Household Debt and Economic Growth in Europe

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Abstract

We investigate the role and impact of household debt on the economic performance of the European economy during the double-dip recession of 2008-2013. We use a loan-level data set of millions of residential mortgages originated between 2000 and 2013 to calculate regional indicators of household debt and property prices. The granular information allows us to construct a measure of interest rate mispricing during the housing boom that we use to identify the effect of a credit shock on household debt. Our analysis provides three main conclusions. First, in the period 2004-2006 the measure of credit shock was negative in most European regions which indicates that credit conditions were significantly relaxed relative to earlier years. Second, we find that regions in which household leverage increased more rapidly during the 2002-2007 period experienced a more severe decline in output and employment after 2008. These results are consistent with the view that an aggregate credit supply expansion in Europe boosted household leverage and house prices. Third, we find that the credit shock had the largest effect on increasing leverage for the low-income and the middle-income households, although the leverage of the high-income households represents a more powerful predictor of the decline in economic activity.

Keywords: Household debt, Great Recession, European Economy, Monetary Union
JEL Classification: E21, E32, E44

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1 Introduction

The Great Recession was a particularly extreme event for the European economy with a double-dip contraction between 2008 and 2013 that shed over 6 million jobs, two-thirds of which in the manufacturing sector. Since then, a growing literature has been trying to identify the forces that lead the global economy to such an adverse economic outcome. Evidence for the United States (US) indicates that the interaction of excessive borrowing by households in the early 2000s and the housing market could be the driving force for the decline in economic activity (Mian and Sufi, 2010 among others). According to this view, a *credit supply* shock (e.g., the relaxation of lending standards) before the crisis led mortgage lenders to expand lending to segments of the population that usually were not able to obtain a mortgage, such as low-income and poor credit-quality borrowers. The credit supply shock had the effect of putting upward pressure on house prices, leading to the accumulation of economy-wide vulnerability. An alternative explanation points at expectations about house price appreciation as a key driver of borrowers' and lenders' decisions during the credit expansion and successive slump. According to this view, known as the *expectations view*, inflated house price expectations led borrowers to exploit the expansion in credit supply and increase demand for housing, at the same time that banks underestimated the potential losses deriving from borrowers' default (Ferreira and Gyourko, 2015, Lane and Pels, 2012, Adelino et al., 2016). The majority of these studies focus on the US and use data at individual, county or regional level to investigate the factors that led to the Great Recession.

The evidence on the relationship between household debt and subsequent economic growth in Europe is limited. Existing studies typically limit the analysis to a single country due to the lack of individual and regional household finance data for European countries over long periods of time (e.g., Gambetti and Musso, 2017, Bentolila et al., 2018, and Cloyne et al., 2019). The evidence in these papers suggests that many European countries experienced an increase in the level of household indebtedness relative to income in the years before the crisis. A possible explanation for the run-up in household debt points at the macroeconomic and financial impact of the European Monetary Union and the development of the Single Market in financial services. Both had the effect of reducing uncertainty and financing costs,

thus increasing the desired spending levels of households (Alter et al., 2018). Blanchard and Giavazzi (2002) suggest that the integration of goods and financial markets in Europe at the end of the 1990s lead to the reallocation of resources from capital-abundant, high-income, core countries to capital-scarce, low-income, peripheral ones. This reallocation had the effect of increasing the availability of capital to households that might have fuelled a bubble in the housing market. An additional factor that played a role in Europe was the loose monetary conditions as discussed in Maddaloni and Peydró (2011) and Jordà et al. (2015).

The goal of this paper is to investigate the dynamics of household debt and house prices in Europe and to understand their potential role on the deep contraction of economic activity that occurred after 2008. In addition, we aim to understand how the dynamics of indebtedness, house prices, and the decline in output and employment affected households across the income distribution. As discussed earlier, the lack of a consistent household finance data set for European countries has severely limited the ability of researchers to conduct a European analysis and to draw general conclusions. To overcome this difficulty, we consider a novel data set on approximately 10 million residential mortgages originated in 8 European countries between 2000 and 2013. We aggregate this data set at the NUTS3 regional level and construct local measures of household debt and house prices, which we match to regional statistics on economic growth and employment. In our analysis we focus on home-secured household debt alone, namely, on that part of household debt that is guaranteed by the value of the main residence as well as other real estate investments. This is an important component of debt given the high concentration of resources in the housing sector observed before the onset of the crisis in several European countries.

The first step of our analysis consists of evaluating whether the rise in household debt can be ascribed to a credit supply shock, such as the deregulation of financial markets that led to the relaxation of mortgage credit conditions, or rather to a demand shock, for instance, an income shock or inflated house price expectations that led borrowers to increase demand for credit. To this end, we exploit the fact that we observe loan-level data to construct a measure of interest rate mispricing during the housing boom. Specifically, we estimate a regression model for the loan interest rate that accounts for a number of observable loan and

borrower characteristics that we assume determine the interest rate, and calculate regional averages of the corresponding regression residuals that we call *credit shocks*. Deviation of the credit shock from zero indicates that, *ceteris paribus*, financial institutions are *mispricing* mortgage credit in that region relative to their earlier pricing strategy. Our first result is to show that most European regions experienced a credit supply expansion, which is similar for borrowers belonging to all income groups, although with consistent heterogeneity across regions and countries. This finding implies that Europe has witnessed a (relative) decline in the cost of credit which points toward the credit supply expansion as a possible explanation for the sudden rise in household debt observed during the years up to 2006.

In a second step, we adopt an instrumental variable (IV) approach and use the regional credit shock as instrument for the Debt-to-Income (DTI) ratio to evaluate the impact of the supply-driven leverage on the subsequent slowdown in output and employment. The second result of our analysis is that we find a significant relationship between household leverage and economic activity. In particular, the evidence indicates that regions hit by a relatively stronger credit supply shock in 2004-2006 are also the regions that experience the most severe decline in output and employment indicators in the post-2008 period. We study separately the recessionary episode of 2008-2011 and the double-dip contractionary period of 2008-2013. We find that the recessionary effect of an increase in household leverage becomes significantly larger when considering the double-dip recession. This suggests that the same regions that experienced a decline in output and employment during the first recession were also hit by the second recession with further worsening of their economic conditions. The estimated effects of an increase in leverage are statistically significant: a unit increase of DTI is associated with a decline in real Gross Domestic Product (GDP) and total employment of 0.6% and 2.8%, respectively, during the first recessionary episode, and of 2.3% and 4.9% when considering the 2008-2013 period. In particular, the largest contractionary effect is consistently achieved by employment in the manufacturing sector rather than in the non-tradable one.

In a third step, we analyze the dynamics of leverage and its effect on economic activity across quartiles of the income distribution. We find that borrowers belonging to the bottom

and middle of the income distribution are more sensitive to the credit supply shock as they increase their leverage significantly more relative to high income borrowers. This is probably due to the fact that low and middle income borrowers are more likely to be credit constrained and increase their level of debt once lending standards are relaxed. However, the evidence seems also to suggest that it is the increase in debt of high income borrowers that has the strongest negative effects on economic activity.

Overall, the evidence we provide seems to support the view that the liberalization of financial markets in the Euro area has fuelled an unsustainable rise in home-secured debt and house prices, which has eventually lead to the build up of the crisis and subsequent severe contraction. The remainder of the paper is structured as follows. Section 2 reviews the existing literature, while Section 3 describes the data set. Section 4 discusses our findings regarding the variation in household debt across European regions. Section 5 and 6 introduce the statistical model and present our identification procedure. Section 7 comments on empirical results and Section 8 concludes.

2 Background literature

Several studies, mostly focused on the US, investigate the link between the increase in household debt and the economic performance during the Great Recession at the regional and country-level. Mian and Sufi (2010) investigate the cross sectional variation of household leverage at the onset of the 2007-2009 financial crisis for a set of counties in the US. They find that, *ceteris paribus*, counties that experienced a large increase in DTI ratio before the financial crisis were also those that, during the crisis, suffered the sharpest decline in durable consumption and the largest rise in unemployment, thus supporting the credit supply hypothesis. Mian et al. (2013) estimate the relationship between the changes in the consumption of non-durable goods with respect to variations in the housing net worth duding the 2006-2009 housing collapse period. The authors find a large effect of housing net worth shocks on consumption, with strong geographical differences, pointing at the role of debt and the geographic distribution of wealth shocks in explaining the large and unequal decline in consumption in those years. A similar analysis is carried out by Mian and Sufi

(2014), with a particular focus on the housing net worth channel. One important result from this study is that housing net worth losses due to the financial crisis led to the significant reduction in employment within the non-tradable sector, namely in those sectors, such as retail and wholesale, that rely heavily on the local demand.

Recent studies look at business dynamics in the OECD countries, using data at the country-level. Mian et al. (2017) perform a panel data regression analysis of 30 countries from 1960 to 2012, and find a negative relationship between the increase in the household debt to GDP ratio and GDP growth. The evidence suggests that this relationship is stronger for countries with less flexible exchange rate regimes. These conclusions are confirmed on a wider set of countries and a wider time interval by Alter et al. (2018).

A number of studies have analysed household debt in Europe and its impact on economic performance. Jappelli et al. (2013) study the differences in (aggregate) household indebtedness across 11 European countries, showing that higher indebtedness is associated with increased financial fragility, as measured by the sensitivity of household arrears and insolvencies to macroeconomic shocks. Ampudia et al. (2016) exploit data from the Household Finance and Consumption Survey in Europe to calculate a set of financial burden indicators for households. The authors calibrate their measures using country-level data on non-performing loan ratios and estimate a set of stress-test elasticities in response to interest rate, income and house price shocks. Cecchetti et al. (2011) study the conditions under which debt goes from good to bad, using data on 18 OECD countries from 1980 to 2010. They show that when household debt crosses a certain level, around 85% of GDP, debt is a drag on growth.

A number of studies try to assess the impact of pre-crisis conditions on the economic performance during the Great Recession in European countries. Mitze (2019) estimates a dynamic panel data model to study the impact of local labour market conditions prior to and during the global economic crisis on regional migration rates. The author shows that local labour market disparities significantly widened during the crisis and led to an orientation of migrants towards urban areas, away from regions with persistently high long-run unemployment rates. Crescenzi et al. (2016) provide a regional study on 254 NUTS2 regions

from EU27 countries, exploring the role of both national level macroeconomic conditions as well as regional factors. The authors identify the current account surplus to be an important national level factor associated with stronger economic performance during the post-2008 recession, and human capital as the single most important positive variable as regional level resistance factor. The sharp increase in external imbalances across Europe during the pre-crisis period has been suggested as an important driver of the European crisis by various studies. Lane and Milesi-Ferretti (2011) observe that the variation in the size of recessions during 2008-2009 was significantly related to the size of outstanding current account imbalances (on this, see also Lane and Milesi-Ferretti, 2012). Lane and Pels (2012) find that the expansion in current account imbalances during 2002-2007 was associated with an increased optimism about future growth, which led to lower savings and higher construction investment, rather than investment in productive capital. In our empirical analysis, we investigate the interrelation between current account balance and household debt and how these impact on the severity of the crisis.

3 Data

The European Datawarehouse (ED) collects information on loans for countries members of the Euro-area as part of the liquidity operations of the European Central Bank (ECB). The program, known as Asset-Backed Securities (ABS) loan-level initiative[1], started in January 2013 and requires financial institutions to report information on the structure and performance of their securitized loan portfolios in a detailed and standardized format. The aim of the program is to increase transparency and to provide market participants with timely information on the underlying loans and their performance. The ABS portfolios include a variety of loans, ranging from residential mortgages, loans associated to credit card use, car purchases, and loans granted to small and medium enterprises. Information provided in the data set include the performance of each loan, updated at least on a quarterly basis since January 2013. In addition, other variables are available at the origination of the loan, such as the total amount of loan and the gross income of the borrower.

[1]More details at `https://www.ecb.europa.eu/paym/coll/loanlevel/html/index.en.html`.

For this study, we use data on loans for the purchase of a residential property, and consider information about the loan, the borrower and the underlying property at the time of the loan origination. More precisely, loan-level information includes the amount of the loan at the origination, the interest rate and type, and the loan term (in number of months). Borrower-level information includes gross annual income and the employment status (e.g., self-employed or unemployed). Finally, asset-level information contains data about the value of the property and the first digits of the postal code where the property is located. We only consider data for 8 countries, namely Belgium, Spain, France, Ireland, Italy, the Netherlands, Portugal and the United Kingdom (UK)[2]. We clean the raw data as detailed in Appendix A and aggregate them at the level of the region where the asset underlying each loan is located using the NUTS3 regional classification. These aggregated data have been matched with regional data on real GDP, total and sectorial employment at the NUTS3 level obtained from the European Commission Joint Research Centre (JRC) Urban Data Platform[3]. By matching these data sources, we obtain a data set for 499 NUTS3 regions with information on household debt, interest rate, house prices and local economic conditions observed between 2000 and 2013. A relevant question to address is how representative our sample is for the financial situation of European households (Gaudêncio et al., 2019). In Appendix B, we investigate the issue of the sample representativeness of the underlying population by comparing the key variables included in our analysis with the same variables constructed from consumer finance household surveys.

In our analysis we define household debt to include only home secured debt, that is, debt that is collateralised by a real estate asset. Clearly, households also hold debt that is non-collateralised and is used for various purposes. While excluding non-home secured debt may provide a biased representation of household debt, it is important to remark that collateralised debt accounts for the bulk of household debt in Europe. According to the Eurosystem Household Finance and Consumption Network (2013) survey, 82.8% of the total outstanding household balances in the Euro area in 2010-2011 is represented by mortgages

[2]Although data are available also for other countries, like Germany or the Scandinavian region, we excluded them because of the limited number of loans reported and the difficulty in covering all their provinces.

[3]For more information see `https://urban.jrc.ec.europa.eu/#/en/download`.

collateralised on the household's main residence or other real estate properties owned by the household. Such percentage ranges between a minimum of 73.5% for Italy and a maximum of 92.1% for Portugal. We define DTI as the ratio between the total amount of new loans originated by a household in one year divided by its total annual gross income, and then aggregate such ratio at the regional level by averaging. This ratio is often used in assessing affordability since it indicates the number of years required to repay the mortgage. Although this ratio has some drawbacks as it only accounts for home-secured debt and incorporates gross rather than net income, it does provide some useful insights into the financial risk a household faces. Households with high DTI are likely to be more sensitive to negative shocks to interest rate, income or house prices and therefore are more likely to default if these occur.

4 The real economy and household debt

In this Section we show some stylized facts about the real economy and household debt in the first two decades of the 2000s. Figure (1) shows the time series of real GDP growth and DTI during the period 2000 to 2015 for the 8 countries in analysis, together with recession periods defined by the CEPR[4]. The output of these European economies was growing rapidly up to 2007 when the Great Recession hit and caused a slump of around 3%. While most countries rebounded in the aftermath, the sovereign debt crisis caused a second slump between the third quarter of 2011 and the first quarter of 2013. Contrary to the 2008-2009 recession, this second episode had a differential effect in some countries (UK, France and Belgium) where output continued to grow, although at a lower rate, and the other countries that experienced a further decline in GDP. In the empirical analysis we investigate whether household debt levels pre-crisis are related to the severity of the contraction in the 2008-2011 period as well as in 2008-2013.

The right plot of Figure (1) shows the time series of DTI. On the one hand, the graph shows clearly that a group of countries (such as Ireland, Italy, Portugal and Spain) experienced an increase in household leverage that reached levels close or above 4 in the period 2002-2007. On the other hand, Belgium, France, the Netherlands and the UK had a DTI

[4]See for more details `https://eabcn.org/dc/chronology-euro-area-business-cycles`.

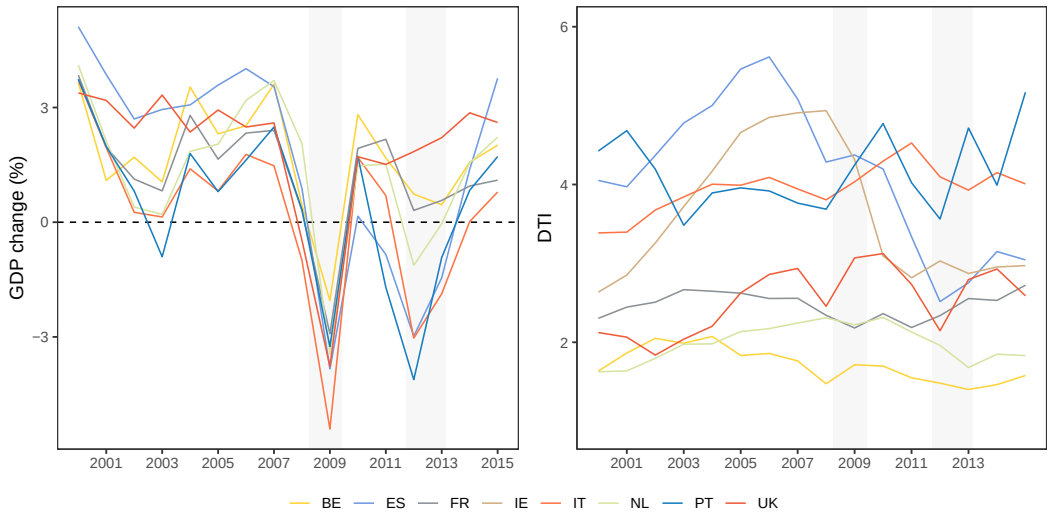

Figure 1: Time series of the percentage growth in real GDP (left) and the level of DTI (right) by country between 2000 and 2015. The grey shaded areas represent the CEPR recessionary periods.

ranging between 2 and 3, and mostly stable in the pre-crisis period. For many countries in the sample we observe a decline of the ratio that started in 2007, that accelerated during the crisis. The different patterns in DTI between the two groups of countries is evident also from Table (1) that provides summary statistics for the DTI by country. We calculate these statistics in the years 2000-2003 versus the years preceding the onset of the global crisis, namely 2004-2006. Our key variable of interest shows consistent heterogeneity occurring not only across countries but also within countries, as indicated by the high standard deviation and inter-quartile differences, in both time periods.

The ED data set does not provide a measure of the borrower's credit worthiness, such as the credit score. To proxy for the credit quality of a borrower, we can look at the income variable available in ED. Although income is an imprecise measure of credit worthiness, it is a key factor to determine the borrower's quality and her ability to repay the loan. In particular, we divide our data set into two income groups: the high income group is composed of households in the top 25% of the income distribution (per country-year), while the low income group represents the bottom 25% of the distribution. The top graph of Figure (2) shows the growth (relative to year 2002) in the fraction of total debt by income group and origination year. The graph shows that in the years between 2002 and 2006 all countries, except France and Portugal, experienced a significant increase of loan origination by the

	2001-2003					2004-2006				
Country	Av.	Median	St.Dev.	25th	75th	Av.	Median	St.dev.	25th	75th .
BE	2.24	1.76	1.73	0.92	3.14	2.36	1.76	2.01	0.89	3.19
ES	5.60	4.91	3.37	3.19	7.14	6.51	5.84	3.93	3.61	8.60
FR	3.09	2.66	2.20	1.74	3.81	3.20	2.67	2.56	1.53	4.09
IE	3.62	3.39	1.66	2.47	4.48	4.96	4.65	2.42	3.30	6.19
IT	4.02	3.73	1.73	2.98	4.72	4.48	4.11	2.31	2.96	5.28
NL	2.22	1.87	1.66	0.96	3.05	2.38	2.15	1.63	1.12	3.25
PT	4.80	4.00	3.67	2.01	6.37	5.11	4.08	4.12	1.85	7.16
UK	2.17	2.02	1.89	1.00	2.93	2.74	2.68	2.08	1.26	3.76
ALL	3.71	3.14	2.82	1.83	4.77	4.10	3.32	3.29	1.79	5.42

Table 1: Descriptive statistics for DTI by country over the periods 2001-2003 and 2004-2006. 25th and 75th denote the first and third quartiles.

low-income group at the same time that the share of origination by the high-income group declined. Another interesting fact is provided by the bottom graph of Figure (2) that shows the change in DTI (relative to year 2002) for the two income groups. For Belgium, Spain, Ireland and Italy we find that low-income households increased significantly their leverage in the pre-crisis period relative to high-income households that experienced only modest or no increases. These countries also experienced a rapid deleveraging phase after that the ECB tightened the credit conditions in 2006 and 2007. For the remaining countries, the results show that leverage increased similarly for the two groups.

What was the effect of these credit conditions on house prices? The top graph of Figure (3) shows the percentage growth of house prices (relative to 2002) for the low and high-income groups. For Belgium, Spain, Italy and the UK the graphs show that house prices increased significantly more for the low-income group relative to the high-income, while for France, Ireland, and the Netherlands the change is quite similar between groups. Only for the case of Portugal the evidence suggests a faster increase of house prices for the high-income households. Overall, these results suggest that the availability of capitals to the banking system was channeled to originate loans to a larger extent to low-income households. This had the effect of increasing demand for housing and contributed to the build-up of leverage for this group of households. Looking at variations in the mortgage interest rate

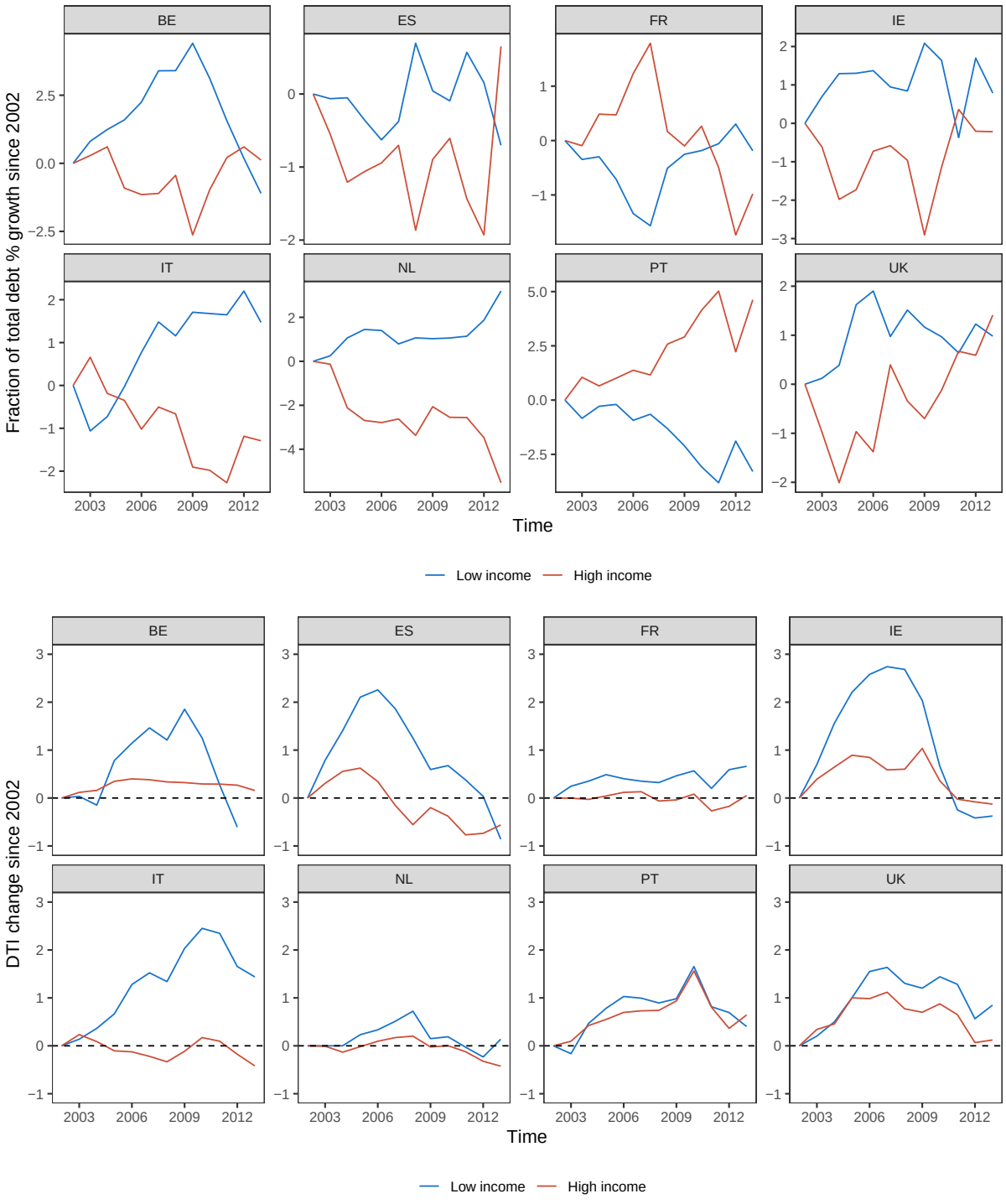

Figure 2: Percentage growth (relative to 2002) of the fraction of total debt owned by the bottom and top income quartiles (top) and change in DTI for the same groups (bottom) in the 2002-2013 period.

in the bottom graph of Figure (3), the drop observed in the years between 2003 and 2006 was generalized among income groups, although there are some differences across countries. One interesting finding is for Portugal, where, prior to the Great Recession, the increase in the demand for mortgages was driven mainly by high income borrowers.

Figure (4) reports the relationship between our key variable DTI in the pre-crisis period and a set of regional variables measuring economic performance over the years 2008 to 2013. As measures of performance we consider the growth in total employment, employment in manufacturing and non-tradable sector and GDP growth. For all variables we find a negative relation between these variables and the average DTI preceding the onset of the crisis. This suggests that regions characterized by higher household leverage pre-crisis were those that experienced a larger drop in employment and GDP during the double-dip recession. In the following Section, we discuss a model that aims at assessing more formally this hypothesis.

5 The model

The hypothesis that we test is whether household leverage has played a significant role in exacerbating business cycle fluctuations across regions in Europe. We adopt the CEPR chronology by assuming that the peak of the business cycle in the Euro-area happened in the first quarter of 2008 and define the pre-crisis period between 2002 and 2007. Our empirical specification aims to explain the change in economic performance in the recessionary period with pre-crisis variables. For each region $g = 1, \ldots, G$, we consider the following equation:

$$\Delta_h y_{g,2008+h} = \beta DTI_{g,2002-07} + \lambda' \mathbf{W}_{g,2000-03} + \varepsilon_{g,2008+h}, \tag{1}$$

where $\Delta_h y_{g,2008+h}$ represents the growth rate of a macroeconomic variable for region g between 2008 and 2008+h, $DTI_{g,2002-07}$ measures the average DTI in region g during the 2002-2007 period, $\mathbf{W}_{g,2000-03}$ is a vector of control variables capturing the structural characteristics of region g in the years preceding the pre-crisis period, and $\varepsilon_{g,2008+h}$ is a Gaussian error term. We estimate the model in Equation (1) at horizons $h = 3$ and 5, that is over the years 2008-2011 and 2008-2013, in order to capture the cumulative effect of the double-dip

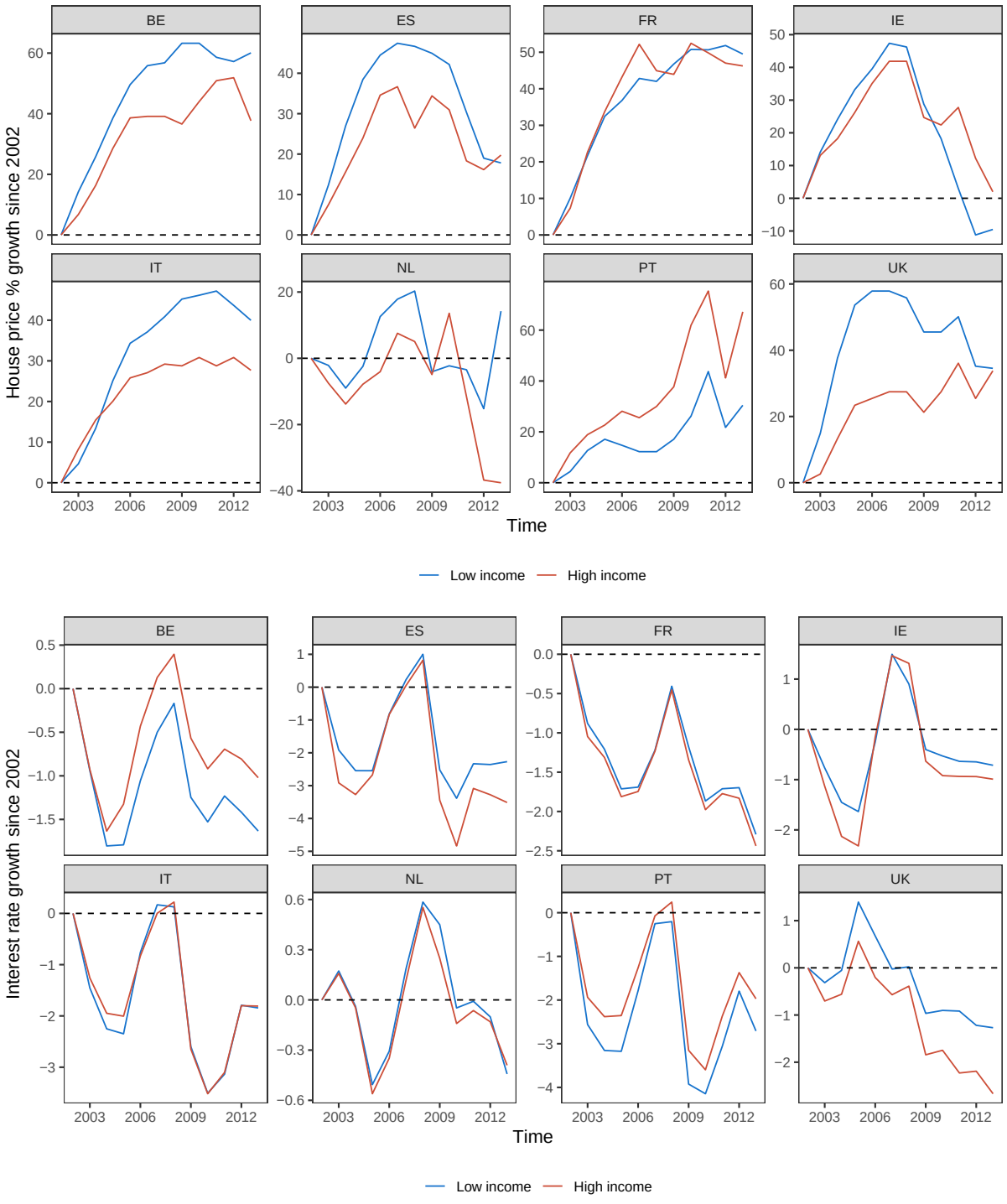

Figure 3: Percentage growth (relative to 2002) of the average house price for the bottom and top income quartiles (top) and change in interest rate for the same groups (bottom) in the 2002-2013 period.

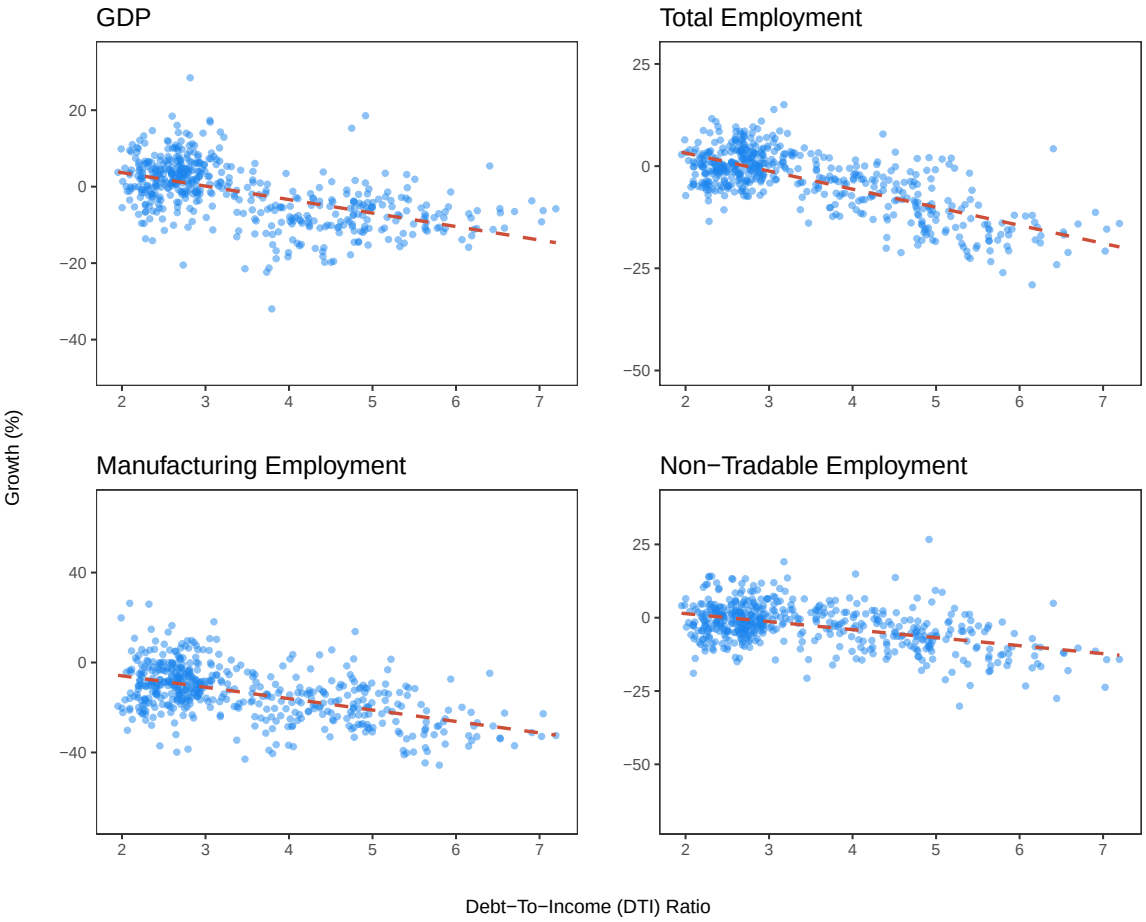

Figure 4: Scatter plot of the average DTI in 2002-2007 and the percentage change of over the period 2008-2013 for the selected macroeconomic variables at the NUTS2 level.

recession that occurred in EU countries, as shown in Figure (1). We are interested in estimating and interpreting the parameter β, which measures the effect of the pre-crisis household indebtedness on the economic performance after the crisis.

We estimate Equation (1) using a number of alternative dependent variables as proxy for the economic performance of a region, $\Delta_h y_{g,2008+h}$. In particular, we consider 4 indicators of economic performance: real GDP, total employment, employment in the manufacturing sector and in the non-tradable sector. Following Mian et al. (2013), we include non-tradable employment, since this sector is found to be highly sensitive to local economic shocks in the US. We construct the employment variable in the non-tradable sector by considering all activities belonging to wholesale and retail trade, accommodation and food service sectors[5].

The vector $\mathbf{W}_{g,2000-03}$ consists of a set of variables that capture both crisis at the international level, as well as regional factors, and that might be relevant in explaining the performance after the onset of the crisis (Dijkstra et al., 2015). Following previous studies, we include as controller the average national debt as a percentage of total GDP measured over the period from 2000 to 2003 for the country where region g is located. High leverage in the public sector, measured by a high level of the debt-to-GDP ratio, could contribute, in addition to household leverage, to explain the poor performance of some countries during the recession. We include in our regression the regional share of employment in the manufacturing and non-tradable sectors. Finally, we also consider the 2003 population density in region g as well as a dummy variable equal to 1 when the region is predominantly urban and zero otherwise, obtained from the urban-rural typology classification of Eurostat. Table (2) presents the summary statistics of the outcome variables and the controllers. Variables such as employment and GDP declined in the years after 2008, whit a deeper drop considering the change up to 2013. For all these variables both the first quartile and the median are in negative territory in both post-crisis periods. The drop hit hardly the manufacturing sector, which shows negative values across all quartiles.

[5]These are sectors G and I according to the NACE Rev.2 classification.

	Average	25th	Median	75th
Variables measuring economic activity				
2008-2011 GDP growth*	0.017	-0.010	0.025	0.055
2008-2011 Total employment growth*	-0.018	-0.044	-0.006	0.015
2008-2011 Manufact. employment growth*	-0.043	-0.081	-0.038	0.004
2008-2011 Non tradable employment growth*	-0.012	-0.038	-0.003	0.021
2008-2013 GDP growth*	0.009	-0.039	0.024	0.069
2008-2013 Total employment growth*	-0.030	-0.077	-0.014	0.021
2008-2013 Manufact. employment growth*	-0.076	-0.137	-0.068	-0.004
2008-2013 Non-tradable employment growth*	-0.026	-0.070	-0.011	0.027
Controllers				
2004-2006 DTI^{+}	3.605	2.617	3.096	4.504
2000-2003 National debt/GDP^{++}	64.564	34.767	56.100	102.367
2000-2003 % Manufact. empl.*	7.760	5.240	7.318	9.566
2000-2003 % Non tradable empl.*	10.698	8.033	9.940	12.655
2000-2003 Population density*	0.419	0.055	0.101	0.260
% of urban regions**	21.335	0.000	0.000	0.000
2003 Population*	446.925	177.874	321.185	565.590

Table 2: Descriptive statistics of the variables included in the analysis. Sources: ($^{+}$) ED data, (*) JRC Urban Data Platform, ($^{++}$) OECD data, (**) Eurostat.

6 Credit supply shock

Several factors can explain the negative relation between household leverage and future output and employment growth posited in Equation (1). On the one hand, agents might expect higher future income and increase their current DTI by borrowing to purchase a home. On the other hand, an influx of foreign capital to the banking system and a relaxation of credit standards can contribute to the increase of residential lending by banks, including lending to more risky borrowers. In order to isolate the component of DTI that can be attributed to variation of credit supply, we construct a measure of the *credit shock* by exploiting the loan-level information provided in the ED data set. Once we have separated the part of the leverage that is due to supply factors, we then analyze its relationship with future economic performance and evaluate its significance[6].

We construct an instrument for household leverage that aims to directly measure the shock to credit markets that might be responsible for the variation of DTI. Identifying supply shocks using credit measures is a strategy followed by Mian et al. (2017) that use the sovereign spread of a country relative to the US as their instrument for aggregate DTI. However, rather than using data about the country-level interest rate, we proxy the credit shock by measuring the difference between the observed interest rate on an individual loan and the predicted interest rate conditional on the loan and borrower characteristics. More precisely, we estimate a model of the interest rate on residential loans originated between 2000 and 2002, which we use to predict the loan's interest rate from 2003 onward. Then, we aggregate the difference between the realized and predicted interest rate at the regional level and refer to this measure as the Credit Shock (CS), which we use to instrument household leverage. This is similar to the approach adopted by Justiniano et al. (2022) to analyze mortgage credit conditions in the US between 2000 and 2007 and Hurst et al. (2016) to study the variation of the risk-adjusted interest rates with local economic conditions.

To construct the NUTS3 regional CS, we first estimate the following loan-level regression:

[6]In Appendix C we follow the strategy proposed by Mian et al. (2013) of using the housing supply elasticity (Saiz, 2010) to proxy for credit supply variations. We construct the measure for the European regions in our sample and discuss the several limitations of the approach.

$$r_{i,g,t} = \alpha + \beta' \boldsymbol{X}_{i,g,t} + \epsilon_{i,g,t}, \tag{2}$$

where $r_{i,g,t}$ represents the interest rate on loan i in region g at time t. The vector $\boldsymbol{X}_{i,g,t}$ controls for a set of loan and borrower characteristics that include the LTV and DTI ratios, their respective squares, the logarithm of the loan amount, the logarithm of the borrower's gross income, the loan term (expressed in number of months), the interest rate type (i.e., floating, tracker, fixed for life, or fixed with periodic resets) and the LIBOR rate. In order to account for country-level heterogeneity, $\boldsymbol{X}_{i,g,t}$ also includes country dummy variables, as well as the interaction of the country dummies with DTI, income, loan term and the interest rate type. In total we include 57 variables in the vector $\boldsymbol{X}_{i,g,t}$. We estimate Equation (2) using all loans originated between 2000 and 2002, and then use the estimated parameters to predict the interest rate on loans originated from 2003 onward. The prediction error, denoted by $\hat{\epsilon}_{i,g,t}$, measures the credit shock for loan i, which we then average at the regional level as follows:

$$\epsilon^*_{g,t} = \frac{1}{N_{g,t}} \sum_{i=1}^{N_{g,t}} \left(r_{i,g,t} - \hat{\alpha} - \hat{\beta}' \boldsymbol{X}_{i,g,t} \right) = \frac{1}{N_{g,t}} \sum_{i=1}^{N_{g,t}} \hat{\epsilon}_{i,g,t}, \tag{3}$$

where $N_{g,t}$ is the number of loans in region g in year t, for $t \geq 2003$. If there are no shocks in the credit market after 2003, we expect the model prediction to provide an accurate pricing for the subsequent years and the average shock $\epsilon^*_{g,t}$ to be close to zero. The credit shock $\epsilon^*_{g,t}$ can arise both because of a demand or a supply shock that occurs in credit markets. In the presence of a credit supply expansion, lenders are willing to lend more or on cheaper terms, while a positive credit demand shock is characterized by households' willingness to borrow more or at higher interest rates. In this sense, we expect the predicted interest rate to be larger (smaller) than the observed interest rate when the economy is hit by a positive supply (demand) shock. The estimation of Equation (2) is summarised in Table (3). The coefficients attached to the squares of LTV and DTI are negative, indicating a nonlinear relationship between the ratios and the interest rate.

Figure (5) shows the (average) predicted and realized interest rate by country and year.

Dependent Variable: $r_{i,g,t}$	Estimate	SE
LTV	0.007^{***}	0.001
LTV^2	-0.0001^{***}	0.000
DTI	0.039^{***}	0.014
DTI^2	-0.007^{***}	0.001
Original balance (logs)	-0.098^{***}	0.019
Income (logs)	-0.193^{***}	0.025
LIBOR	0.516^{***}	0.005
N	182,390	
R^2	0.297	

Table 3: Estimation results for Equation (2), that regresses the interest rate of an individual loan on a set of loan and borrower characteristics, country dummy variables and their interaction with the loan and borrower characteristics (total of 57 variables). The model is estimated on loans originated between 2000 and 2002. To save space, we only report the coefficient estimates of the loan and borrower characteristics. Statistical significance is denoted by * at 10%, ** at 5%, and *** at 1%.

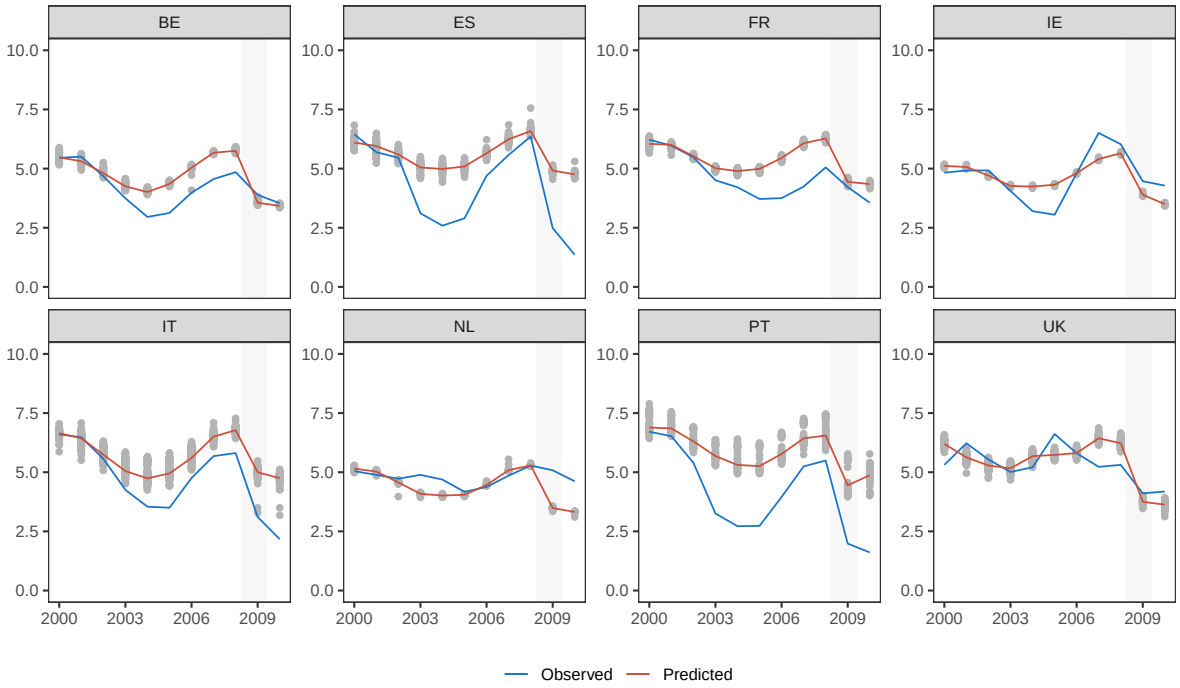

Figure 5: The predicted and observed (average) interest rate by country as in Equation (2). The dots around the predicted line represent the regional predicted interest rates.

The predicted and realized rates are approximately at the same level in 2000-2002 by construction, whereas they tend to diverge in the following years. An example is Spain where interest rate declined from over 5% in 2002 to 2.5% in 2005, followed by a rapid increase to 5% by 2008. However, the model in Equation (2) predicts a considerably smaller reduction in the mortgage rate. This indicates that the changes in baseline interest rates and in loan and borrower characteristics did not vary enough to justify such a rapid decline in mortgage rates as documented in the Figure. This situation occurs, to different extents, also in Belgium, France, Ireland, Italy and Portugal. The exceptions to this pattern are the Netherlands and the UK, where we obtain similar values for the predicted and realized (average) interest rates throughout the period. It is interesting to notice that the analysis by Justiniano et al. (2022) finds a similar pattern in the behavior of US mortgage rates in approximately the same period we consider.

The model in Equation (2) does not unequivocally identifies the nature of the shock since the negative value of $\epsilon^*_{g,t}$ could arise from a negative demand shock that reduces the household demand for residential mortgages, but also from a positive supply shock that increases the

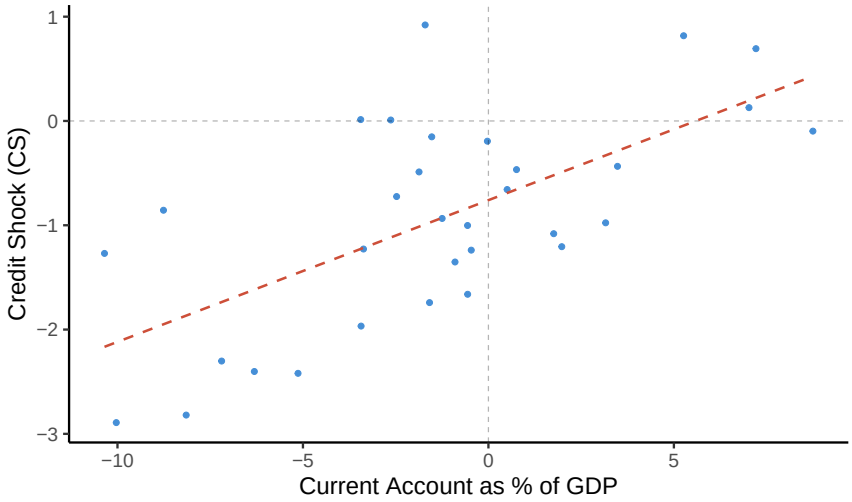

Figure 6: Scatter plot of the average credit shock (CS) in a country-year and the current account of the country for that year as a percentage of GDP. The years included in this graph are 2003 to 2006.

supply of credit. In our opinion, the evidence points in the direction of a credit supply shock as the main factor explaining the CS in Europe in the early to mid 2000s. A negative CS is consistent with the view that banks in these countries relaxed their lending standards due to the ample availability of capital. As we discussed earlier, the creation of the euro and the European Monetary Union, in addition to reforms to harmonize the financial sector, generated internal (and external) capital flows toward the capital-scarce European countries due to the elimination or currency risk and transaction costs (Blanchard and Giavazzi, 2002). While in some countries the capitals flowed to the purchase of government debt, a large portion was channeled to bank lending (in particular in Spain, Portugal, and Ireland). To evaluate more precisely this hypothesis, Figure (6) compares the average credit shock in a country and its current account (as a percentage of GDP) between 2003 and 2006. The two variables are positively related suggesting that large and negative CS occurred in countries that run large current account deficits and viceversa for countries that had surpluses. This indicates that our loan-based CS measure proxies for the influx of capitals that some countries experienced in the years following the creation of the euro. The relationship in the Figure appears quite strong and supports the view of the credit nature of the CS.

The effect of a credit supply shock should also appear in significant changes of the distri-

bution of borrower's characteristics after 2003[7]. The LTV ratios did not increase remarkably in most countries, except Ireland, as house prices and loan balances grew at similar rates. On the other hand, the DTI increased in many countries for two reasons. The first is that high-income households borrowed more and the loan balances grew faster than their income. Second, more credit was extended to low-income household that are typically characterized by larger DTI levels. The evidence on the contribution of these two effects is mixed across Europe. While Figure (2) suggests that increased lending to high-income households is the predominant effect in France and Portugal, in the other countries the largest change was a surge of lending to low-income borrowers. Another indicator of the relaxation of lending standards is the loan term that increased in several countries, such as Spain, Ireland, and Portugal. Overall, the combination of lower interest rates, longer loan terms and higher DTI ratios seem to favor the view of a credit supply, rather than demand, shock. An alternative explanation is that financial institutions had optimistic beliefs about the housing market and thus lent to household at lower interest rates as argued in Kaplan et al. (2020). This is certainly a possible effect which might have been triggered by the mechanism discussed earlier and reinforcing its effects. However, it seems unrealistic to be the main driver of the CS in the European case.

For all Euro-area countries, the credit shock reduces significantly starting in 2006 and up to the Great Recession. We believe that an explanation for this change resides in the ECB decision to tighten monetary policy starting from the meeting of December 6, 2005 when the marginal lending facility rate was raised by 25 basis points to 3.25%. The change of monetary policy continued up to the meeting of July 9th, 2008 when rates reached 5.25%, marking the end of the credit supply expansion in many European countries. Figure (5) also reports the average predicted interest rates by region. In terms of within-country dispersion, we find that for some countries the predicted rate is quite similar across regions (see Belgium, France, Ireland, and the Netherlands), while for other countries there is a significant dispersion among regions.

Additional evidence on the supply nature of the shock is provided in Figure (7) that shows the change in house prices and DTI (relative to year 2000) for regions in the first and last

[7]See Appendix D for a detailed discussion.

quartile of the CS in that year. An interesting finding is that regions with negative $\epsilon^*_{g,t}$ (i.e., a credit supply expansion) are more likely to experience a larger increase in house prices and in household leverage relative to regions with positive shocks. In particular, the low CS group endured a rapid increase in leverage between 2000 and 2006, followed by a steep decline that by 2013 had brought leverage back to its 2000-level. Instead, for the high CS group, DTI started to increase after 2004 and declined moderately between 2011 and 2013. In terms of house prices, while in the early 2000s both low and high CS regions experienced a similar increase in house prices, they grew more rapidly starting from 2003 in the low group, while the price growth flattened out in high CS regions. By 2013 house prices had increased by a similar amount in both low and high credit shock regions. This evidence supports the view that an aggregate credit shock in Europe boosted household leverage and house prices, although with a different effect across regions. Figure (7) also reports the median GDP level for the low and high credit shocks group and we observe no relevant differences between the two up to the first recessionary period, and started diverging afterwards as the low CS regions experienced a deeper decline in output relative to high CS regions.

We adopt the proposed CS measure as an instrument to identify the component of household leverage, at the regional level, that can be attributed to credit supply shocks. This component of household leverage is then used as a predictor of future output and employment. In particular, we employ the average regional CS between 2003 and 2006, denoted by $\epsilon^*_{g,2003-2006}$, as an instrument for the average DTI ratio between 2002 and 2007 and denote this quantity by $DTI_{g,2002-07}$.

7 Regression results

Table (4) shows the results of the first stage estimation of Equation (1) when considering the CS as an instrument for household leverage between 2002-2007. The estimate of the CS coefficient is negative and indicates that, on average, large negative (positive) CS are expected to be associated with large (small) values of leverage, as measured by DTI. The negative sign of the coefficient is consistent with the credit supply hypothesis in the sense it predicts that the regions with larger DTI are those that experienced larger declines in

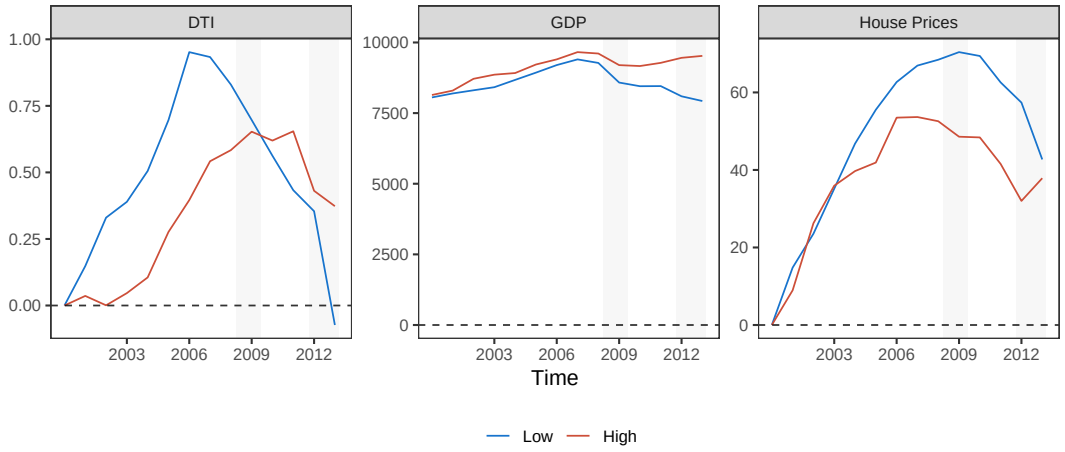

Figure 7: Change (relative to year 2000) of DTI and percentage growth of real GDP (in Euro) and house prices for the top and bottom quartiles of the distribution of the credit shock. The bottom quartile is denoted as *Low* and the top quartile is defined as *High*.

interest rates (relative to the model's prediction). Specifically, a 1% decline in the credit shock is associated with an average increase of the household leverage ratio by 1.348 points, *ceteris paribus*. The coefficients associated to the control variables (not shown in the Table), $\mathbf{W}_{g,2000-03}$ in Equation (1), show comparable significant effects which give us some confidence to interpret the IV estimates.

Table (5) reports the OLS and two-stage least-square estimation results of Equation (1). As outcome variables we consider the growth rate of GDP and several definitions of employment (total, manufacturing, and non-tradable) over the period 2008-2011 and 2008-2013. The results show that the IV estimates are, in most cases, smaller than the OLS estimates and significantly different, although the qualitatively magnitude of the effect is similar. If we instrument the DTI in 2002-2007 using the CS, the expected effect of a point increase in household leverage decreases regional GDP growth by, on average, 0.6% at the three-year horizon and 2.3% at the five-year horizon, while the employment measures reduce between 1.5% and 7%, respectively.

We find that the increase in credit supply-driven leverage has a larger impact on manufacturing employment relative to employment in the non-tradable sector. This result is in constrast with the findings of Mian et al. (2013) for the US, where the non-tradable sector is more sensitive to declines in local demand. A possible explanation is that banks reduced overall lending in response to losses on household loans during the financial crisis. This

Dependent Variable: $DTI_{2002-2007}$	Estimate	SE
CS	-1.348***	0.057
Observations	490	
R^2	0.600	
F Statistic	120.960***	

Table 4: Estimation results of the first stage regression for $DTI_{2002-2007}$ using the credit shock (CS) as the instrumental variable. Additional variables included in the regression are: Public Debt/GDP, share of manufacturing employment, share of non-tradable employment, population density, and an urban area dummy variable. Statistical significance is denoted by * at 10%, ** at 5%, and *** at 1%.

generalized contraction in lending affected, in particular, the manufacturing sector with the effect of reducing its employment significantly more relative to the non-tradable sector.

The first recessionary period in Europe was a synchronized contraction of output and employment that affected all countries in our sample, irrespective of the accumulation of household leverage in the previous years. However, the second recession developed quite differently since it affected mostly the regions and countries in which DTI had increased the most. The different nature of the two recessions contributes to explain the larger coefficient estimates that we find for the 2008-2013 relative to 2008-2011 period across all variables, and in particular for real GDP. To get further insights on the estimated effects, one can interpret Equation (1) in the spirit of the local projection approach of Jordà (2005). By estimating the model at different horizons h, we can obtain the impulse response function (IRF) for the effect of a unit change in $DTI_{2002-2007}$ on the outcome variable. Figure (8) shows the IRF when the model is estimated by IV at horizons $h = 1, \ldots, 8$. The graph shows the increasingly negative effect of household leverage on output and employment as the horizon increases. The estimates are between 0 and -3% at the short horizons that include only the first recession, while they more than double as the horizon expands to include the second recessionary period.

	GDP	Total Employment	Manufacturing Employment	Non-tradable Employment
			2008-2011	
OLS	-0.011***	-0.028***	-0.036***	-0.016***
	(0.002)	(0.001)	(0.003)	(0.002)
IV (CS)	-0.006***	-0.028***	-0.042***	-0.015***
	(0.002)	(0.002)	(0.004)	(0.002)
R^2	0.143	0.529	0.293	0.210
			2008-2013	
OLS	-0.029***	-0.046***	-0.064***	-0.031***
	(0.002)	(0.002)	(0.003)	(0.002)
IV (CS)	-0.023***	-0.049***	-0.070***	-0.036***
	(0.003)	(0.003)	(0.004)	(0.003)
R^2	0.450	0.596	0.468	0.323

Table 5: The effect of DTI and public debt on economic growth: OLS and IV regression results. Statistical significance is denoted by * at 10%, ** at 5%, and *** at 1%.

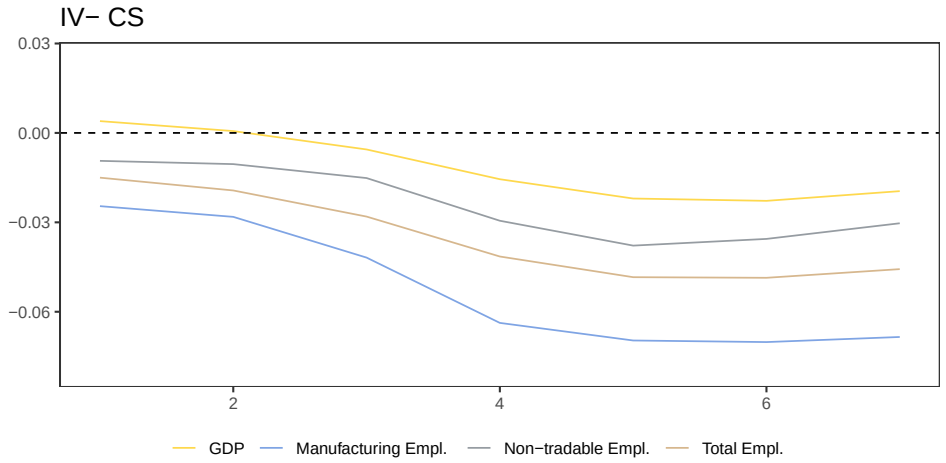

Figure 8: Impulse Response Function (IRF) of output and employment indicators to DTI using the IV estimation; the x-axis represents the horizon $h = 1, \ldots, 8$ and the y-axis represents the coefficient estimate in Equation (1).

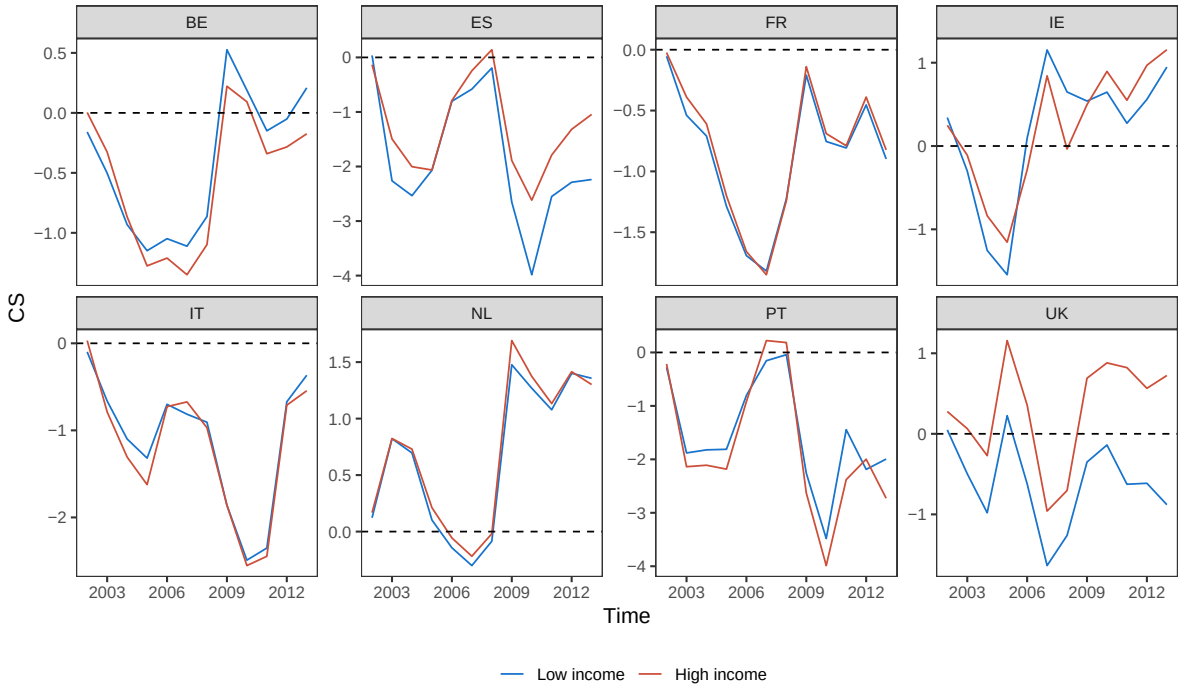

Figure 9: The graphs show the average CS by country for the bottom and top quartile households.

The aggregate analysis discussed so far hides the fact that the credit supply shock might have had different effects based on the income level of the borrower. To evaluate this hypothesis we construct measures of the CS and DTI based on quartiles of the income distribution in the region, rather than pooling all borrowers as done previously. Figure (9) shows the average CS for the bottom and top income quartile in each country. The results show that, in most countries, the supply shock was of a similar magnitude for both groups, except in the UK where the decline in rates seems to have benefited more the low-income group. However, the first-stage results reported in Table (6) show that the effect of the CS on household leverage was larger for low-income households relative to high-income ones. In particular, the findings indicate that we expect an average increase of DTI by 0.676 points for a one percent decline in CS, while at the top quantile the effect is only 0.352. In addition, the coefficient estimate for the lowest three quartiles are qualitatively close, but the estimate for the forth quartile drops by 48% (relative to the estimate for the first quartile). Although the credit supply shock contributed to the increase of leverage across all income levels, it seems that it had a larger effect for low-income households.

The results for the second stage also show significant differences across income groups. For both horizons and all variables, we find that the decline in output and employment post-2008 seems to be explained by credit-supply driven leverage of the high-income households rather than the lower income groups. In other words, regions that experienced the largest increase of credit-supply leverage by high-income households experienced the largest declines in output and employment when the financial crisis hit the European countries. On the other hand, the increase in leverage by middle and low-income households appears to have a smaller effect on the outcome variables that we consider. This result seems to be consistent with the findings of Adelino et al. (2016) for the US. They identify a sharp increase in delinquencies for high income borrowers during the crisis relative to earlier years. While we do not have information on the default of these borrowers, we observe that their increase in debt is strongly associated to the regional economic slump.

8 Concluding remarks

There is substantial evidence for the US that household debt plays an important role in accentuating business cycle fluctuations (see Mian and Sufi, 2010, among many others). In this paper, we provide evidence that this mechanism was also a determining factor in the double-dip recession that occurred in Europe between 2008 and 2013. We exploit a novel loan-level data set of residential mortgages in 8 European countries to proxy household debt levels from 2000 to 2013 at the NUTS3 regional level: in particular, we are interested in estimating whether the household leverage levels before the Great Recession can explain the severity of the subsequent economic slowdown. For all regions in our data set, we propose an instrument for household leverage represented by the credit shock, based on a loan-level model of interest rates.

Our findings confirm that the European regions where household leverage increased relatively more in the first half of the 2000s were also the regions that were more affected by the subsequent decline in economic activity. We estimate that a point increase in the DTI ratio in the pre-recessionary period predicts a decline by 2.3% of regional GDP between 2008 and 2013 and even larger effects on the employment measures. These estimates indicate

Income quartile	First stage	GDP	Total Employment	Manufacturing Employment	Non-tradable Employment
		2008-2011			
1st	-0.676***	-0.006	-0.051***	-0.071***	-0.027***
	(0.043)	(0.004)	(0.004)	(0.007)	(0.004)
2nd	-0.682***	-0.007*	-0.054***	-0.076***	-0.029***
	(0.043)	(0.004)	(0.004)	(0.008)	(0.005)
3rd	-0.611***	-0.009**	-0.061***	-0.088***	-0.032***
	(0.005)	(0.005)	(0.009)	(0.005)	(0.015)
4th	-0.352***	-0.035***	-0.121***	-0.176***	-0.071***
	(0.039)	(0.009)	(0.013)	(0.022)	(0.012)
		2008-2013			
1st		-0.040***	-0.093***	-0.121***	-0.068***
		(0.006)	(0.007)	(0.009)	(0.007)
2nd		-0.040***	-0.093***	-0.128***	-0.069***
		(0.006)	(0.007)	(0.010)	(0.007)
3rd		-0.044***	-0.106***	-0.150***	-0.078***
		(0.007)	(0.008)	(0.012)	(0.009)
4th		-0.099***	-0.197***	-0.300***	-0.149***
		(0.015)	(0.023)	(0.033)	(0.021)

Table 6: IV estimation using the 2003 regional credit shock for different income groups of borrowers as instrument for 2004-2006 DTI. The first column provides the estimation results for the first stage regression while the remaining columns indicate the dependent variable. Statistical significance is denoted by * at 10%, ** at 5%, and *** at 1%.

the potentially large effects on the local economic activity of excessive household debt. We believe that the most likely explanation for the significant increase in household leverage are supply-side factors, also referred to as *credit supply* shock. In the early 2000s, most European countries experienced a decline in mortgage rates driven by the post-euro convergence of rates across Europe. This created capital flows from capital-abundant regions toward other regions that, coupled with the liberalization of financial markets, sparked rapid increases in house prices and in household leverage, in particular for households in the lowest quartiles of the income distribution. The housing market played a major role in this mechanism by transmitting the credit supply shocks from the financial sector to the real economy through households balance sheets. In addition, we find that the credit supply shock had a stronger impact on low and middle-income borrowers that increased significantly their leverage before the crisis, although the decline in regional economic activity seems to have responded more markedly to the increase of credit-supply leverage by high-income households.

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Appendix A: European Datawarehouse preparation

We cleansed the data set by eliminating records with missing entries, errors as well as duplicated entries. We only kept data on borrower's gross income if the income has been verified by the bank, rather than self reported, to avoid fraudulently overstated income, a problem that has been pointed out by Mian and Sufi (2017) for the US case. We also dropped records in the first and last percentiles of the continuous variables in our analysis, calculated for each year and each country in the sample. In addition, we consider only loans originated after the year 2000 for the purchase of a property, with interest rate type from 1 to 4 (fixed for life, fixed with resets, floating for life, and floating with resets), that have a Loan-to-Value (LTV) ratio smaller than 130, household income larger than 10 thousand Euro annually, and interest rate between 0 and 15%. The outcome of this filtering is a data set of over 4.6 million loans across 8 European countries, namely, Belgium, France, Ireland, Italy, the Netherlands, Portugal, Spain and the UK[8]. We aggregate these data at the level of the region where the asset underlying each loan is located using the NUTS3 regional classification. To obtain reliable NUTS3 level aggregates, we drop all observations in regions for which the number of loans observed at each point in time is below the threshold of 50 loans.

The interest rate provided in the data set refers to the rate currently charged on the loan, rather than the rate applied at origination. In our application we are interested in the interest rate at origination and we use the current rate to reconstruct it using the following rules. If the loan has a rate defined as "floating for life", we consider the current interest rate as the rate at origination if it is within 1% of the average mortgage rate (for maturities less than 5 years) published by the ECB for the country. Otherwise we multiply the current interest rate by the ratio of the current ECB average mortgage rates and its value at the origination date. In case the floating rate is linked to an index we calculate the current spread and add it to the value of the index at origination to obtain the interest rate. For fixed rate loans we compare the current rate on the loan to the ECB average rate on maturities of 5 years or longer at origination. We set the rate at origination equal to the current rate if it is within 1% of the ECB rate for the country otherwise we rescale it using the benchmark rates. Although the "fixed for life" category suggests that the current interest rate should also be the rate at origination, there is large degree of inconsistency between the values reported in the data set and the prevalent rates at the time the mortgage was originated. *The cleaned data set aggregated at NUTS3 level will be available online with the supplementary material.*

[8]The participation of German banks to this ECB operation has been limited and it is possibly associated to low German home-ownership rate (Voigtländer, 2009). The lack of a sufficient number of loans for many NUTS regions has lead to exclude Germany from the analysis.

Appendix B: Sample representativeness

This Section addresses the relevant question of how representative the European Datawarehouse (ED) is for the financial situation of European households (Gaudêncio et al., 2019). Table (7) reports the summary statistics for the sample size at the level of NUTS3 region by country. The median number of observations per region ranges between 213 and 2,568, and the minimum of the first quartile equal to 120 while the maximum of the third quartile is 4,857. We next investigate the issue of how representative our sample is for the underlying population by comparing the key variables included in our analysis to the same variables constructed from consumer finance household surveys.

There are several concerns that the loans submitted to the ECB for these financing operations might not be representative of the underlying population. First, the ECB sets a threshold on the credit quality of the ABS which requires banks to include in the pool high quality loans. In this sense the sample might provide a sample that is of significantly higher credit quality relative to the overall level in a country and under-represent low credit quality loans (that are more likely to have higher DTI and default rates). Second, banks participating more actively to the ECB liquidity operations might be those with a precarious financial situation and unable to access capital markets. In this sense the pool of loans that they submit might be larger and of lower quality relative to the population. Both of these effects can potentially bias our results, although in opposite directions. To evaluate to what extent our sample is representative of the underlying household financial situation, we consider the Household Finance and Consumption (HFCS) survey[9] that is coordinated by the ECB and provides a standardized set of variables across European countries (except for the UK that is not part of the Euro-area). With respect to the interest rate, we obtained the average interest rate on new residential loans from the European Mortgage Federation (EMF)[10]. Unfortunately, both the HFCS and EMF provide information only at the country-level rather than for regions. Hence, we compare the key variables obtained from ED and the HFCS survey at the national level, with the caveat that the representativeness at the regional level remains to be demonstrated due to lack of information in the Survey.

We focus the evaluation of the representativeness of the ED data set on three important variables that are used in our empirical analysis, namely, the DTI, house prices and the loan interest rate. For the HFCS, we construct a national weighted average of DTI and house prices over time, where observations are weighted to ensure the representativeness of the Survey[11]. Figure (10) shows the number of observations in ED data versus the HFCS survey by origination year of the loan. The ED data set has (relatively) fewer observations in the early 2000s while loans originated after 2010 are scarcer in the HFCS. For both ED and HFCS, the year with most observations is 2006, when we have approximately 500 thousand

[9]More information at `https://www.ecb.europa.eu/stats/ecb_surveys/hfcs/html/index.en.html`.
[10]More information at `https://hypo.org/`.
[11]The design weight is adjusted for non-response and ensures the representativeness of the survey.

loans for ED and 1.1 thousand for the HFCS survey. In general, ED provides for each country and year thousands of loans as opposed to a few hundreds from the HFCS. In terms of the geographical distribution of the loans, the countries more represented in ED are the Netherlands, France and Spain while in HFCS they are France, Ireland, and Portugal. Figure (11) compares the temporal evolution of the median DTI in the two data sets, with the bands representing the first and third quartile of the cross-sectional distribution of the variable in that year. For most countries the median DTI and its distribution are quite similar both in level and evolution over time. The DTI calculated in the HFCS is more volatile due to the small sample of the Survey, while the ED vary more smoothly. The largest differences between the two data sets appears when considering Italy and the Netherlands. For Italy, the median DTI from ED is approximately 1.5 point higher on average relative to HFCS and its distribution seems to be shifted upwards. This might indicate that the pool of loans originated in Italy represents riskier loans than those included in the Survey. For the Netherlands, we find the opposite result that the median DTI of the ED loans is on average close to 2, while almost 3.5 for the loans in the HFCS survey.

In Figure (12) we show the median house price obtained from the HFCS survey and from ED. Similarly to the DTI ratio, the time series of house prices overlap for most countries, including Italy. Only for the Netherlands we find that the median house price is significantly higher for HFCS than ED (205 thousand euro vs 131 thousand on average over the sample period). Hence, loans originated in the Netherlands in ED have lower DTI ratio and higher house purchase price relative to those collected in the HFCS survey. This points to the fact that Dutch loans in ED might be of higher credit quality relative to the population since more expensive properties require bigger loans and larger incomes to keep the DTI ratio low. This feature might bias our results against finding a role for household leverage, given that the pool of Dutch loans are very high quality and Figure (11) shows no significant increase in leverage before the Great Recession. Finally, Figure (13) shows the average interest rate in ED and the average provided by the EMF. Overall, there is consistency between the rates both in level as well as in dynamic behavior.

Summarizing, graphs from Figures (10) to (13) seem to suggest the broad consistency of the main household finance variables in ED with alternative sources such as the HFCS. However, ED provides two significant advantages over using survey data. Firstly, it provides regional information that allows to analyze and model the within-country variability of the variables of interest. Secondly, the availability of several thousand loans per region-year delivers more robustness to the analysis.

Appendix C: Housing supply elasticity

Saiz (2010) proposes a measure of housing supply elasticity (HSE) that depends on the geographic characteristics of a region, such as terrain elevation and water bodies. In areas

Country	25th perc.	Median	Mean	75th perc.
BE	431	926	1,639	2,185
ES	268	682	1,902	1,798
FR	346	773	1,228	1,610
IE	473	1,559	2,774	4,790
IT	136	302	509	580
NL	1,281	2,568	3,704	4,857
PT	150	354	840	858
UK	120	213	315	388

Table 7: Descriptive statistics for the number of loans per year-NUTS3 region by country.

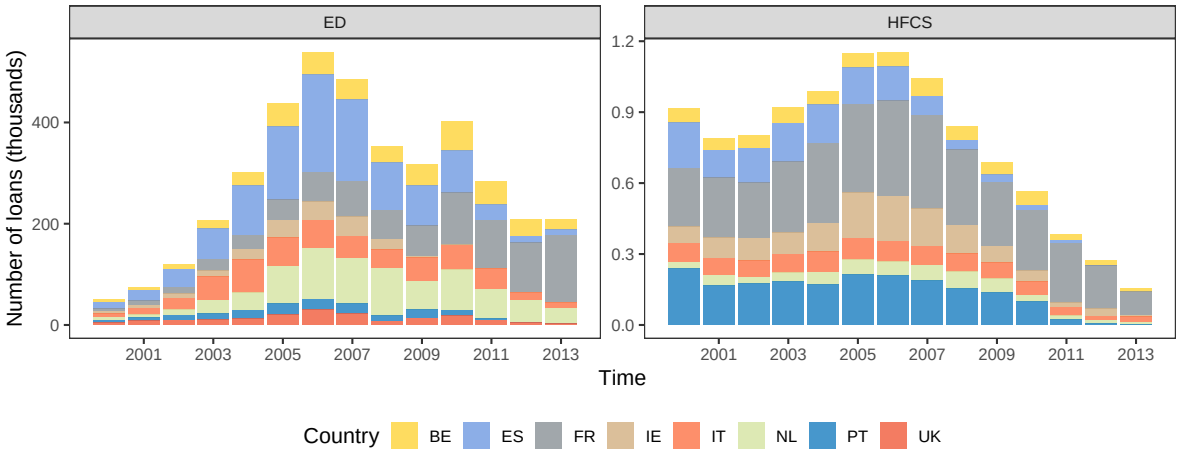

Figure 10: Number of loans (thousands) in the ED data set (left panel) and the HFCS survey (right panel) by country and year of origination.

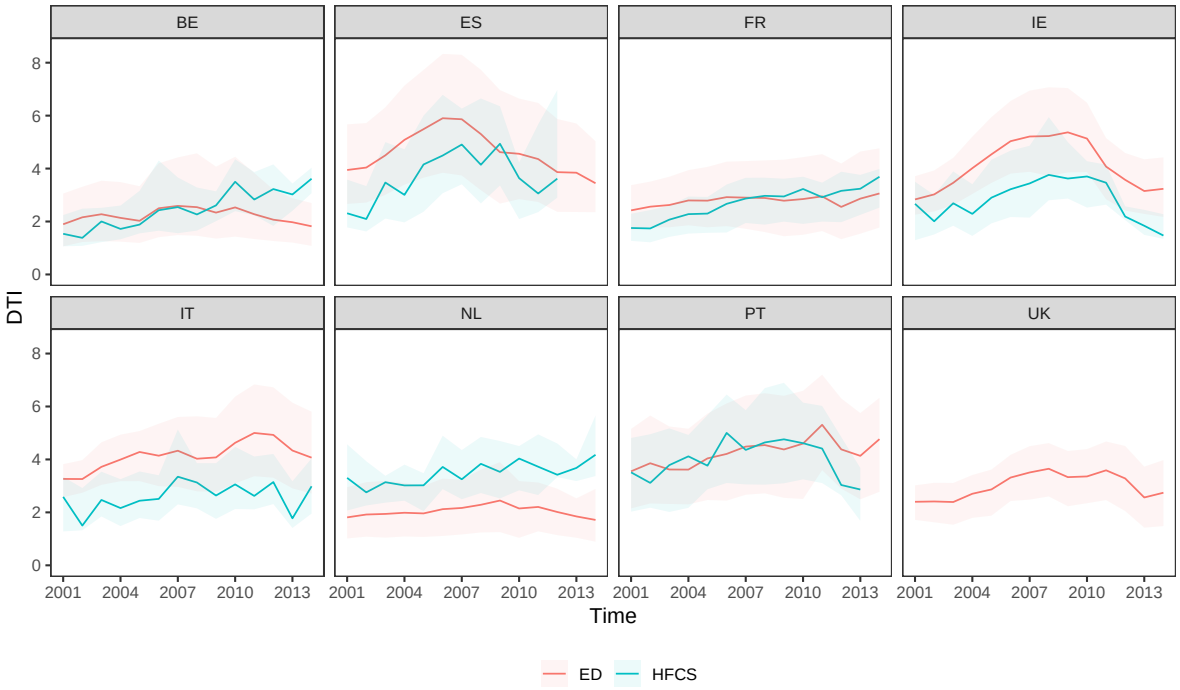

Figure 11: Median DTI calculated on all loans originated in a country-year using data from the ED and the HFCS. The bands represent the first and third quartiles of the cross-sectional distribution of DTI. The United Kingdom does not participate to the HFCS survey.

Figure 12: Median house price from all loans originated in a country-year using the ED and the HFCS data. The bands represent the first and third quartiles of the cross-sectional distribution of the house price. The United Kingdom does not participate to the HFCS survey.

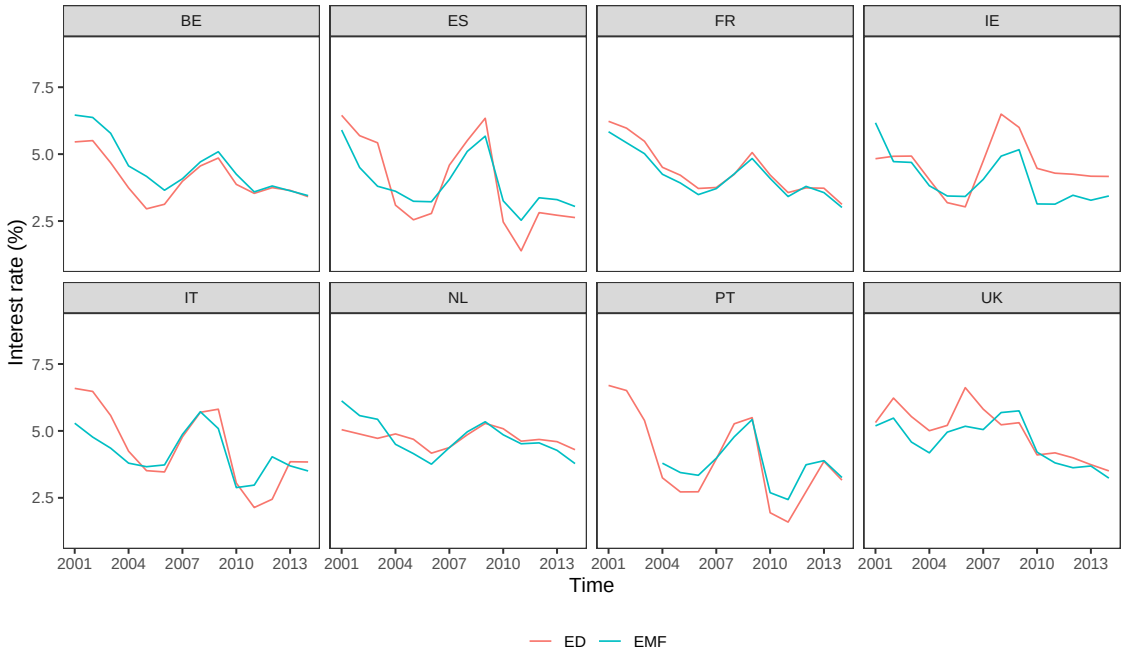

Figure 13: Average interest rate at loan origination in the ED data set (in red) and the averages reported by the European Mortgage Federation (in green) for a country-year.

with few geographic constraints the housing supply is elastic and adjusts quickly to changes in demand with a small impact on house prices. Instead, prices will react significantly when geographical constraints are binding and housing supply cannot react fully to accommodate demand. An expansion of the mortgage supply has the effect of increasing housing demand and produces differential effects on house prices in elastic and inelastic regions. In particular, prices will increase rapidly in those regions with inelastic housing supply, thus requiring borrowers to apply for larger loans: inelastic regions are characterized by higher house prices growth and household leverage relative to elastic regions. Mian and Sufi (2010) find empirical evidence that house prices increased significantly in US counties with relatively inelastic housing supply. Moreover, they show that these regions were the most severely hit by the slump in output and employment during the Great Recession.

To construct his measure of HSE, Saiz (2010) considers the following housing supply equation:

$$\Delta P_g = \alpha + \beta_g \Delta H_g + \sigma_g \Delta CC_g + \boldsymbol{R}_g + \epsilon_g, \tag{4}$$

where ΔP_g is the log-difference in housing prices in area g over the period from 1970 to 2000, H_g is the growth in the number of housing units, CC_g is the percentage growth in construction costs in the same period, and $\boldsymbol{R}_g$ is a set of regional dummies. In the above equation, β_g is the so-called *inverse housing supply elasticity*. It represents the price sensitivity to demand shocks, and is assumed to be a decreasing function of land availability. Accordingly, the

author suggests to approximate β_g by:

$$\beta_g = \beta_1 + \beta_2 \mathrm{UL}_g, \tag{5}$$

where UL_g represents the share of land that is unavailable for residential development. Following Mian et al. (2013), regions with larger β_g (thus with more unavailable land for building) have a relatively inelastic housing supply, for which we expect larger values of DTI. Accordingly, the authors use Equation (5) as instrument for the change in DTI in the IV estimation of Equation (1). We observe that β_g is a linear transformation UL_g and its variability across regions is only due to variation in UL_g. Hence, IV estimation results are identical whether one uses β_g or the share of unavailable land, UL_g. Given that the ED data set has few mortgages originated before 1996, we do not have reliable data on house prices over a long period of time: we overcome this shortcoming by instrumenting DTI in Equation (1) with UL_g, rather than β_g, and refer to such instrument as HSE. We expect land-constrained regions (i.e., with large UL_g values) to have a relatively inelastic housing supply and thus larger DTI.

We proxy the share of unavailable land using data from the JRC LUISA Territorial Modelling Platform[12]. Such data combine information from several sources, including satellite images on human and industrial settlements, data on elevation of the earth's surface, and information on protected areas where building is not permitted by the law. Data are available at each decennial census, for 1990, 2000 and 2010. We calculate the total area that is not available for building purposes by considering (i) areas that have already been built, (ii) non-buildable slopes, (iii) protected or green urban areas and (iv) water bodies. We obtain UL_g by dividing the total area that is not available for building calculated for the year 2000 by the total area in the NUTS3 region[13]. Figure (14) displays the map of unavailable land, showing substantial across-country heterogeneity. Regions with the largest constraints belong to the mountainous areas of the north of Italy and Spain, south of France as well as some densely populated large urban areas. Peripheral countries like Spain, Italy and Portugal are on average more land-constrained than the core countries UK, France, the Netherlands and Belgium, probably due to the physical constraints in the form of mountainous terrain for the first group of countries. The high percentage of constrained land that can be observed for the Netherlands may rather reflect the adoption of restrictive land use regulation (Vermeulen and Rouwendal, 2007).

Figure (15) shows the average growth of DTI and house prices relative to their levels in 2000, together with the median GDP in euro. In these graphs we split the regions in those

[12]More information can be found at `https://ec.europa.eu/jrc/en/luisa`.

[13]We observe that Saiz (2010) only restricts his calculation to the area within the 50km radii from the centroid of each metropolitan statistical areas, in order to capture the portion of land around cities that is not available for residential or commercial development. Although in our application we do not have information to identify the area surrounding each city, we observe that the NUTS3 classification allow a subdivision in relatively small-sized regions, covering one or more urban centers.

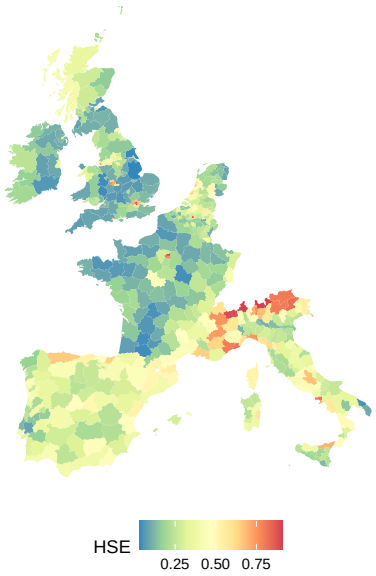

Figure 14: Map of the Housing Supply Elasticity (HSE) at the NUTS3 level.

with an inelastic housing supply (top quartile of the HSE distribution), versus those with an elastic supply (bottom HSE quartile). Leverage for these two groups grows at a similar pace between 2003 and 2007, while it diverges after 2008 when the DTI for the inelastic regions continues to grow until 2011. Instead, the house prices in both elastic and inelastic regions grew at a similar rate to about 40% until 2007, followed by a decline of approximately 20% for the inelastic regions and relatively stable prices in the elastic regions. As for GDP, it is interesting to observe that inelastic regions are characterised by a median GDP consistently higher than elastic regions. Overall, the HSE does not seem to be able to correctly identify those regions that increase leverage, although the increase is not driven by the diverging dynamics of the housing market in the two groups. Under the approach advanced by Mian and Sufi for the US, we should expect that areas with relatively small percentage of land available for building are those that registered the highest growth in house prices, while this does not seem to be the case for Europe. One possible explanation for this result is that, at least for Europe, the regions with high land constraint are mostly scarcely populated regions located in the mountainous regions of north Italy, Spain and southern France.

Overall, the HSE does not seem to be an appropriate instrument for DTI for the European case for a number of reasons. First, in Europe areas with relatively small percentage of land available for building are a mix of wealthy, high densely populated region with tough laws for home builders, such as the Netherlands, and poor, sparsely populated areas with severe land constrains due to mountainous territories, such as the north of Spain or the South of Italy. We also observe that the large differences in population density across European countries may mask important intra-country differences, thus making the HSE unreliable. For instance, Belgium and the Netherlands have almost four time the population density of Spain or Portugal. Finally, the validity of such an instrument has been questioned also for

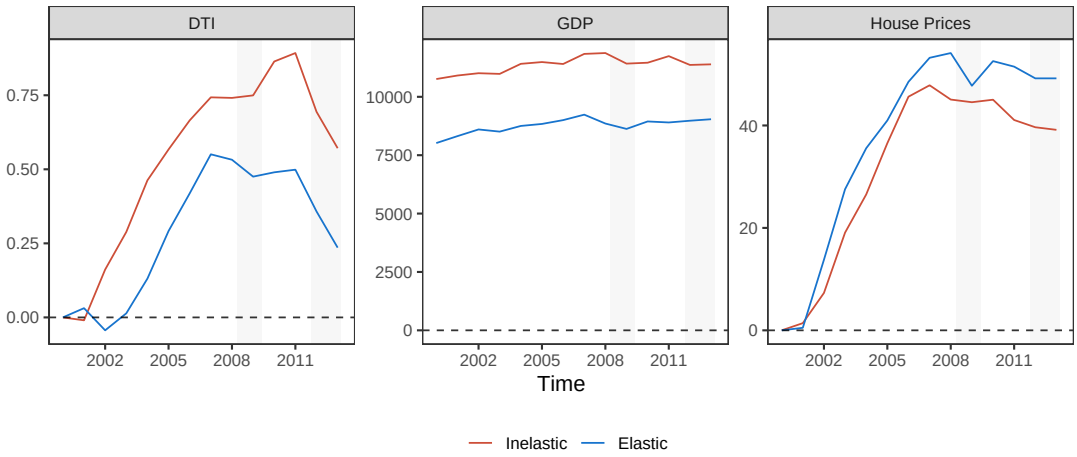

Figure 15: Change (relative to year 2000) of DTI and percentage growth of real GDP (in Euro) and house prices for the top and bottom quartiles of the distribution of the HSE instrument. The top quartile is denoted as *inelastic* and the bottom quartile as *elastic*.

the US case: among others, Davidoff (2016) claims that strictly regulated regions are not only expensive because building in those areas is costly, but also because they offer better employment opportunities, thus attracting high-income workers. Given these motivations, we next introduce an alternative instrument for DTI that we believe better captures the credit supply shock in Europe.

Appendix D: Lending Standards

We consider some loan and borrower characteristics to evaluate their behavior between 2000 and 2010. In Figure 16 we show the loan balance at origination (in euro), the Debt-to-Income ratio, the house prices, the borrower's income (in euro), the loan's interest rate, the Loan-to-Value ratio, and the loan term (in months). These values are averages across all loans originated in a country in a certain year.

The overall picture that emerges from the Figure is that most countries experienced a large increase in average house prices and loan balances, in particular in Ireland and Spain. The trend was already in place in the early 2000s, but accelerated significantly after 2003 reaching a peak in 2006-2007. The similar growth in these two variables lead to a LTV ratio that was relatively stable in most countries. However, household incomes grew in these years but not fast enough to keep up with house prices and loan balances. This caused the DTI ratio to increase significantly, in particular in those countries with larger increases in house prices. The affordability of larger mortgages to purchase more expensive houses was maintained by a combination of lower interest rates and, in most countries, significantly longer loan terms.

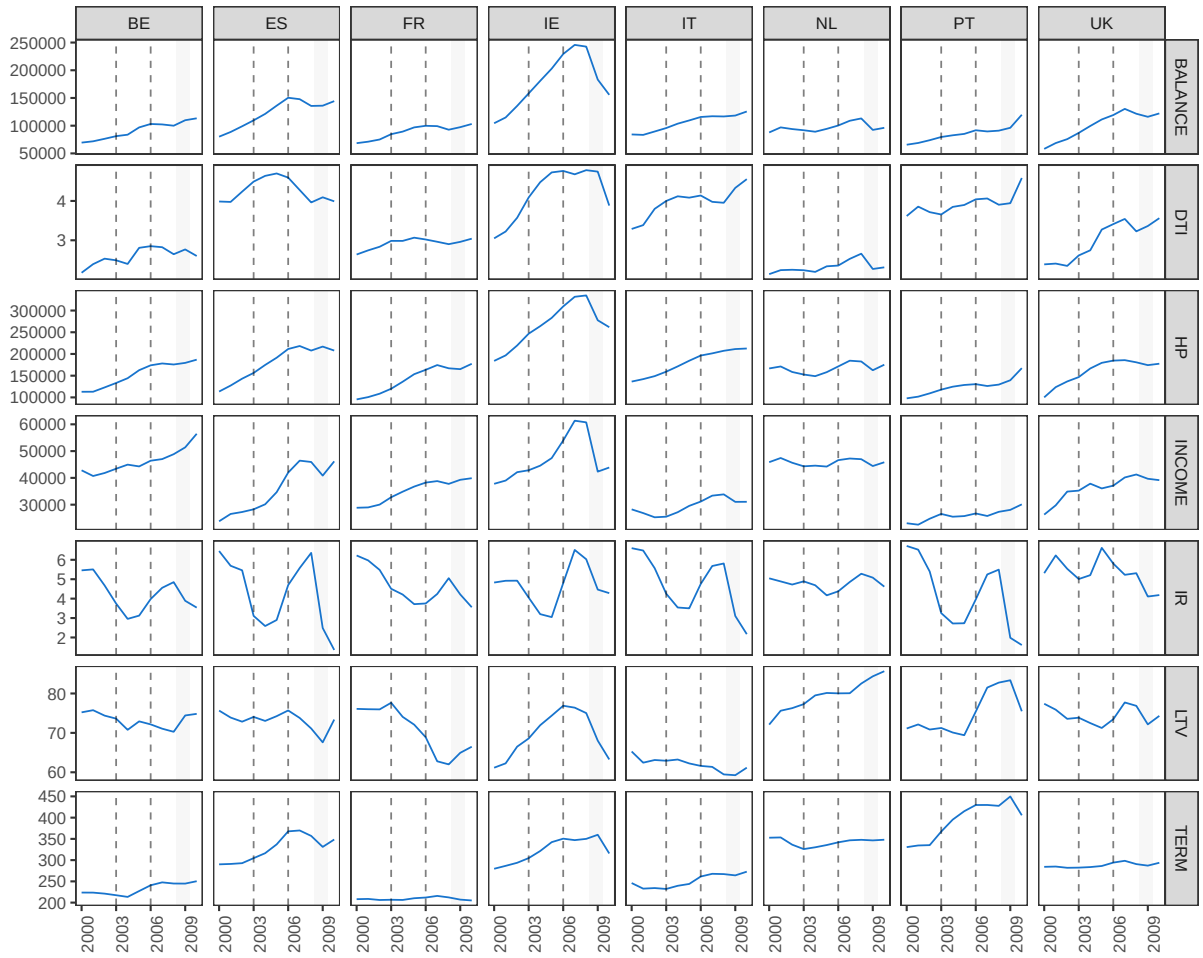

Figure 16: Variation over time of average loan and borrower characteristics: *BALANCE* represents the loan balance at origination (unit: euro), *DTI* the Debt-to-Income ratio, *HP* the house price, *INCOME* is the annual borrower income (unit: euro), *IR* the interest rate at origination, *LTV* the Loan-to-Value ratio, and *TERM* the duration of the loan (unit: months). The vertical bars are for 2003 and 2006, while the gray shaded area represents the CEPR recession period.