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Mortgage arrears, regulation and institutions: Cross-country evidence ☆

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ABSTRACT

Using a newly constructed database for 26 countries over 2000-2014, we analyze cross-country and within-country differences in mortgage arrears. We find that restrictive macro-prudential policies, in particular lower regulatory loan-to-value ratios, are significantly associated with a lower share of mortgage arrears in total residential debt. Likewise, better institutions are related with lower delinquency rates, both directly and by enhancing the impact of macro-prudential policies and the right to recourse. We also find that the effect of macro-prudential policies is conditioned by several mortgage market characteristics, such as the maturity of loans, interest rate fixity, and tax deductibility of interest payments.

1. Introduction

The global financial crisis highlighted the devastating effects that fragilities in the residential mortgage market may have on the financial system at large. The initial shock of an increase in mortgage arrears (due to a decline in house prices) in the US and some European countries was the trigger for a liquidity crisis that ultimately turned into a full-blown financial crisis. Despite a significant contraction of the sector in the aftermath of the crisis, mortgage lending still accounts for a large share of both households' debt and banks' assets.[1] Yet, there are important differences in the depth of mortgage markets across countries. Likewise, as we show in this paper, the incidence of mortgage arrears differs considerably across countries, as well as over time for individual countries.

A better understanding of the factors that explain cross-country and within-country differences in mortgage delinquency is important for at least two reasons. First, mortgage defaults dilute the fundamentals of financial institutions and amplify disruptions in financial markets, as revealed during the financial crisis. Second, mortgage defaults reduce households' creditworthiness, thereby making it more difficult in terms of volume and price to access future financing. This may increase consumption volatility, both at the household and aggregate level, with repercussions for the real economy.

This paper examines the incidence of mortgage arrears in a large sample of countries based on a newly constructed panel dataset.[2] We explore how a comprehensive set of factors is related to cross-country and within country differences in delinquency rates. These factors can be grouped into four main categories: macroeconomic variables, macro-prudential regulation, institutional factors, and housing market characteristics. Previous

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[1] The IMF's Global Financial Stability Report (2017) finds that the median household debt-to-GDP ratio in advanced economies was 63 percent in 2016, with mortgage debt accounting for more than 50 percent of total household debt. Similarly, Cerutti et al. (2017b) report that the median share of mortgages in total household debt in a sample of 53 countries was about 70 percent in 2011.

[2] Throughout the paper, we use "arrears", "delinquencies" and "defaults" interchangeably, referring to past due payment obligations.

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studies have investigated only subsets of these factors or merely looked at general credit volumes due to data limitations. We complement this literature and provide a wide-ranging view of variables associated with mortgage defaults, as well as the interactions that are at play between these variables.

Our paper makes four contributions. First, we compile a unique comparative dataset on mortgage arrears at the macro level for a reasonably large number of countries over 2000-2014, which allows us to analyze the variation of mortgage delinquency rates in a panel set-up. Although several previous papers have analyzed the determinants of mortgage defaults at the country level (see, for instance, Demyanyk et al., 2011; Blanco and Gimeno, 2012; Aron and Muelbauer, 2016; Goodstein et al., 2017), only a few of them provide cross-country databases at the macro level. Our database contains more countries and covers a longer time period than those used in previous studies.[3] A careful study of aggregate data is relevant given the paucity of micro data on mortgage defaults in many countries.

Second, our paper is among the first to examine to what extent macro-prudential policies are related to mortgage defaults. Recently, macro-prudential policies have become much more important in most countries, as the financial crisis showed that micro-prudential supervision needs to be complemented by a macro-prudential perspective to maintain financial stability. Several papers have examined the impact of such policies on credit growth and housing prices. For instance, Akinci and Olmstead-Rumsey (2018) argue that macro-prudential tightening is associated with lower housing credit growth, as well as with lower house price inflation, but they do not examine the impact of macro-prudential policies on mortgage defaults.[4] Three previous studies come closer to this part of our work (Wong et al., 2011; Gerlach-Kristen and Lyons, 2015; Allen et al., 2018). While these studies mainly focus on one single instrument aimed at borrowers' leverage, namely loan-to-value (LTV) ratios, we consider a broader range of (housing-targeted) macro-prudential instruments. These instruments are aggregated in comprehensive indexes that capture changes in the intensity of their usage. Our results suggest that restrictive macro-prudential policies, and in particular lower regulatory LTV ratios, are associated with a reduction in mortgage defaults.

Third, we examine to what extent institutional factors, which are often associated with the cost of default and efficiency of the judicial system, are related to the variation of mortgage default rates across countries. Only few studies that we are aware of do something similar. For example, Japelli et al. (2008) and Dygan-Bump and Grant (2009) argue that institutional factors may foster household credit but are also related to insolvencies. We complement these findings and show that better institutions are associated with lower levels of mortgage default.

Finally, we examine interaction effects and show how the relationship between macro-prudential policies and mortgage defaults is conditioned by institutional arrangements. We provide evidence that the effect of macro-prudential policies is enhanced by institutional quality: lower default rates are strongly associated with restrictive macro-prudential policies in the presence of better institutions. Likewise, the relationship between recourse procedures and mortgage arrears is enhanced by institutional quality. In addition, we find that certain other characteristics of the mortgage market, such as loan maturity, the loans' interest rate type, and the tax deductibility of interest payments, are associated with fewer mortgage defaults when restrictive macro-prudential policies are in place. These housing market characteristics have received hardly any attention in the literature.[5]

The paper is structured as follows. Section 2 provides a literature review identifying potential drivers of mortgage defaults. Section 3 describes the data sources and presents stylized facts. Section 4 presents the methodology and the results, while section 5 offers several robustness tests. Section 6 concludes.

2. What drives mortgage defaults?

2.1. Potential drivers

The theoretical literature suggests two main explanations for mortgage arrears: ability-to-pay and strategic default (Whitley et al., 2004).[6] According to the ability-to-pay theory of default, individuals default involuntarily when they are unable to meet current payments. In case households face affordability problems—which may be caused by an income drop (e.g., due to unemployment), higher mortgage payments (e.g., due to higher interest rates), or a decline in house prices (leading to negative equity)—strategic default may be an option.

The strategic default theory holds that households choose to default voluntarily after a rational analysis of all future costs and benefits associated with maintaining the mortgage. Thus, a borrower may default if his gains exceed the perceived costs of the expected sanctions, including access to future finance and its price.[7] As pointed out by Jappelli et al. (2008), these costs not only depend on lenders' willingness to inflict sanctions, but on the entire set of institutional arrangements governing the credit market, such as the rule of law, creditor rights and bankruptcy laws. Likewise, Duygan-Bump and Grant (2009) show in their European panel study on household debt arrears that the extent to which adverse shocks matter depends on the punishment associated with default.

We do not intend to provide empirical evidence for any of the aforementioned theories of mortgage default, nor to distinguish between various factors that have been associated with one particular type of default or the other. Instead, for the purpose of our empirical investigation, we use the insights from these theories to identify potential covariates of mortgage repayment.

In addition to macroeconomic and institutional factors, regulation (in particular macro-prudential policies targeting the household sector) is likely related to mortgage defaults. Although there is increasing evidence that macro-prudential policies affect housing credit growth and house prices (Galati and Moessner, 2018), there is limited evidence on whether these instruments influence the incidence of mortgage defaults. Wong et al. (2011) investigate the

[3] For instance, Wong et al. (2011) use data for 13 countries over the period 1991-2010, while Jappelli et al. (2008) employ data for 11 European Union member states over the period 1994-2001.

[4] Other relevant studies on the effects of macro-prudential policies include Claessens et al. (2013), Kuttner and Shim (2013), Vandenbussche et al. (2015), Zhang and Zoli (2016), Meeks (2017), Cerutti et al. (2017b), Bekkum et al. (2019) and Poghosyan (2019). See Galati and Moessner (2013, 2018) for excellent reviews on the effectiveness of various macro-prudential tools.

[5] An exception is the work by Aristei and Gallo (2012) who consider variables such as mortgage maturity in their analysis of Italian mortgage defaults.

[6] Both theories suggest that macroeconomic factors (such as lower house prices, higher interest rates and higher unemployment) may increase mortgage defaults by reducing the ability of households to pay their mortgages. Several studies focusing on mortgage defaults at the country level provide evidence for the importance of these macroeconomic variables (Whitley et al., 2004; Elul et al., 2010; Demyanyk et al., 2010; Magri and Pico, 2011; Blanco and Gimeno, 2012; Aron and Muelbauer, 2016; and Goodstein et al., 2017). The same holds for studies using micro-level data for several countries (Diaz-Serrano, 2004; Gerlach-Kristen and Lyons, 2015).

[7] For instance, in the models of Kocherlakota (1996), Kehoe and Levine (2001) and Chatterjee et al. (2007) households compare the costs of default with the benefits of reneging on their debts and default if it is advantageous to do so.

role of maximum LTV ratios on mortgage delinquency by estimating the responsiveness of delinquency ratios to changes in property prices and to macroeconomic fluctuations. They find that maximum LTV ratios are effective in reducing the systemic risk stemming from the boom-and-bust cycle of housing markets. Likewise, Gerlach-Kristen and Lyons (2015) argue for a policy enforcing LTV limits in order to reduce arrears as their evidence suggests that defaults seem particularly strong in countries with high LTV ratios. Using micro-simulations, Allen et al. (2018) find that LTV policies reduce the impact of interest rate shocks on household vulnerabilities in Canada.

Finally, mortgage market characteristics are key factors to consider when analyzing the likelihood of mortgage default. One important variable that plays a role in deciding for or against default is recourse legislation. If the price of a property is less than the value of the mortgage (i.e., a household has negative equity), default is less attractive under recourse legislation as the household remains responsible for the negative equity. Under non-recourse mortgage legislation, any shortfall between the mortgage and the property value is borne by the lender. Most European countries and many states in the U.S. allow mortgage lenders to claim borrowers' financial assets when the collateral falls short of the loan balance. Evidence from the U.S. supports the hypothesis that homeowners in states with recourse legislation are less likely to default (Ghent and Kudlyak, 2011; Li and Oswald, 2017).

The type of loan (fixed vs. flexible interest rate) and loan maturity could also have an impact on mortgage defaults. Borrowers are more likely to face difficulties in making their mortgage-related payments when interest rates are more volatile (the impact being larger for variable-rate mortgages) and/or when the periodic installments are higher (as for loans with short maturities). Another feature of the mortgage market that may be conducive to an increase in households' leverage, and subsequently to more arrears, is the tax treatment of interest payments.[8] Some countries give preferential treatment to mortgages in the form of deductibility of interest payments. The tax deductibility policy can be substantial in some countries, as an instrument to encourage homeownership. Yet, in other countries such favorable tax treatment is limited or even non-existing.

2.2. Previous studies

Three different types of studies on the determinants of mortgage defaults can be discerned in the literature, namely individual country studies, multiple country studies, and panel studies. These studies consider different dimensions of the variation in mortgage defaults and they all have benefits as well as shortcomings. Although conclusions in these studies are sometimes phrased in terms of causality, in most cases the data available does not allow for strong identification strategies. The same holds for our data. We address this problem using an instrumental variable approach and discuss this issue in the methodology and robustness sections.

Several studies examine the development of mortgage arrears over time in individual countries, either using macro- or micro-level data (see Aristei and Gallo, 2012; Gerlach-Kristen and Lyons, 2015; Aron and Muelbauer, 2016, for reviews). A major advantage of individual country studies is that the respective time series data is immune from the problem of international data comparability. A major disadvantage of this type of studies is that several potential determinants of mortgage default cannot be considered, such as different institutional arrangements and credit market characteristics.

Cross-country regressions can account for some of these variables. A good example is the study by Japelli et al. (2008) who use cross-country regressions for 45 countries to show how the size of the household credit market is associated with institutional variables, such as enforcement of creditor rights and information sharing arrangements. Other papers consider micro databases, which have the advantage that individual borrower characteristics can be considered (e.g., Diaz-Serrano, 2004; Duygan-Bump and Grant, 2009). However, as the number of countries in this type of studies is generally restricted due to paucity of micro data (Aron and Muelbauer, 2016), a disadvantage is the limited variability in the cross-country determinants of mortgage defaults. Furthermore, some of these studies cannot account for the large variation over time in the developments of mortgage markets.

An alternative is therefore using panel data at the macro level. This is done, for instance, in studies by Japelli et al. (2008) and Wong et al. (2011) which were discussed earlier. The main advantage of the panel approach is that it allows for both cross-country and within-country variables to be considered. Our analysis shows the importance of accounting for both the cross-country and time dimensions as there is considerable variation in mortgage defaults both across countries and over time within individual countries. Macro-panel models have been widely employed to address questions where interactions are important (see e.g. Beck et al., 2007; 2013). However, using macro data comes at the cost of not accounting for the potential contribution of individual borrower characteristics in explaining mortgage delinquencies. Furthermore, this set-up faces potential endogeneity (simultaneity) problems. We therefore also run a panel VAR model to address these concerns.

3. Data

This section describes our newly constructed database for mortgage defaults as well as the various data sources from which information on the macroeconomic variables, macro-prudential tools, institutional arrangements, as well as mortgage markets characteristics has been obtained. We merge data from various sources with the collected information on mortgage defaults in order to build a comprehensive panel dataset.

3.1. Mortgage defaults

We collected information about mortgage defaults in 26 countries covering the period 2000-2014.[9] Since data on actual defaults is not available for most countries in our sample, we use the ratio of the total value of mortgage arrears (over 3 months past due) to total value of outstanding mortgage loans as a proxy for mortgage defaults.[10] Data on mortgage arrears is collected from the respective central banks or from supervisory authorities.[11] As shown in the first row of Table 1, there is significant variability in annual

[8] Jappelli and Pistaferri (2007) use data on Italian households to study the relationship between tax deductibility and leverage.

[9] The main criteria for selecting specific countries in our sample are the existence of comprehensive and comparable data on mortgage markets, as well as information on macroeconomic factors, macro-prudential policies and the institutional environment.

[10] This proxy has been used in previous studies (cf. Duygan-Bump and Grant, 2009) and is in line with the guidelines on the definition of default as proposed by the European Banking Authority (see the consultation paper *Guidelines on the application of the definition of default under Article 178 of Regulation (EU) 575/2013 (EBA/CP/2015/15)*. Moreover, the cross-country consistency of this definition allows for international comparison. The majority of countries in our sample has a delinquency definition based on the 90 days past due criterion, with few national definitions deviating from this threshold (e.g., Denmark and Italy use 3.5 and 6 months past due, respectively).

[11] See Appendix F for detailed information on the main sources for the data. At the country level, data is available with either monthly, quarterly, or annual frequency. We use the average of monthly or quarterly default rates where annual information is not available. Note that our aggregate data does not allow for comparison of delinquency rates across different vintage years.

Table 1
Summary statistics of the variables used in the cross-country analysis.

Variable	N	Mean	Standard deviation	Minimum	Maximum
Mortgage defaults	289	3.2	4.24	0.01	28.6
Between variation			3.42	0.08	12.43
Within variation			2.75	-5.90	19.30
Macroeconomic variables					
Unemployment	390	7.61	4.34	0.7	27.2
House prices (%)	306	4.35	8.35	-18.74	31.15
Interest spread	344	1.6	2.87	-8.5	35.47
Macro-prudential policy					
Macro-pru policy index (MPI)	390	0.23	0.76	-1	5
Macro-pru instruments	390	0.48	2.67	-6	11
LTV index	390	0.05	0.35	-1	2
Institutional quality					
Legal rights	24	6.88	2.37	3	10
Rule of law	24	0.69	0.11	0.47	0.87
Property protection	26	6.44	0.88	5.1	8.1
Investor protection	26	6.42	1.54	4.3	9.3
Creditor rights	26	1.81	1.11	0	4
Institutional quality index (IQ)	23	-0.02	1.75	-2.76	3.08
Mortgage market					
Average maturity	26	26.31	7.45	15	45
Recourse	24	0.79	0.41	0	1
Loan type	26	0.15	0.36	0	1
Funding type	24	0.63	0.48	0	1
Tax deductibility	26	0.62	0.49	0	1

Notes: This table shows summary statistics of the data used in the empirical analysis. See the main text for variables definitions. Tables A.1 (in Appendix A) and B1-B3 (in Appendix B) provide summary statistics at the country level.

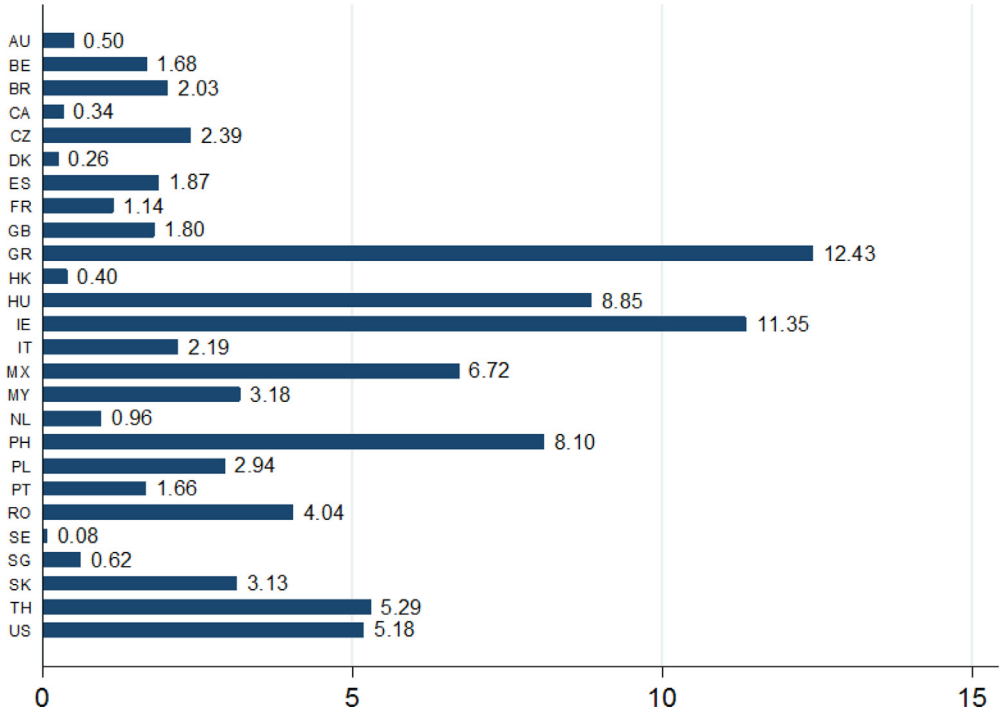

Fig. 1. Average mortgage default rates per country (2000-2014).

default rates. The ratio ranges from 0.01% to 28.6% per annum with a mean of 3.2%. Average mortgage defaults over the sample period differ sharply across countries (see Fig. 1), ranging from below 1% in Australia, Canada, Denmark, and the Netherlands, to above 8% in Greece, Hungary, Ireland, and the Philippines.

As Table A.1 in Appendix A shows, there is also substantial variation within countries. Some countries have experienced significant fluctuations in the annual default rates during 2000-2014 (for example, Mexico from around 3% to a maximum of 18.5%, or Hungary from around 3% to a maximum of 14%, or the Philippines from around 3% to a maximum of 15%). Table 1 shows that the between-country variation (3.42) is slightly larger than the within-country variation (2.75), but the two numbers are relatively close.[12] This points to the importance of both within and cross-country vari-

[12] The within-variation number for mortgage defaults refers to the deviation from each country's average, and therefore some of those deviations are negative.

ation of default rates and suggests that a panel data approach is appropriate for studying mortgage delinquency.

3.2. Macroeconomic variables

We investigate the role of macroeconomic conditions using three macroeconomic variables: unemployment, changes in house prices and interest rates spread. Previous studies have documented a strong relationship between these variables and mortgage defaults. Data on unemployment comes from the World Development Indicators (World Bank) database. Data on house prices is from the Bank for International Settlements (BIS) and the European Mortgage Federation (2015). As a proxy for the interest rate we use the spread between the long-term government bond yield and the rate of treasury bills. The sources for these variables are the IMF's International Financial Statistics and FRED Economic Data (St. Louis Fed). The spread captures borrowers' financial constraints by linking the yields relevant for borrowing costs and for savings. An increase in the spread may signal affordability problems for mortgage borrowers. There are two potential sources for spread widening. On the one hand, it can be caused by an increase in mortgage costs (usually linked to the long-term yield) that is not compensated by a similar increase in the savings rate (usually linked to the short-term yield). On the other hand, the spread widens when the savings rate decreases more than mortgage costs. Appendix C shows the co-movement of these variables and the mortgage default rates.

3.3. Macro-prudential policy

We investigate macro-prudential instruments that target the housing market, since the intensity of their usage is likely related to variation in mortgage default rates. We take information on macro-prudential policy from Akinci and Olmstead-Rumsey (2018) and Cerutti et al. (2017a). The macro-prudential index compiled by Akinci and Olmstead-Rumsey (2018) (*Macro-pru policy index* or *MPI*, hereafter) aggregates four instruments that specifically target the housing sector (i.e., loan-to-value cap, debt service-to-income cap, capital and provisioning requirements). For this reason, we choose the MPI to be the main proxy for macro-prudential policy in our study. The index is constructed as follows: for each instrument a monthly value of 1 is assigned if the measure is introduced or tightened in the respective month. If the macro-prudential instrument is loosened, a monthly value of -1 is assigned. If there is no action taken with respect to that instrument, a value of 0 is recorded.[13] We aggregate the index in order to match the yearly frequency of our sample.

To explore a more comprehensive set of macro-prudential measures designed for both the real estate and the non-real estate sector, we also use an index that aggregates over a broader range of instruments such as capital buffers, interbank exposure limits, concentration limits, LTV ratio limits, and reserve requirements *(Macro-pru instruments*, hereafter). This cumulative index is taken from the database of Cerutti et al. (2017a) and it sums in each quarter the tightening net of easing in order to capture the tightness of the respective tool at a given point in time. For both *MPI* and *Macro-pru instruments*, a larger positive value of the index suggests a tightening process.[14] Finally, since the data from the above-mentioned sources show that LTV caps are the most commonly used instrument, we also collect information about changes in the regulatory LTV ratios for all countries in our sample (from Cerutti et al., 2017a) and create an index that captures tightening and easing of this particular macro-prudential tool. Appendix C graphically shows the relationship between the intensity in the usage of macro-prudential tools and the incidence of mortgage defaults.

3.4. Institutional quality

To capture cross-country differences in institutional and legal frameworks we compile an index of institutional quality (*IQ*, hereafter). The index is based on five selected indicators of institutional quality which capture judicial efficiency, bankruptcy regulation and property protection.

The first institutional variable we consider is the strength of the Legal Rights index from the World Bank's Doing Business database. The index measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders thereby facilitating lending. The index ranges from 0 to 12, with higher scores indicating that these laws better enable access to credit. The second measure we use is the Rule of Law index from the World Justice Project (2015). The index provides a comprehensive description of the extent to which countries adhere to the rule of law in practice. This index ranges from 0 to 1, where 1 signifies the highest score. Finally, we collect data on three different proxies for the protection of property. We use an index for the protection of Physical Property from the International property rights index (2015) (the index takes values ranging from 0 to 1, where 1 signifies the highest score), an index for Investor Protection from the World Bank's Doing Business database (the index ranges from 0 to 10, where 10 signifies the highest score), and an index that measures the Creditors Rights against defaulting borrowers (ranging from 0 = poor creditor rights to 4 = strong rights; source: Djankov et al., 2007).[15]

In constructing our institutional quality (IQ) index we employ principal component analysis on these data and retain the first component, which explains 61.3% of the total variation in the institutional variables (see Appendix D). The loadings of each of the five variables on the first component are balanced, with Legal Rights and Physical Property having the highest loadings (49.19% and 49.88%, respectively), followed by Investor Protection (42.80%), Rule of Law (41.04%) and Creditor Rights (39.7%). Figure C.5 in Appendix C illustrates the relationship between our index for institutional quality and the incidence of mortgage defaults.

3.5. Mortgage market

We collect data on various mortgage market characteristics for the countries in our sample. Data on loan type (fixed vs. variable mortgage rate), average maturity (in years), bank funding type (retail vs. other sources such as covered bonds or securitization), and degree of lender recourse (full recourse vs. no or partial recourse) comes from Cerutti et al. (2015) and the European Mortgage Federation (2015). Data on tax deductibility of interest payments comes from Cerutti et al. (2015) and the International Bureau of Fiscal Documentation (Tax research platform).

[13] The index covers 57 advanced and emerging economies over the period 2000-2013. Over this time period, tightenings were much more common than easings. The macro-prudential policies were used more actively in emerging than in developed economies, and more often after the global financial crisis of 2008 rather than in the pre-crisis period. The index records the date at which a change in the instrument takes place. As these changes might not bind immediately, we control for delayed effects in our econometric specification.

[14] Both indexes are measured at a quarterly basis. We derive the annual values for each index by cumulating the quarterly values per annum. Table B.1 in Appendix B provides summary statistics at the country level.

[15] Table B.2 in Appendix B provides an overview of the institutional quality variables at the country level.

Table 1 reports sample statistics for these characteristics. The average maturity of mortgage loans ranges from 15 to 45 years, with a mean of 26 years. In most countries in our sample, a full recourse procedure is in place. There are important differences with respect to the importance of fixed-interest vs. variable-rate mortgages: the latter category (which consists of both variable-rate mortgages and a mix of fixed and variable-rate mortgages) seems to be present in a larger number of countries. More than half of the countries allow for some form of tax deductibility and have retail deposits as the preferred source for bank funding. Figures C.7-C.12 in Appendix C illustrate the relationship between mortgage default rates and each of the specific mortgage market variables.

3.6. Correlations across the main variables and mortgage default rates

Table A.2 in Appendix A shows the correlation between the variables used in our analysis. As shown in column (1), the correlations between the explanatory variables and the mortgage default rates have the expected sign (i.e., they are in line with the patterns documented in Sections 3.2–3.5). The highest correlations are for the institutional quality index (-0.47), unemployment (0.38) and house price changes (-0.34). This suggests that the quality of institutions and variables describing macro-economic conditions are closely correlated with default rates. Furthermore, there is a low negative correlation between default rates and most other variables - the macro-prudential index (-0.16), average maturity (-0.03), recourse procedures (-0.12), loan type (-0.17) and bank funding type (-0.04).

Table A.3 in Appendix A summarizes the expected relationship between the variables introduced in this section and mortgage defaults.

4. Methodology and results

4.1. Methodology

In this section, we present the methodology employed to analyze the potential factors related to mortgage defaults. We start the analysis by focusing on macroeconomic and macro-prudential variables and proceed with expanding the model by including additional variables describing institutional quality and the mortgage market. We employ the fixed effects (FE) estimator whenever the model includes only time-varying variables and switch to random effects (RE) whenever we investigate non-time varying variables.

The baseline model is as follows:

$$ln\ (M_{it}) = \alpha + \beta MP_{it-1} + \boldsymbol{\gamma' Z_{it-1}} + \tau_t + \mu_i + \varepsilon_{it}, \quad (1)$$

where the indices i and t stand for country and time, respectively, $ln(M_{it})$ is the logarithm of the mortgage defaults rate, MP is a macro-prudential policy index, $\boldsymbol{Z}$ is a vector of macroeconomic controls and ε_{it} is a scalar disturbance term. The macro-prudential measure MP is either a macro-prudential index (MPI or Macro-pru instruments) or an index capturing changes in the regulatory LTV ratio. The vector of controls consists of unemployment, house price changes and interest rate spread.[16]

The model includes country fixed effects μ_i to control for unobserved time-invariant differences across countries that might affect mortgage defaults and time fixed effects τ_t to control for common time trends. We assume a one or two period lag for all regressors in order to account for the delayed effect that some of the explanatory variables (like macro-prudential policies) might have on mortgage defaults. The model is estimated using the within estimator and we employ robust standard errors clustered at the country level to account for heteroscedasticity and autocorrelation in the residuals.

One concern with this model is that the macro-prudential policy index and mortgage defaults may have a reverse causal relationship, since countries with higher default rates are more likely to implement macro-prudential policies. If simultaneity is present, the estimates of β based on the fixed-effects estimator are biased. In Section 5.4, we employ two different modelling strategies to account for the potential reverse causality and check the robustness of the effects of macro-prudential policy variables (MPI and Macro-pru instruments). One is based on instrumental variables (IV) estimation. The second is a panel VAR model which allows for the dependency among the variables to run both ways, as well as for an autoregressive component of mortgage defaults. First, we estimate Eq. (1) based on an instrumental variable (IV) approach to check the robustness of the relationship between macro-prudential policy and mortgage defaults. We employ an instrument constructed based on macro-prudential policy implementation in neighboring countries and complement it with functional form identification (Lewbel, 2012). Second, we estimate a panel VAR which includes four variables: mortgage defaults, house price changes, macro-prudential policy and unemployment.

We extend the baseline model by including other factors or interaction terms which we hypothesize to be associated with mortgage defaults. In the first extension, we explore the role of institutional quality and test whether it is significantly associated with a reduction in mortgage default rates. Since our proxies for institutional quality are non-time-varying, we employ random effects to estimate the effect of institutional quality:

$$ln\ (M_{it}) = \alpha + \beta MP_{it-1} + \boldsymbol{\gamma' Z_{it-1}} + \delta\ IQ_i + \tau_t + \varepsilon_{it}. \quad (2)$$

Next, the institutional quality index (IQ)—based on the first principal component analysis of five institutional attributes—is interacted with macro-prudential policy variables to assess whether the effects of macro-prudential policies on mortgage defaults vary with the quality of institutions. Since the interaction term is time varying, we estimate the model with the fixed effects estimator:

$$ln\ (M_{it}) = \alpha + \beta MP_{it-1} + \boldsymbol{\gamma' Z_{it-1}} + \theta\ IQ_i MP_{it-1} + \mu_i + \tau_t + \varepsilon_{it}. \quad (3)$$

We use a similar specification to test interactions between the macro-prudential indexes and mortgage market variables. In that case, IQ in Eq. (3) is replaced by variables such as average loan maturity, interest rate type, and tax deduction.

Finally, we explore the effects of recourse (RP) as well as the interaction between the institutional quality index and the recourse dummy. This interaction captures the fact that the role of recourse procedures in deterring defaults crucially depends on the efficiency of the judicial process (an attribute of the institutional quality indicator). As both variables are time-invariant, we employ random effects in order to be able to estimate the effect of these variables on mortgage default rates.

$$ln\ (M_{it}) = \alpha + \beta MP_{it-1} + \boldsymbol{\gamma' Z_{it-1}} + \zeta RP_i + \pi\ IQ_i RP_i + \tau_t + \varepsilon_{it}. \quad (4)$$

[16] In contrast to several previous studies, we do not include a lagged endogenous variable in the baseline model as by construction this would make the unobserved panel-level effects correlated with the lagged dependent variable, hence the within (fixed effects) estimator would be inconsistent. This could be addressed with the Arellano and Bond (1991) GMM estimator or Blundell and Bond (1998) system estimator that uses additional moment conditions. However, this approach is not suitable for our sample since these estimators rely on the assumption of large N and small T. When we apply these estimators to our data, The Hansen J-test indicates that we reject the joint null hypothesis that our instruments are uncorrelated with the residuals and the excluded instruments are correctly left out from the second stage regression. The rejection implies that at least one of these instruments is invalid.

Table 2
Macro-prudential policy and mortgage defaults.

VARIABLES	(1)	(2)	(3)	(4)
Unemployment	0.062**	0.057**	0.034	0.059**
	[0.027]	[0.026]	[0.027]	[0.027]
House price changes	-0.029***	-0.029***	-0.031***	-0.030***
	[0.008]	[0.008]	[0.007]	[0.008]
Interest spread	0.013	0.009	0.015*	0.012
	[0.009]	[0.010]	[0.009]	[0.009]
MPI		-0.118*		
		[0.059]		
Macro-pru instruments			-0.178***	
			[0.056]	
LTV index				-0.303**
				[0.117]
Constant	0.074	0.156	0.643	0.138
	[0.339]	[0.334]	[0.392]	[0.345]
Observations	220	220	220	220
Number of countries	26	26	26	26
R^2	0.386	0.402	0.464	0.413
Adj. R^2	0.337	0.352	0.419	0.364
Model	FE	FE	FE	FE

Notes: This table shows panel FE results for mortgage defaults using data for 26 countries over the 2000-2014 period. The dependent variable is expressed in logs. We use one-period lagged values of all regressors. Country fixed effects and time fixed effects (yearly dummies) are included in all specifications. We use robust standard errors clustered at the country level (shown in brackets) to correct for serial correlation and heteroscedasticity.

*** $p<0.01$
** $p<0.05$
* $p<0.1$.

4.2. Results

Table 2 presents the estimates obtained for the effects of macro-economic variables and macro-prudential policies on mortgage defaults, based on the estimation of the baseline model (Eq. (1)). In line with the results of previous studies, our findings suggest that higher unemployment is significantly associated with an increase in mortgage defaults, while higher house prices have a negative association with defaults. From a theoretical perspective, defaults are more likely when house prices decline for two reasons. First, the ability to finance consumption out of housing wealth declines. Second, negative equity may create incentives for strategic default.

The coefficient on the lagged interest rate spread is positive, but it is not statistically significant. Jappeli et al. (2008) report similar results for their interest rate variable. Our results suggest that it may take time for financial constraints (proxied by the interest rate spread) to materialize in affordability problems.[17]

In column (2), the MPI is added as explanatory variable. Our expectation is that defaults are less likely if macro-prudential policy is tightened (i.e., the index goes up). The coefficient on our first proxy for macro-prudential policy is negative and significant. A one-unit increase in the MPI index translates into a decrease in the average mortgage default ratio of 0.3%, which is economically not very large.[18] As an alternative, we employ the cumulative macro-prudential index (Macro-pru instruments) from Cerutti et al. (2017a). As the results in column (3) show, the coefficient on this proxy for macro-prudential policy is also significantly negative.[19] This broader index captures the effects of cumulative changes in prudential regulations on banking activities (i.e., housing and non-housing activities) at a given point in time. Thus, this significant association between the index and mortgage defaults is suggestive for the long-term impact of prudential regulations.[20]

Finally, the results for our proxy for changes in the regulatory LTV ratios presented in column (4) suggest that the relationship between this particular instrument and mortgage defaults is significant. The magnitude of the effect is large and indicates that the LTV ratio has a strong association with mortgage defaults.[21] This result is in line with the findings of Wong et al. (2011) which highlight the importance of LTV caps in reducing the responsiveness of mortgage default risk to volatility in property prices.[22]

Still, due to the discrete character of the variable, one has to be careful in interpreting the economic significance of our estimates. Our results suggest that when the regulatory policy with respect to the LTV ratio tightens (i.e., the LTV cap goes down), which translates into a change for our LTV index from 0 to 1, the default rates decrease by 30%. But a one-unit increase in the LTV index represents a large change, as this is equivalent with approximately 3 standard deviations of the variable. To the extent that macro-prudential policies, including LTV ratios, apply only to newly originated loans, it is intriguing that their impact on arrears materializes so quickly (i.e., within a year). A potential explanation for this immediate effect may be due to one of the characteristics of the mortgage market, namely the loan type. In most countries in our sample, variable-rate mortgages are the predominant type of loans. This loan category consists of both variable-rate mortgages and a mix of fixed and variable-rate mortgages. There is however, a large variability across countries with respect to the time for which the loan interest rate is fixed (unfortunately our aggregate data does not allow us to control for this variability). For example, in the UK the interest rate is fixed for around three years while in the Netherlands this fixity of interest rates can go up to twenty years. A shorter period of interest rate fixity may create incentives for loan refinancing (into another loan which assures a fixed interest rate for a period of time) when credit becomes more expensive. Thus, this refinancing behavior may accelerate the transmission mechanism of macro-prudential policies.

Given that the MPI is by construction better suited for analyzing cross-country heterogeneity in the usage of prudential tools (including LTV caps) applied to the housing sector, in the remainder of the paper we use the MPI as our main proxy for macro-prudential regulation. We therefore keep model (2) of Table 2 as our baseline specification and extend it with the other proposed covariates of mortgage defaults.

Table 3 shows the random effects (RE) estimation results if we add several institutional variables. We expect that better institutions—like high judicial efficiency making it easier for banks

[17] We therefore considered more lags for the interest rate spread. It turns out that for longer time lags our proxy for financial constraints is significantly associated with mortgage defaults (results available on request).

[18] Our baseline specification is a log-linear model (Eq. (1)), therefore the interpretation of our estimates is as follows: [exp($\hat{\beta}$)-1] x 100 is the expected change in the mortgage default ratio for a one-unit increase in a particular explanatory variable X. Specifically, an estimated coefficient for the MPI index of -0.118 implies a decrease of 11.1% in the mortgage default ratio for a one-unit increase in the MPI index. For a mean default ratio across countries of around 3% (see Table 1), a one-unit increase in the MPI index translates into a decrease in the average mortgage default ratio of 0.333% (11.1%*3%).

[19] The estimated coefficient for the index is -0.178, which implies a decrease of 16.3% in the mortgage default ratio for a one-unit increase in the index. For a mean default ratio across countries of around 3%, a one-unit increase in the Macro-pru index translates into a decrease in the mortgage default ratio of 0.489% (16.3%*3%).

[20] We considered the cumulative version of the MPI index (compiled in a similar fashion as the cumulative Macro-pru instruments index). Our results remain the same: the coefficient is negative and significant, albeit only at the ten percent level (results available on request).

[21] The estimated coefficient for the index is -0.303, which implies a decrease of 25% in the mortgage default ratio for a one-unit increase in the LTV index. For a mean default ratio across countries of around 3%, a unit increase in the LTV index translates into a decrease in the mortgage default ratio of 0.75% (25%*3%).

[22] We also interacted our macro-prudential variables with macro-economic variables to examine whether the responsiveness of mortgage defaults to changes in house prices or macroeconomic fluctuations is conditioned by macro-prudential policies. We did not find support for this (results available on request).

Table 3
Mortgage defaults and institutions.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Unemployment	0.055***	0.057***	0.039*	0.055**	0.054**	0.041*
	[0.021]	[0.017]	[0.022]	[0.022]	[0.021]	[0.021]
House price changes	-0.037***	-0.044***	-0.034***	-0.033***	-0.033***	-0.039***
	[0.009]	[0.010]	[0.008]	[0.008]	[0.008]	[0.009]
Interest spread	0.005	0.013	0.013	0.009	0.009	0.010
	[0.009]	[0.008]	[0.008]	[0.009]	[0.009]	[0.008]
MPI	-0.172**	-0.218**	-0.178**	-0.161**	-0.165***	-0.164**
	[0.070]	[0.108]	[0.075]	[0.065]	[0.061]	[0.068]
Legal rights	-0.196*					
	[0.103]					
Rule of law		-7.843***				
		[1.676]				
Property protection			-0.809***			
			[0.299]			
Investor protection				-0.199		
				[0.179]		
Creditor rights					-0.399	
					[0.253]	
IQ index						-0.433***
						[0.149]
Constant	1.580**	5.576***	5.611***	1.529	0.989*	0.244
	[0.633]	[1.094]	[1.876]	[1.123]	[0.582]	[0.328]
Observations	210	208	220	220	220	204
Number of countries	24	24	26	26	26	23
R^2	0.345	0.612	0.464	0.302	0.326	0.435
Model	RE	RE	RE	RE	RE	RE

Notes: This table shows panel RE results for mortgage defaults using data over the period 2000-2014. The dependent variable is expressed in logs. We use one-period lagged values of all time variant regressors. Yearly dummies are included in all specifications. We use robust standard errors clustered at the country level (shown in brackets) to correct for serial correlation and heteroscedasticity.
*** p<0.01
** p<0.05
* p<0.1.

to enforce their rights—are associated with a reduction in the level of mortgage defaults. We use several proxies for institutional quality.[23] In column (1) we add the legal rights index. The results suggest that better legal rights have a negative and significant association with mortgage defaults. As shown in column (2), also a higher score on the rule of law index is associated with fewer defaults. Columns (3)-(5) show the estimates for our three proxies for the protection of property. In all cases, our results suggest that better protection of property rights is associated with a lower level of mortgage arrears. This holds for the index for the protection of physical property, for the index for investor protection, and for the index of the strength of creditor rights, although only the coefficient on the first proxy is significantly different from zero.

Finally, column (6) shows the results for our institutional quality (IQ) index, which is the first principal component of the five variables used above (see Appendix C for details). This index varies from -3 (= low quality) to 3 (=high quality). The results suggest that a unit increase in the index is associated with a decrease in mortgage defaults by 43%. This finding reflects the importance of institutional arrangements in deterring mortgage delinquencies.

Table 4 presents the results of FE regressions when macro-prudential policies are interacted with institutional quality and several characteristics of the mortgage market. Column (1) of Table 4 shows estimates for the interaction of the macro-pru policy index MPI and our proxy for institutional quality.[24] The results suggest that the association between macro-prudential regulation and mortgage defaults is stronger in countries that have better institutions.[25] In other words, the effect of tougher macro-prudential policies (that reduce household leverage and ultimately deter defaults) is amplified in an institutional environment with an efficient judicial system, with better protection of lenders' rights and better enforcement capabilities.

The second column of Table 4 suggests that restrictive macro-prudential policies in countries that have mortgage contracts with longer maturities are associated with lower incidence of mortgage arrears. This result complements the findings of Aristei and Gallo (2012) who show that the maturity of mortgages reduces the probability of mortgage delinquency in the Italian mortgage market. The intuition for this result is that the combination of a restrictive macro-prudential environment, which may limit household indebtedness, with longer maturities, which make periodic mortgage payments more affordable to borrowers, is conducive to repayment.

Column (3) shows the interaction effect of macro-prudential policy and a dummy for the flexibility of the interest rate on the mortgage (the dummy is one if most loans have a fixed interest rate in a given country and zero otherwise). The evidence suggests that in countries with fixed-interest mortgages, restrictive macro-prudential policies are significantly negatively associated

[23] We consider more proxies for institutional quality (see the robustness section).
[24] The tightening of macro-prudential policy may have a delayed effect on defaults, because it affects only new mortgages. We considered longer lags for the interacted variables. We report here the significant associations only (which start from the second lag onwards) pointing to the fact that it takes time for macro-prudential measures to have a significant impact on mortgage arrears (when controlling for heterogeneity in institutional quality and mortgage market characteristics). Using the first lag for the interaction gives similar negative (but not statistically significant) coefficients.
[25] The estimated coefficients of the interaction terms are interpreted as marginal effects. For example, the interpretation of the interaction term between the MPI index and IQ index is given by the following marginal effect (based on equation (3)): $\partial Default\ ratio/\partial MPI = \hat{\beta} + \hat{\theta}\ IQ$. The coefficients reported in Table 4 indicate that the IQ index amplifies the effect of the MPI on the mortgage defaults ratio by -6.5%, leading to an overall decrease in the mortgage defaults ratio of approximately 16% (9.4%+6.5%).

Table 4
The impact of the interaction of mortgage market variables and macro-prudential policy on mortgage defaults.

VARIABLES	(1)	(2)	(3)	(4)	(5)
Unemployment	0.050**	0.052*	0.058**	0.054**	0.056**
	[0.024]	[0.026]	[0.026]	[0.026]	[0.026]
House price changes	-0.035***	-0.028***	-0.029***	-0.028***	-0.032***
	[0.008]	[0.008]	[0.008]	[0.008]	[0.008]
Interest spread	0.007	0.007	0.008	0.006	0.005
	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]
MPI	-0.094**	-0.097**	-0.125**	-0.106**	-0.112*
	[0.045]	[0.045]	[0.060]	[0.044]	[0.062]
MPI * IQ index	-0.065**				
	[0.026]				
MPI * Maturity		-0.004*			
		[0.002]			
MPI * Loan type			-0.243***		
			[0.066]		
MPI * Tax deduction				-0.178*	
				[0.095]	
MPI * Funding					-0.059
					[0.051]
Constant	0.186	0.261	0.161	0.218	0.176
	[0.340]	[0.348]	[0.335]	[0.336]	[0.354]
Observations	201	217	217	217	207
Number of countries	23	26	26	26	24
R^2	0.437	0.418	0.407	0.417	0.417
Adj. R^2	0.384	0.368	0.356	0.315	0.307
Model	FE	FE	FE	FE	FE

Notes: This table shows panel FE results for mortgage defaults using data over the period 2000-2014. The dependent variable is expressed in logs. Country fixed effects and time fixed effects (yearly dummies) are included in all specifications. We use one-period lagged values for the regressors, except for the interactions with MPI where we use two lags. We use robust standard errors clustered at the country level (shown in brackets) to correct for serial correlation and heteroscedasticity.

*** p<0.01

** p<0.05

* p<0.1.

with mortgage arrears.[26] This most likely captures the effect of a reduction in the volatility of payment obligations on defaults. First, a restrictive macro-prudential environment reduces the amount that can be borrowed. In addition, households are able to fix their payment obligations over a certain period of time, thus reducing the volatility of their payment obligations. The volatility of payment obligations caused by changes in the interest rates (and its subsequent impact on mortgage delinquencies) is expected to be higher in countries where variable-rate mortgages are prevalent. However, we did not find a significant relationship between mortgage arrears and the interaction between interest rate spread and loan type. This result is in line with the findings of Gerlach-Kristen and Lyons (2015) who also did not find support for the impact of monetary policy on mortgage arrears.

Column (4) presents the estimation results for the interaction of macro-prudential policy and a dummy for tax-deductibility of interest payments, which takes the value of one if some form of tax-deductibility is allowed and zero otherwise. The results suggest that in countries with mortgage interest deductibility, restrictive macro-prudential measures are weakly associated with lower delinquency rates.[27] While there is empirical evidence on the relationship between mortgage interest deduction and higher house prices (or higher households leverage), our results point to a novel effect: in the presence of restrictive borrowing constraints (i.e., stricter macro-prudential policies), the tax-deductibility of interest payments increases borrowers' ability to pay by reducing their periodic payments.[28]

Finally, column (5) shows the interaction effect of macro-prudential policy and a dummy for the bank-funding model (the dummy is one if most funding is retail and zero otherwise). Non-retail funding may lead to higher leverage in the banking sector (Hahm et al., 2011) and higher banking leverage has often been associated with more risk-taking and lax lending standards. We therefore expect that defaults are less likely in case of retail funding. The results indicate that the coefficient on this interaction is indeed negative, but it is not statistically significant.

Table 5 presents three RE regressions to further examine the effects of recourse and institutional quality, controlling for macroeconomic variables and macro-prudential policy. The first column adds a dummy to the model shown in column (6) of Table 3 which is one for countries with recourse and zero otherwise. A full recourse procedure is expected to increase borrowers' incentives to repay their debt because it gives more rights to the lenders in pursuing borrowers' assets in case of default (Ghent and Kudlyak, 2011; Li and Oswald, 2017). Indeed, the coefficient on the recourse variable is negative and significant.

Column (2) shows the outcomes if the recourse variable is interacted with our institutional quality index. The results show a significant relationship between the degree of lender recourse on borrowers and mortgage arrears, in particular for those countries with higher institutional quality. These results are suggestive

[26] The marginal effect of the interest rate fixity indicates that the predominance of fixed interest mortgages amplifies the effect of the MPI on mortgage defaults ratio by approximately -24.3%, leading to an overall decrease in the default ratio of about 37% (12.5%+24.3%).

[27] The marginal effect of the tax deduction indicates that having some form of tax-deductibility of interest payments amplifies the effect of the MPI on mortgage default ratio by approximately -17.8%, leading to an overall decrease of about 28.4% (10.6%+17.8%).

[28] More than half of the countries in our sample allow for some form of tax deductibility. However, the amount that can be deducted varies substantially across countries. We also examined whether tax deductibility has a direct relationship with mortgage defaults. Although our initial results suggested that deductibility increases mortgage defaults, robustness checks indicated that this result was driven by just two countries (i.e., Greece and Ireland) and we therefore conclude that it is not a robust relationship.

Table 5
Recourse, institutional quality and mortgage defaults.

VARIABLES	(1)	(2)	(3)
Unemployment	0.063***	0.032	0.036*
	[0.022]	[0.020]	[0.020]
House price changes	-0.039***	-0.040***	-0.038***
	[0.009]	[0.009]	[0.008]
Interest spread	0.006	0.009	0.010
	[0.010]	[0.009]	[0.009]
MPI	-0.195**	-0.181**	-0.117**
	[0.084]	[0.073]	[0.049]
IQ index			-0.391***
			[0.135]
MPI * IQ index			-0.087***
			[0.028]
Recourse	-1.062**	-0.995***	
	[0.416]	[0.317]	
Recourse * IQ index		-0.568***	
		[0.175]	
Constant	0.998***	1.203***	0.374
	[0.319]	[0.299]	[0.315]
Observations	210	204	201
Number of countries	24	23	23
R^2	0.410	0.602	0.471
Model	RE	RE	RE

Notes: This table shows panel RE results for mortgage defaults using data over the period 2000-2014. The dependent variable is expressed in logs. We use one-period lagged values of all time variant regressors, except for the interaction between MPI and IQ where we use two lags. Yearly dummies are included in all specifications. We use robust standard errors clustered at the country level (shown in brackets) to correct for serial correlation and heteroscedasticity.

*** $p<0.01$
** $p<0.05$
* $p<0.1$

for the importance of institutional arrangements (in particular those attributes that capture judicial efficiency, bankruptcy regulation and property protection) in alleviating banks' problems related with an increase in mortgage arrears.

Finally, the results in column (3) confirm the results of the FE regressions (reported in column (1) of Table 4) that the impact of stricter macro-prudential regulation on mortgage defaults is significantly stronger in countries that have better institutions.

5. Robustness tests

5.1. Additional controls

Results are robust to the inclusion of additional macroeconomic control variables such as inflation (taken from the World Development Indicators database), credit to households as a percentage of GDP (taken from the BIS), and a measure for social safety net (taken from the World Development Indicators database). These results are shown in the first columns of Table 6. It turns out that the coefficients on these variables are insignificant. To further assess the robustness of our core results we also control for some characteristics of the banking sector, such as bank capital to total assets and loan loss provisions ratios (from the Global Financial Development database). The results, as presented in columns (4) and (5) of Table 6, show that only loan loss provisions is significantly associated with mortgage default rates. Adding these variables does not affect our main findings, except that in column (5) the unemployment rate loses significance.

Next, we consider alternative proxies for the efficiency of the judicial system. In Table 7, we examine whether our results change if we use the number of procedures required to legally recover debt, number of days required to enforce a contract, the depth of private credit bureaus and public credit registries (as the proportion of adult population for whom there is information about repayment history) as alternative proxies for institutional quality (data comes from the World Development Indicators (WDI) and the World Bank Doing Business (DB) databases). As argued by Padilla and Pagano (2000), sharing creditor information by borrowers may provide an incentive for creditors to perform. We find that the results are very much in line with our previous findings, although the coefficients on the last two alternative proxies for institutional quality are not significant. Finally, we control for supervisory enforcement power in terms of prompt corrective action, declaring insolvency, and restructuring. We use the supervisory control index from Klomp and de Haan (2012) (data comes from the World Bank survey on Regulation and Supervision).[29] We report the results in column (6) of Table 7. The variable turns out to be insignificant and does not affect our main results.[30]

5.2. Correlated random effects

The institutional quality index probably does not have a reverse causal relationship with mortgage defaults, as the underlying institutional variables are not likely to be affected by mortgage defaults and the variables measuring the quality of institutions are time-invariant. However, the institutional quality index might be correlated with the country-specific effects. Therefore, we employ the correlated random effects specification proposed by Mundlak (1978) as a robustness test. The Mundlak specification estimates random-effects regression models by adding group-means of the regressors that display within group variation. This technique relaxes the assumption in the random-effects estimator that the observed variables are uncorrelated with the unobserved variables. The results shown in Table 8 indicate that our findings based on the random effects estimator are robust: the estimated coefficients found using the Mundlak specification are similar in sign and magnitude as the RE estimates.

5.3. Sample split

The results reported are robust to the exclusion of one country at a time. The macro-pru policy index remains statistically significant as well as the macroeconomic variables. However, the coefficient on the MPI variable is not statically significant if we exclude all Asian countries and estimate the model on a sample containing only EU countries and the US (results available on request). This may be due to the fact that Asian countries had the most active macro-prudential policies in place during the time frame covered in our study, while EU countries only started to introduce these policies after the crisis.

5.4. Endogeneity of macro-prudential policy

As mentioned in the methodology section, one limitation of the analysis is a potential bias in the estimates due to simultaneity between the dependent variable and the macro-prudential policy index. There may be reverse causality if macro-prudential policy is implemented in anticipation of increased mortgage default rates. The graphs depicting the evolution of the MPI and mortgage defaults across time suggest that anticipation does not seem to be present (see Figures E.1 and E.2 in Appendix E).[31] Nevertheless, we

[29] The index is constructed by summing up the individual zero/one answers. This method gives equal weight to each of the questions in constructing the supervisory control variable.

[30] We use the 2003 version of the survey. The results are very similar to those reported for the 2007 version.

[31] One can also think of the direction of the potential bias. Since our estimated coefficients on the MPI are negative and the bias would be positive (because the MPI increases in response to higher mortgage defaults), macro-prudential policies may have a stronger negative impact on mortgage defaults than suggested by our estimates. As a consequence, the estimates indicate a lower bound of the effects of macro-prudential policies on mortgage defaults.

Table 6
Robustness to additional macroeconomic and banking controls.

VARIABLES	(1)	(2)	(3)	(4)	(5)
Unemployment	0.044*	0.049*	0.003	0.057**	0.021
	[0.025]	[0.024]	[0.052]	[0.023]	[0.028]
House price changes	-0.036***	-0.035***	-0.032***	-0.036***	-0.034***
	[0.009]	[0.009]	[0.009]	[0.009]	[0.008]
Interest spread	0.008	0.008	0.022	0.011	0.016*
	[0.010]	[0.010]	[0.017]	[0.010]	[0.009]
MPI	-0.096**	-0.092*	-0.147**	-0.089**	-0.102*
	[0.042]	[0.045]	[0.052]	[0.042]	[0.050]
MPI x IQ index	-0.059**	-0.068**	-0.057*	-0.053**	-0.066**
	[0.026]	[0.028]	[0.028]	[0.025]	[0.031]
Inflation	-4.580				
	[4.681]				
Households credit		-0.004			
		[0.015]			
Social safety net			0.005		
			[0.007]		
Capital to assets				0.122	
				[0.077]	
Provisions					-0.006**
					[0.002]
Constant	0.314	0.463	0.944*	-0.836	0.814*
	[0.336]	[1.131]	[0.516]	[0.560]	[0.442]
Observations	201	196	151	200	181
Number of countries	23	22	20	23	23
R^2	0.440	0.439	0.367	0.455	0.487
Model	FE	FE	FE	FE	FE

Notes: This table shows panel results for mortgage defaults using data over the period 2000-2014. The dependent variable is expressed in logs. We use one-period lagged values of all time variant regressors, except for the interaction between MPI and IQ where we use two lags. Fixed effects and yearly dummies are included in all specifications. We use robust standard errors clustered at the country level (shown in brackets) to correct for serial correlation and heteroscedasticity.

*** p<0.01
** p<0.05
* p<0.1

Table 7
Additional institutional variables.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Unemployment	0.053**	0.049**	0.052**	0.052**	0.050**	0.057**
	[0.025]	[0.024]	[0.023]	[0.023]	[0.022]	[0.023]
House price changes	-0.036***	-0.037***	-0.033***	-0.034***	-0.033***	-0.034***
	[0.010]	[0.010]	[0.008]	[0.009]	[0.010]	[0.008]
Interest spread	0.012	0.014*	0.004	0.014	0.013	0.007
	[0.008]	[0.008]	[0.010]	[0.009]	[0.010]	[0.010]
MPI	-0.153**	-0.153**	-0.171**	-0.158**	-0.141**	-0.170**
	[0.070]	[0.067]	[0.068]	[0.072]	[0.069]	[0.071]
No procedures	0.230*					
	[0.119]					
Time to enforce (WDI)		0.002*				
		[0.001]				
Time to enforce (DB)			0.002***			
			[0.001]			
Private coverage				-0.001		
				[0.003]		
Public coverage					0.013	
					[0.012]	
Supervisory control						0.121
						[0.077]
Constant	-1.176	-0.852	-0.670	0.326	0.057	-0.882
	[0.916]	[0.738]	[0.570]	[0.444]	[0.400]	[0.839]
Observations	194	194	220	188	188	219
Number of countries	23	23	26	26	26	26
R^2	0.432	0.412	0.384	0.380	0.289	0.366
Model	RE	RE	RE	RE	RE	RE

Notes: This table shows panel RE results for mortgage defaults using data over the period 2000-2014. The dependent variable is expressed in logs. We use one-period lagged values for all time variant regressors. Yearly dummies are included in all specifications. We use robust standard errors clustered at the country level (shown in brackets) to correct for serial correlation and heteroscedasticity.

*** p<0.01
** p<0.05
* p<0.1

Table 8
Correlated RE (Mundlak approach).

VARIABLES	(1)	(2)	(3)	(4)
Unemployment	0.054***	0.041*	0.050***	0.036*
	[0.019]	[0.021]	[0.019]	[0.020]
House price changes	-0.035***	-0.039***	-0.035***	-0.038***
	[0.007]	[0.009]	[0.007]	[0.008]
Interest Spread	0.008	0.010	0.007	0.010
	[0.016]	[0.008]	[0.016]	[0.009]
MPI	-0.122**	-0.164**	-0.094*	-0.117**
	[0.054]	[0.068]	[0.054]	[0.049]
IQ index	-0.288**	-0.433***	-0.323**	-0.391***
	[0.131]	[0.149]	[0.136]	[0.135]
MPI x IQ index			-0.065**	-0.087***
			[0.027]	[0.028]
Observations	204	204	201	201
Number of countries	23	23	23	23
R^2	0.837	0.435	0.860	0.471
Model	Mundlak	RE	Mundlak	RE

Notes: This table shows panel RE and Mundlak results for mortgage defaults using data over the period 2000-2014. The dependent variable is expressed in logs. We use one-period lagged values of all time variant regressors, except in the interaction between MPI and IQ where we use two lags. Yearly dummies are included in all specifications. We use robust standard errors clustered at the country level (shown in brackets) to correct for serial correlation and heteroscedasticity.

*** p<0.01
** p<0.05
* p<0.1

cannot rule out this possibility, therefore we employ two different modelling strategies to account for the potential reverse causality and check the robustness of the effects of macro-prudential policy variables (MPI and Macro-pru instruments). One is based on instrumental variables (IV) estimation and the second is a panel VAR model, which allows for the dependency among the variables to run both ways.

5.4.1. IV estimation

Identification based on the instrumental variable approach requires that for each macro-prudential policy variable we have at least one exogenous instrument that is correlated with the macro-prudential policy changes but unrelated to mortgage arrears. We employ identification based on functional form (Lewbel, 2012) and complement it with an instrument constructed based on macro-prudential policy in neighboring countries. We build a variable that captures for each country whether the closest neighboring country (from our sample) made a change in macro-prudential regulation one period before.[32] This variable is correlated with the MPI but does not affect mortgage arrears in that particular country. We use macro-prudential policy in neighboring countries as an instrument since this variable satisfies the two necessary criteria for instrument validity: it is correlated with the macro-prudential policy instrument and it doesn't affect the mortgage defaults across the border.

Lewbel (2012) shows that heteroscedasticity in the errors in the first stage regression can be also used as a source of identification. The main assumption is that the errors in a linear projection of the endogenous regressor on the other regressors are heteroscedastic. The generated instruments Z_j are constructed from the first stage residuals, multiplied by each of the included exogenous variables in mean-centered form:

$$Z_j = (X_j - \bar{X})\ \hat{u}_j,$$

where j indexes each of the exogenous regressors included in the model and u_j is the vector of residuals from the first stage regression of each endogenous regressor on all the exogenous regressors. The auxiliary regression residuals have zero covariance with each of the regressors used to construct them, but their element-wise products with the centered regressors comprise sizeable elements if heteroscedasticity is present. The higher the degree of heteroscedasticity in the errors, the larger is the correlation of instruments with the endogenous variables.

[32] In case there are two or more neighboring countries in our sample for a given country, we select as the closest neighbor the largest country in terms of GDP.

Table 9
IV panel regression results.

VARIABLES	(1)	(2)	(3)	(4)
MPI	-0.149**	-0.149**		
	[0.061]	[0.062]		
Unemployment	0.068***	0.068***	0.075***	0.075***
	[0.013]	[0.013]	[0.013]	[0.013]
House price changes	-0.034***	-0.034***	-0.033***	-0.033***
	[0.005]	[0.005]	[0.005]	[0.005]
Interest spread	0.012	0.012	0.015**	0.015**
	[0.007]	[0.007]	[0.008]	[0.008]
Macro-pru instruments			-0.105***	-0.105***
			[0.029]	[0.029]
Observations	220	220	220	220
Number of countries	26	26	26	26
R^2	0.351	0.351	0.381	0.381
Estimator	2SLS	LIML	2SLS	LIML
Underid (p-val)	0.02	0.02	0.00	0.00
Overid (p-val)	0.80	0.80	0.81	0.81
F-stat	6.95	6.95	23.19	23.19

Notes: This table shows panel IV results for mortgage defaults using data over the 2000-2014 period. The dependent variable is expressed in logs. We use one-period lagged values of all regressors. We use robust standard errors clustered at the country level (shown in brackets). Overid test reports the p-value of Hansen J statistic. Underid reports the p-value of Kleibergen and Paap rk statistic. The set of instruments is obtained based on the Lewbel (2012) approach. Excluded instruments are unemployment, house prices and interest rate spread demeaned and interacted with the first-stage residuals. F-stat reports the Sanderson-Windmeijer F-statistic of excluded instruments.

*** p<0.01
** p<0.05, * p<0.1

Table 10
IV panel regression results (extended instruments).

VARIABLES	(1)	(2)	(3)	(4)
MPI	-0.149**	-0.149**		
	[0.062]	[0.062]		
Unemployment	0.068***	0.068***	0.075***	0.075***
	[0.013]	[0.013]	[0.013]	[0.013]
House price changes	-0.034***	-0.034***	-0.033***	-0.033***
	[0.005]	[0.005]	[0.005]	[0.005]
Interest spread	0.012	0.012	0.015**	0.015**
	[0.007]	[0.007]	[0.008]	[0.008]
Macro-pru instruments			-0.103***	-0.103***
			[0.028]	[0.029]
Observations	220	220	220	220
R^2	0.35	0.35	0.38	0.38
Number of countries	26	26	26	26
Estimator	2SLS	LIML	2SLS	LIML
Underid (p-val)	0.05	0.05	0.00	0.00
Overid (p-val)	0.93	0.93	0.85	0.81
F-stat	5.35	5.35	26.56	23.19

Notes: This table shows panel IV results for mortgage defaults using data over the 2000-2014 period. The dependent variable is expressed in logs. We use one-period lagged values of all regressors. We use robust standard errors clustered at the country level (shown in brackets). Overid test reports the p-value of Hansen J statistic. Underid reports the p-value of Kleibergen and Paap rk statistic. The set of instruments based on the Lewbel (2012) approach is complemented with the constructed instrument based on the macro-prudential index. Excluded instruments are unemployment, house prices and interest rate spread demeaned and interacted with the first-stage residuals, as well as the macro-prudential index capturing changes in the neighboring countries. F-stat reports the Sanderson-Windmeijer F-statistic of excluded instruments.

*** p<0.01
** p<0.05, * p<0.1

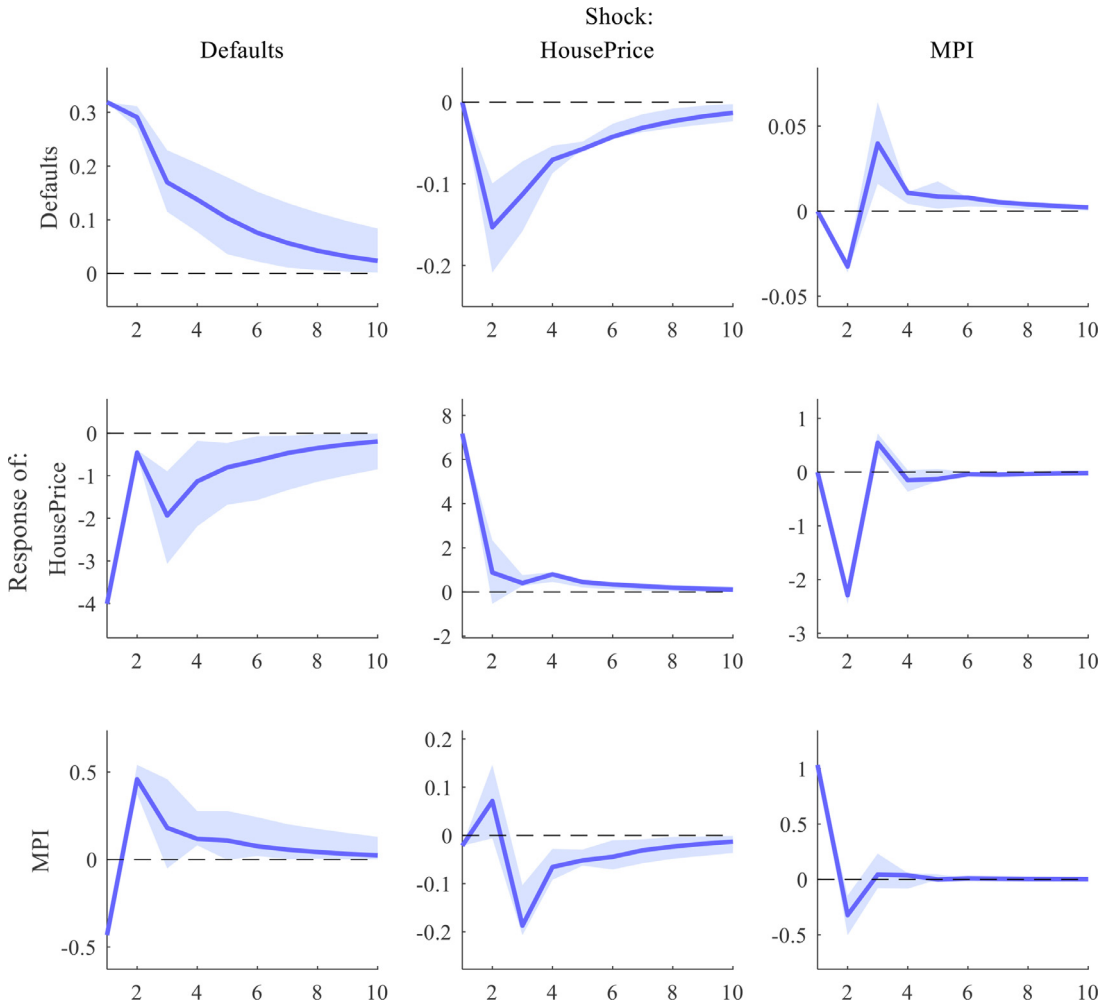

Fig. 2. Impulse-response functions based on the panel VAR estimation.
Notes: The bands denote the confidence intervals at 95% significance level. On the x-axis we done time in years. The VAR model is estimated with one lag and identification is based on the Choleski factorization. The model satisfies the stability requirements.

The results obtained based on the set of instruments constructed with the Lewbel (2012) approach are presented in Table 9. We complement this set of instruments with the constructed instrument based on macro-prudential changes in the closest neighboring country and present the results in Table 10. The tables report p-values of the under-identification tests based on the Kleibergen and Paap (2006) rk statistic with rejection implying identification. They also show p-values of the over-identification test based on the Sargan (1958) and Hansen (1982) J-test, with rejection implying that the model is mis-specified or that at least one of these instruments is invalid. Finally, the tables present the Sanderson and Windmeijer (2016) F-statistic as a test for weak identification of the individual endogenous regressors. The Hansen J-test indicates that we do not reject the joint null hypothesis that our instruments are uncorrelated with the residuals and the excluded instruments are correctly left out from the second stage regression. Furthermore, for every model specification we reject the null that the model is under-identified based on the Kleibergen-Paap rk statistic.

We notice that the results obtained based on the instrumental variable estimation are robust and similar in both sign and magnitude with the ones obtained with the OLS within estimator (FE). We therefore conclude that macroeconomic variables and macro-prudential policy have significant effects on the incidence of mortgage defaults.

5.4.2. Panel VAR

Our second approach is to estimate a panel VAR model. A panel VAR allows for the lagged feedback effects to run both ways, as well as for an autoregressive component of mortgage defaults. We estimate a panel VAR which includes the main variables of interest: mortgage defaults, house price changes, and macro-prudential policy.[33] The Akaike information criterion indicates a lag specification of order one and the identification is based on the Cholesky factorization. The results are presented in Fig. 2 and are robust to different orderings.

Our main results hold through as we note that a macro-prudential policy shock (tightening) has a significant negative effect on mortgage defaults. The negative impact is present for the first two years and afterwards it becomes insignificant.[34] This is similar with the result from our baseline specification, where we obtain a significant negative effect for the lagged MPI

[33] We also include unemployment as an endogenous variable and the results remain robust.

[34] Figure 2 also suggests that an MPI shock reduces house prices two years later. This finding points to a possible adverse side effect of macro-prudential policies. In particular, it suggests that macroprudential policies may not be costless: although they can be helpful for reducing mortgage defaults, their effect on housing prices may increase the number of households having negative equity which, at some point, may increase mortgage defaults. We leave this issue for future research.

index.[35] A positive house price shock reduces the mortgage defaults ratio. The strongest magnitude is achieved after two years and the effect is persistent. We also notice that a positive shock to mortgage defaults leads to a strong decline in house prices. Furthermore, the effect of the MPI index is negative and significant, and it shows that the macro-prudential policy is loosened in response to a surge in mortgage defaults.

As the IRFs in Fig. 2 show, a positive mortgage default shock increases MPI as well, suggesting that there is a feedback effect. In our baseline panel model, this feedback effect, by construction, is not taken into account, which might explain the difference in the magnitude of the effect of MPI on mortgage defaults in our baseline model and our VAR model.

The panel VAR modelling strategy has an important limitation in the context of our data. The panel VAR precludes us from using a richer specification by including interaction effects and/or other relevant control variables that we have in the dataset. This is because on the one hand, the number of parameters to be estimated increases very fast as more variables and lags are included in the analysis,[36] while on the other hand, our sample size is limited, therefore not suitable for a larger model. Thus, given our small unbalanced panel, we have to limit the specification of the VAR model only to the most important control variables. Avoiding the curse of dimensionality is the reason why we estimate the panel VAR model with three and four variables.

To conclude, we provide two approaches to deal with simultaneity: one based on IV estimation and one based on the panel VAR. The results of the paper remain consistent across these different specifications in terms of sign and statistical significance. The magnitudes are slightly different which is as expected since the effects do not have the same exact dynamic interpretation across different models.

6. Conclusions

Using a newly constructed database for 26 countries over the period 2000-2014, we examine potential covariates for the cross-country and within-country heterogeneity in mortgage defaults. A major advantage of using panel data at the macro level is that several important covariates of mortgage defaults can be considered. Some of these variables are time varying (e.g., changes in the macro-prudential policies), while others are not (e.g., institutional attributes, housing market characteristics). For this reason, we employ both fixed and random effect estimators in our empirical analysis.

Our results suggest that macro-prudential policies, and in particular lower regulatory LTV ratios, and proxies for institutional quality (such as judicial efficiency, bankruptcy regulation and property protection), are statistically significantly associated with a lower share of mortgage arrears. We also find that the effects of macro-prudential policy and institutional quality on mortgage defaults are mutually reinforcing: average default rates are the lowest in countries with better institutions and restrictive macro-prudential policies.

Our findings also indicate that several mortgage market characteristics are important for explaining variation in mortgage defaults. Longer maturities, fixed-interest rate contracts, and tax-deductibility of interest payments are associated with lower default rates in countries with restrictive macro-prudential policies. In addition to that, legislation that allows mortgage lenders to claim borrowers' assets (if the proceedings do not cover the outstanding loan balance), may deter mortgage defaults. We find a strong relationship between the degree of lender recourse on borrowers and mortgage arrears, in particular in those countries with better institutions.

From a policy perspective, our evidence suggests that a mix of policies may be required in order to reduce mortgage defaults. Such a mix should consist of both macro-prudential regulation and improvements in institutional design, in particular improvements of judicial efficiency and bankruptcy regulation.

[35] Similar results (available on request) are obtained when we use the cumulative MPI index as an alternative proxy for the macro-prudential policies.

[36] The number of parameters to be estimated increases in a quadratic fashion with the number of variables included in the model.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jbankfin.2020.105889.

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