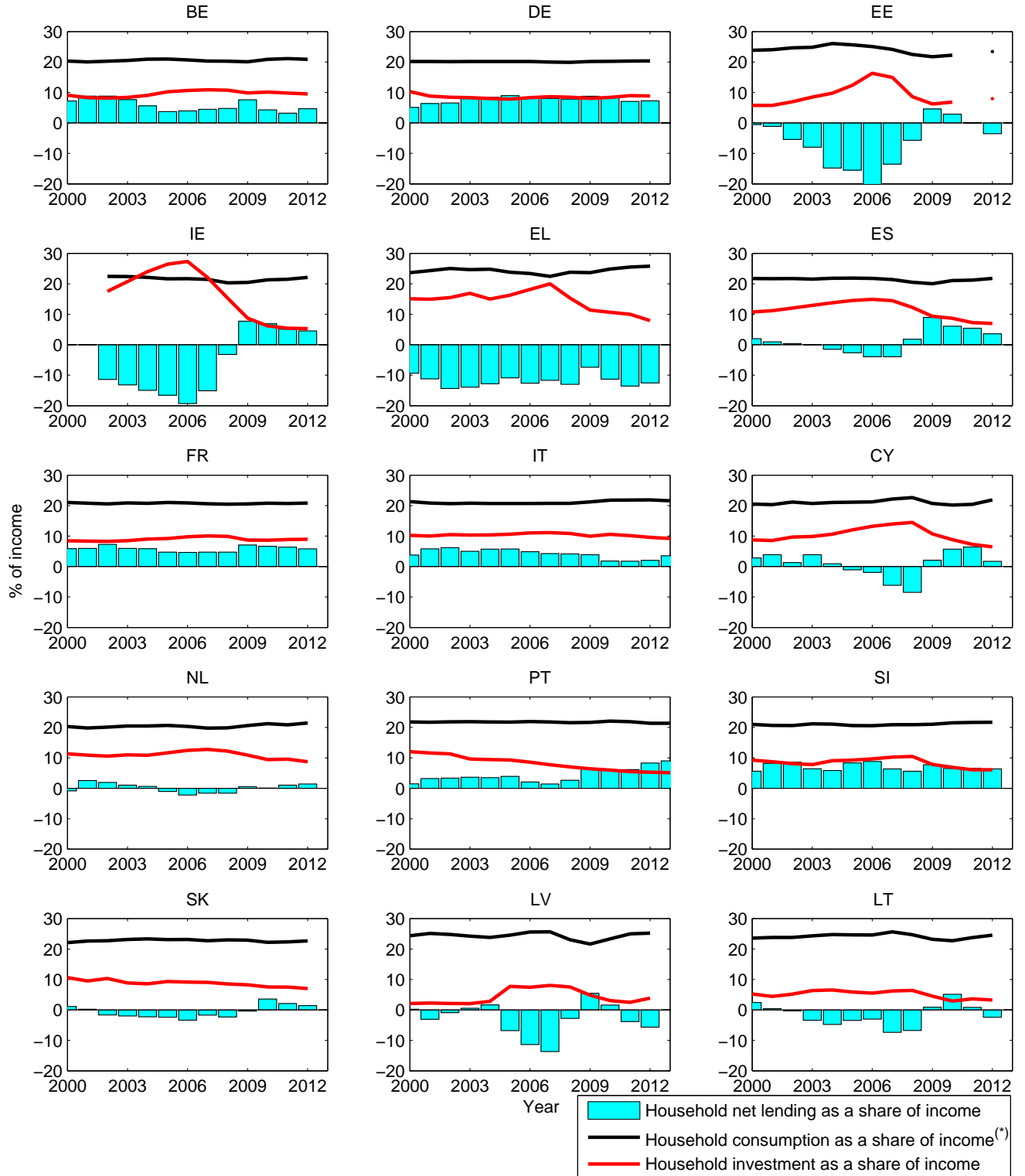
Note: The graph presents the average level of the net lending/net borrowing account for the household sector in the periods before and after the financial crisis. Net lending/net borrowing is displayed as a share of disposable income. A negative value signifies that the sector is a net borrower from other sectors, while a positive value means that the sector is a net lender. Euro Area member states are split into core, periphery, and CEE countries. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.11: Average Corporate Leveraging and Deleveraging Effort Before and After the Financial Crisis



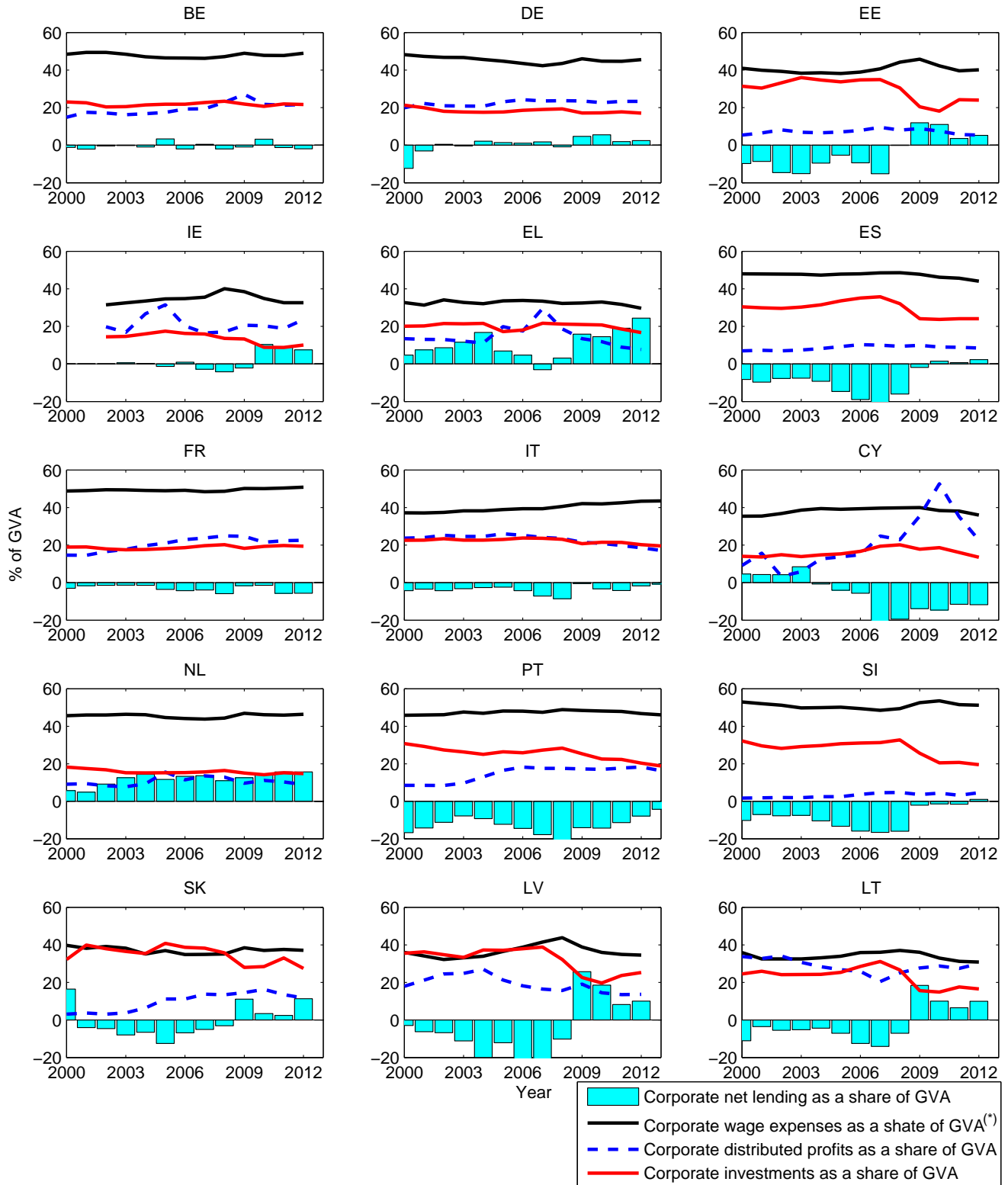
Note: The graph presents the average level of the net lending/net borrowing account for the corporate sector in the periods before and after the financial crisis. Net lending/net borrowing is displayed as a share of income. A negative value signifies that the sector is a net borrower from other sectors, while a positive value means that the sector is a net lender. Euro Area member states are split into core, periphery, and CEE countries. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.12: Shifts in Household Spending Allocations During Deleveraging



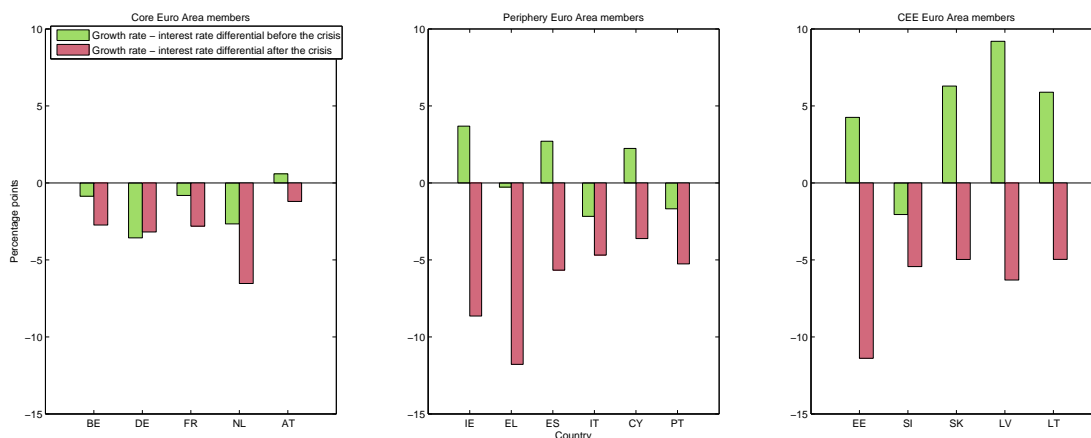
Note: The graph presents the evolution of the shares of income that households allocate to consumption and investment and relates it to the net lending of the sector. (*) Household final consumption as a share of income is reduced by 75% in order to lower the y-scale of the graph. As the graph highlights trends rather than exact values, this adjustment has no impact on variables' dynamics. Each individual plot corresponds to a member country. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.13: Shifts in Corporate Expenditures During Deleveraging



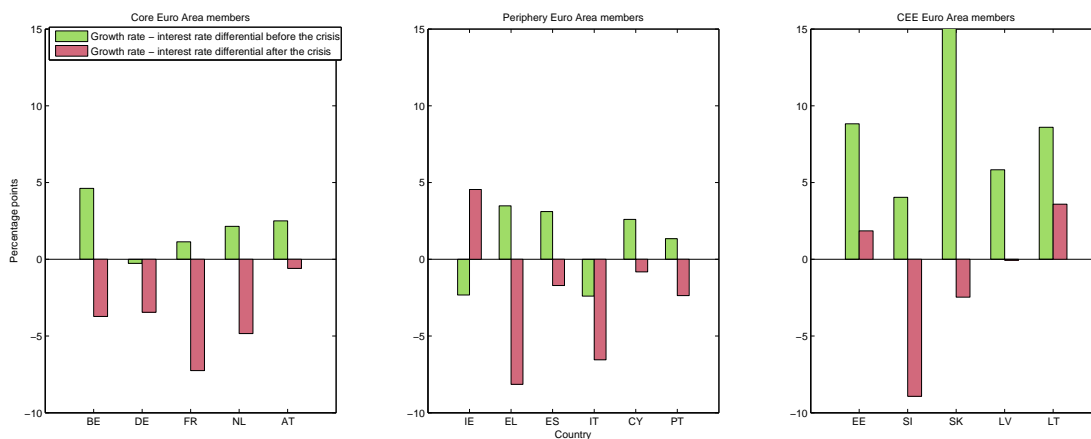
Note: The graph presents the evolution of corporate wage expenditure, capital investment and profit payoffs as a share of gross value added (GVA) and relates it to the net lending of the sector. Gross value added (GVA) has the standard definition of total output minus the cost of intermediate goods used in production. (*) Corporate wage expenditure as a share of GVA is reduced by 25% in order to lower the y-scale of the graph. As the graph highlights trends rather than exact values, this adjustment has no impact on variables' dynamics. Each individual plot corresponds to a member country. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.14: Household Sector Average Growth Rate-Interest Rate Differential Before and After the Financial Crisis



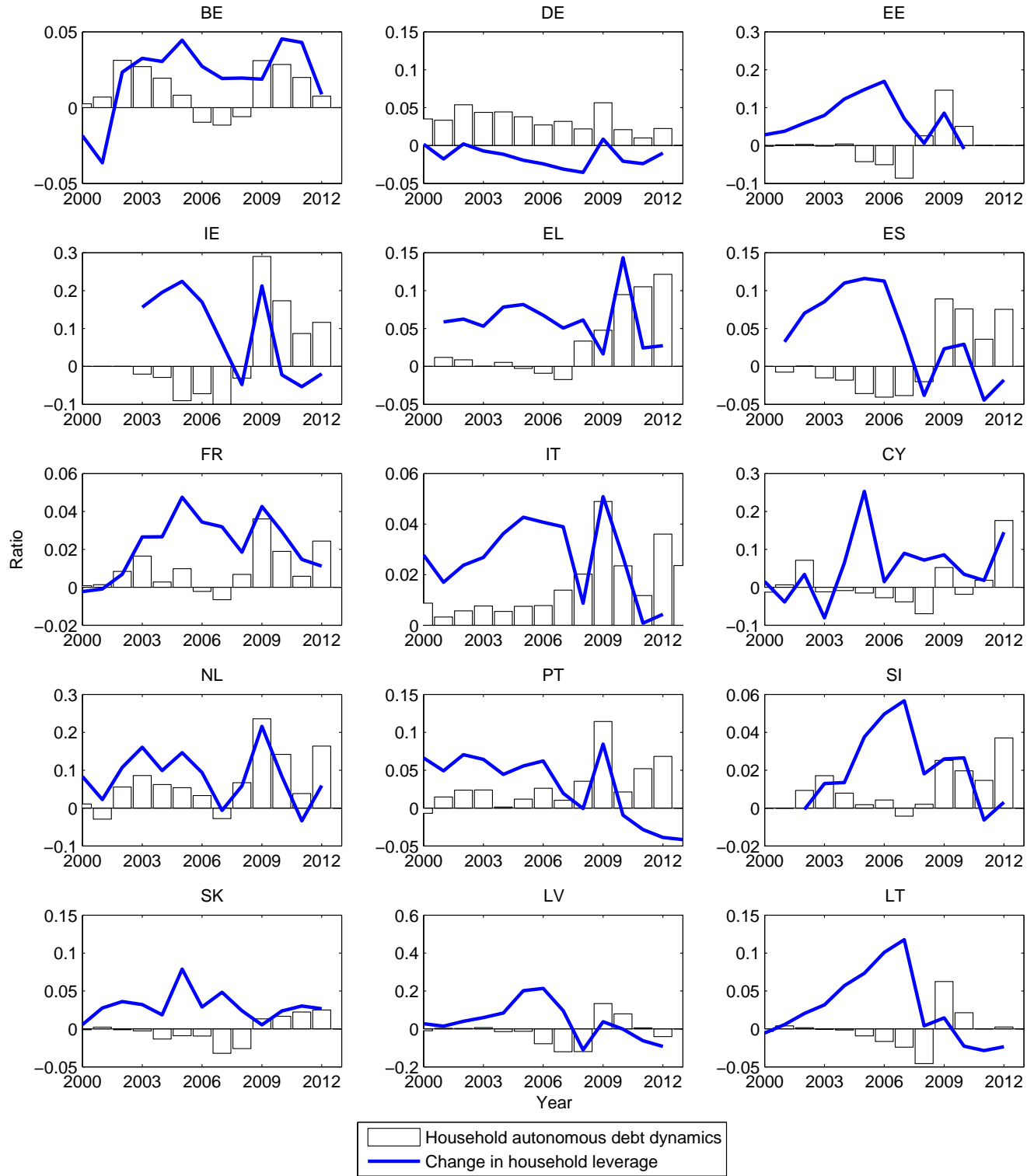
Note: The graph presents the average level of the household growth rate-interest rate differential in the periods before and after the onset of the financial crisis. Each bar presents the mean of $(g + \pi) - i$ over the specified period. Positive values signify that the growth rate of nominal income is higher than the effective interest rate which corresponds to positive debt dynamics, i.e. the level of leverage would decrease if no new debt is borrowed. Euro Area countries are split into core, periphery, and CEE members. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.15: Corporate Sector Average Growth Rate-Interest Rate Differential Before and After the Financial Crisis



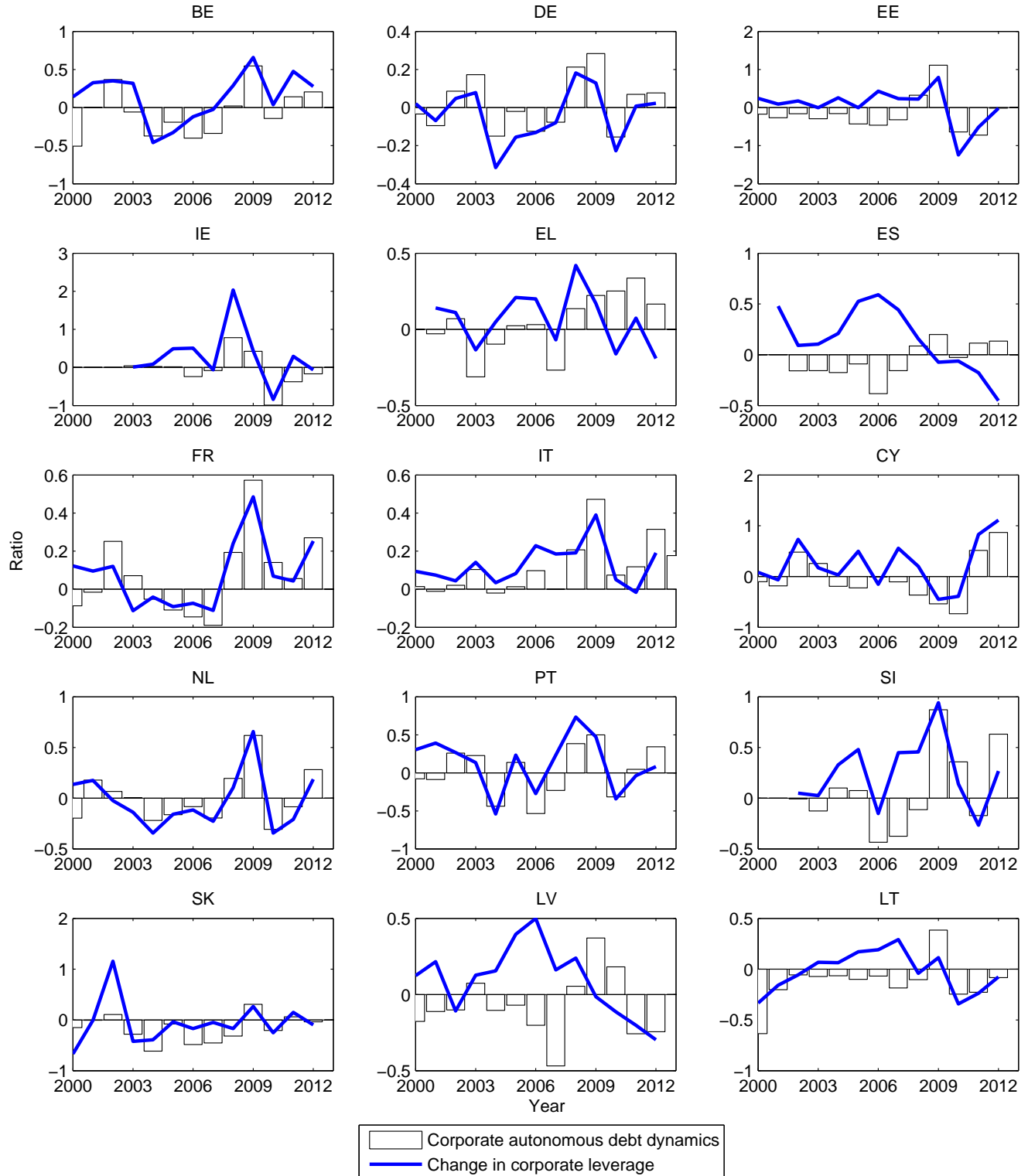
Note: The graph presents the average level of the corporate growth rate-interest rate differential in the periods before and after the onset of the financial crisis. Each bar presents the mean of $(g + \pi) - i$ over the specified period. Positive values signify that the growth rate of nominal income is higher than the effective interest rate which corresponds to positive debt dynamics, i.e. the level of leverage would decrease if no new debt is borrowed. Euro Area countries are split into core, periphery, and CEE members. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.16: Contribution of Autonomous Debt Dynamics to the Evolution of Household Leverage



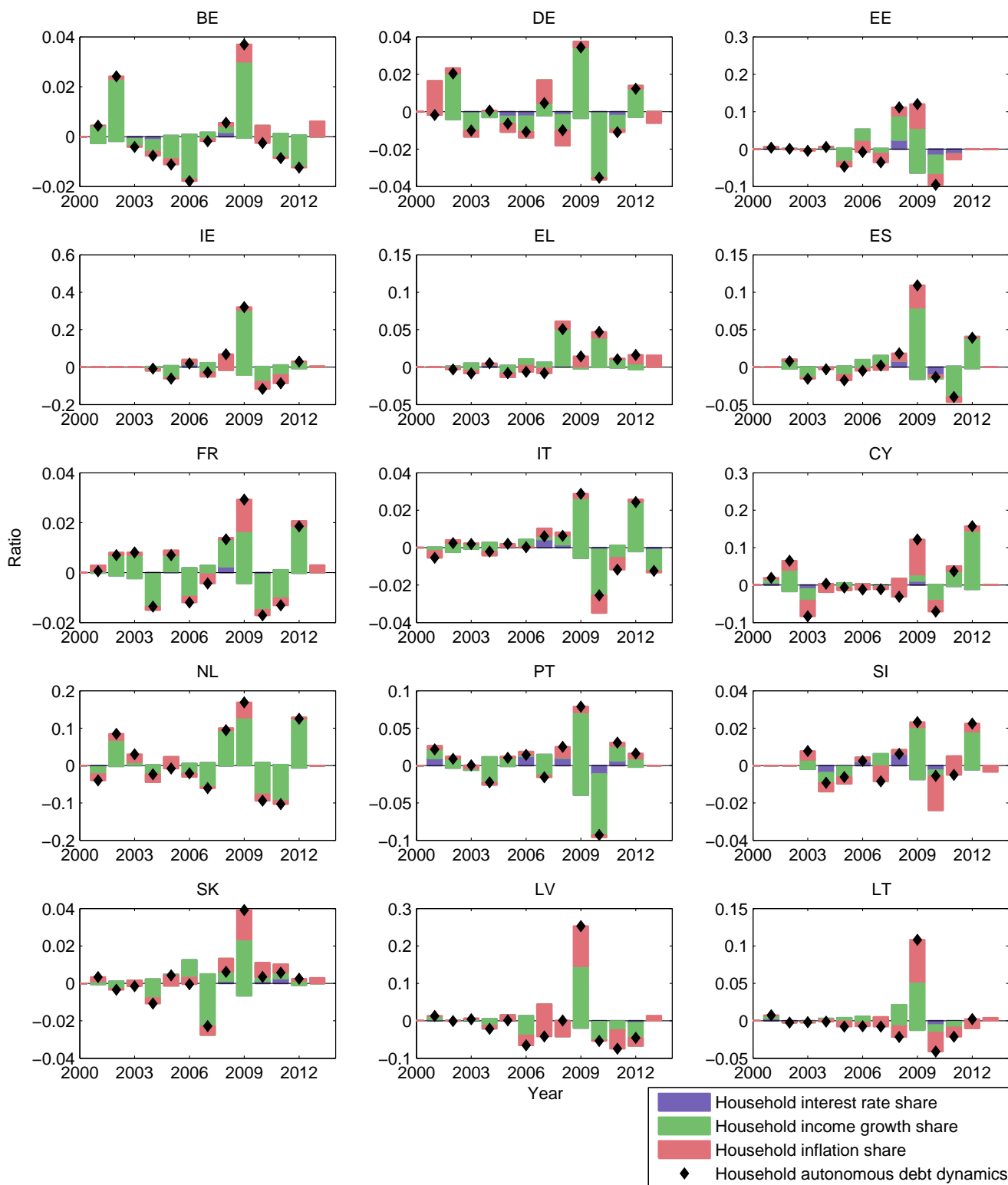
Note: The graph links changes in the household leverage ratio to the contribution of autonomous debt dynamics. The blue line reflects one period differences in the household leverage ratio, i.e. $\left[\frac{B_t}{P_t Y_t} \right] - \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right]$. White bars correspond to aggregate autonomous debt dynamics, i.e. $i_t \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right] - g_t \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right] - \tilde{\pi}_t \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right]$. Positive values of the blue line denote an increase in leverage. Positive values of the white bars indicate negative autonomous debt dynamics that push the leverage ratio upward. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.17: Contribution of Autonomous Debt Dynamics to the Evolution of Corporate Leverage



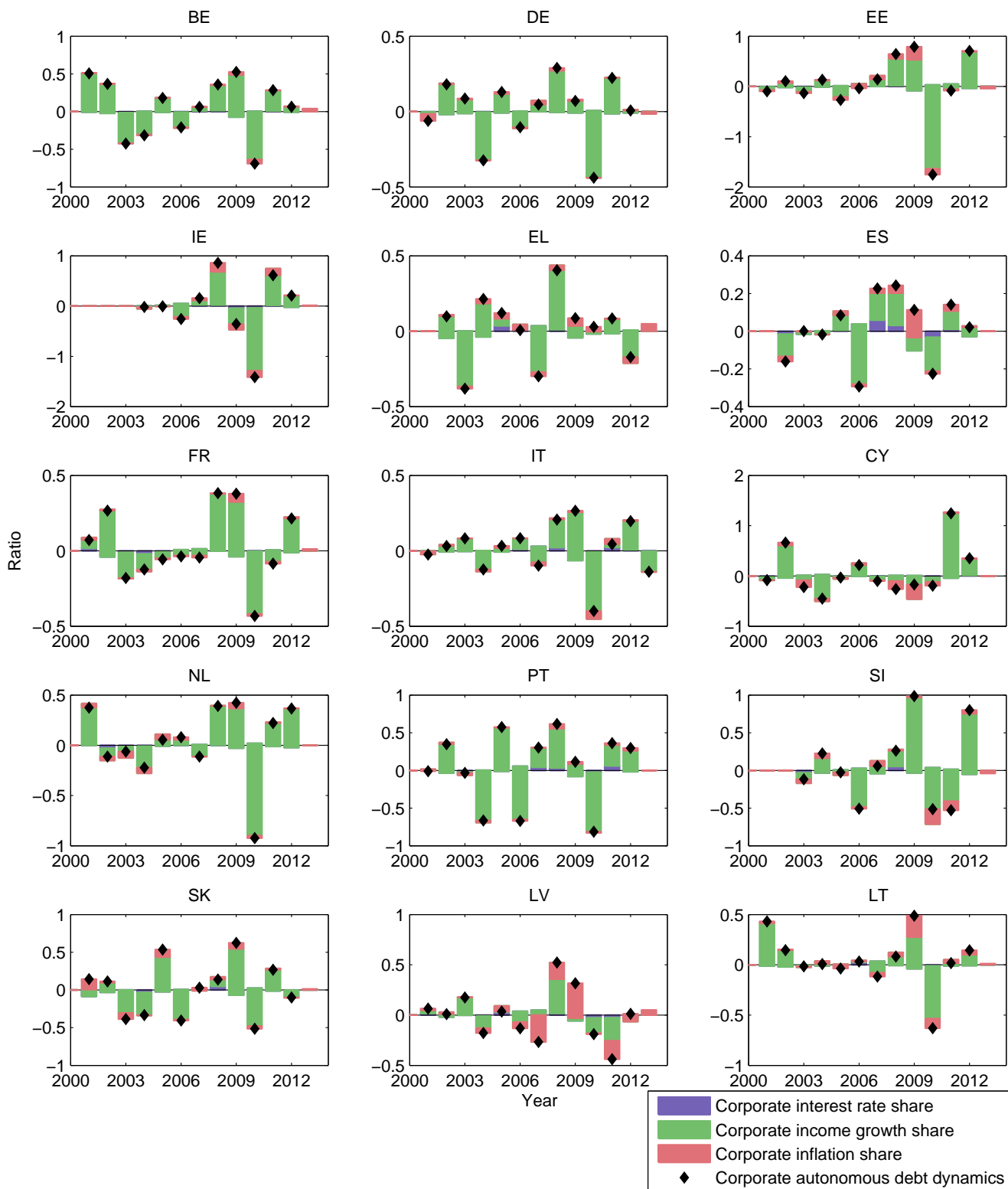
Note: The graph links changes in the corporate leverage ratio to the contribution of autonomous debt dynamics. The blue line reflects one period differences in the corporate leverage ratio, i.e. $\left[\frac{B_t}{P_t Y_t} \right] - \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right]$. White bars correspond to aggregate autonomous debt dynamics, i.e. $i_t \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right] - g_t \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right] - \tilde{\pi}_t \left[\frac{B_{t-1}}{P_{t-1} Y_{t-1}} \right]$. Positive values of the blue line denote an increase in leverage. Positive values of the white bars indicate negative autonomous debt dynamics that push the leverage ratio upward. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.18: Sub-Components of the Autonomous Debt Dynamics of the Household Sector



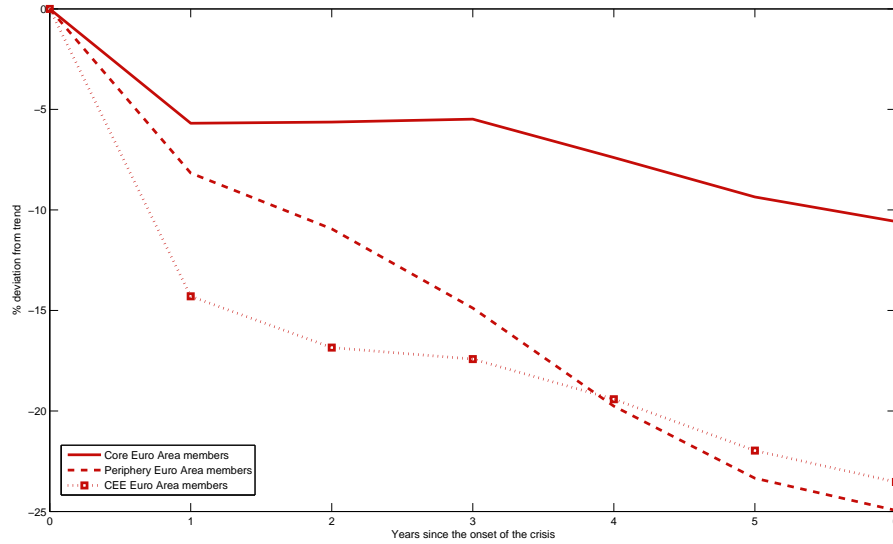
Note: The graph presents the contribution of individual sub-components to the annual changes in the level of autonomous debt dynamics. Black diamonds reflect the difference in the level of autonomous debt dynamics between periods t and $t - 1$. The contribution of individual sub-components is presented with stacked bars. Individual plots correspond to member countries. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.19: Sub-Components of the Autonomous Debt Dynamics of the Corporate Sector



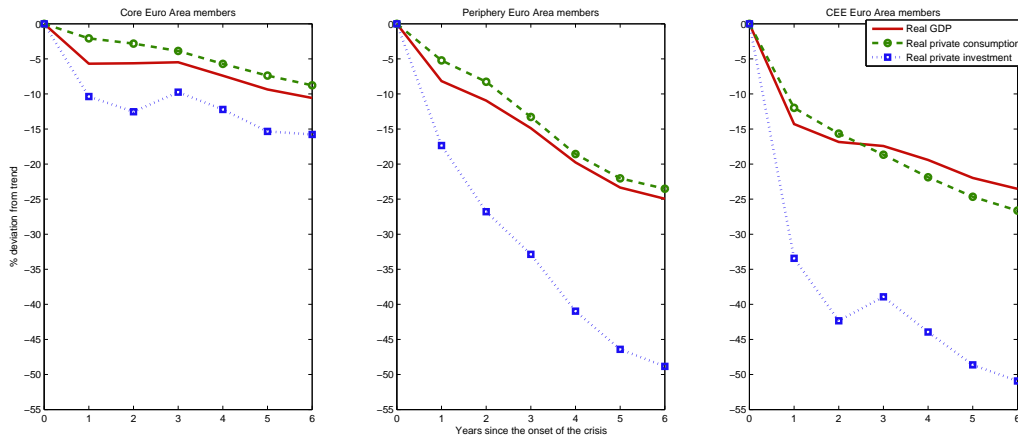
Note: The graph presents the contribution of individual sub-components to the annual changes in the level of autonomous debt dynamics. Black diamonds reflect the difference in the level of autonomous debt dynamics between periods t and $t - 1$. The contribution of individual sub-components is presented with stacked bars. Individual plots correspond to member countries. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure 3.20: Deviation of Real GDP from a Pre-Boom Linear Trend by Country Groups



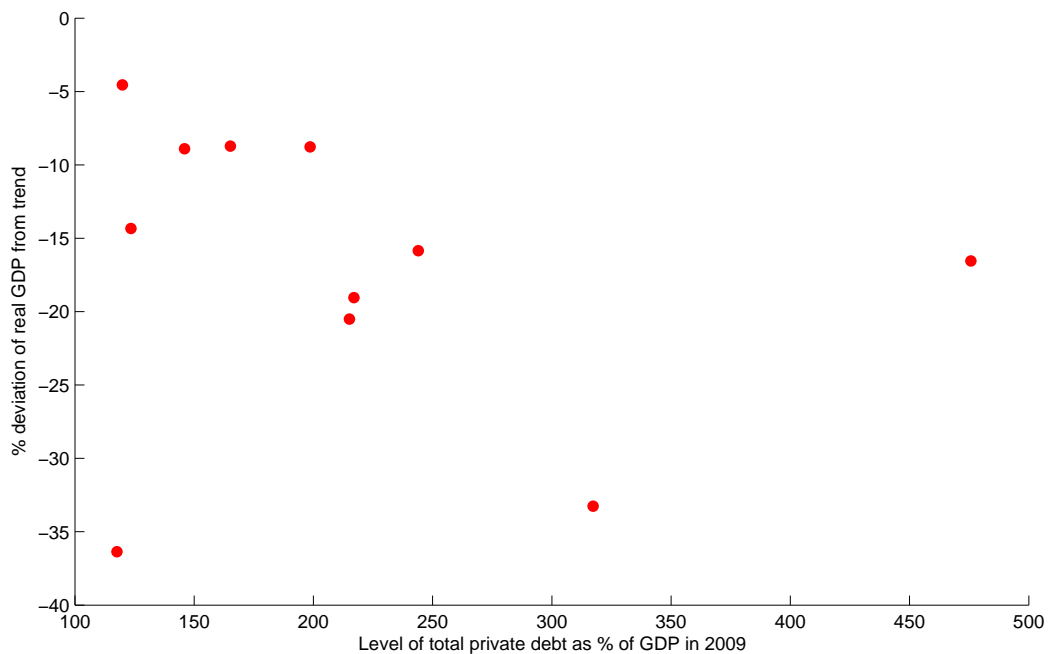
Note: The graph presents the deviation of real GDP from a linear pre-boom trend averaged across country groups: core, peripheral, and CEE Euro Area economies. The graph covers a six year period following the 2008 financial crisis (2008-2014). Deviations are computed as percentage differences between the observed historic series of real GDP and a pre-boom linear trend estimated over the period 1990 to 2004. **Source:** OECD and author's calculations.

Figure 3.21: Deviation of Real GDP, Consumption and Investment from a Pre-Boom Linear Trend by Country Groups



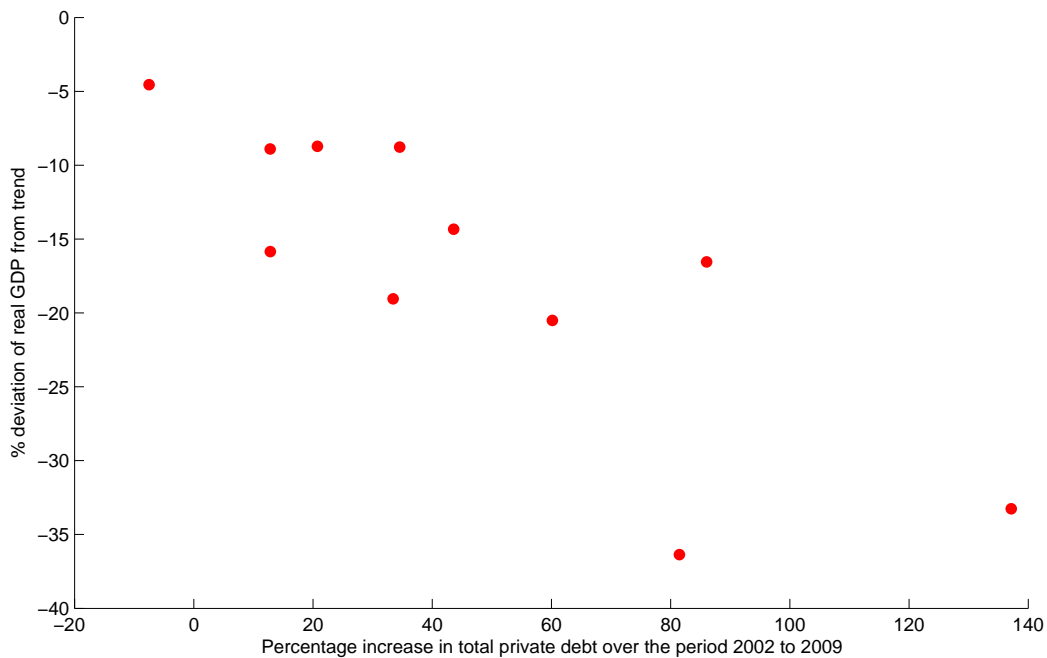
Note: The graph presents the deviations of real GDP, private consumption and private investment from linear pre-boom trends averaged across country groups: core, peripheral, and CEE Euro Area economies. The graph covers a six year period following the 2008 financial crisis (2008-2014). Deviations are computed as percentage differences between the observed historic series and a pre-boom linear trend estimated over the period 1990 to 2004. In case there is no available data since 1990, the first available data point is used. **Source:** OECD and author's calculations.

Figure 3.22: Relation Between Private Indebtedness in 2009 and the Subsequent Economic Contraction



Note: The graph plots the relation between the level of private indebtedness at the end of 2009 and the percentage deviation of real GDP from a linear pre-boom trend observed five years after the onset of the financial crisis. Private indebtedness is measured by the ratio of total private debt outstanding at the end of period to nominal GDP. Deviation of real GDP is computed on the base of a linear trend estimated over the period 1990 to 2004. **Source:** BIS, OECD and author's calculations.

Figure 3.23: Relation Between the Increase in Private Indebtedness Over the Period 2002-2009 and the Subsequent Economic Contraction



Note: The graph plots the relation between the percentage increase in private indebtedness between 2002 and 2009 and the percentage deviation of real GDP from a linear pre-boom trend observed five years after the onset of the financial crisis. The percentage increase is computed as the change in private debt over the period 2002 to 2009 divided by the private debt level at 2002. Deviation of real GDP is computed on the base of a linear trend estimated over the period 1990 to 2004. **Source:** BIS, OECD and author's calculations.

3.9 TABLES

Table 3.1: Average Change in Private Leverage During Periods of Positive Autonomous Debt Dynamics

Variable	Households		Corporates	
	All countries	Non-core	All countries	Non-core
Intercept (β_0)	0.029**	0.027**	0.26**	0.34**
Dummy (+) spread (β_1)	0.026**	0.041**	-0.28**	-0.25**
Sample size (N)	200	135	201	136

Note: The table presents the parameter estimates for the average annual change in the leverage ratio observed in the period 2000 to 2013. The regression analysis is performed using a panel data fixed effects estimator. The estimated specification is $Y_{i,t} = \beta_0 + \beta_1 X_{i,t} + u_i + \epsilon_{i,t}$, where $Y_{i,t}$ is the one period difference of the leverage ratio and $X_{i,t}$ is a dummy variable that takes a value of 1 when the growth rate of nominal income exceeds the effective interest rate. The presence of a unit root for the dependent variable has been rejected using the Im-Pesaran-Shin and Fisher-type panel unit root tests. In the table, "***" denotes significance at the 5% level.

Table 3.2: The Contribution of Autonomous Debt Dynamics Before and After the Financial Crisis

Variable	Households			Corporates
	All countries	Core	Non-core	All countries
Intercept (β_0)	0.05**	0.01**	0.05**	0.14**
Dummy post 2007 (β_1)	-0.05**	-0.01**	-0.06**	-0.14**
Auto debt dynamics (β_2)	-0.56	1**	-0.97**	0.51**
Interaction (β_3)	0.97**	-0.48	1.41**	0.44**
Sample size (N)	199	65	134	201

Note: The table presents the parameter estimates for the contribution of autonomous debt dynamics to the evolution of private leverage over the period 2000 to 2013. The regression analysis is performed using a panel data fixed effects estimator. The estimated specification is $Y_{i,t} = \beta_0 + \beta_1 X_{i,t} + u_i + \epsilon_{i,t}$, where $Y_{i,t}$ is the one period difference of the leverage ratio and $X_{i,t}$ is a vector of regressors: a dummy that takes a value of 1 after the year 2007 (dummy post 2007), the aggregate autonomous debt dynamics $i_t \left[\frac{B_{t-1}}{P_{t-1}Y_{t-1}} \right] - g_t \left[\frac{B_{t-1}}{P_{t-1}Y_{t-1}} \right] - \tilde{\pi}_t \left[\frac{B_{t-1}}{P_{t-1}Y_{t-1}} \right]$ (auto debt dynamics), and an interaction variable between the post 2007 dummy and the autonomous debt dynamics (interaction). A unit root for the dependent variable and for autonomous debt dynamics has been rejected using the Im-Pesaran-Shin and Fisher-type panel unit root tests. In the table, "***" denotes significance at the 5% level.

Table 3.3: Deviation of Real GDP from a Linear Pre-Boom Trend

Core EA members		Peripheral EA members		CEE EA members	
Country	% deviation	Country	% deviation	Country	% deviation
Austria	-8.9%	Greece	-36.4%	Estonia	-25.2%
Belgium	-8.8%	Ireland	-33.3%	Latvia	-26.5%
France	-8.7%	Italy	-14.3%	Slovakia	-13.4%
Germany	-4.6%	Luxembourg	-16.5%	Slovenia	-22.9%
Netherlands	-15.8%	Portugal	-19.0%		
		Spain	-20.5%		

Note: The table presents the deviation of real GDP from a linear pre-boom trend five years after the onset of the financial crisis. Deviations are computed as percentage differences between the observed historic series of real GDP and a pre-boom linear trend estimated over the period 1990 to 2004.

Table 3.4: Regression Results of the Link Between Private Debt and Economic Activity

Variable	(i)	(ii)	(iii)
Total private debt in 2009	-0.036**	-0.028**	-0.024**
% change in private debt between 2002 and 2009		-0.06**	-0.065**
Change in interest rate	-1.668**	-1.363**	-1.251**
Public and private debt interaction			-0.014
Sample size (N)	28	28	28
Adj. R^2	0.67	0.71	0.73
BIC	3.342	3.285	3.306

Note: The table presents the parameter estimates of three regression specifications that analyze the link between debt overhang and economic contraction in the recent financial crisis. The dependent variable is the deviation of real GDP from a linear pre-boom trend five years after the onset of the crisis. Explanatory variables used in the three specifications are: the ratio of total private debt to nominal GDP in 2009, the percentage increase in private debt from 2002 to 2009 relative to the initial stock of debt at the end of 2002, the change in the 10Y government bond yields between 2007 and the highest rate reached between 2009 and 2012, and an interaction variable between the ratio of total private debt to GDP in 2009 and a dummy variable that takes the value of 1 if the ratio of public debt to nominal GDP at the end of 2009 exceeds 60%. The 60% threshold for public debt is consistent with the Maastricht criteria. In the table, "***" denotes significance at the 5% level. Regressions are computed using a heteroskedasticity robust estimator.

APPENDIX A

APPENDIX TO CHAPTER 2

A.1 DIXIT-STIGLITZ AGGREGATOR OF INDIVIDUAL GOODS DEMAND

In the model, households consume consumption bundles of goods. All individual consumption goods form a continuum of measure 1 where individual goods are imperfect substitutes. The elasticity of substitution is governed by the parameter θ . Individual consumption goods in the model are aggregated in consumption bundles using a Dixit-Stiglitz aggregator:

$$C_t^i = \left[\int_0^1 c_t^i(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}$$

where $i = s, b, e$ stands for each type of household.

Given the preferences' aggregator, agents maximize their aggregate consumption for a given level of expenditure M_t . If we consider the maximization problem of savers:

$$\max_{c_t^s(j)} \left[\int_0^1 c_t^s(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}$$

s.t.

$$\int_0^1 p_t(j) c_t^s(j) dj \leq M_t$$

where $p_t(j)$ is the price of the j -th variety and M_t is total expense. As agents' utility function is strictly increasing in the level of consumption, the maximization of aggregate consumption C_t^s , maximizes agents' utility. The maximization problem is solved using the Lagrangian

$$\mathcal{L}_t = \left[\int_0^1 c_t^s(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}} + \zeta_t^c \left[M_t - \int_0^1 p_t(j) c_t^s(j) dj \right]$$

The first order optimality conditions of the maximization problem are

$$\frac{\partial \mathcal{L}_t}{\partial c_t^s(j)} = \left[\int_0^1 c_t^s(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{1}{\theta-1}} c_t^s(j)^{-\frac{1}{\theta}} - \zeta_t^c p_t(j) = 0$$

$$[C_t^s]^{\frac{1}{\theta}} c_t^s(j)^{-\frac{1}{\theta}} = \zeta_t^c p_t(j)$$

which should hold for every j .

$$\left[\frac{c_t^s(j)}{c_t^s(i)} \right]^{-\frac{1}{\theta}} = \frac{p_t(j)}{p_t(i)}$$

$$c_t^s(j) = \left[\frac{p_t(j)}{p_t(i)} \right]^{-\theta} c_t^s(i)$$

Therefore, the optimal consumption choice of individual varieties depends on their relative prices. Using this optimal allocation of varieties, we substitute it in the formula for total expenditure

$$M_t = \int_0^1 p_t(j) c_t^s(j) dj = \int_0^1 p_t(j) \left[\frac{p_t(j)}{p_t(i)} \right]^{-\theta} c_t^s(i) dj = c_t^s(i) p_t(i)^\theta \int_0^1 p_t(j)^{1-\theta} dj$$

$$c_t^s(i) = \frac{M_t p_t(i)^{-\theta}}{\int_0^1 p_t(j)^{1-\theta} dj}$$

The above formula expresses individual varieties' demand as a function of individual prices and total expenditure. Substituting the derived formula in the Dixit-Stiglitz aggregator, we obtain

$$C_t^s = \left[\int_0^1 c_t^s(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}} = \left[\int_0^1 \left(\frac{M_t p_t(j)^{-\theta}}{\int_0^1 p_t(i)^{1-\theta} di} \right)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}$$

$$C_t^s = \left(\frac{M_t}{\int_0^1 p_t(i)^{1-\theta} di} \right) \left[\int_0^1 p_t(j)^{1-\theta} dj \right]^{\frac{\theta}{\theta-1}}$$

$$C_t^s = M_t \left[\int_0^1 p_t(j)^{1-\theta} dj \right]^{\frac{1}{\theta-1}}$$

From where it follows that

$$M_t = C_t^s \left[\int_0^1 p_t(j)^{1-\theta} dj \right]^{-\frac{1}{\theta-1}}$$

Thus, for one unit of aggregate consumption (i.e. $C_t^s = 1$), the total expenditure can be written as

$$M_t = 1 \left[\int_0^1 p_t(j)^{1-\theta} dj \right]^{-\frac{1}{\theta-1}} = P_t$$

which gives us the aggregate price P_t that corresponds to the Dixit-Stiglitz consumption aggregator. Returning to the total consumption expenditure M_t , we substitute the optimal consumption allocation in the formula for M_t

$$M_t = \int_0^1 p_t(j) c_t^s(j) dj = \int_0^1 p_t(j) \left[\frac{p_t(j)}{p_t(i)} \right]^{-\theta} c_t^s(i) dj = c_t^s(i) p_t(i)^\theta P_t^{1-\theta} = P_t \left[\frac{p_t(i)}{P_t} \right]^\theta c_t^s(i)$$

$$c_t^s(i) = \frac{M_t}{P_t} \left[\frac{p_t(i)}{P_t} \right]^{-\theta}$$

The obtained result are substituted in the consumption aggregator formula

$$C_t^s = \left[\int_0^1 c_t^s(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}} = \left[\int_0^1 \left(\frac{M_t}{P_t} \left[\frac{p_t(i)}{P_t} \right]^{-\theta} \right)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}} = M_t P_t^{\theta-1} P_t^{-\theta} = M_t P_t^{-1}$$

$$M_t = C_t^s P_t$$

The combination of the Dixit-Stiglitz consumption aggregator and the derived aggregate price P_t constitute the optimal consumer choice that maximized agents' utility for a given level of expenditure M_t ¹. As a last step,

¹Notice that in the identity above $M_t = P_t$, which implies that $C_t^s = 1$. This is consistent with the assumption we made to derive P_t , namely that P_t is the total expenditure that corresponds to 1 unit of consumption ($C_t^s = 1$).

$$c_t^s(j) = \frac{M_t}{P_t} \left[\frac{p_t(j)}{P_t} \right]^{-\theta} = \frac{C_t^s P_t}{P_t} \left[\frac{p_t(j)}{P_t} \right]^{-\theta}$$

$$c_t^s(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} C_t^s$$

The ratio of individual varieties' consumption to total aggregate consumption corresponds to the ratio of individual prices $p_t(j)$ to the aggregate price level P_t . Using the same derivation steps, we can show that for borrowers and entrepreneurs the demand for individual goods is defined has the form:

$$c_t^b(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} C_t^b$$

$$c_t^e(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} C_t^e$$

A.2 DEMAND FACED BY FIRMS

The demand faced by each firm can be derived from the structure of the consumption bundles computed in Appendix A.1. Employing the Dixit-Stiglitz consumption aggregator, we have calculated the demand for each individual consumption variety relative to the total consumption bundle. More specifically, the following equations were derived

$$c_t^s(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} C_t^s$$

$$c_t^b(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} C_t^b$$

$$c_t^e(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} C_t^e$$

Assuming identical Dixit-Stiglitz aggregators for investment I_t and government expenditure G_t , we have

$$I_t(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} I_t$$

$$G_t(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} G_t$$

There are three types of households in the model with shares χ_s , χ_b and χ_e . The total aggregate consumption in the economy is the sum of the consumption of the three agent types

$$C_t = \chi_s C_t^s + \chi_b C_t^b + \chi_e C_t^e$$

and for each variety j

$$c_t(j) = \chi_s c_t^s(j) + \chi_b c_t^b(j) + \chi_e c_t^e(j)$$

Combining individual equations, we derive that

$$\begin{aligned}
c_t(j) &= \chi_s c_t^s(j) + \chi_b c_t^b(j) + \chi_e c_t^e(j) = \chi_s \left[\frac{p_t(j)}{P_t} \right]^{-\theta} C_t^s + \chi_b \left[\frac{p_t(j)}{P_t} \right]^{-\theta} C_t^b + \chi_e \left[\frac{p_t(j)}{P_t} \right]^{-\theta} C_t^e = \\
&= \left[\frac{p_t(j)}{P_t} \right]^{-\theta} (\chi_s C_t^s + \chi_b C_t^b + \chi_e C_t^e) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} C_t
\end{aligned}$$

In a closed economy model, produced goods can be utilized for one of three final uses: consumption, investment or government expenditure. For each variety this means that

$$y_t(j) = c_t(j) + \chi_e (I_t(j) + \Phi(I_t(j))) + G_t(j)$$

and for the aggregate

$$Y_t = C_t + \chi_e (I_t + \Phi(I_t)) + G_t$$

By combining all equations, this leads to

$$y_t(j) = c_t(j) + \chi_e (I_t(j) + \Phi(I_t(j))) + G_t(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} [C_t + \chi_e (I_t + \Phi(I_t)) + G_t] = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} Y_t$$

Therefore, each firm faces the following downward sloping demand function

$$y_t(j) = \left[\frac{p_t(j)}{P_t} \right]^{-\theta} Y_t$$

A.3 CALVO PRICES

In the model, firms produce goods using a Cobb-Douglas production function

$$y_t(j) = k_t^\alpha(j) l_t^{1-\alpha}(j)$$

Given the functional form of the Cobb-Douglas production function, the total production cost of each firm can be presented as a function of the produced amount $y_t(j)$. Total cost can be expressed as

$$TC(y_t(j)) = \left(\frac{1}{\alpha} \right)^\alpha \left(\frac{1}{1-\alpha} \right)^{1-\alpha} (P_t W_t)^{1-\alpha} (P_t R_t^K)^\alpha y_t(j)$$

Considering firms' profit maximization problem - maximize revenue minus expenditure for a given level of demand - we can substitute total cost with the above expression which leads to the updated maximization problem

$$\max_{l_t(j), k_t(j)} [(1-\tau)p_t(j)y_t(j)] - \left[\left(\frac{1}{\alpha} \right)^\alpha \left(\frac{1}{1-\alpha} \right)^{1-\alpha} (P_t W_t)^{1-\alpha} (P_t R_t^K)^\alpha y_t(j) \right]$$

In the model, we employ Calvo pricing, making the assumption that firms are able to readjust prices with probability $(1-\gamma)$. In this setting, all firm that are able to reset their prices select the same price level P_t^* . Since optimizing firms need to discount their expected future profits, an appropriate discount factor should be selected. In the model, there are three different agent types. With the aim of simplicity, we make the assumption that firms are owned only by savers and, hence, we use their discount factor to discount firms' future profits. The optimization problem faced by firms when setting their price P_t^* has the form

$$\max_{P_t^*} \mathbb{E}_t \sum_{T=t}^{\infty} \left\{ (\gamma\beta)^{T-t} \left[\frac{u_c^s(C_T^s) P_t}{u_c^s(C_t^s) P_T} \right] \left[(1-\tau)P_t^* y_T(j) - \left(\frac{1}{\alpha}\right)^\alpha \left(\frac{1}{1-\alpha}\right)^{1-\alpha} (P_T W_T)^{1-\alpha} (P_T R_T^K)^\alpha y_T(j) \right] \right\}$$

s.t.

$$y_T(j) = \left[\frac{P_t^*(j)}{P_T} \right]^{-\theta} Y_T$$

The solution of the optimization problem above yields an optimality condition that relates the adjusted price level selected by firms P_t^* to the present price level P_t . The ratio can be written as

$$\frac{P_t^*}{P_t} = \frac{\frac{\theta}{\theta-1} \sum_{T=t}^{\infty} (\gamma\beta)^{T-t} u_c^s(C_T^s) \left(\frac{P_T}{P_t}\right)^\theta Y_T \left(\frac{1}{\alpha}\right)^\alpha \left(\frac{1}{1-\alpha}\right)^{1-\alpha} W_T^{1-\alpha} R_T^{K,\alpha}}{\sum_{T=t}^{\infty} (\gamma\beta)^{T-t} u_c^s(C_T^s) \left(\frac{P_T}{P_t}\right)^{\theta-1} Y_T (1-\tau)}$$

In addition, Calvo pricing implies the following law of motion for the price index P_t

$$P_t = \left[(1-\gamma)(P_t^*)^{1-\theta} + \gamma P_{t-1}^{1-\theta} \right]^{\frac{1}{1-\theta}}$$

which can be re-written as

$$\left(\frac{P_t^*}{P_t}\right) = \left[\frac{1 - \gamma \Pi_t^{-(1-\theta)}}{1-\gamma} \right]^{\frac{1}{1-\theta}}$$

Lastly, if we denote the index of price dispersion by $\Delta_t \equiv \int \left(\frac{p_t(j)}{P_t}\right)^{-\theta} dj$, we can derive the relationship

$$\Delta_t = (1-\gamma) \left(\frac{P_t^*}{P_t}\right)^{-\theta} + \gamma \Delta_{t-1} \Pi_t^\theta$$

which is the full set of equations that govern prices in the model.

A.4 STEADY STATE DERIVATIONS

In this appendix, we provide a detailed derivation of the deterministic steady state of the model. The steady state is derived from the non-linear system of equations and it is a function of the deep parameters of the model. As a starting point, we set that at the steady state prices are stable, i.e. $P_t = P_{t-1} = P_t^*$, $\Pi_t = \frac{P_t}{P_{t-1}} = 1$ and $\frac{P_t^*}{P_t} = 1$.

From savers' Euler equation (2.20) we obtain ²,

$$\frac{1}{(\bar{C}^s)\xi_s} = \beta \frac{(1+i^d)}{1} \frac{1}{(\bar{C}^s)\xi_s}$$

which after cancellation yields

$$i^d = \frac{1}{\beta} - 1$$

Again starting from an Euler equation, combining (2.15), (2.16), and (2.19) leads to

$$\frac{1}{(\bar{C}^b)\xi_b} = \beta_b \frac{(1+i^d)}{(\bar{C}^b)\xi_b} \left(1 + \kappa + \Xi \left(e^{\bar{b}-b^j} - 1\right)\right) \left[1 + \frac{\Xi e^{\bar{b}-b^j}}{1 + \kappa + \Xi \left(e^{\bar{b}-b^j} - 1\right)} \bar{b}\right]$$

²Variables with a bar, i.e. \bar{X} , denote a steady state value.

$$1 = \beta_b \beta^{-1} \left[1 + \kappa + \Xi \left(e^{\bar{b}-b^j} - 1 \right) + \Xi \left(e^{\bar{b}-b^j} \right) \bar{b} \right]$$

$$\frac{\beta}{\beta_b} - 1 - \kappa = \Xi \left(e^{\bar{b}-b^j} - 1 \right) + \Xi \left(e^{\bar{b}-b^j} \right) \bar{b}$$

$$\frac{\beta}{\beta_b} - 1 - \kappa + \Xi = \left(1 + \bar{b} \right) \Xi e^{\bar{b}-b^j}$$

$$\frac{1}{\Xi} \left[\frac{\beta}{\beta_b} - 1 - \kappa + \Xi \right] = \left(1 + \bar{b} \right) e^{\bar{b}-b^j}$$

At this point, we make the assumption that $\bar{b} = b^j$ ³. Substituting above yields

$$\frac{1}{\Xi} \left[\frac{\beta}{\beta_b} - 1 - \kappa + \Xi \right] = 1 + \bar{b} = 1 + b^j$$

Any combination of values for κ, Ξ and b^j that satisfy the equation can serve as a solution. However, in the parametrization of the model, both κ and b^j are set to target a debt level and interest rate spread. Therefore, the value of Ξ needs to be selected to satisfy the expression.

$$\frac{\beta}{\beta_b} - 1 - \kappa = \Xi b^j$$

$$\Xi = \frac{1}{b^j} \left(\frac{\beta}{\beta_b} - 1 - \kappa \right)$$

Now, we have the information needed to calculate the interest rate of borrowers

$$\left(1 + i^b \right) = \frac{1}{\beta} \left(1 + \kappa + \Xi \left(e^{\bar{b}-b^j} - 1 \right) \right)$$

κ is selected to target the steady state interest rate spread. Therefore, we can select a steady state value of i^b and back out κ

$$\kappa = \left(1 + i^b \right) \beta - 1$$

and from (2.16)

$$\bar{\omega} = \kappa$$

Similarly, using equations (2.17), (2.18), and (2.21), we derive the following relationship for entrepreneurs

$$\frac{1}{\Xi^e} \left[\frac{\beta}{\beta_e} - 1 - \kappa^e + \Xi^e \right] = \left(1 + \bar{b}^e \right) e^{\bar{b}^e - b^{e,j}}$$

and we assume that $\bar{b}^e = b^{e,j}$, i.e. the steady state level of debt equals the optimal "safe" level

$$\frac{1}{\Xi^e} \left[\frac{\beta}{\beta_e} - 1 - \kappa^e + \Xi^e \right] = 1 + \bar{b}^e = 1 + b^{e,j}$$

As values of κ^e and $b^{e,j}$ target steady state levels of debt and interest rate spread for entrepreneurs, Ξ^e is computed

³We assume that the steady state level of debt corresponds to the "safe" level of debt determined by banks.

$$\Xi^e = \frac{1}{b^{e,j}} \left(\frac{\beta}{\beta_e} - 1 - \kappa^e \right)$$

The above results help to calculate the interest rate of entrepreneurs

$$(1 + i^e) = \frac{1}{\beta} \left(1 + \kappa^e + \Xi^e \left(e^{\bar{b}^e - b^{e,j}} - 1 \right) \right)$$

The value of κ^e is selected to target a steady state interest rate spread. Therefore, we select a steady state value of i^b and back out κ^e

$$\kappa^e = (1 + i^e) \beta - 1$$

and from equation (2.18)

$$\bar{\omega}^e = \kappa^e$$

Using the no-arbitrage condition of entrepreneurs (2.22), we have

$$\begin{aligned} (1 - \delta) + \zeta \left(\frac{\bar{K}}{\bar{K}} - 1 \right) + \frac{1}{2} \zeta \left(\frac{\bar{K}}{\bar{K}} - 1 \right)^2 &= \\ = \left[1 + \zeta \left(\frac{\bar{K}}{\bar{K}} - 1 \right) - \bar{R}^K \right] \frac{1 + i^e}{1} \left[1 + \frac{\Xi^e e^{\bar{b}^e - b^{e,j}}}{1 + \kappa^e + \Xi^e \left(e^{\bar{b}^e - b^{e,j}} - 1 \right)} \bar{b}^e \right] \end{aligned}$$

which after cancellation can be reduced to

$$(1 - \delta) = \left[1 - \bar{R}^K \right] (1 + i^e) \left[1 + \frac{\Xi^e e^{\bar{b}^e - b^{e,j}}}{1 + \kappa^e + \Xi^e \left(e^{\bar{b}^e - b^{e,j}} - 1 \right)} \bar{b}^e \right]$$

In addition, from the Euler equation of entrepreneurs (2.21), we derive the steady state relationship

$$(1 + i^e) \left[1 + \frac{\Xi^e e^{\bar{b}^e - b^{e,j}}}{1 + \kappa^e + \Xi^e \left(e^{\bar{b}^e - b^{e,j}} - 1 \right)} \bar{b}^e \right] = \frac{1}{\beta_e}$$

Therefore, the no-arbitrage condition boils down to the simple steady state relationship

$$(1 - \delta) = \left[1 - \bar{R}^K \right] \frac{1}{\beta_e}$$

$$\bar{R}^K = 1 - (1 - \delta) \beta_e$$

Further, using the three equations for Calvo pricing (2.25), (2.26), and (2.27) and imposing a steady state produces

$$\bar{P}N = \frac{1}{1 - \gamma\beta} \left[\frac{1}{(\bar{C}^s)^{\xi_s}} \bar{Y} \left(\frac{1}{\alpha} \right)^\alpha \left(\frac{1}{1 - \alpha} \right)^{1 - \alpha} \bar{W}^{1 - \alpha} (\bar{R}^K)^\alpha \right]$$

$$\bar{P}D = \frac{1}{1 - \gamma\beta} \left[\frac{1}{(\bar{C}^s)^{\xi_s}} \bar{Y} (1 - \tau) \right]$$

and

$$1 = \frac{\frac{\theta}{\theta - 1} \left(\frac{1}{\alpha} \right)^\alpha \left(\frac{1}{1 - \alpha} \right)^{1 - \alpha} \bar{W}^{1 - \alpha} (\bar{R}^K)^\alpha}{1 - \tau}$$

Since we have already computed the steady state value of \bar{R}^K , we can obtain \bar{W} as a function of \bar{R}^K

$$\bar{W} = \left[(1 - \tau) \left(\frac{\theta - 1}{\theta} \right) \left(\frac{1}{\alpha} \right)^{-\alpha} \left(\frac{1}{1 - \alpha} \right)^{\alpha - 1} (\bar{R}^K)^{-\alpha} \right]^{\frac{1}{1 - \alpha}}$$

As a next step, we start from equation (2.29)

$$\bar{\Delta} = (1 - \gamma) \left(\frac{P^*}{P} \right)^{-\theta} + \gamma \bar{\Delta} \Pi^\theta$$

$$\bar{\Delta} = (1 - \gamma) (1)^{-\theta} + \gamma \bar{\Delta} 1$$

which finally boils down to

$$\bar{\Delta} = 1$$

We use equation (2.36)

$$\bar{Y} \bar{\Delta} = (\chi_e \bar{K})^\alpha \bar{L}^{1 - \alpha}$$

divide both sides by \bar{Y}

$$1 = \left(\chi_e \frac{\bar{K}}{\bar{Y}} \right)^\alpha \left(\frac{\bar{L}}{\bar{Y}} \right)^{1 - \alpha}$$

and introduce the notation $\bar{K}/\bar{Y} = \bar{K}_Y$ and $\bar{L}/\bar{Y} = \bar{L}_Y$

$$1 = (\chi_e \bar{K}_Y)^\alpha \bar{L}_Y^{1 - \alpha}$$

Also, from equation (2.37)

$$\bar{W} \bar{L} = \left(\frac{1 - \alpha}{\alpha} \right) \bar{R}^K (\chi_e \bar{K})$$

$$\bar{W} \bar{L}_Y = \left(\frac{1 - \alpha}{\alpha} \right) \bar{R}^K (\chi_e \bar{K}_Y)$$

and we solve for \bar{K}_Y and \bar{L}_Y ⁴

$$\bar{K}_Y = \frac{1}{\chi_e} \left[\left(\frac{1 - \alpha}{\alpha} \right) \frac{\bar{R}^K}{\bar{W}} \right]^{\alpha - 1}$$

$$\bar{L}_Y = \left[\left(\frac{1 - \alpha}{\alpha} \right) \frac{\bar{R}^K}{\bar{W}} \right]^\alpha$$

and from (2.32)

$$\bar{K} = \bar{I} + (1 - \delta) \bar{K}$$

$$\bar{I}_Y = \delta \bar{K}_Y$$

Directing our attention to the entrepreneurs' budget constraint (2.34) and assuming that $\bar{I}^e = 0$

⁴In what follows, we introduce the notation $\bar{X}/\bar{Y} = \bar{X}_Y$ for any variable X . It represents the ratio of the particular variable to output.

$$\bar{b}^e = \bar{C}^e + \bar{I} + \frac{1}{2}\zeta \left(\frac{\bar{I}}{\bar{K}} - \delta \right)^2 \bar{K} - \bar{R}^K \bar{K} + 0 + (1 + i^e) \bar{b}^e 1^{-1}$$

$$\bar{C}^e = \bar{R}^K \bar{K} - \bar{I} - i^e \bar{b}^e$$

$$\bar{C}_Y^e = \bar{R}^K \bar{K}_Y - \bar{I}_Y - i^e \bar{b}_Y^e$$

We make an assumption about the steady state ratio of debt to income for the two indebted sectors. Therefore, \bar{b}_Y^e is provided exogenously to the model. Since all other variables are known, the equation above specifies the steady state value of \bar{C}_Y^e .

Similarly, using borrowers' budget constraint (2.33) and assuming that at the steady state $\bar{T}^b = 0$

$$\bar{b} = \bar{C}^b - \bar{W} \bar{h}^b + 0 + (1 + i^b) \bar{b} 1^{-1}$$

$$\bar{C}_Y^b = \bar{W} \bar{h}_Y^b - i^b \bar{b}_Y \tag{A.1}$$

Again we place an assumption on the steady state debt to output ratio \bar{b}_Y .

The next step of the process of computing the steady state of the model involves equations (2.23) and (2.24)

$$\bar{W} = (\bar{h}^b)^{\varepsilon_b} (\bar{C}^b)^{\xi_b} = (\bar{h}^s)^{\varepsilon_s} (\bar{C}^s)^{\xi_s}$$

We impose the assumption that $\varepsilon_b = \varepsilon_s$ and $\xi_b = \xi_s$ ⁵.

$$(\bar{h}^b)^{\varepsilon_b} (\bar{C}^b)^{\xi_b} = (\bar{h}^s)^{\varepsilon_b} (\bar{C}^s)^{\xi_b}$$

$$(\bar{h}_Y^b)^{\varepsilon_b} (\bar{C}_Y^b)^{\xi_b} = (\bar{h}_Y^s)^{\varepsilon_b} (\bar{C}_Y^s)^{\xi_b} \tag{A.2}$$

Using the aggregate demand equation (2.31) and setting $\bar{G} = 0$

$$\bar{Y} = \bar{C} + \chi_e \left[\bar{I} + \frac{1}{2}\zeta \left(\frac{\bar{I}}{\bar{K}} - \delta \right)^2 \bar{K} \right] + \bar{G}$$

$$\bar{Y} = \bar{C} + \chi_e \bar{I}$$

$$1 = \bar{C}_Y + \chi_e \bar{I}_Y$$

We also use (2.30) in combination with the above results

$$\bar{C}_Y = \chi_s \bar{C}_Y^s + \chi_b \bar{C}_Y^b + \chi_e \bar{C}_Y^e$$

$$\chi_b \bar{C}_Y^b + \chi_s \bar{C}_Y^s = 1 - \chi_e (\bar{C}_Y^e + \bar{I}_Y) \tag{A.3}$$

Now, we turn to the labor market clearing condition (2.35)

$$\bar{L} = \chi_s \bar{h}^s + \chi_b \bar{h}^b$$

⁵The steady state calculations can be performed as long as $\varepsilon_b + \xi_b = \varepsilon_s + \xi_s$. However, for simplicity, we go a step further and assume they are equal.

$$\bar{L}_Y = \chi_s \bar{h}_Y^s + \chi_b \bar{h}_Y^b \quad (\text{A.4})$$

The derivations above produce a system of 4 equations (A.1, A.2, A.3, and A.4) and 4 unknown variables $\bar{C}_Y^s, \bar{C}_Y^b, \bar{h}_Y^s$ and \bar{h}_Y^b . By combining the equations, we can solve for \bar{h}_Y^b

$$1 = \left[\frac{1 - \chi_e (\bar{C}_Y^e + \bar{I}_Y)}{\chi_s (\bar{W} \bar{h}_Y^b - i^b \bar{b}_Y)} - \frac{\chi_b}{\chi_s} \right]^{\xi_b} \left[\frac{\bar{L}_Y}{\chi_s \bar{h}_Y^b} - \frac{\chi_b}{\chi_s} \right]^{\varepsilon_b}$$

The equation above determines the value of \bar{h}_Y^b . Other variables are computed using the remaining three equations of the system.

$$\bar{h}_Y^s = \frac{1}{\chi_s} (\bar{L}_Y - \chi_b \bar{h}_Y^b)$$

$$\bar{C}_Y^b = \bar{W} \bar{h}_Y^b - i^b \bar{b}_Y$$

$$\bar{C}_Y^s = \frac{1}{\chi_s} \left[1 - \chi_e (\bar{C}_Y^e + \bar{I}_Y) - \chi_b (\bar{W} \bar{h}_Y^b - i^b \bar{b}_Y) \right]$$

Finally, using equation (2.23) we solve for \bar{Y}

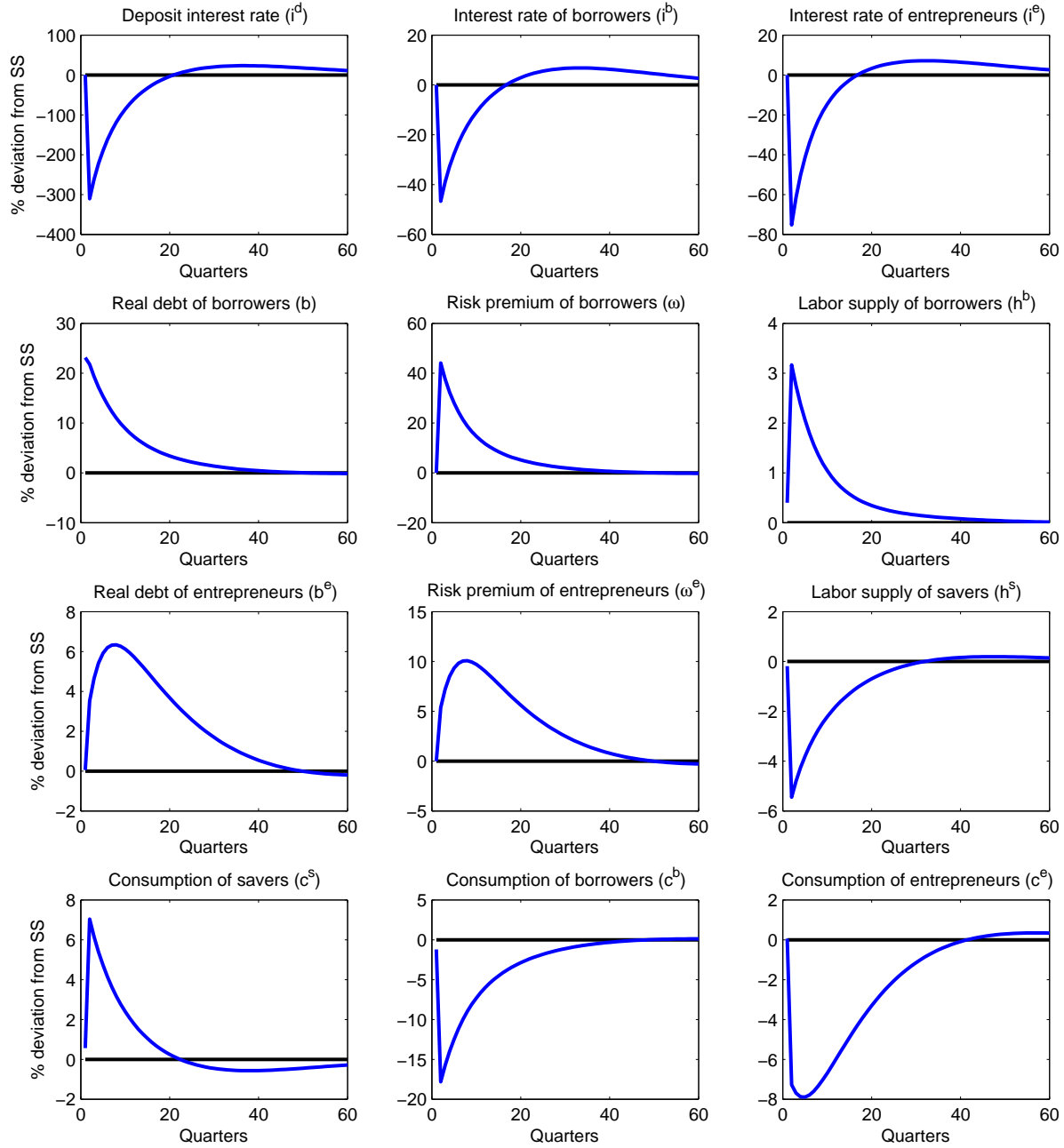
$$\bar{Y} = \left[\frac{\bar{W}}{(\bar{h}_Y^b)^{\varepsilon_b} (\bar{C}_Y^b)^{\xi_b}} \right]^{\frac{1}{\varepsilon_b + \xi_b}}$$

Having the value of \bar{Y} , the ratios of any variable to output is used to calculate the actual steady state value of the variable which completes the list of endogenous variables and their steady state values.

A.5 DYNAMIC PATH OF THE ENDOGENOUS VARIABLES IN THE MODEL

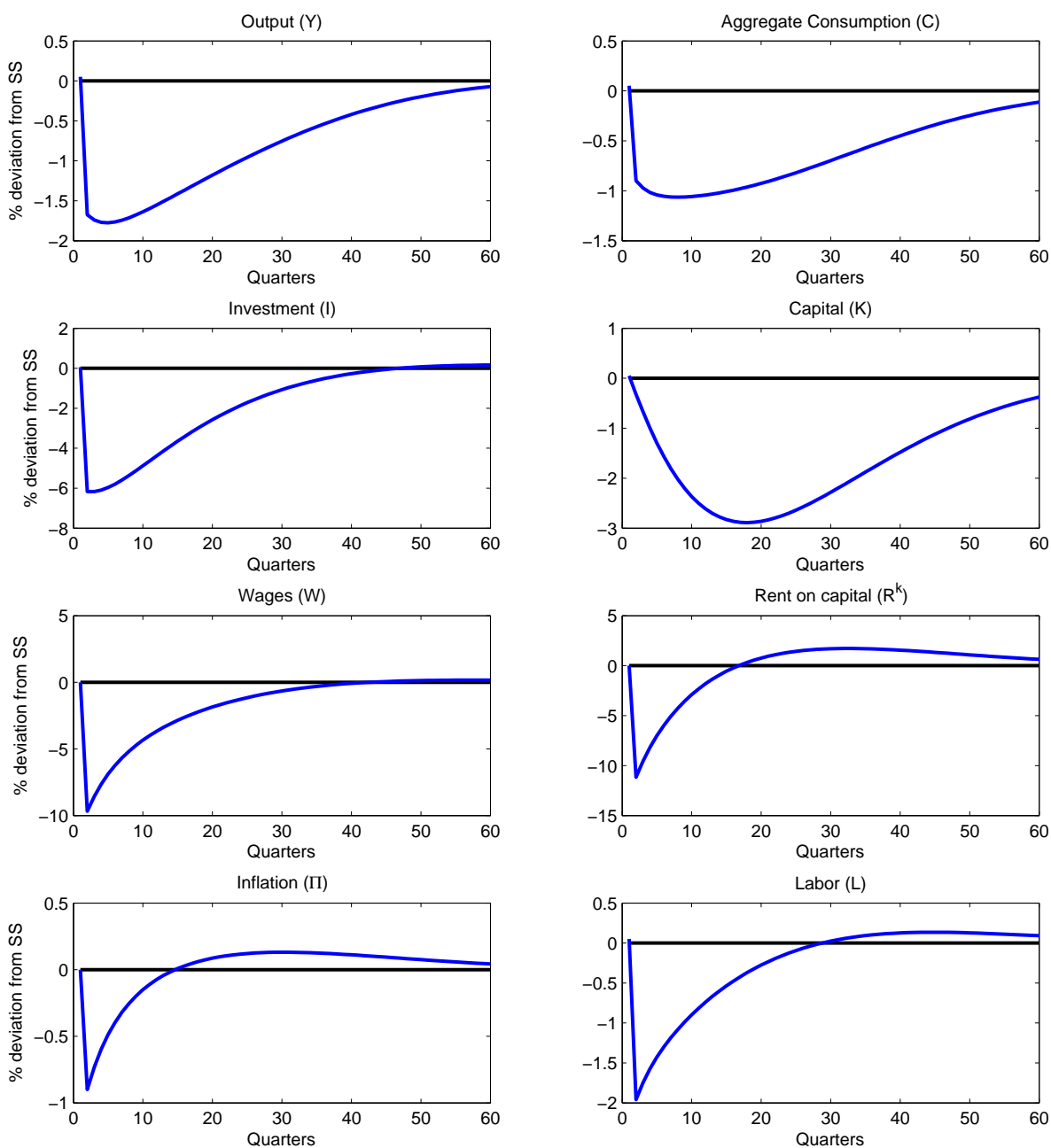
The appendix presents the paths of the endogenous variables in the model following a deleveraging shock. It provides the dynamics of the full list of variables that expands on the variables discussed in the main body of the paper.

Figure A.1: Economic Impact of Borrowers' Deleveraging (A)



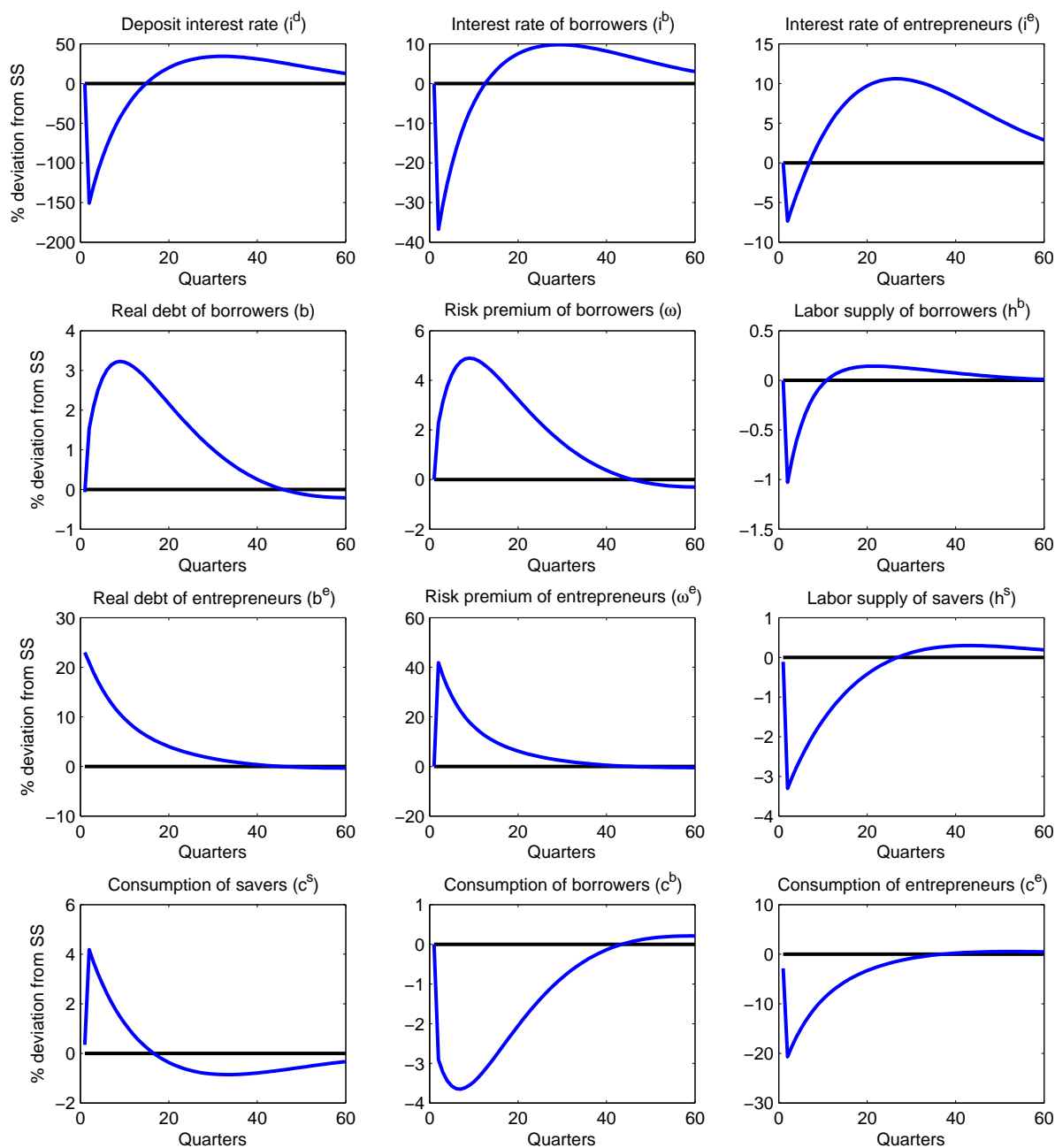
Notes: Responses of economic variables following a deleveraging shock to borrowers. In the simulation, the real debt of borrowers decreases to the new "safe" level. The plots cover the first 15 years of the simulation. All variables are presented in percentage point deviations from the steady state.

Figure A.2: Economic Impact of Borrowers' Deleveraging (B)



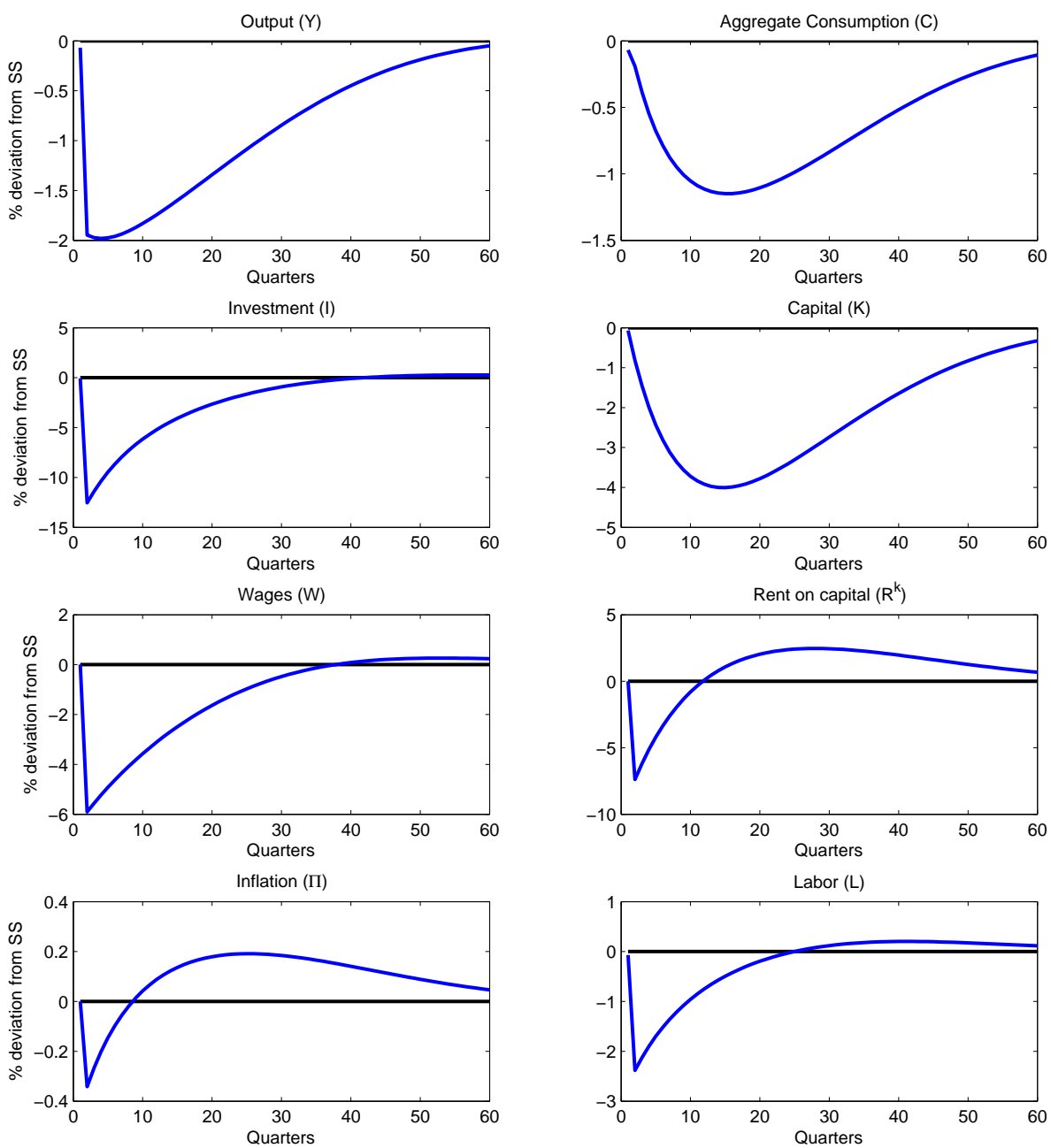
Notes: Responses of economic variables following a deleveraging shock to borrowers. In the simulation, the real debt of borrowers decreases to the new "safe" level. The plots cover the first 15 years of the simulation. All variables are presented in percentage point deviations from the steady state.

Figure A.3: Economic Impact of Entrepreneurs' Deleveraging (A)



Notes: Responses of economic variables following a deleveraging shock to entrepreneurs. In the simulation, the real debt of entrepreneurs decreases to the new "safe" level. The plots cover the first 15 years of the simulation. All variables are presented in percentage point deviations from the steady state.

Figure A.4: Economic Impact of Entrepreneurs' Deleveraging (B)



Notes: Responses of economic variables following a deleveraging shock to entrepreneurs. In the simulation, the real debt of entrepreneurs decreases to the new "safe" level. The plots cover the first 15 years of the simulation. All variables are presented in percentage point deviations from the steady state.

A.6 INTRODUCING A ZERO LOWER BOUND OF THE MONETARY POLICY RATE

In the main body of the paper, we assume that the monetary authority can set a negative policy rate (i_t^d). Even though the current crisis has witnessed example of negative policy rates, only a handful of central banks have experimented with this drastic measure⁶. Instead, central banks have resorted to non-conventional monetary policy measures in order to provide additional monetary stimulus to the economy. Therefore, the negative deposit rate in the model could be treated as a proxy for the non-conventional monetary policy measures undertaken by banks.

However, it is interesting to inspect the role of the zero lower bound (ZLB) on the deposit rate (the monetary policy rate) on the broad model dynamics. The ZLB is introduced in the functional form of the Taylor rule. With that adjustment, the model is simulated. The updated Taylor rule has the form

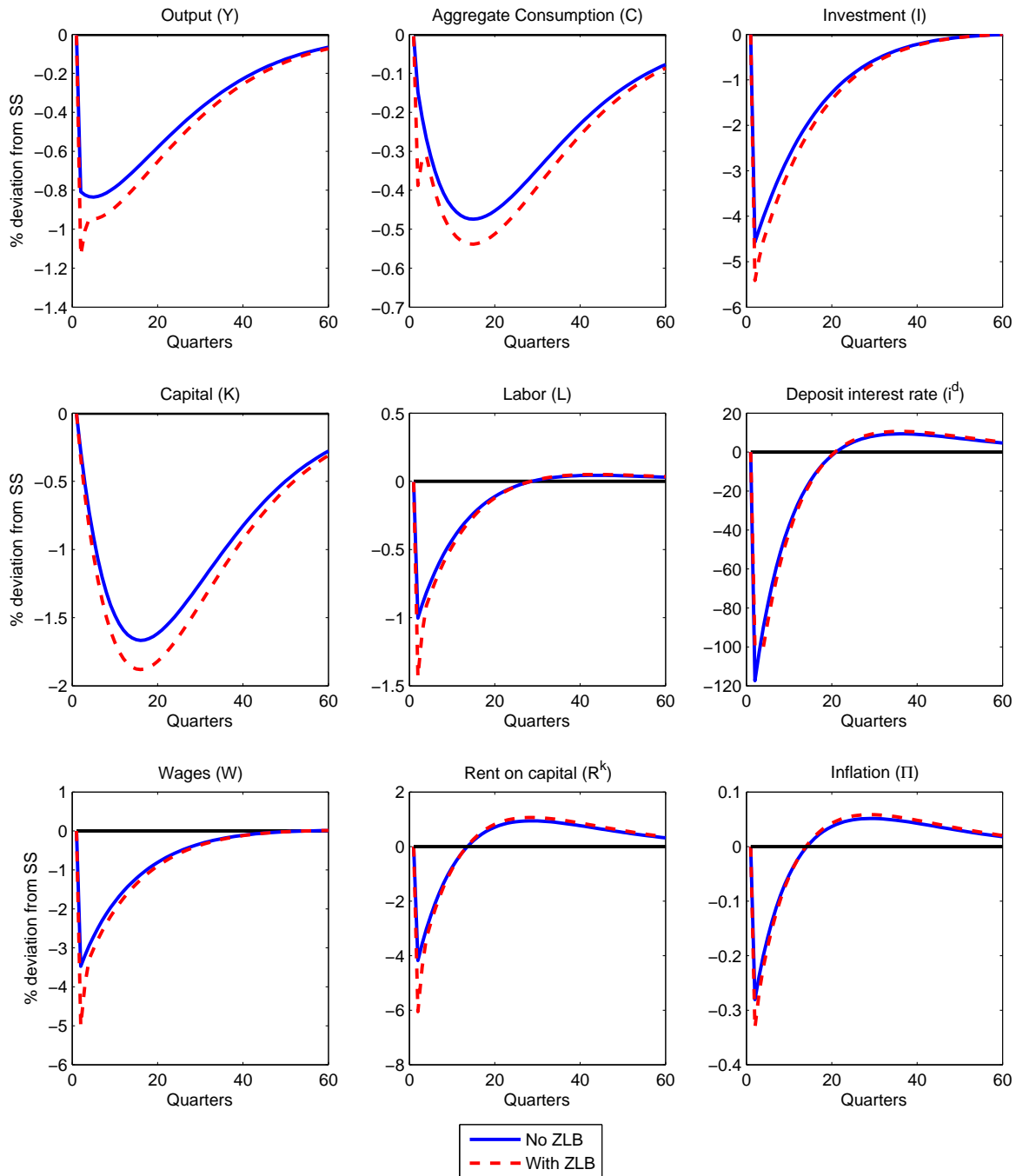
$$i_t^d = \max \left\{ 0, i^d + \phi_{\Pi} (\Pi_t - 1) + \phi_Y \ln \left(\frac{Y_t}{\bar{Y}} \right) \right\}$$

Since the ZLB is a form of nominal rigidity, its introduction into the model leads to a larger economic downturn following the deleveraging shock. Figure A.5 presents the results. We simulate a two sector simultaneous deleveraging with and without a ZLB on the deposit interest rate. The presence of the ZLB leads to a sizable increase in the negative impact of the shock for all variables. We can see that in the first 3 periods when the lower bound is binding, there is an additional drop in consumption and output. After this initial period, the model dynamics replicate the baseline. The simulation results demonstrate that while the presence of a ZLB does not change the broad dynamics of the model, the magnitude of the impact of the deleveraging shock is amplified. The intuition behind the results is simple. As the deleveraging shock hits, over-indebted agents embark of a process of debt reduction which is achieved through a contraction in spending. The monetary authority has only one lever to counteract this process - decrease the deposit interest rate. This has two effects. First, it reduces the debt servicing costs of indebted agents, assisting them in their deleveraging effort, and second, it motivates savers to use up portion of their deposits to increase consumption. When the monetary policy rate can be reduced freely, savers are stimulated to pick up part of the slack in demand generated by deleveraging agents. As a result, the fall in total economic activity is not as severe. However, when the monetary policy rate is bounded from below by 0, rates can not adjust to the extend needed and demand collapses.

As demand drops, consumer prices also fall which triggers deflation. As the real interest rate is the difference between nominal rate and inflation, falling prices push the real rate of return in the economy up which demotivates savers to consume. Furthermore, deflation intensifies the process of debt deflation that transfers wealth from borrowers to savers. As a consequence, both borrowers and lenders have lower incentives to spend. This initial contraction in demand is then transferred to factor markets, slashing wages and return on capital and aggravating the second round effects of the shock. As a consequence, when the nominal interest rate hits the zero bound, downward pressured are put on current debt and more intensive deleveraging occurs. Compared to the baseline specification of the model without a ZLB, the contraction of economic activity is larger and it lasts longer.

⁶Negative deposit rates on extra reserves have been introduced by the central banks in Sweden, Denmark, Switzerland and the ECB.

Figure A.5: The Role of the Zero Lower Bound on Model's Dynamics



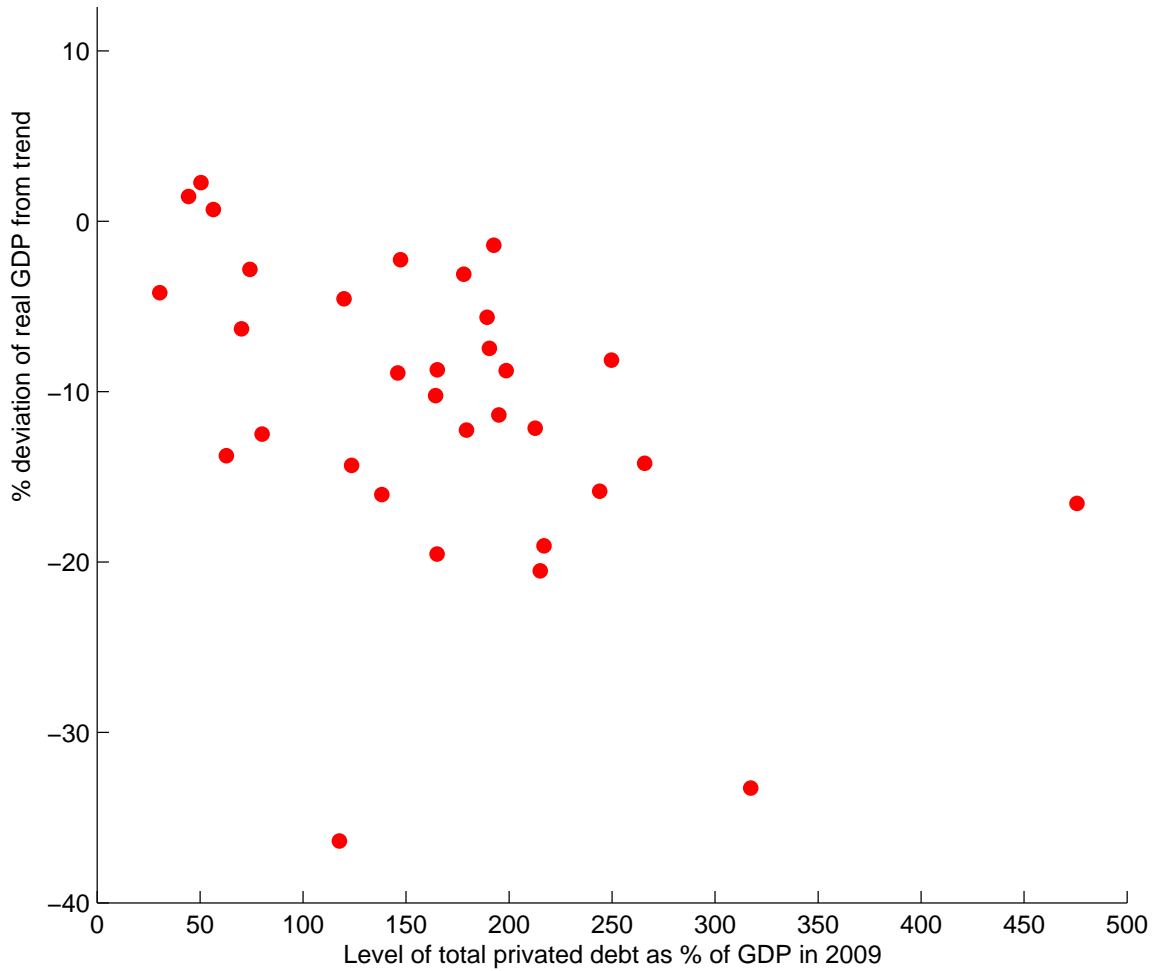
Notes: Responses of economic variables in the case of a two sector simultaneous deleveraging and a zero lower bound on the risk-free deposit interest rate. The plots cover the first 15 years of the simulation. All variables are presented in percentage point deviations from the steady state. The continuous lines denote the series in the baseline case when a zero lower bound is not imposed to the model. The dashed red lines denote the series when the zero lower bound is imposed. Since the zero lower bound generates a larger economic downturn, the deleveraging shock is reduced to around 50% of the shock in the main body of the paper.

APPENDIX B

APPENDIX TO CHAPTER 3

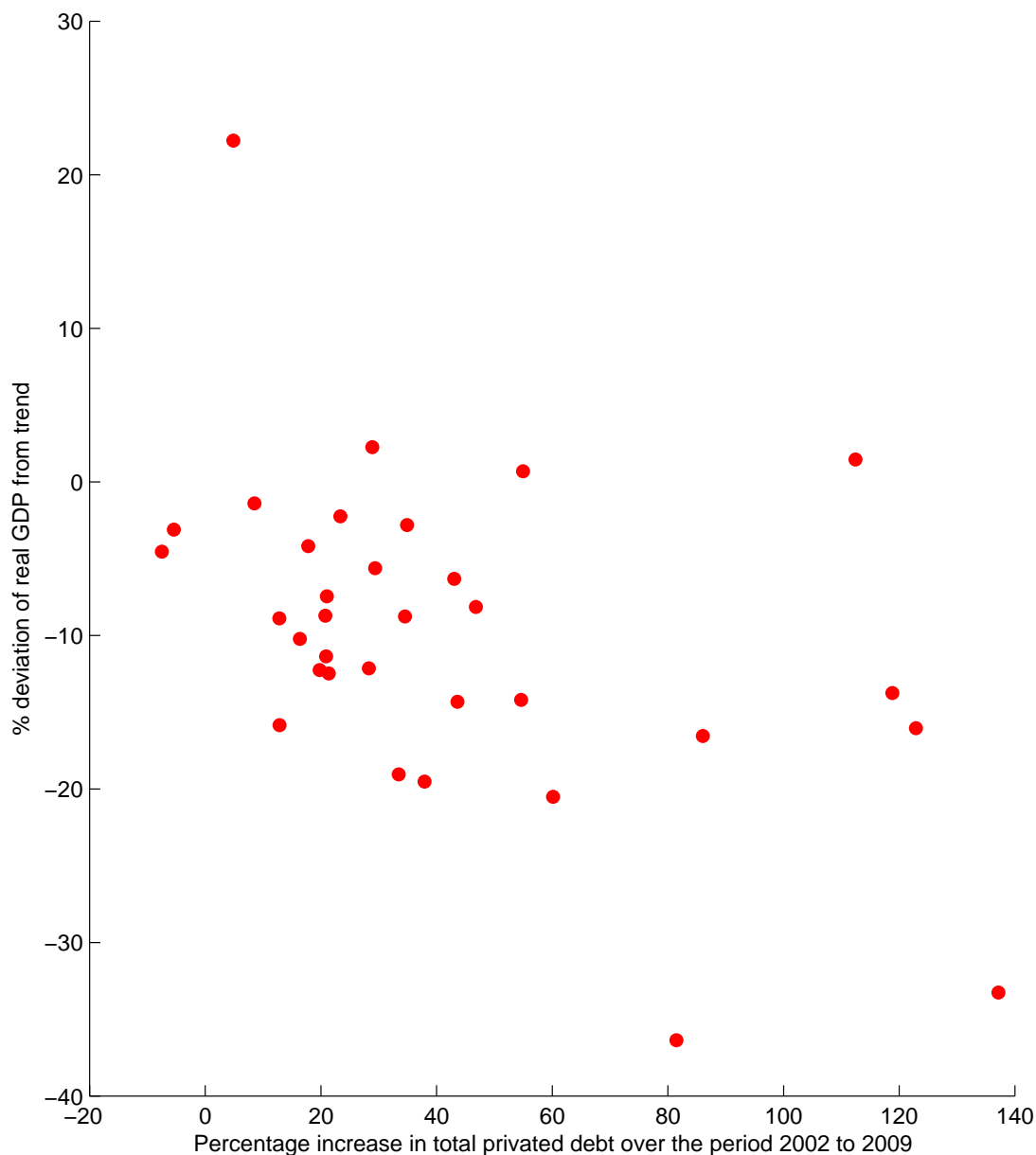
B.1 FIGURES

Figure B.1: Relation Between Private Indebtedness in 2009 and the Subsequent Economic Contraction for OECD Countries



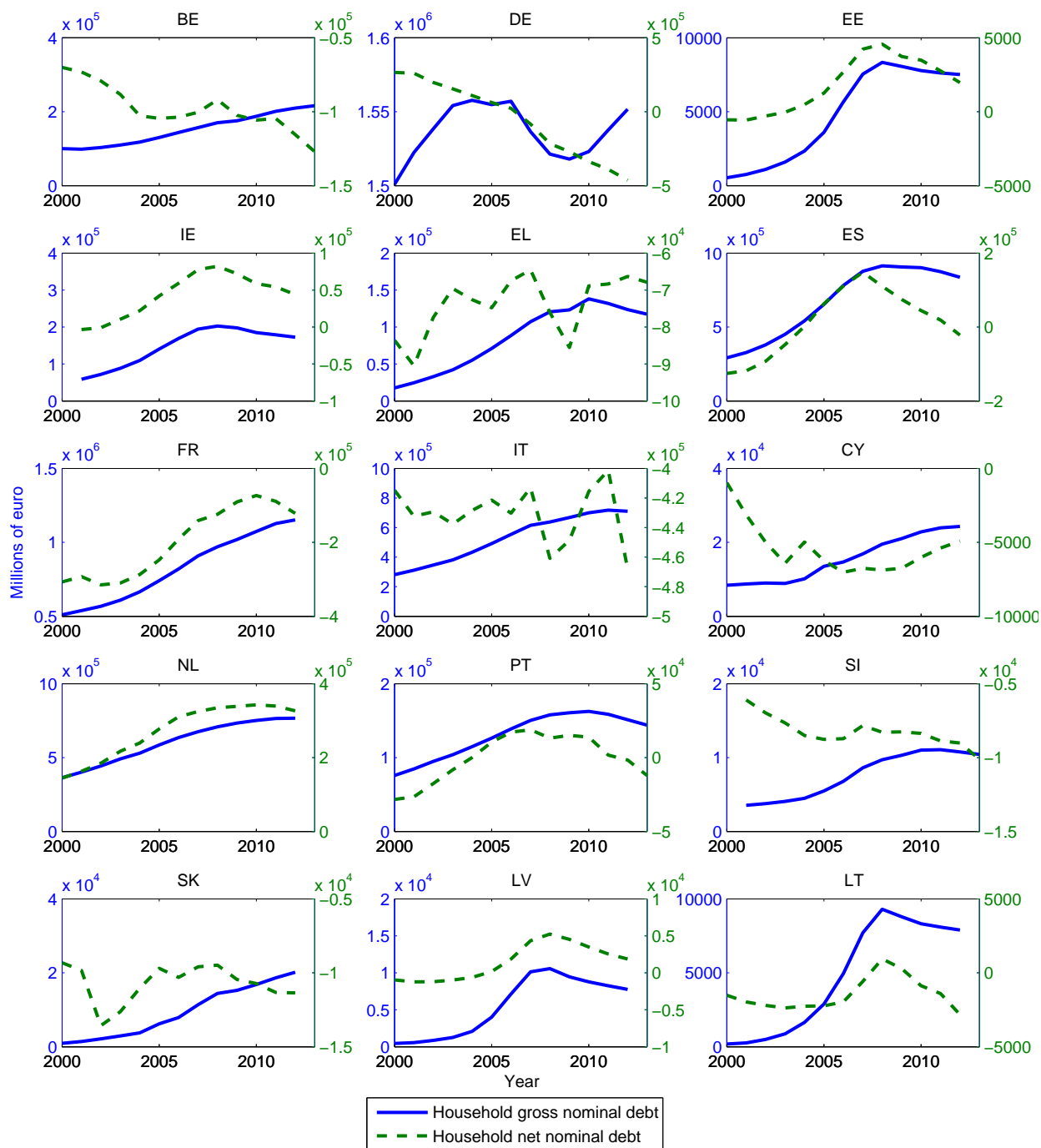
Note: The graph plots the relation between the level of private indebtedness at the end of 2009 and the percentage deviation of real GDP from a linear pre-boom trend observed five years after the onset of the financial crisis. Private indebtedness is measured by the ratio of total private debt outstanding at the end of period to nominal GDP. Deviations of real GDP from trend are computed on the base of a linear trend estimated over the period 1990 to 2004. In case no data is available since 1990, the first available data point is used. Points represent individual OECD members. **Source:** BIS, OECD and author's calculations.

Figure B.2: Relation Between the Increase in Private Indebtedness Over the Period 2002-2009 and the Subsequent Economic Contraction for OECD Countries



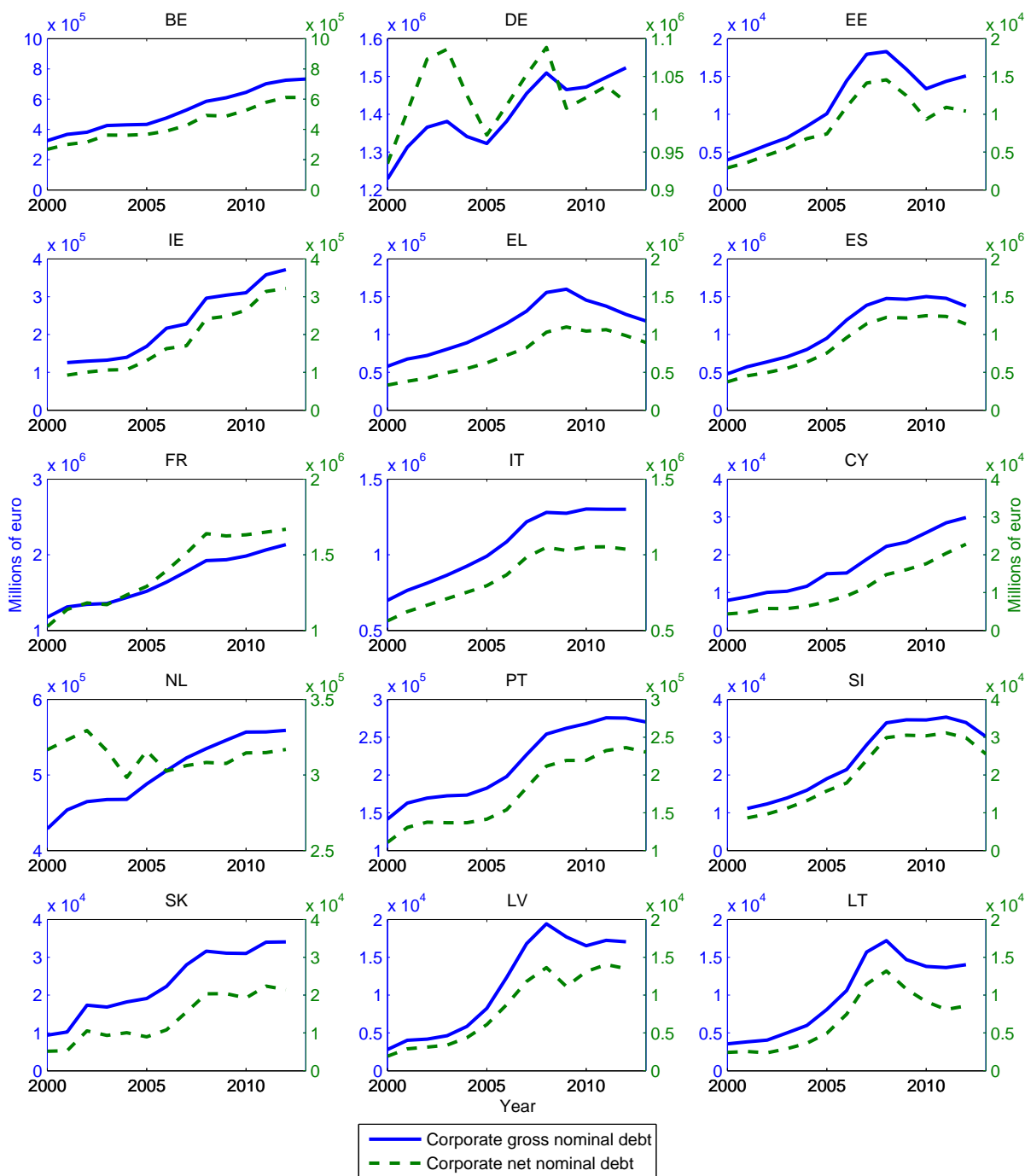
Note: The graph plots the relation between the percentage increase in private indebtedness between 2002 and 2009 and the percentage deviation of real GDP from a linear pre-boom trend observed five years after the onset of the financial crisis. The percentage increase is computed as the change in private debt over the period 2002 to 2009 divided by initial level of private debt at 2002. Deviations of real GDP from trend are computed on the base of a linear trend estimated over the period 1990 to 2004. In case no data is available since 1990, the first available data point is used. Points represent individual OECD members. **Source:** BIS, OECD and author's calculations.

Figure B.3: Evolution of Nominal Gross Debt and a Broad Measure of Net Debt of the Household Sector



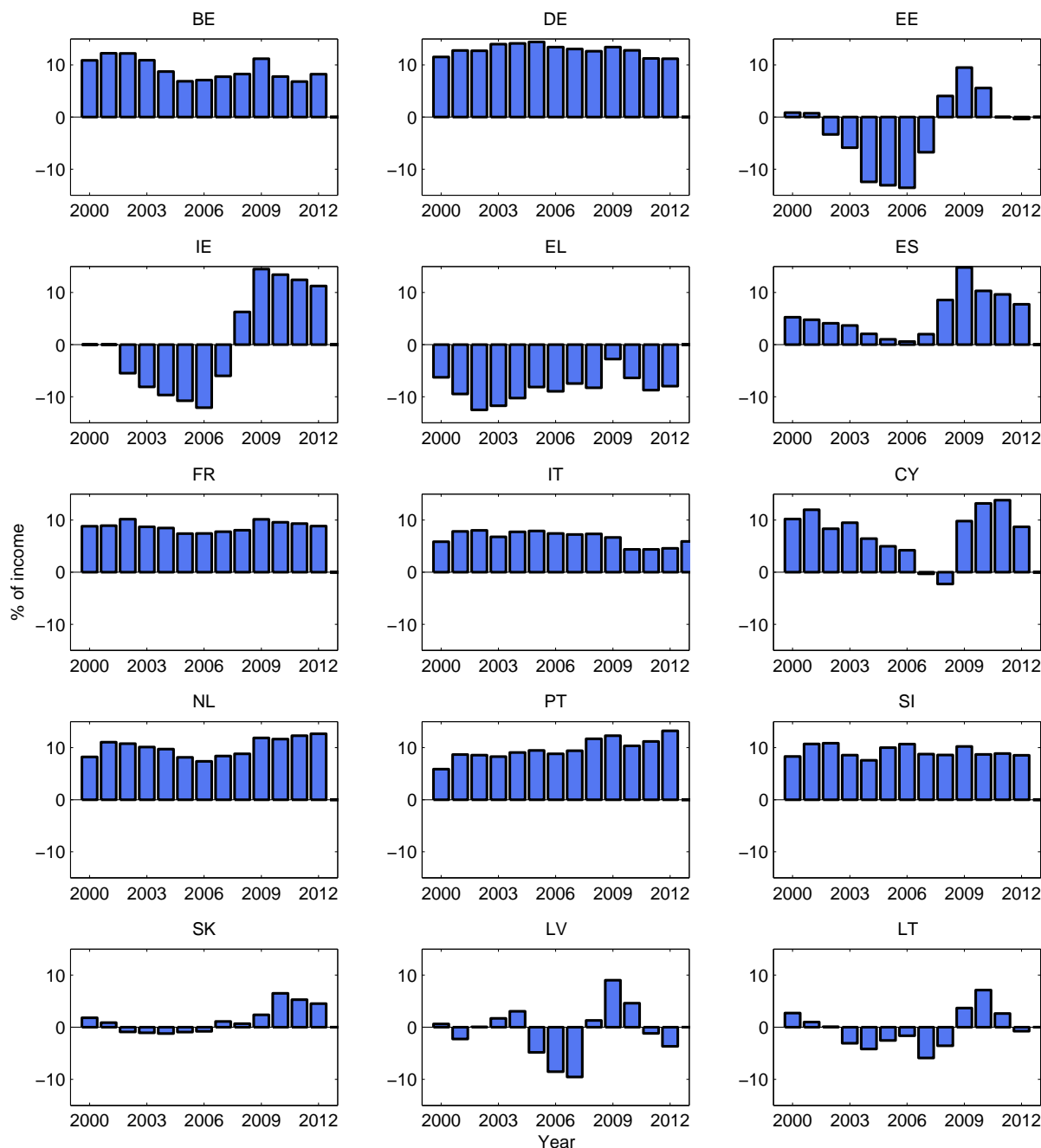
Note: The graph presents the evolution of two alternative measure of debt for the household sector: nominal gross debt and a broad measure of net debt. Nominal gross debt includes total loans and credit securities of the household sector. Net debt is defined as gross debt minus household deposits which are the most liquid form of household financial assets. Both variables are measured in millions of euros. Individual plots correspond to member countries. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure B.4: Evolution of Nominal Gross Debt and a Broad Measure of Net Debt of the Corporate Sector



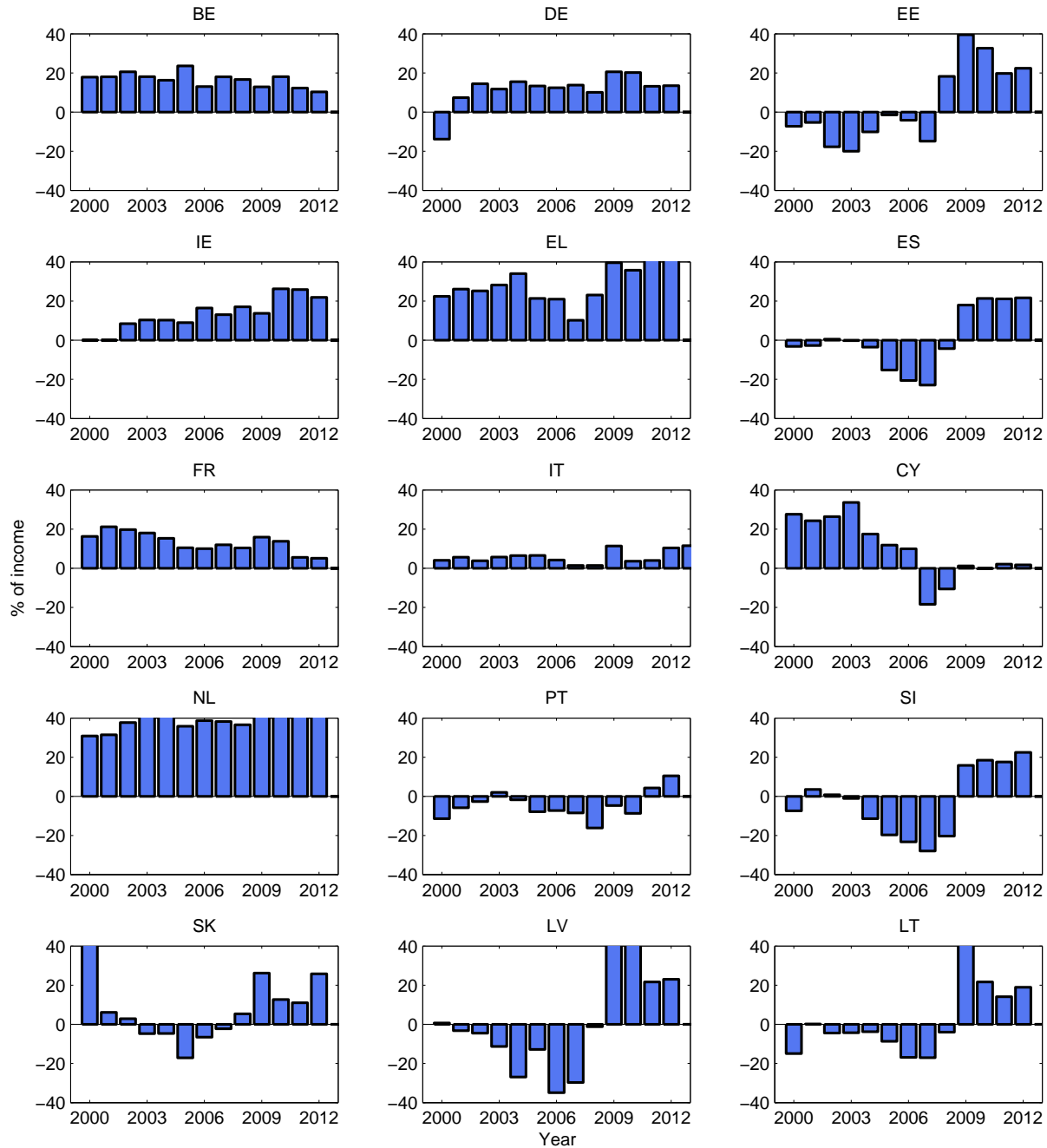
Note: The graph presents the evolution of two alternative measure of debt for the corporate sector: nominal gross debt and a broad measure of net debt. Nominal gross debt includes total loans and credit securities of the corporate sector. Net debt is defined as gross debt minus corporate deposits which are the most liquid form of corporate financial assets. Both variables are measured in millions of euros. Individual plots correspond to member countries. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure B.5: Deleveraging Effort: Financial Shortfall or Surplus of the Household Sector



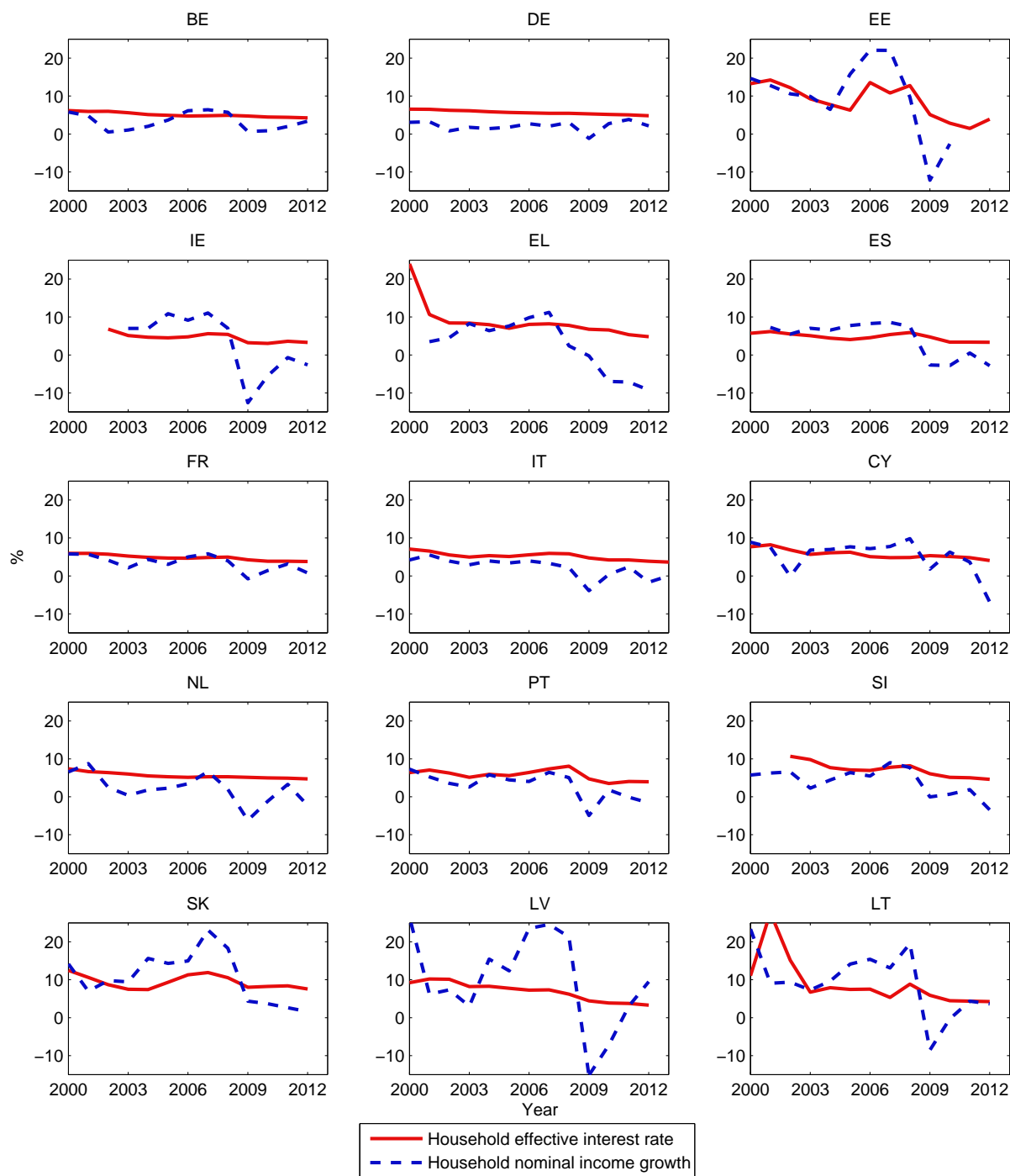
Note: The graph presents the evolution of the net lending/net borrowing account of the household sector over the period 2000 to 2013. Net lending/net borrowing of the sector is presented as a percentage of disposable income. Positive amounts signify that the sector is a net lender to other sector and the rest of the world, while negative amounts denote that the sector is a net borrower. Net lending/net borrowing is the amount available to the sector for the purchase of financial assets (i.e. deposits, stocks) if positive and equals the acquisition of financial liabilities (i.e. loans) if negative. Individual plots correspond to member countries. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure B.6: Deleveraging Effort: Financial Shortfall or Surplus of the Corporate Sector



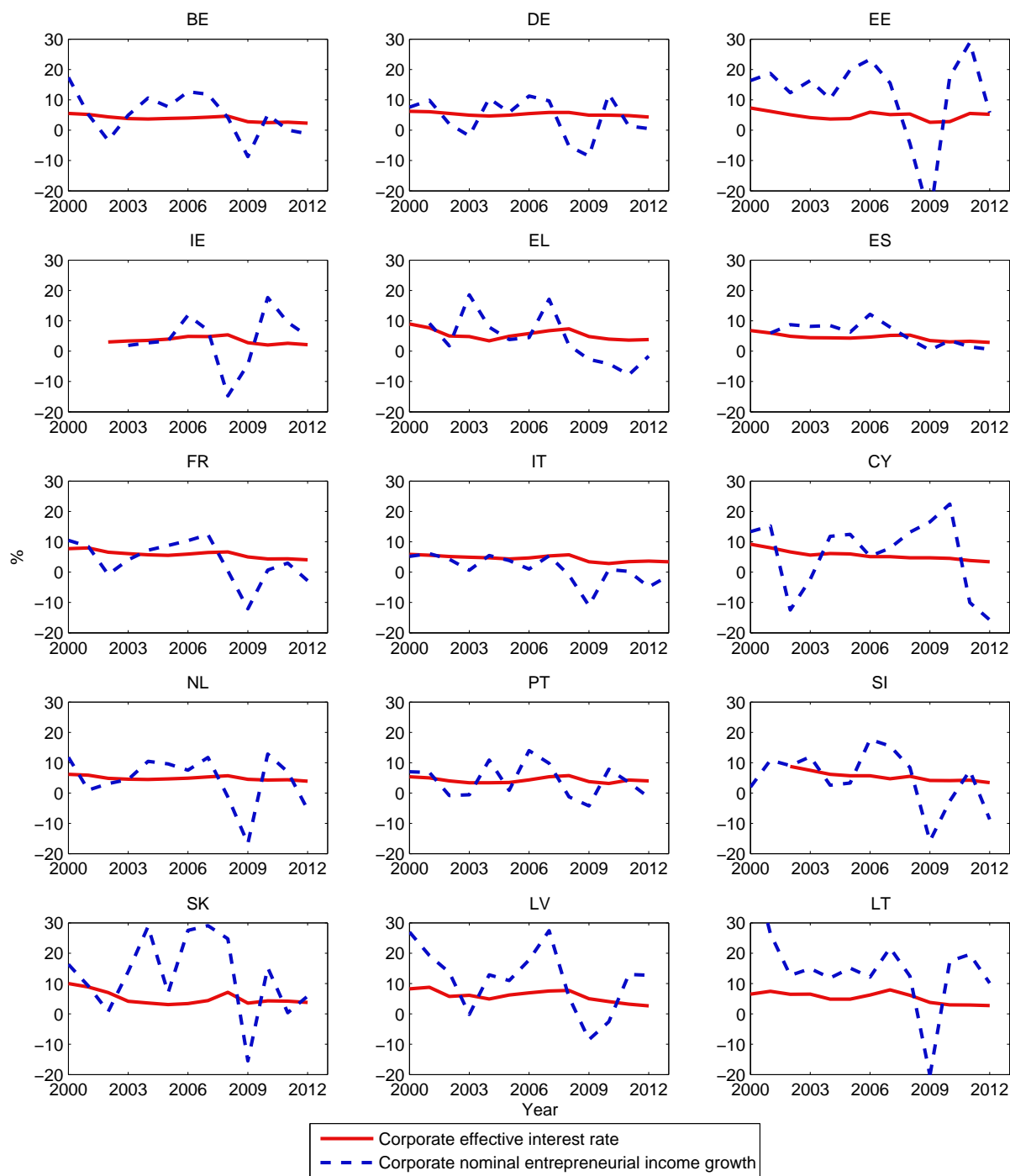
Note: The graph presents the evolution of the net lending/net borrowing account of the corporate sector over the period 2000 to 2013. Net lending/net borrowing of the sector is presented as a percentage of entrepreneurial income. Positive amounts signify that the sector is a net lender to other sector and the rest of the world, while negative amounts denote that the sector is a net borrower. Net lending/net borrowing is the amount available to the sector for the purchase of financial assets if positive and equals the acquisition of financial liabilities if negative. Individual plots correspond to member countries. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure B.7: Effective Nominal Interest Rate and Nominal Income Growth for the Household Sector



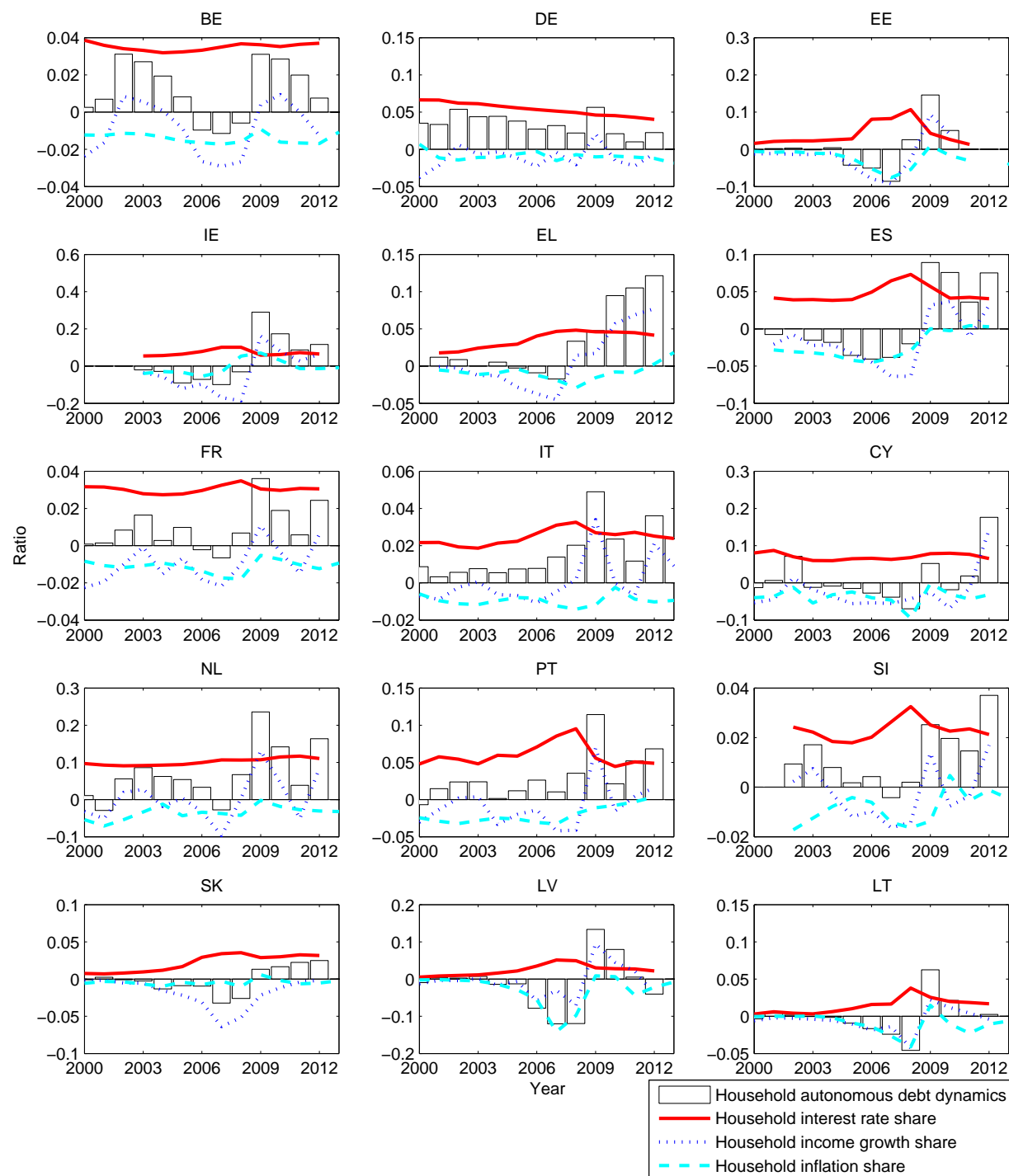
Note: The graph presents the evolution of the effective interest rate of the household sector and the growth rate of nominal income. The interest and growth rates are presented in percentage points. Periods when the effective interest rate (red line) stays below the nominal growth rate (blue dashed line) are characterized by positive autonomous debt dynamics, i.e. mechanically the leverage level should decrease if there is no new borrowing. Individual plots correspond to member countries. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure B.8: Effective Nominal Interest Rate and Nominal Income Growth for the Corporate Sector



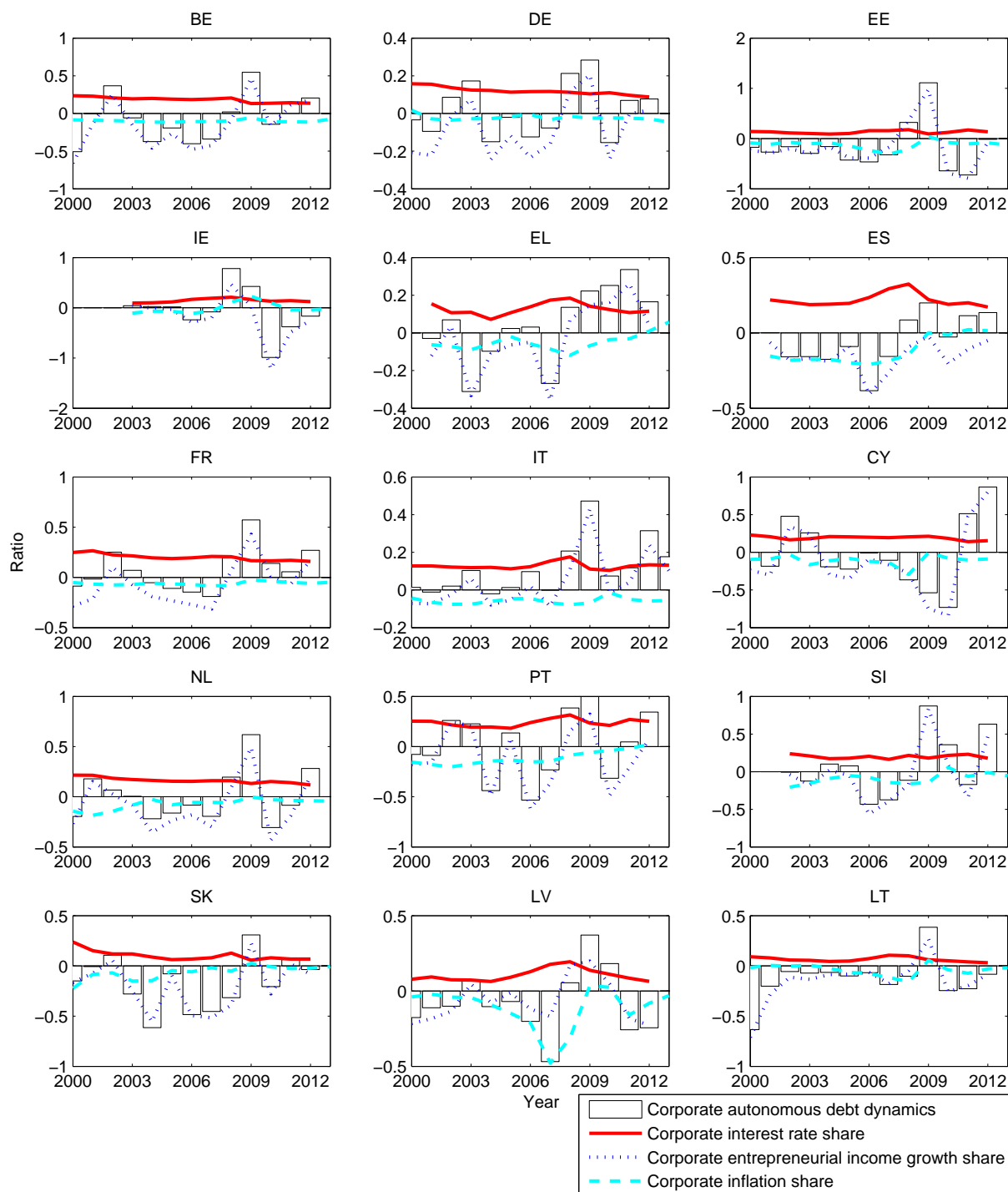
Note: The graph presents the evolution of the effective interest rate of the corporate sector and the growth rate of nominal income. The interest and growth rates are presented in percentage points. Periods when the effective interest rate (red line) stays below the nominal growth rate (blue dashed line) are characterized by positive autonomous debt dynamics, i.e. mechanically the leverage level should decrease if there is no new borrowing. Individual plots correspond to member countries. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure B.9: Decomposition of Autonomous Debt Dynamics into Sub-Components for the Household Sector



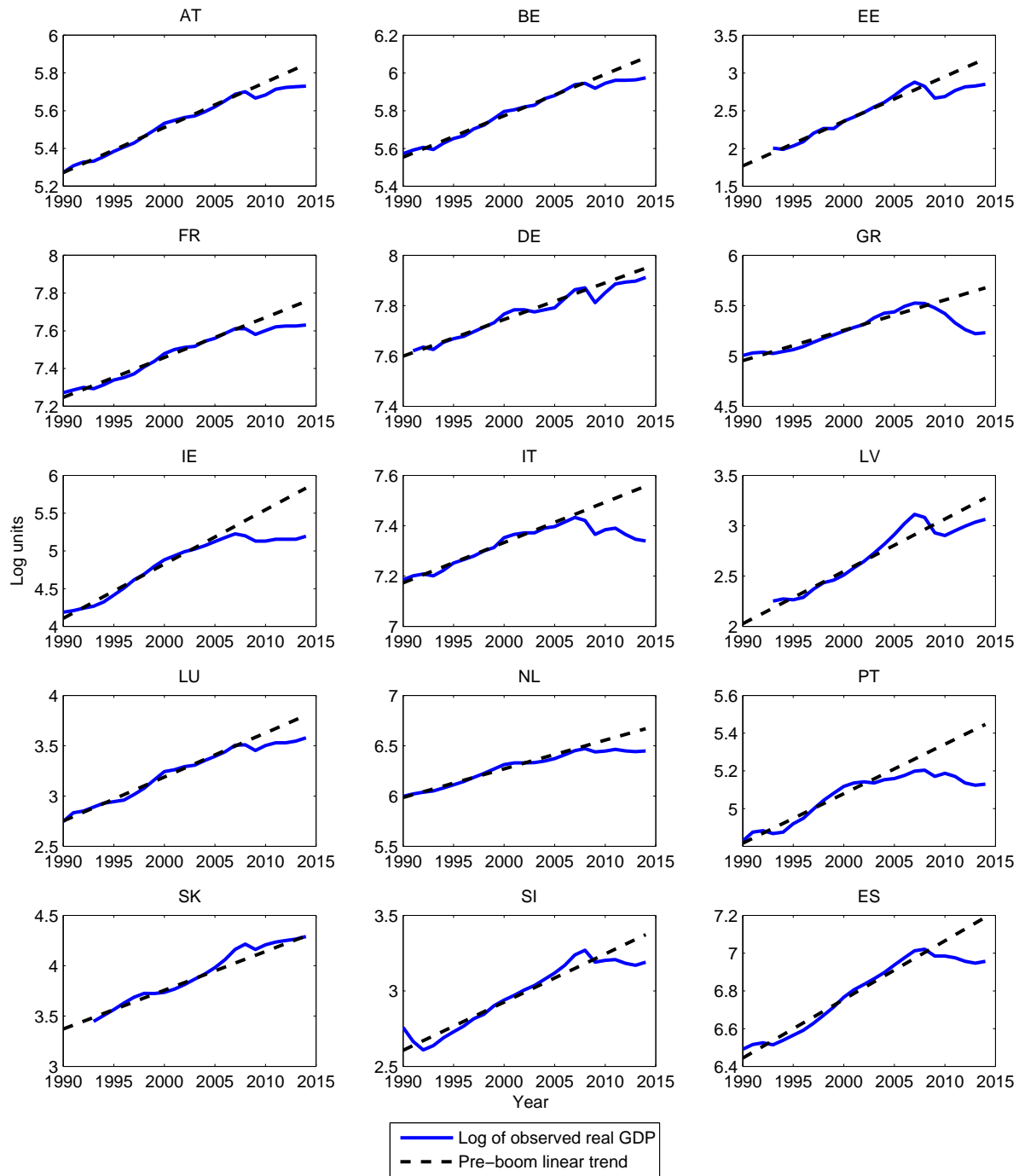
Note: The graph presents the decomposition of autonomous debt dynamics into sub-components - interest rate share, income growth share and inflation share. The graph allows to trace the role of individual components in determining the aggregate dynamics. Individual plots correspond to member countries. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure B.10: Decomposition of Autonomous Debt Dynamics into Sub-Components for the Corporate Sector



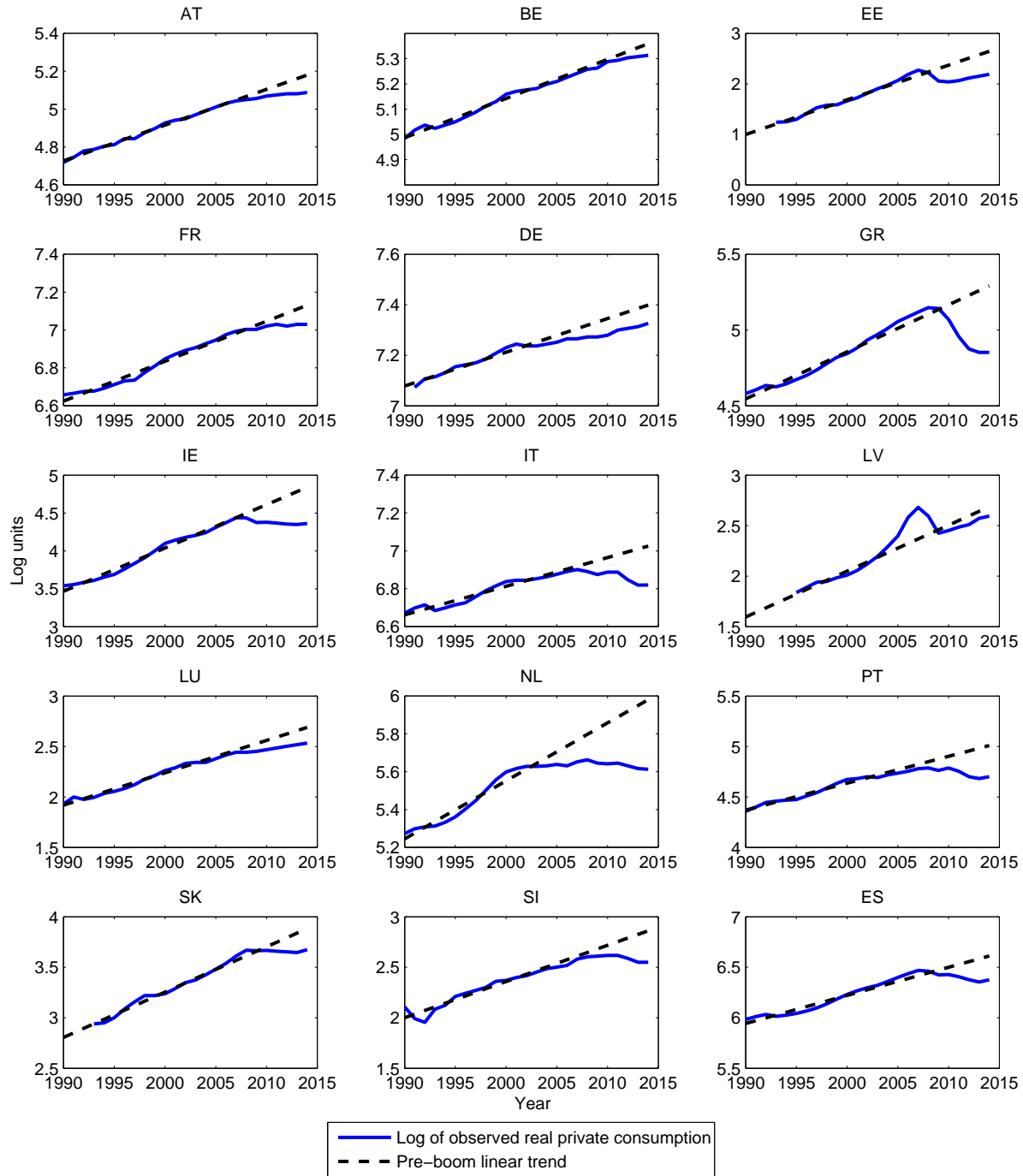
Note: The graph presents the decomposition of autonomous debt dynamics into sub-components - interest rate share, income growth share and inflation share. The graph allows to trace the role of individual components in determining the aggregate dynamics. Individual plots correspond to member countries. Country names' abbreviations are as defines by EUROSTAT. **Source:** EUROSTAT National Sector Accounts and author's calculations.

Figure B.11: Observed Real GDP Versus a Pre-Boom Linear Trend



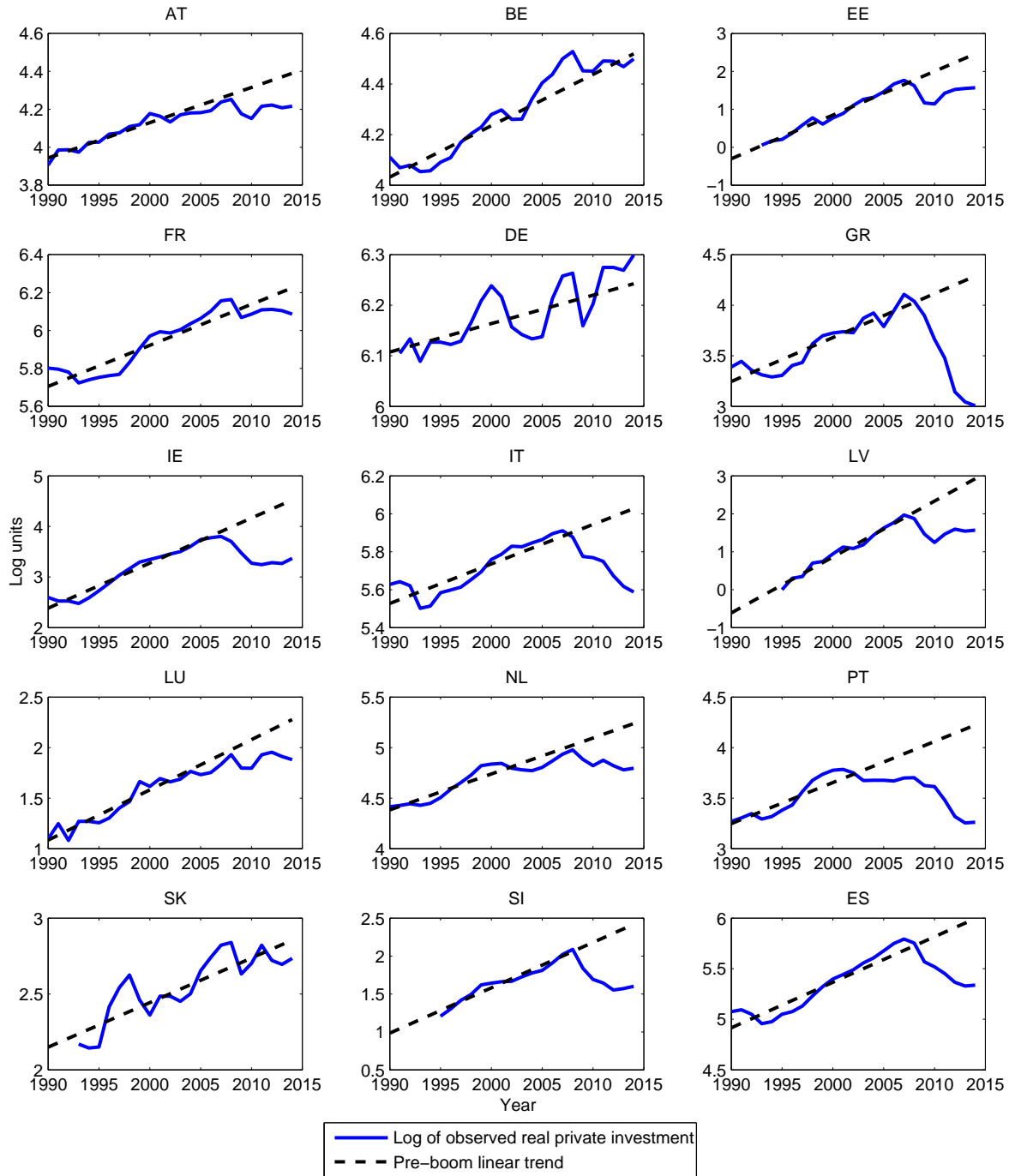
Note: The graph presents the evolution of real GDP for individual Euro Area members states (blue continuous line) versus a linear pre-boom trend (black dashed line). The linear trend is computed over the period 1990 to 2004. A log transformation has been applied to the historic series of real GDP to facilitate the computation of the linear historic trend. Individual plots correspond to member countries. Country names' abbreviations are as defined by EUROSTAT. **Source:** OECD and author's calculations.

Figure B.12: Observed Real Private Consumption Versus a Pre-Boom Linear Trend



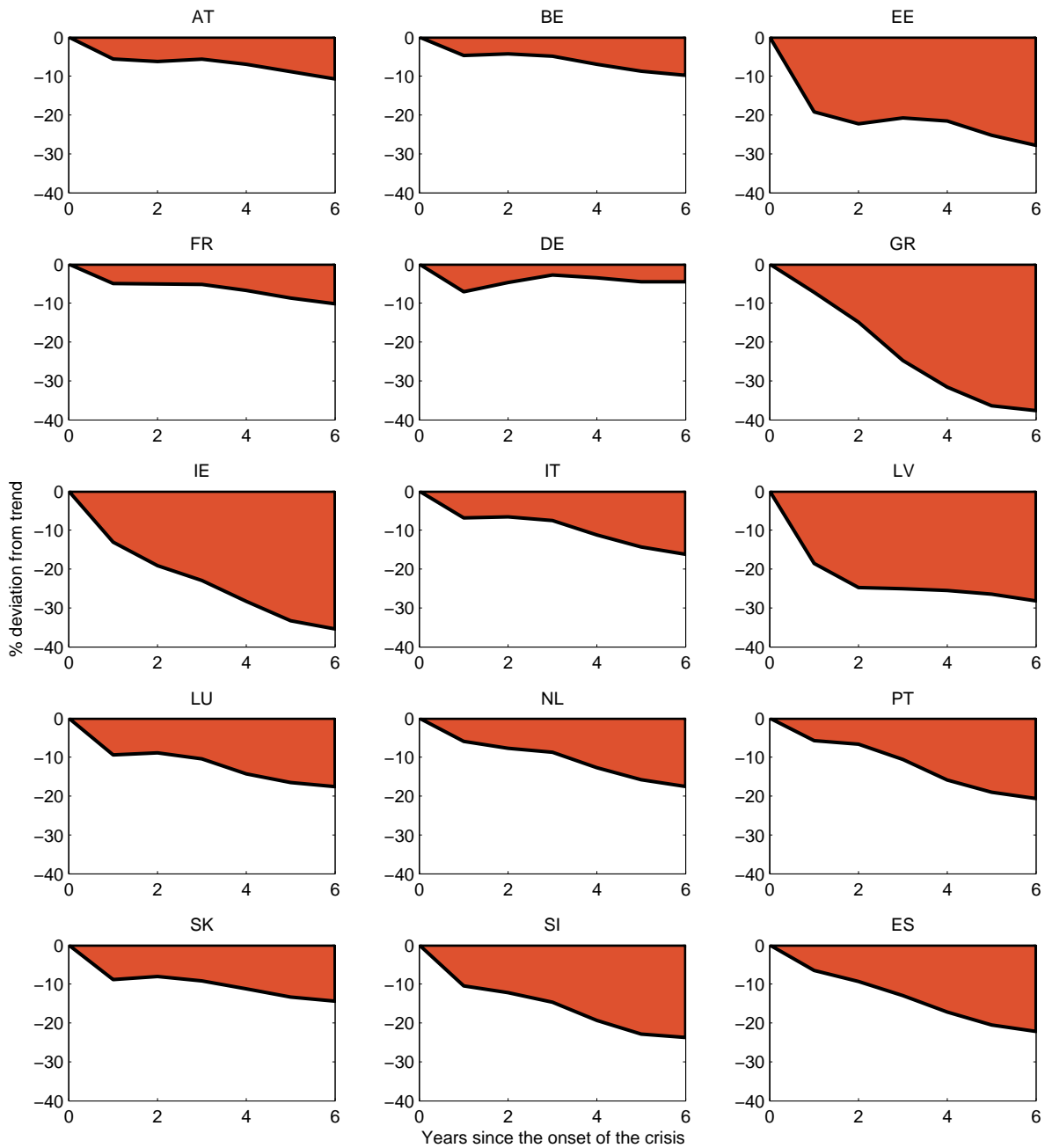
Note: The graph presents the evolution of real private consumption for individual Euro Area members states (blue continuous line) versus a linear pre-boom trend (black dashed line). The linear trend is computed over the period 1990 to 2004. In case historic data is not available since 1990, the linear trend is computed from the first available data point. A log transformation has been applied to the historic series of real private consumption to facilitate the computation of the linear historic trend. Individual plots correspond to member countries. Country names' abbreviations are as defined by EUROSTAT. **Source:** OECD and author's calculations.

Figure B.13: Observed Real Private Investment Versus a Pre-Boom Linear Trend



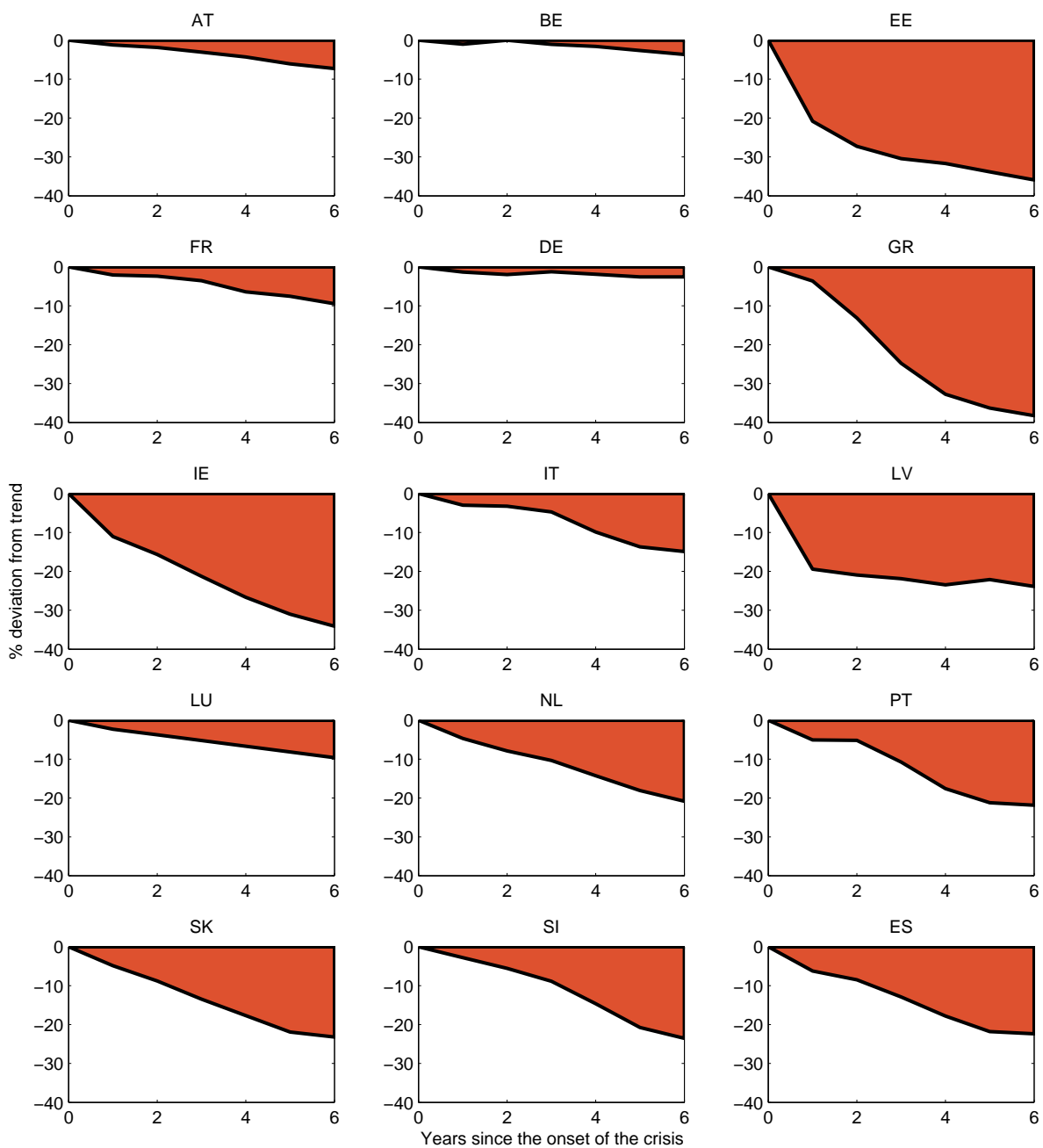
Note: The graph presents the evolution of real private investment for individual Euro Area members states (blue continuous line) versus a linear pre-boom trend (black dashed line). The linear trend is computed over the period 1990 to 2004. In case historic data is not available since 1990, the linear trend is computed from the first available data point. A log transformation has been applied to the historic series of real private investment to facilitate the computation of the linear historic trend. Individual plots correspond to member countries. Country names' abbreviations are as defined by EUROSTAT. **Source:** OECD and author's calculations.

Figure B.14: Deviation of Real GDP from a Pre-Boom Linear Trend (2008 - 2014)



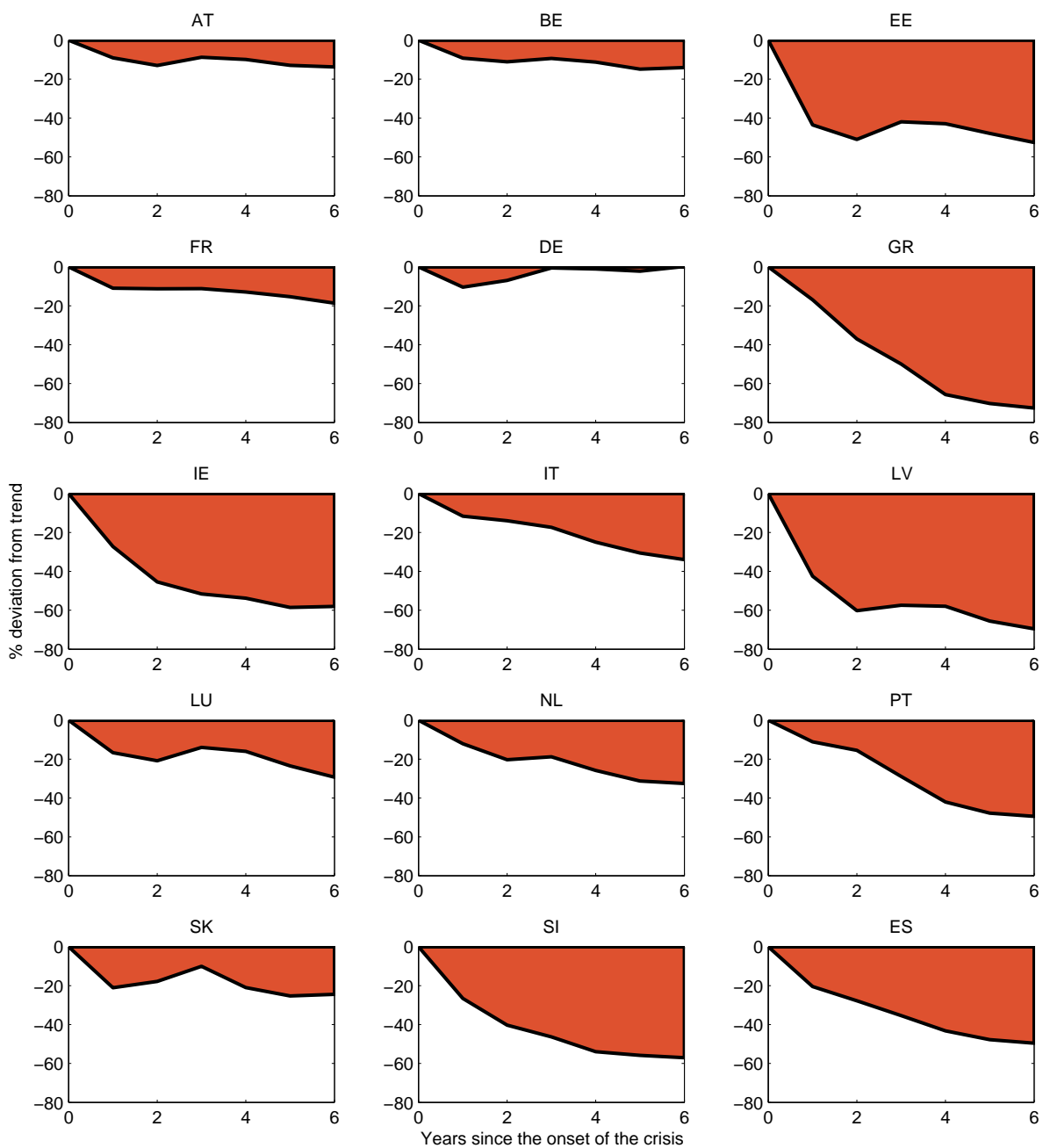
Note: The graph presents the deviation of real GDP from a pre-boom linear trend for individual Euro Area member states. The difference to trend is computed as a percentage of the trend level. The graph covers a period of six years after the onset of the crisis (2008-2014). Individual plots correspond to member countries. Country names' abbreviations are as defined by EUROSTAT. **Source:** OECD and author's calculations.

Figure B.15: Deviation of Real Private Consumption from a Pre-Boom Linear Trend (2008 - 2014)



Note: The graph presents the deviation of real private consumption from a pre-boom linear trend for individual Euro Area member states. The difference to trend is computed as a percentage of the trend level. The graph covers a period of six years after the onset of the crisis (2008-2014). Individual plots correspond to member countries. Country names' abbreviations are as defined by EUROSTAT. **Source:** OECD and author's calculations.

Figure B.16: Deviation of Real Private Investment from a Pre-Boom Linear Trend (2008 - 2014)



Note: The graph presents the deviation of real private investment from a pre-boom linear trend for individual Euro Area member states. The difference to trend is computed as a percentage of the trend level. The graph covers a period of six years after the onset of the crisis (2008-2014). Individual plots correspond to member countries. Country names' abbreviations are as defined by EUROSTAT. **Source:** OECD and author's calculations.

BIBLIOGRAPHY

- [1] Abbas, SM Ali, Nazim Belhocine, Asmaa El-Ganainy, and Mark Horton. "Historical Patterns and Dynamics of Public Debt-Evidence From A New Database." *IMF Economic Review* 59, no. 4 (2011): 717-742.
- [2] Abiad, Abdul, Enrica Detragiache, and Thierry Tressel. "A new database of financial reforms." No. 2008-2266. International Monetary Fund, (2008).
- [3] Acharya, Viral, Thomas Philippon, Matthew Richardson, and Nouriel Roubini. "The financial crisis of 2007-2009: Causes and remedies." *Financial markets, institutions and instruments* 18, no. 2 (2009): 89-137.
- [4] Acharya, Viral V., and Matthew Richardson. "Causes of the financial crisis." *Critical Review* 21, no. 2-3 (2009): 195-210.
- [5] Adahl, Martin. "Banking in the Baltics-The Development of the Banking Systems of Estonia, Latvia, and Lithuania since Independence: The Internationalization of Baltic Banking (1998-2002)." *Focus on Transition* 2, no. 2002 (2002): 107-131.
- [6] Ahearne, Alan, and Guntram B. Wolff. "The debt challenge in Europe." *Transatlantic Economic Challenges in an Era of Growing Multipolarity* 22 (2012): 273.
- [7] Aizenman, Joshua, and Nancy Marion. "Using inflation to erode the US public debt." *Journal of Macroeconomics* 33, no. 4 (2011): 524-541.
- [8] Ammer, John, Clara Vega, and Jon Wongswan. "International transmission of US monetary policy shocks: Evidence from stock prices." *Journal of Money, Credit and Banking* 42, no. s1 (2010): 179-198.
- [9] Auerbach, Alan J., and Yuriy Gorodnichenko. "Fiscal multipliers in recession and expansion." In *Fiscal Policy after the Financial crisis*, University of Chicago press, (2012): 63-98.
- [10] Babecky, Jan, and Kamil Dybczak. "Real Wage Flexibility in the European Union: New Evidence from the Labor Cost Data." Czech National Bank, Research Department, (2012).
- [11] Baker, Scott R. "Debt and the consumption response to household income shocks." Available at SSRN (2015).
- [12] Banks in Bulgaria, Bulgarian National Bank, 1999 - 2012.
- [13] Bean, Charles. "Joseph Schumpeter Lecture The Great Moderation, The Great Panic, and The Great Contraction." *Journal of the European Economic Association* 8, no. 2-3 (2010): 289-325.
- [14] Benigno, Pierpaolo, Gauti B. Eggertsson, and Federica Romei. "Dynamic Debt Deleveraging and Optimal Monetary Policy." No. w20556. National Bureau of Economic Research, (2014).
- [15] Benigno, Pierpaolo, and Federica Romei. "Debt Deleveraging and the Exchange Rate." No. W17944. National Bureau of Economic Research, (2012).

- [16] Benito, Andrew, Matt Waldron, Garry Young, and F. Zampolli. "The role of household debt and balance sheets in the monetary transmission mechanism." Bank of England Quarterly Bulletin (2007): Q1.
- [17] Bernanke, Ben. "Essays on the Great Depression." Princeton University Press, (2000).
- [18] Bernanke, Ben S. "The global saving glut and the US current account deficit." No. 77. (2005).
- [19] Bernanke, Ben S. "The global saving glut and the US current account deficit." Board of Governors of the Federal Reserve System (US), Speech Mar 10 (2005).
- [20] Bernanke, Ben S., Mark Gertler, and Simon Gilchrist. "The financial accelerator in a quantitative business cycle framework." Handbook of macroeconomics 1 (1999): 1341-1393.
- [21] Bernanke, Ben S., and Kenneth N. Kuttner. "What explains the stock market's reaction to Federal Reserve policy?." The Journal of Finance 60, no. 3 (2005): 1221-1257.
- [22] Bernoth, Kerstin, and Jurgen von Hagen. "The Euribor futures market: Efficiency and the impact of ECB policy announcements." International finance 7, no. 1 (2004): 1-24.
- [23] Blanchard, Olivier J. "The crisis: basic mechanisms and appropriate policies." International Monetary Fund, (2009).
- [24] Bordo, Michael D., and Christopher M. Meissner. "Does inequality lead to a financial crisis?." Journal of International Money and Finance 31, no. 8 (2012): 2147-2161.
- [25] Borio, Claudio. "Ten propositions about liquidity crises." CESifo Economic Studies 56, no. 1 (2010): 70-95.
- [26] Bornhorst, Fabian, and Marta Arranz. "Growth and the importance of sequencing debt reductions across sectors." Jobs and Growth: Supporting the European Recovery (2014): 13.
- [27] Bredin, Donal, Caroline Gavin, and Gerard O'Reilly. "International policy rate changes and Dublin interbank offer rates." *mimeo*, (2004).
- [28] Bredin, Don, Stuart Hyde, and Gerard O. Reilly. "Monetary policy surprises and international bond markets." Journal of International Money and Finance 29, no. 6 (2010): 988-1002.
- [29] Buiters, Willem H., Torsten Persson, and Patrick Minford. "A guide to public sector debt and deficits." *Economic policy* (1985): 14-79.
- [30] Buiters, W., and E. Rahbari. "Debt, Financial Crisis and Economic Growth." In Conference on Monetary Policy and the Challenge of Economic Growth at the South Africa Reserve Bank, Pretoria, South Africa, (2012).
- [31] Bulgarian Banking Sector Overview. Elana Trading, August 2012.
- [32] Bulgaria: Selected Issues. IMF Country Report No. 10/159, (2010).
- [33] Cabanillas, Laura Gonzalez, and Eric Ruscher. "The Great Moderation in the euro area: What role have macroeconomic policies played?." No. 331. Directorate General Economic and Financial Affairs (DG ECFIN), European Commission, (2008).
- [34] Canova, Fabio. "The transmission of US shocks to Latin America." Journal of Applied econometrics 20, no. 2 (2005): 229-251.
- [35] Carney, Mark. "Fortune Favours the Bold." Speech delivered to the Greater Charlottetown Area Chamber of Commerce, Charlottetown, (2015).

- [36] Cecchetti, Stephen Giovanni, Madhusudan S. Mohanty, and Fabrizio Zampolli. "The real effects of debt." Bank for International Settlements, Monetary and Economic Department, (2011).
- [37] Ceylan, Nildag Basak, and Hakan Berument. "The Effects of Anticipated and Unanticipated Federal Funds Target Rate Changes on Domestic Interest Rates: International Evidence." *International Review of Applied Financial Issues and Economics* 2 (2010): 328-340.
- [38] Cicinska, Jonas. "Evolution of the Banking System in Lithuania: From State-Owned Monobanks to a Modern Banking System (1988-2004)." *Ekonomika* 74 (2006): 7-20.
- [39] Cochrane, John H., and Monika Piazzesi. "The Fed and interest rates—a high-frequency identification." *The American Economic Review* 92, no. 2 (2002): 90.
- [40] Collingnon, Stefan. *European Monetary Policy*, Pinter, 1997.
- [41] Cooray, Arusha. "The Fisher effect: A review of the literature." No. 0206, Macquarie University, Department of Economics, (2002).
- [42] Coric, Bruno. "The Global Extent of the Great Moderation." *Oxford bulletin of economics and statistics* 74, no. 4 (2012): 493-509.
- [43] Crotty, James. "Structural causes of the global financial crisis: a critical assessment of the 'new financial architecture'." *Cambridge Journal of Economics* 33, no. 4 (2009): 563-580.
- [44] Cuerpo, Carlos, Ines Drumond, Julia Lendvai, Peter Pontuch, and Rafal Raciborski. "Indebtedness, deleveraging dynamics and macroeconomic adjustment." No. 477. Directorate General Economic and Monetary Affairs (DG ECFIN), European Commission, (2013).
- [45] Curdia, Vasco and Michael Woodford. "Credit spreads and monetary policy." *Journal of Money, Credit and Banking* 42 (2010), 3-35.
- [46] Cushman, David O., and Tao Zha. "Identifying monetary policy in a small open economy under flexible exchange rates." *Journal of Monetary Economics* 39, no. 3 (1997): 433-448.
- [47] Cussen, Mary, and Bridin O'Leary. "Why are Irish non-financial corporations so indebted?." *Quarterly Bulletin* 1 (2013): 13.
- [48] Das, Piyali. "Decomposition of Debt-GDP Ratio for United Kingdom: 1984-2009." *mimeo*, (2011).
- [49] Drehmann, Mathias, Claudio EV Borio, and Kostas Tsatsaronis. "Anchoring countercyclical capital buffers: the role of credit aggregates." Bank for International Settlements, Monetary and Economic Department, (2011).
- [50] Druant, Martine, Silvia Fabiani, Gabor Kezdi, Ana Lamo, Fernando Martins, and Roberto Sabbatini. "Firms' price and wage adjustment in Europe: Survey evidence on nominal stickiness." *Labour Economics* 19, no. 5 (2012): 772-782.
- [51] Eggertsson, Gauti B., and Paul Krugman. "Debt, Deleveraging, and the Liquidity Trap: A Fisher-Minsky-Koo Approach*." *The Quarterly Journal of Economics* 127, no. 3 (2012): 1469-1513.
- [52] Ellingsen, Tore, Ulf Soderstrom, and L. Masseng. "Monetary policy and the bond market." Stockholm School of Economics. Photocopy (2003).
- [53] Estonia: Review of the Financial System, OECD, (2011).

- [54] Estonian Bank Annual Report, Eesti Pank, 1999 - 2011.
- [55] Estonian Economy and Financial Sector: Interim Report, Estonian Banking Association, 2006 - 2008.
- [56] EUROSTAT European system of national accounts ESA 2010, Publications Office of the European Union, (2013).
- [57] Faust, Jon, John H. Rogers, Shing-Yi B. Wang, and Jonathan H. Wright. "The high-frequency response of exchange rates and interest rates to macroeconomic announcements." *Journal of Monetary Economics* 54, no. 4 (2007): 1051-1068.
- [58] Financial Stability Review, Bank of Lithuania, 2004 - 2012.
- [59] Fisher, Irving. "The debt-deflation theory of great depressions." *Econometrica* (1933): 337-357.
- [60] Fleming, Michael J., and Monika Piazzesi. "Monetary policy tick-by-tick." *mimeo*, August (2005).
- [61] Fornaro, Luca. "International debt deleveraging." *mimeo* (2012).
- [62] Fornaro, Luca. "Debt Deleveraging, Debt Relief and Liquidity Traps." *mimeo* (2013).
- [63] Francois, Lequiller, and Blades Derek. "Understanding national accounts." OECD Publishing, (2007).
- [64] Gali, Jordi. *Monetary Policy, inflation, and the Business Cycle: An introduction to the new Keynesian Framework*. Princeton University Press, (2009).
- [65] Georgiev, Yordan, and Ivan Lozev. "Sectoral Debt Deleveraging in an Environment of Nominal Rigidities." *mimeo*, (2015).
- [66] Giavazzi, Francesco, and Luigi Spaventa. "Why the Current Account Matters in a Monetary Union." No. 8008. CEPR Discussion Paper, (2010).
- [67] Glick, Reuven, and Kevin J. Lansing. "Global household leverage, house prices, and consumption." FRBSF Economic Letter 1 (2010).
- [68] Goodhart, C. A. E. "Central Bank Evolution: Lessons learnt from the Sub-prime Crisis." In Unpublished article presented at Norges Bank's conference 'Of the Uses of Central Banks: Lessons from history'. (2014).
- [69] Schmitt-Grohe, Stephanie, and Martin Uribe. "Closing small open economy models." *Journal of international Economics* 61, no. 1 (2003), 163-185.
- [70] Schmitt-Grohe, Stephanie, and Martin Uribe. "The making of a great contraction with a liquidity trap and a jobless recovery." No. w18544. National Bureau of Economic Research, (2012).
- [71] Schmitt-Grohe, Stephanie, and Martin Uribe. "Downward Nominal Wage Rigidity and the Case for Temporary Inflation in the Eurozone." *The Journal of Economic Perspectives* 27, no. 3 (2013): 193-211.
- [72] Gros, Daniel. "Macroeconomic Imbalances in the Euro Area: Symptom or cause of the crisis?." CEPS Policy Brief 266 (2012).

- [73] Gros, Daniel, and Cinzia Alcidi. "Adjustment difficulties and debt overhangs in the eurozone periphery." CEPS Working Documents (2011).
- [74] Guerrieri, Veronica, and Guido Lorenzoni. "Credit crises, precautionary savings, and the liquidity trap." No. W17583. National Bureau of Economic Research, (2011).
- [75] Gurkaynak, Refet S., Brian Sack, and Eric T. Swanson. "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements." *International Journal of Central Banking*, Vol 1, (2005): 55-93.
- [76] Hall, Robert E. "The Long Slump." *American Economic Review* 101, no. 2 (2011): 431-69.
- [77] Hall, George J., and Thomas J. Sargent. "Interest Rate Risk and Other Determinants of Post-WWII US Government Debt/GDP Dynamics." No. w15702, National Bureau of Economic Research, (2010).
- [78] Holinski, Nils, Clemens JM Kool, and Joan Muysken. "Persistent macroeconomic imbalances in the euro area: Causes and consequences." *Federal Reserve Bank of St. Louis Review* 94, no. January/February 2012 (2012).
- [79] Igan, Deniz, Daniel Leigh, John Simon, and Petia Topalova. "Dealing with Household Debt." *Financial Crises, Consequences, and Policy Responses*, forthcoming (2013).
- [80] Ila, Enrique Alberola, Luis Molina, and Pedro del Rio Lopez. "Boom-bust Cycles, Imbalances and Discipline in Europe." *Moneda y credito* 234 (2012): 169-225.
- [81] "What's the Damage? Medium-Term Output Dynamics after Financial Crises." *IMF World Economic Outlook*, (2009).
- [82] Issing, Otmar, Vitor Gaspar, Ignazio Angeloni, and Oreste Tristani. "Monetary Policy in the Euro Area: Strategy and Decision-Making at the European Central Bank." Cambridge University Press, (2001).
- [83] Jauch, Sebastian, and Sebastian Watzka. "The Effect of Household Debt on Aggregate Demand-The Case of Spain." (2012).
- [84] Jayadev, Arjun, and Gerald Epstein. "The correlates of rentier returns in OECD countries." *mimeo* (2007).
- [85] Jorda, Oscar, Moritz HP Schularick, and Alan M. Taylor. "When credit bites back: leverage, business cycles, and crises." No. w17621. National Bureau of Economic Research, (2011).
- [86] Kim, Soyoung. "International transmission of US monetary policy shocks: Evidence from VAR's." *Journal of Monetary Economics* 48, no. 2 (2001): 339-372.
- [87] Koo, Richard. "The Holy Grail of Macroeconomics: Lessons from Japan's Great Recession.", New York: Wiley, (2008).
- [88] Koo, Richard C. "The world in balance sheet recession: causes, cure, and politics." *real-world economics review*, No. 58, (2011): 19-37.
- [89] Krueger, Joel T., and Kenneth N. Kuttner. "The fed funds futures rate as a predictor of Federal Reserve policy." *Journal of Futures Markets* 16, no. 8 (1996): 865-879.
- [90] Kuttner, Kenneth N. "Monetary policy surprises and interest rates: Evidence from the Fed funds futures market." *Journal of monetary economics* 47, no. 3 (2001): 523-544.

- [91] Lahnsteiner, Mathias. "Private Sector Debt in CESEE EU Member States." *Focus on European Economic Integration* 3 (2013): 30-47.
- [92] Lane, Philip R., and Barbara Pels. "Current Account Imbalances in Europe." *Moneda y credito* 234 (2012): 225-250.
- [93] Lattemae, Raoul. "Monetary transmission mechanism in Estonia-Some theoretical considerations and stylized aspects." No. 2001-4. Bank of Estonia Working Papers series, (2001).
- [94] Leon, Angel, and Szabolcs Sebestyen. "New measures of monetary policy surprises and jumps in interest rates." *Journal of Banking and Finance* 36, no. 8 (2012): 2323-2343.
- [95] Levine, Ross. "Finance and growth: theory and evidence." *Handbook of economic growth* 1 (2005): 865-934.
- [96] Liviatan, Nissan, ed. "Proceedings of a conference on currency substitution and currency boards." Vol. 207. World Bank Publications, (1993).
- [97] Lo, Stephanie H., and Kenneth Rogoff. "Secular stagnation, debt overhang and other rationales for sluggish growth, six years on." (2015).
- [98] Mason, Josh W., and Arjun Jayadev. "Fisher Dynamics" in *US Household Debt, 1929-2011.* *American Economic Journal: Macroeconomics* 6, no. 3 (2014): 214-234.
- [99] "Debt and deleveraging: Uneven progress on the path to growth." McKinsey Global Institute, (2012).
- [100] Medaiskyte, Ruta, Andrius Adomkus. "Lithuania Financial System Overview." *Finasta*, September 2011.
- [101] Mian, Atif, and Amir Sufi. "Consumers and the Economy, Part II: Household Debt and the Weak US Recovery." *FRBSF Economic Letter* 2 (2011).
- [102] Mian, Atif R., and Amir Sufi. "What explains high unemployment? The aggregate demand channel." No. w17830. National Bureau of Economic Research, (2012).
- [103] Mian, Atif, Kamalesh Rao, and Amir Sufi. "Household Balance Sheets, Consumption, and the Economic Slump*." *The Quarterly Journal of Economics* 128, no. 4 (2013): 1687-1726.
- [104] Midrigan, Virgiliu, and Thomas Philippon. "Household leverage and the recession." Centre for Economic Policy Research, (2011).
- [105] Minea, Alexandru, and Christophe Rault. "Some New Insights into Monetary Transmission Mechanism in Bulgaria." *Journal of Economic Integration* (2009): 563-595.
- [106] Minsky, Hyman. *Stabilizing an Unstable Economy.* Yale University Press, (1986).
- [107] Monticini, Andrea, David Peel, and Giacomo Vaciago. "The impact of ECB and FED announcements on the Euro interest rates." *Economics Letters* 113, no. 2 (2011): 139-142.
- [108] Nenovsky, Nikolay, Kalin Hristov, and Mihail Mihaylov. "Comparing the institutional and organizational design of currency boards in transition countries." *Eastern European Economics* 40, no. 1 (2002): 6-35.
- [109] Newey, Whitney K., and Kenneth D. West. "A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix." *Econometrica*, Vol. 55, No. 3, (1987): 703-708.

- [110] Obstfeld, Maurice. "Finance at center stage: Some lessons of the euro crisis." *mimeo*, (2013).
- [111] Pikkani, Rasmus. "Monetary transmission mechanism in Estonia-empirical model." No. 2001-5. Bank of Estonia, (2001).
- [112] Reinhart, Carmen M., and Kenneth S. Rogoff. "Growth in a Time of Debt." No. w15639, National Bureau of Economic Research, (2010).
- [113] Republic of Estonia: Financial System Stability Assessment. IMF Country Report No. 09/89, March 2009.
- [114] Republic of Lithuania: Financial Sector Assessment. IMF, June 2008.
- [115] Rigobon, Roberto, and Brian Sack. "The impact of monetary policy on asset prices." *Journal of Monetary Economics* 51, no. 8 (2004): 1553-1575.
- [116] Romer, Christina D., and David H. Romer. "Does monetary policy matter? A new test in the spirit of Friedman and Schwartz." In *NBER Macroeconomics Annual 1989*, Volume 4, pp. 121-184. MIT Press, (1989).
- [117] de Rougemont, Philippe, and Bernhard Winkler. "The Financial Crisis in the Light of the Euro Area Accounts: Selected Issues." *A Flow-of-Funds Perspective on the Financial Crisis Volume II: Macroeconomic Imbalances and Risks to Financial Stability 2* (2013): 155.
- [118] Rudebusch, Glenn D. "Do measures of monetary policy in a VAR make sense?." *International economic review* (1998): 907-931.
- [119] Ruscher, Eric, and Guntram B. Wolff. "Corporate balance sheet adjustment: stylized facts, causes and consequences." No. 2012/03. Bruegel Working Paper, (2012).
- [120] Ruscher, Eric, and Guntram B. Wolff. "Corporate Balance Sheet Adjustment: Stylized Facts, Causes and Consequences." *Review of Economics/Jahrbuch fur Wirtschaftswissenschaften* 64, No. 2 (2013).
- [121] Schulten, Thorsten. "Wages and the Euro Crisis." *Presentation*, (2013).
- [122] "Scoreboard for the surveillance of macroeconomic imbalances." European Commission, Occasional Papers 92, (2012).
- [123] Smaghi, Lorenzo Bini. "Imbalances in the Euro Area." Speech at the Halle Institute for Economic Research, Halle an der Saale, (2011).
- [124] Soderstrom, Ulf. "Predicting Monetary Policy with Federal Funds Futures Prices." *Journal of Futures Markets*, Vol. 21, Issue 4, (2001): 377-391.
- [125] Tang, Garry and Christian Upper. "Debt reduction after crises." *BIS Quarterly Review* (2010): 25.
- [126] Taylor, Alan M. "The Great Leveraging." No. w18290. National Bureau of Economic Research, (2012).
- [127] Taylor, John B. "The financial crisis and the policy responses: An empirical analysis of what went wrong." No. w14631. National Bureau of Economic Research, (2009).
- [128] The Monetary Policy of the ECB. European Central Bank, (2004).
- [129] Tirole, J. "Illiquidity and all its friends." *Journal of Economic Literature*, 49(2), (2011): 287-325.

- [130] Tobin, James. "Asset accumulation and economic activity: reflections on contemporary macroeconomic theory." University of Chicago Press, (1982).
- [131] Vernengo, Matias, and Esteban Perez-Caldentey. "The euro imbalances and financial deregulation." *Real-world Economics Review* (2012): 83.
- [132] Vetlov, Igor. "Monetary transmission mechanism in Lithuania." *The monetary transmission mechanism in Baltic States* (2004): 61-107.
- [133] Wilhelmsen, Bjorn-Roger, and Andrea Zaghini. "Monetary policy predictability in the euro area: an international comparison." *Applied Economics* 43, no. 20 (2011): 2533-2544.
- [134] Williamson, John. "What Role for Currency Boards?" Institute for International Economics, (1995).
- [135] Yellen, Janet. "A minsky meltdown: lessons for central bankers." In *Speech at the 18th Annual Hyman P. Minsky Conference, New York.* (2009).